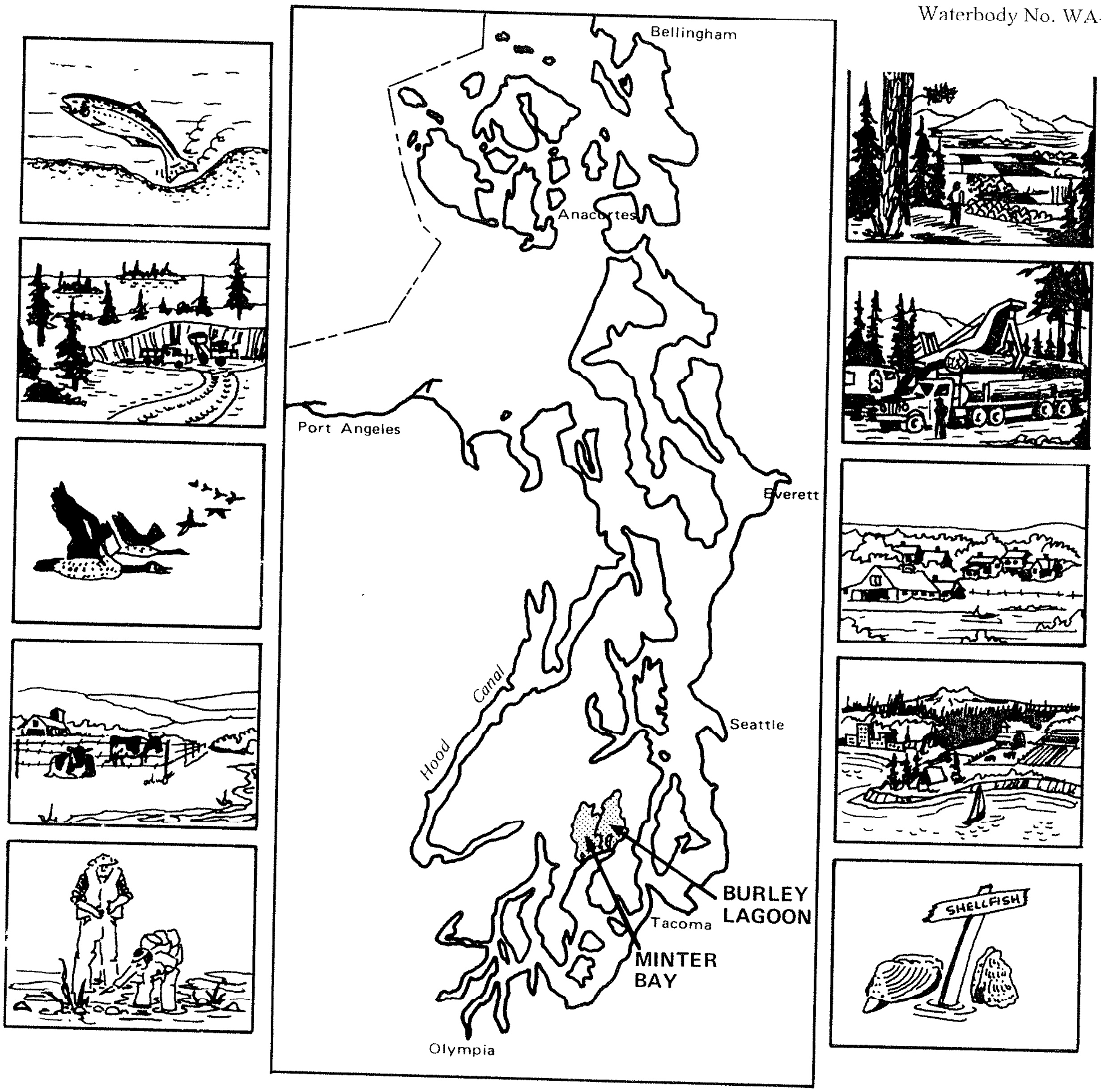
SOURCES AFFECTING THE SANITARY CONDITIONS OF WATER AND SHELLFISH IN MINTER BAY AND BURLEY LAGOON

Publication No. 84-10

Waterbody No. WA-15 1400



WASHINGTON STATE DEPARTMENT OF ECOLOGY

WDOE 84-10

SEPTEMBER 1985

BOOTH GARDNER
GOVERNOR

ANDREA BEATTY RINIKER
DIRECTOR

Segment No. 07-15-03

SOURCES AFFECTING THE SANITARY CONDITIONS OF WATER AND SHELLFISH IN MINTER BAY AND BURLEY LAGOON

by

Timothy A. Determan
Barbara M. Carey
William H. Chamberlain
Dale E. Norton

September, 1985

Washington State Department of Ecology
Water Quality Investigations Section
Olympia, WA 98504

WDOE Report No. 84-10

TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

TABLE OF CONTENTS - Continued

FIGURES

FIGURES - Continued

FIGURES - Continued

TABLES

TABLES - Continued

ACKNOWLEDGMENTS

Complex projects require the cooperation of many individuals. The authors gratefully acknowledge the contributions of the following persons:

Harold Wiksten (Minterbrook Oyster Company) provided space to launch and store our boat during estuarine studies. Jerry Yamashita of Western Oyster Company provided historical information on shellfish harvesting in the region, and access to Burley Lagoon.

Robert Courson (EPA, Region X) and the Environmental Monitoring Systems Division in Las Vegas, Nevada, provided an aerial infrared photographic survey of land use in the watersheds (Hoppus, 1984).

Paul Pedersen (Manager, Minter Creek Salmon Hatchery) provided hatchery facilities to conduct special studies. He also supplied rain data and useful information on activities in the watersheds.

Jack Lilja (Supervisor, Department of Social and Health Services [DSHS] Shellfish Program) arranged the analyses of quality assurance samples by the DSHS Water and Shellfish Laboratory.

Bea McKamey (Pierce/Kitsap County Soil Conservation Districts) provided us with important observations and assisted several times during routine background sampling.

Special mention should be made of the many residents along the streams and estuaries who entertained requests from strangers in hip boots and rain suits for samples from their shore or access to the plumbing in their homes; and who tolerated our comings and goings at unlikely times of day.

Study review was provided by members of the Sensitive Areas Technical Committee and the Sensitive Area Citizens Committee.

Word processing specialist Carol Perez patiently endured several major revisions of the text. Jeffery Stewart prepared the soils plates. WDOE cartographer John Milhollin prepared the land-use plates, and finalized the figures and report cover.

This page is purposely blank for duplex printing

ACKNOWLEDGMENTS

Complex projects require the cooperation of many individuals. The authors gratefully acknowledge the contributions of the following persons:

Harold Wiksten (Minterbrook Oyster Company) provided space to launch and store our boat during estuarine studies. Jerry Yamashita of Western Oyster Company provided historical information on shellfish harvesting in the region, and access to Burley Lagoon.

Robert Courson (EPA, Region X) and the Environmental Monitoring Systems Division in Las Vegas, Nevada, provided an aerial infrared photographic survey of land use in the watersheds (Hoppus, 1984).

Paul Pedersen (Manager, Minter Creek Salmon Hatchery) provided hatchery facilities to conduct special studies. He also supplied rain data and useful information on activities in the watersheds.

Jack Lilja (Supervisor, Department of Social and Health Services [DSHS] Shellfish Program) arranged the analyses of quality assurance samples by the DSHS Water and Shellfish Laboratory.

Bea McKamey (Pierce/Kitsap County Soil Conservation Districts) provided us with important observations and assisted several times during routine background sampling.

Special mention should be made of the many residents along the streams and estuaries who entertained requests from strangers in hip boots and rain suits for samples from their shore or access to the plumbing in their homes; and who tolerated our comings and goings at unlikely times of day.

Study review was provided by members of the Sensitive Areas Technical Committee and the Sensitive Area Citizens Committee.

Word processing specialist Carol Perez patiently endured several major revisions of the text. Jeffery Stewart prepared the soils plates. WDOE cartographer John Milhollin prepared the land-use plates, and finalized the figures and report cover.

And finally, special thanks are given to John Bernhardt for his guidance and review from the project's inception.

This page is purposely blank for duplex printing

SUMMARY AND DISCUSSION

The results of the Burley Lagoon and Minter Bay evaluations were similar enough to justify combining the overall findings into a single section. These findings are summarized below:

1. Both watersheds are small, each encompassing about 10,000 acres. The setting for both is similar to many other rural areas within commuting distance of rapidly expanding urban areas. Growth has been rapid, almost tripling between 1970 and 1980.

2. About one-third of the land in both drainages is presently developed. Land use consists primarily of small farms and various residential tracts scattered over an otherwise rural landscape. Such development has occurred first in the lowlands and along roads and lower streams. It is now advancing toward the forested uplands.

3. Soils in both watersheds are generally typical of many areas in western Washington, being poorly drained and not well-suited to on-site disposal systems. Soils unsuitable for wastewater disposal cover about 50 percent of the Minter Watershed and 75 percent of the Burley/Purdy Watershed.

4. Rainfall during 1983 exceeded the 30-year average by approximately 23 percent. Thus, the results of this study reflect wetter-than-usual climatological conditions.

5. Fecal coliform conditions were evaluated using two methods of measurement, concentration and load. It is important to note the distinction before attempting to review the findings of this study. Concentration is defined simply as the number of fecal coliforms counted in a given volume of water. The counts are expressed as organisms per 100 mL of water. Load refers to the total number of fecal coliforms flowing down a stream over a specified period of time. It is calculated by multiplying the concentration by streamflow during a specified time period. Concentration is of most value when relating data to water quality standards, but load is of greater importance when the objective is to identify and quantify sources.

6. The routine monitoring data indicated tributary waters adjacent to developed areas in both the Minter and Burley/Purdy watersheds violated the state water quality standard (concentration) for fecal coliform bacteria. Tributary waters near undeveloped areas generally met the fecal coliform standard.

7. Fecal coliform loads from all undeveloped upstream areas were well below loads observed in developed stretches located downstream.

8. Fecal coliform concentrations appeared to increase during the summer months in the developed downstream creek stretches. However, no significant seasonal changes in fecal coliform loads were evident. These findings indicated the discharge from fecal coliform sources was relatively constant over time, being diluted during periods of high flow and concentrated during low-flow periods.

9. A brief overview of land-use characteristics, soil types, and fecal coliform loads from the watersheds' streams is given in Table 1. In Minter Watershed, nearly 70 percent of the loading originated from upper Minter Creek. Similarly, in the Burley/Purdy Watershed, nearly 80 percent of the load came from upper Burley Creek. Any cleanup actions undertaken should initially focus on these two areas.

10. It was not possible to clearly identify and quantify specific sources of fecal coliform pollution based on data collected during the study even though the effort to do so was quite intensive. There were a number of complicating factors where many small, diverse sources were involved. Land-use and soil type, proximity of sources to streams, stream-bank vegetation, fecal coliform die-off and re-growth, and variations in stream flow all were important factors. However, the results did tend to show that:

    a. Streams were the dominant source of fecal coliforms reaching both estuaries.

    b. Homes along the perimeter of Minter Bay did not appear to be a significant bacteria source. Shoreline development may have affected water quality in Burley Lagoon slightly. Isolated shoreline sources may exist in both bays.

    c. Incoming marine waters had low bacteria levels and were not identified as a problem.

    d. Sea birds were not a significant fecal bacteria source.

11. About 50 percent of the Minter Watershed segments and 75 percent of Burley/Purdy stream segments produced measurable fecal coliform loads. Many of the segments had mixed residential-agricultural use. It was not possible to determine which sources were the most important in mixed segments. Planning and enforcement efforts should address these segments as a single category.

12. Fecal coliform stream loads increased as much as several hundred times during heavy rains. Estuarine and shellfish concentrations responded to the changes; however, shellfish levels did not increase as readily as water. Rainfall intensity and duration may be as important as seasonality in causing fecal coliform contamination.

13. There was no discernible pattern in bacterial species composition for any particular stream. The incidence of Escherichia coli (an enteric coliform bacteria residing mainly in mammalian intestinal tracts) and Klebsiella sp. (found mainly in nature but also in mammals) appeared to be associated more with environmental factors (temperature, light, nutrients, sediments, etc.) than land use. Escherichia coli dominated at all sites. Salmonella paratyphi-A, a pathogenic coliform, was found near the mouth of Bear Creek once in four samplings.

Table 1. Land-use characteristics, soils, and fecal coliform loads along the major tributaries in Minter and Burley/Purdy Watersheds.

	Land-Use Characteristics (percent)				Soils		Load
	Resi-dential	Agri-tural	Other[1]	Total Developed	Good[2]	Poor[3]	(Percent)
Minter Watershed							
Unnamed Creek	12	20	7	39	48	52	9
Huge Creek	10	6	16	32	17	83	24
Upper Minter	10	9	14	33	17	83	67
	(Total annual load into Minter Bay: 11.8×10^{12} FC/yr)						
Burley/Purdy Watershed							
Bear Creek	16	9	8	33	15	85	10
Upper Burley Creek	19	6	6	31	39	61	78
Purdy Creek	10	4	2	16	15	85	12
	(Total annual load into Burley Lagoon: 31.3×10^{12} FC/yr)						

[1]Commercial, forestry, wetlands, etc.
[2]Soils type A; Plates 2, and 4.
[3]Soils types B, C, D; Plates 2, and 4.

14. Fecal coliform concentrations in the streams draining into Minter Bay were typical for western Washington streams in general. This finding plus the fact that the watershed was only moderately developed indicated the estuary was extremely sensitive to fecal coliform pollution. Small changes in land use appeared to have a significant adverse impact on oyster culturing operations. Similar problems existed in Burley Lagoon although the sensitivity did not appear as great.

15. Overall, Burley/Purdy streams contained concentrations of fecal coliform bacteria about three times higher than Minter Bay streams. But concentrations in the waters and shellfish of Burley Lagoon were only about one-third of the levels observed in Minter Bay. Likewise, violations of state water quality standards occurred less often in Burley Lagoon. Dilution is probably the reason. The volume of Henderson Bay waters that circulate in and out of Burley Lagoon is about eight times greater than that of Minter Bay.

16. There was good correlation between fecal coliform concentrations in the waters and shellfish of Burley Lagoon. There was also a significant correlation between rainfall and fecal coliforms. These relationships were not apparent in Minter Bay, possibly due to greater data variability.

INTRODUCTION

Since 1980, six commercial oyster-growing areas in Puget Sound have been partly or completely closed because of bacterial contamination (Saunders, 1984). These include Burley Lagoon, Minter Bay, Henderson Inlet, Port Susan, Eld Inlet, and Penn Cove. Other areas are threatened. In response to growing concerns expressed by private industry and the public, a Shellfish Advisory Committee was formed in 1982 to provide a unified response to the problem. A wide range of interests are represented on the committee. These include shellfish industries, local planning and environmental health departments, and state agencies involved in environmental matters.

As a committee member, the Department of Ecology (WDOE) agreed to develop a shellfish protection strategy addressing the problem (Saunders, 1984) . The Department also agreed to devote "one intensive survey per year to shellfish-culturing areas with the area to be determined annually in cooperation with the Shellfish Advisory Committee." The purpose would be to identify, to the extent possible, specific sources of bacterial pollution and provide a framework for addressing similar problems in the future. The information collected would be used to make management decisions regarding the problems identified.

Minter Bay and Burley Lagoon were selected for the first and second years of study because of chronic bacteria problems. Also, both areas are relatively small and have well-defined watersheds suitable for efficient study. This report documents the results of the investigations conducted during 1983-85. Recommendations are presented based on these findings.

REVIEW OF PREVIOUS INVESTIGATIONS

During 1978-80, the Departments of Social and Health Services and Ecology performed water quality and shellfish tissue studies in Burley Lagoon and Minter Bay (Thielen, 1980; Clark, 1980; Clark and Determan, 1981). The findings of these and other studies resulted in the closure of both to shellfish harvesting. Followup studies by the U.S. Food and Drug Administration (FDA) during 1981-82 showed that bacterial conditions in both estuaries were still degraded (Furfari and Carr, 1982). Neither met the approved growing-area criteria of the National Sanitation Program during either dry or wet weather. The two areas have been closed since that time. However, two major shellfish producers continue to rear shellfish in these two areas and purify the adult crop at other locations.

The FDA study provided the impetus for the present effort. The key conclusions are listed below:

1. Pollution from Burley Creek increased total and fecal coliforms in Burley Lagoon to unacceptable levels during wet-weather studies. Most of the pollution load came from Bear Creek and the lower stretch of Burley Creek.

2. The dry-weather Burley Lagoon study indicated that pollution sources were present along the shores of Burley Lagoon and not confined to freshwater stream contributions.

3. During wet weather, Minter Creek contributed to raising the total and fecal coliforms in Minter Bay to unacceptable levels. Fecal coliform-fecal streptococcus ratios indicated the organisms to be of animal origin.

4. The total bacterial load from Minter Creek and its tributaries was relatively low, but was spread through the entire length of the bay to elevate bacterial counts. Stratification in January compounded this.

5. Fecal contributions into Minter Bay were not confined to Minter Creek and its tributaries. Fecal coliform-fecal streptococcus ratios, sediment samples from Minter Bay, and total and fecal coliform comparisons indicated local influences in the bay.

Based on these conclusions and other information, it was determined that detailed followup surveys were needed in the drainages and along the shorelines of both estuaries. The FDA study generally characterized the feeder streams and shoreline inputs as the major sources of coliform loading, in that order of importance. Specific sources were not identified or quantified. Such information was needed before an effective approach to pollution control could be developed for either estuary. A baseline of data on soil characteristics, land use, seasonal changes in ambient water quality, and cause-and-effect relationships was required. The present study was initiated in response to this need.

OBJECTIVES

The objectives which are the same for both estuaries follow:

1. Characterize baseline levels of coliform bacteria in watershed creeks and each estuary.

2. Locate specific sources of bacterial contamination in the watersheds and along the shorelines of the bay.

3. Evaluate non-point source pollution associated with various land-use types.

4. Estimate the total annual fecal coliform load to the marine receiving waters.

5. Relate environmental and water quality data to levels of contamination in shellfish.

6. Recommend methods for reducing or controlling existing coliform sources and preventing future pollution.

7. Develop a standardized approach for investigating future sanitation problems similar to those facing Burley Lagoon and Minter Bay.

LOCATION AND DESCRIPTION

Minter and Burley/Purdy Watersheds are located near the north end of Henderson Bay in Carr Inlet, about ten miles northwest of Tacoma, Washington (Figure 1). Land use surrounding Burley Lagoon and Minter Bay is a reflection of early development patterns. Permanent white settlements were established by immigrants in the 1850s drawn by fishing and logging interests. Lumber mills were often built in protected harbors, marking the beginning of the towns that now exist. Substantial population increases coincided with the end of World War I and again during World War II due primarily to activity at the Bremerton Naval Shipyard. From 1970 to 1980, the population nearly tripled from 3,300 persons to aproximately 10,000 (L. Weisser, U.S. Census Bureau, personal communication). Much of this population has settled in scattered housing developments and subdivided small tracts. Small subsistence farms are evident in many areas. Much of the growth has taken place along the small creeks and streams which ultimately discharge to the embayments under study.

The Burley Lagoon and Minter Bay tide lands were originally sold to producers under the Bush Act of 1895 (Jerry Yamashita, oyster grower, personal communication). Oyster beds at Burley Lagoon have been continuously worked since 1900 to present. Beds within Minter Bay have been worked since 1941. The present operator has expanded oyster production outside Minter Bay into Henderson Bay during the last twenty years (Harold Wiksten, oyster grower, personal communication). Burley Lagoon and Minter Bay both are considered to be quite good areas for oyster production.

Geology and soil characteristics are important considerations in evaluating the susceptibility of a waterbody to bacterial contamination. As is the case for the Puget Sound basin in general, the most recent glacial activity is responsible for most of the physical characteristics of Burley Lagoon and Minter Bay. Till or hardpan was the major deposit of this activity. Till is a compact blend of cobbles, pebbles, silt, and clay, varying from one to fifty feet in depth. Although usually impermeable, openings in the till are present as soft, sandy areas of high permeability. Most of the overlying soil in the Minter/Burley area is comprised of a soft topsoil layer of varying thickness. This causes high water tables because runoff is not able to penetrate deeper than the thickness of the topsoil. Exposed clay layers are present along the shorelines of the estuaries, sometimes underneath fine silt or sand.

The region enjoys a maritime climate, typified by short, dry summers and prolonged, mild, wet winters. Storms or moisture-laden air usually approach the Minter/Burley area from the southwest. Existing rainfall records for nearby Grapeview, Washington, show average annual rainfall to be about fifty-two inches (National Climatic Center, 1982). The greatest monthly rainfall totals occur from November through January; the least from June through August. Ambient temperatures in this area are moderated by Puget Sound. Summer highs are seldom more than 70°F, while wintertime lows are usually in the 30- to 40°F range.

Both Burley Lagoon and Minter Bay are classified as AA marine water (WAC 173-201-085[21] (WDOE, 1980). Clam, oyster, and mussel rearing, spawning, and harvesting are included in the list of beneficial uses to be protected by this classification. Streams and creeks that drain the upland watersheds of these estuaries also are classed as AA because they are "tributaries" to class AA marine waters (WAC 173-201-070[6]- General Classifications). Class AA (Extraordinary) waters are given the highest level of protection in the state.

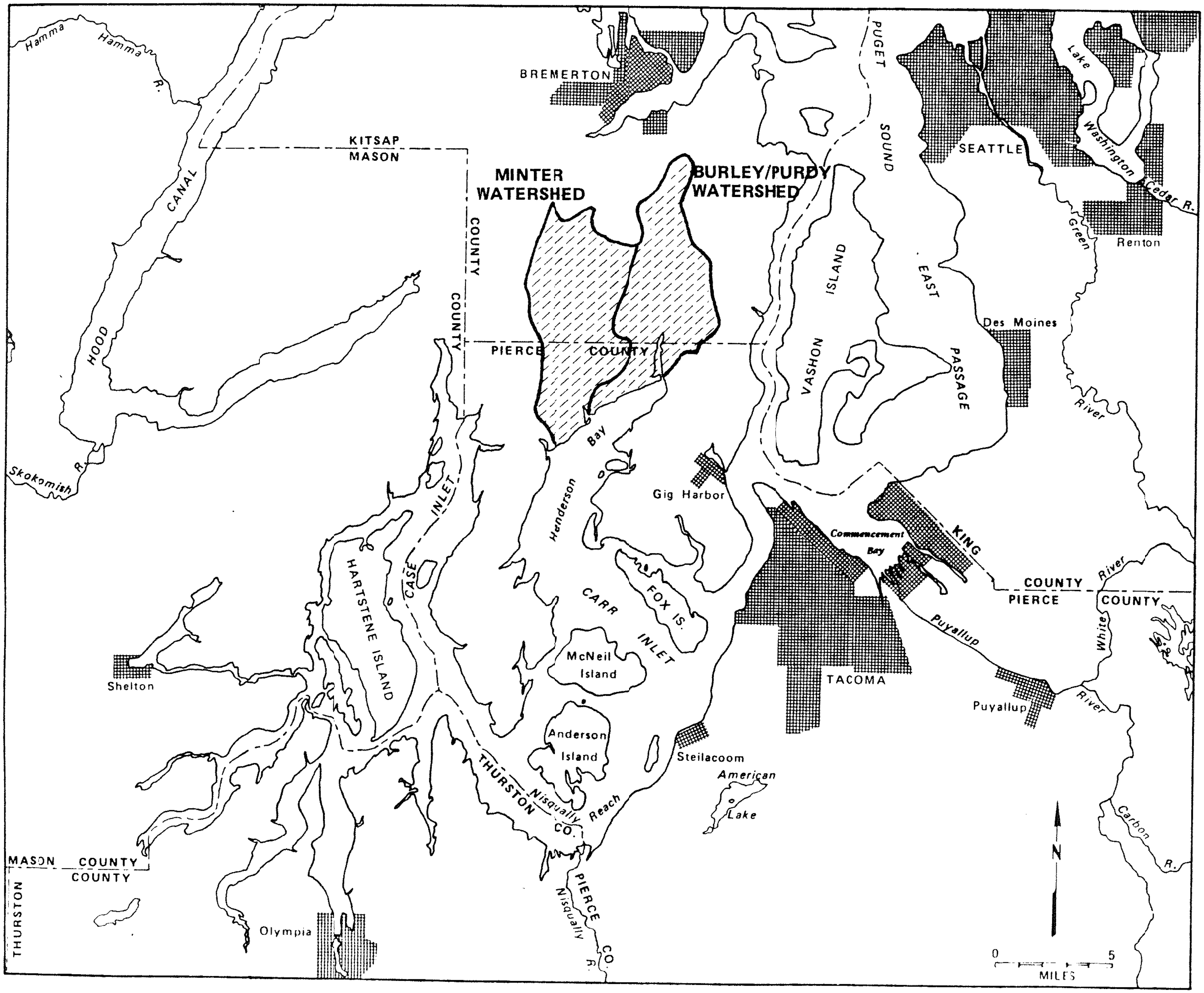


Figure 1. SOUTHERN PUGET SOUND SHOWING MINTER AND BURLEY/PURDY WATERSHEDS

Numerical criteria for fecal coliforms in Class AA (extraordinary) waters are as follows:

Part 1: Fecal coliforms are not to exceed a geometric mean of 14 FC per 100 mL (marine) or 50 FC per 100 mL (freshwater);

Part 2: Not more than 10 percent of samples are to exceed 43 FC per 100 mL (marine) or 100 FC per 100 mL (freshwater).

METHODS

Minter and Burley/Purdy watersheds were evaluated individually. However, the same investigative format was used for each evaluation. The study approach included three main elements: baseline monitoring, intensive surveys, and supplemental studies.

Baseline Monitoring

The goal of this program was to provide a baseline of water quality data for both watersheds and associated estuaries. Data were collected at the mouths and headwaters of the creeks and their tributaries. Several smaller tributaries draining undeveloped subbasins (Burley/Purdy Watershed only) were also sampled as controls. Two sites were sampled in both Burley Lagoon and Minter Bay. A mid-bay site over oyster beds was sampled during receding tide, and a site at the entrance of each estuary was sampled during rising tide. Mid-bay sites were sampled to characterize water quality in the enclosed embayments. Samples taken at the entrances measured the quality of incoming water from Henderson Bay.

Samples were collected every other week from January 10, 1983, to December 12, 1983. Each watershed was sampled on separate days during winter and autumn. Both were sampled on the same day during the long daylight hours in spring and summer. Inclement weather or unfavorable tides caused occasional data gaps in the estuaries.

Figures 2 and 3 show stations sampled during most studies. These studies are identified in the box located under each station name. The names of stream sampling sites are identified by a code which includes the first or first several letters of the river name followed by the upstream distance in river miles. Mid-estuary sites are MES and BES for Minter Bay and Burley Lagoon, respectively. Likewise, stations located at the estuaries' mouths are MEX and BEX.

The following physical and chemical parameters were measured at each sampling station:

Field	Laboratory	Laboratory (cont'd)
Temperature (°C)	pH (S.U.)	Ammonia-nitrogen (mg/L)
Salinity (ppt)*	Specific Conductivity (umhos/cm)**	Total Phosphate-P (mg/L)
Flow (cfs)**	Turbidity (NTU)	Orthophosphate-P (mg/L)
	Total Suspended Solids (mg/L)	Fecal Coliform (MF) (fc/100 mL)
	Nitrate-nitrogen (mg/L)	Fecal Coliform (MPN) (fc/100 mL)
	Nitrite-nitrogen (mg/L)	Fecal Coliform (MPN) (fc/100 g)** (shellfish tissue)

*Saltwater stations only
**Freshwater stations only

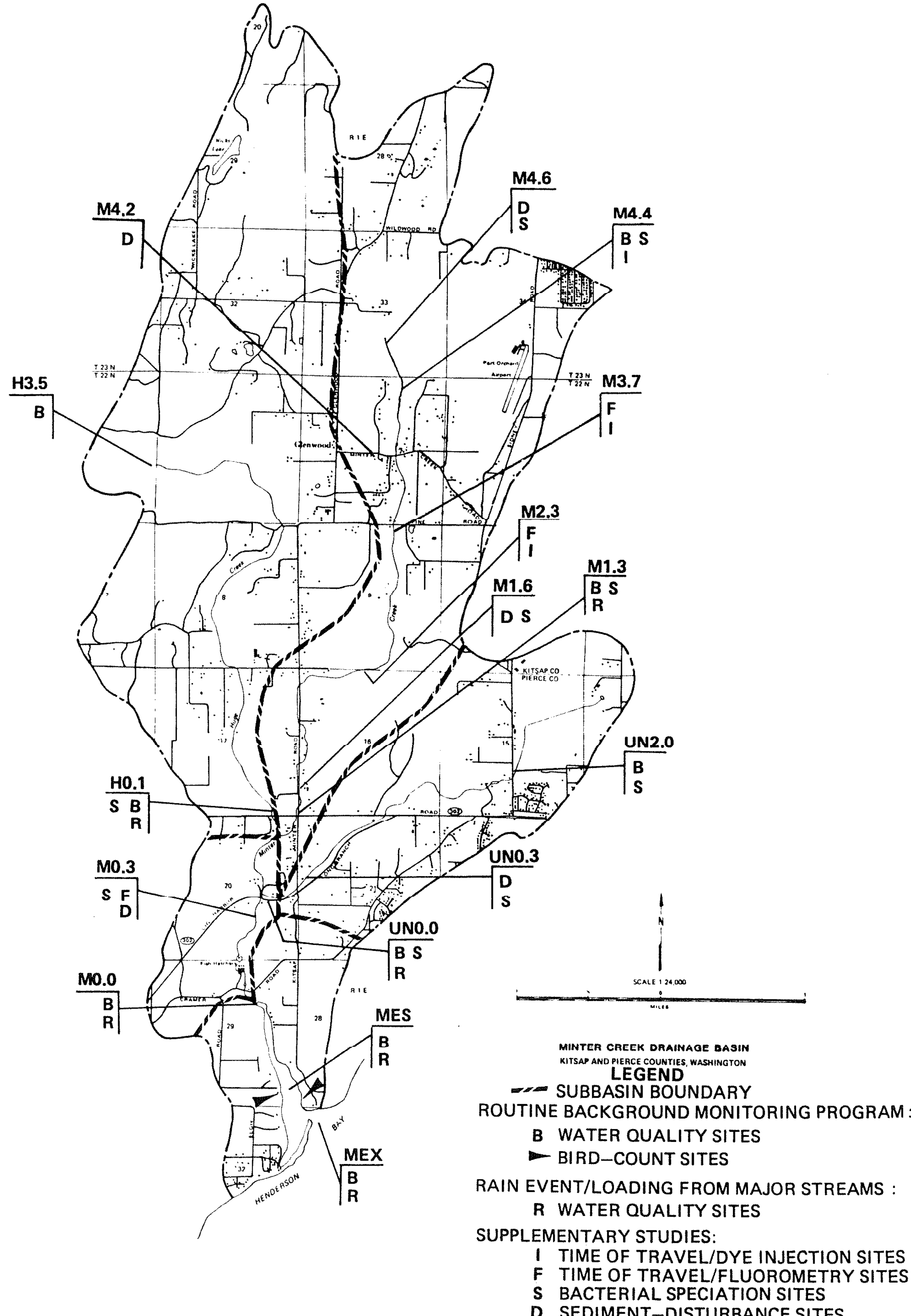


Figure 2. STATIONS SAMPLED DURING VARIOUS PROGRAMS AND STUDIES IN MINTER WATERSHED IN 1983.

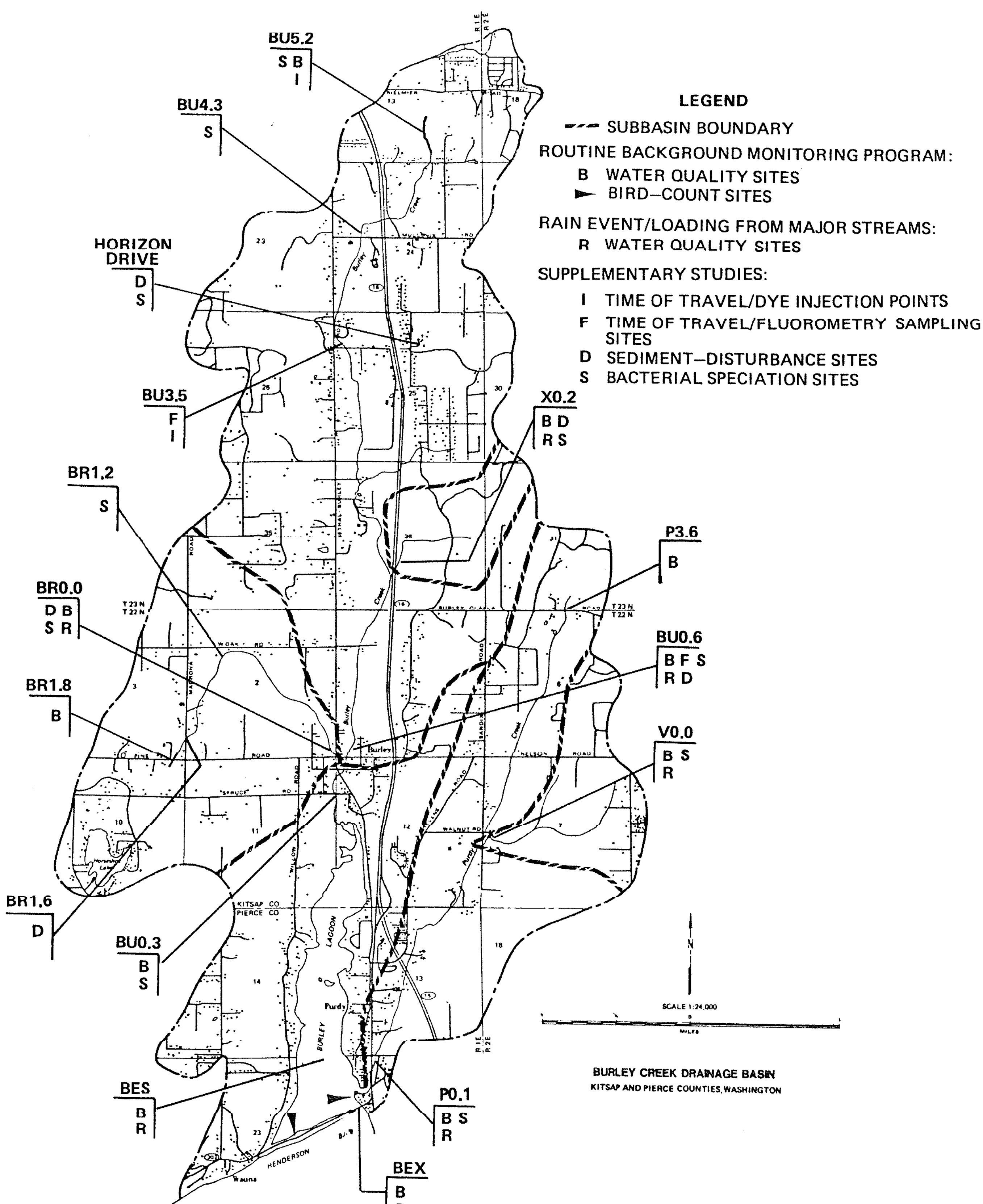


Figure 3. STATIONS SAMPLED DURING VARIOUS PROGRAMS AND STUDIES IN BURLEY/PURDY WATERSHED IN 1983.

Shellfish samples were collected directly from the growing beds at each mid-bay site when water samples were taken. From fifteen to twenty oysters were taken with a sampling net and rake initially and a tonging tool later. Ten oysters were selected for analysis after examination for condition and uniformity in size.

There were some adjustments in the sampling program as the study progressed. Prior to March 22, the membrane filter (MF) procedure was used for both freshwater and estuarine samples. After March 22, the most probable number (MPN) method (96-hour, EC medium) was adopted for estuarine samples to be compatible with current DSHS- and FDA-recognized methods. DSHS uses a modified MPN procedure (24-hour, A-1 medium) while WDOE does not. However, periodic quality assurance checks on split water and shellfish samples showed good agreement between the WDOE water laboratory and the DSHS shellfish laboratory.

Both MF and MPN analyses were performed on all estuarine samples during the remainder of the study. MF values were generally less than those done by the MPN method. Correlation analysis was performed on log-transformed data ($n = 71$) using a Hewlett-Packard HP 25 programmable calculator. Correlation was found to be highly significant ($r = +0.95$; $p = 0.05$; Sokal and Rohlf, 1969). Least squares regression was then performed (Hewlett-Packard Co., 1975). The following equation was used to estimate FC (MPN) values from FC (MF) results obtained earlier in the study.

$$\log_{10} FC(MPN) = 0.95 \log_{10} MF + 0.23$$

The use of loads provides a means of making quantitative comparisons among streams. Fecal coliform loads were calculated using Kittrell (1969):

$$\text{FC load (FC per day)} = [FC] \times Q \times 24.6 \times 10^6$$

where: [FC] = fecal coliform count (No. per 100 mL)
and: Q = stream flow in cubic feet per sec. (cfs)

The formula was adjusted slightly for different studies. Fecal coliform loadings expressed as FC per second changed the constant (24.6×10^6) to 284.7.

A detailed description of the parameters sampled including units, methods of analysis, and applicable standards, is given in Appendix B. The fecal coliform standard for shellfish is that used by the U.S. Food and Drug Administration (FDA) and the Washington State Department of Social and Health Services (DSHS) to determine their marketability (Houser, 1965).

In addition to the water quality data, estimates of the numbers of birds and bird species were made in the estuaries. Identifications were made using Peterson (1961). Replicate counts were taken within a fixed area that was consistently used. Time of day, tide conditions, light, water conditions, etc. contributed to some variation in the results.

Daily rainfall data were obtained from workers at the Minter Creek Department of Fisheries Salmon Hatchery. These data are collected for the National Weather Service (NWS). A standard NWS rain gauge is read at 8:00 a.m. each day.

Historical rain data were collected at Grapeview, Washington, on Case Inlet, about seven statute miles WSW of the hatchery (National Climatic Center, 1982). The period of record is 1951 through 1980. The data were provided by state climatologist Howard J. Critchfield (Western Washington University).

Intensive Surveys

Intensive surveys were conducted to fulfill specific objectives of the study. The surveys describe pollution mechanisms basin-wide, within tributaries, and within segments of streams. In this manner, both point- and non-point sources could be located and their effects measured.

Land-use Evaluation

Data from other sources were used to examine land-use patterns and suitability of soils for septic tank/leaching field disposal systems.

Land-use maps were constructed for each watershed using existing maps from Pierce and Kitsap Counties planning agencies, and aerial photographs. Black-and-white photographs were obtained form the Washington State Department of Natural Resources. These were taken in 1981. In addition, infrared photographs from Hoppus (1984) were examined. Plates 1 and 3 (inside rear jacket) are the results.

Soils maps were adapted from U.S. Department of Agriculture (1979, 1980) soils surveys. The soil classifications and the boundaries shown on Plates 2 and 4 (inside rear jacket) are taken directly from the soils surveys without modification. The codes specifically address the ability of the soil to absorb and retain leachate from a septic system.

The relative cover of each category of soils was estimated by repeatedly placing a quadrat with 81 interior grid points on each soils map. The general soil caregory (A, B, C, or D) under each point was tallied. Percent cover was calculated as the number of points in each soil category divided by the total number of points in all categories multiplied by 100.

Both land-use and soils maps were reproduced from U.S. Geological Survey 7.5-minute Quadrangle series with 1:24,000 scale (1 inch = 2000 feet).

In order to determine the effects of land-use practices on stream quality, information from the following elements and results of the supplemental studies were combined into a segment-by-segment discussion.

a. Observations and fecal coliform results from the streamwalks.

b. Loading data gained during dry-period and storm-event sampling within tributaries.

c. Land-use and soils maps.

d. Results of certain supplemental studies.

Streamwalk Surveys

Streamwalk surveys were carried out during April and May 1983 to locate and identify point sources along streams and tributaries in each watershed. Surveyors walked along creeks and collected a single fecal coliform sample from each drain, ditch, or side tributary. Replicate samples were also taken in the main stream near land-use boundaries. Samplers recorded land-use patterns, animals sighted, and other observations (Appendix D).

Information collected from these surveys was used to help establish correlations between various land uses and inputs affecting water quality.

Rain-Event Studies

Past studies have shown that the effects of pollution within a developed watershed tend to be greatly amplified during periods of intense rainfall (Jackson and Glendening, 1982). Typically, stream pollution increases after watershed soils become saturated and runoff occurs. In some watersheds, pollution levels tend to rise rapidly after wastes on the ground are washed into the streams and then level off after the initial material is washed away. In others, elevated pollutant levels persist during a rain event due to constant high rate of waste generation within the watershed.

Two types of rain-event studies were performed. In the first type, intensive sampling was performed over several days of heavy rainfall to describe fecal coliform loading in the major streams of Burley and Minter watersheds. A combination of weather forecasts and on-site observations were used to time each study. Each study was begun as soon it appeared that a prolonged rainfall had commenced and was continued until the rainfall tapered off. Sampling was carried out from February 8 through February 10, 1983, in the Minter Watershed. Burley Watershed was sampled from March 7 through March 10, 1983. All sampling was done during daylight hours.

A sampling site was maintained at the mouth of each major tributary during the studies. Each site was sampled several times each day. During the Burley study, two small streams from undeveloped subbasins were sampled. These served as "controls" against which results from developed basins could be compared. No suitable control site was available in Minter Watershed.

Each day, two sites within each estuary were sampled; the mid-bay site located over shellfish beds, and the site at the mouth of the estuary. These sites were sampled several times during the day at Minter Bay. One set of samples was taken daily at each site in Burley Lagoon. The mid-bay site was sampled during ebbing tide, and the entrance site during rising tide. The samples were taken at a depth of about 10 cm.

Water quality parameters included fecal coliform densities (water or shellfish, MF or MPN), temperature, total suspended solids, turbidity, nutrients, conductivity (or salinity), and stream flow. Field and laboratory methods are discussed in Appendix B. Fecal coliform samples were taken during each run, while other variables were measured once a day.

Instantaneous FC loadings were calculated using a method from Kittrell (1969) which was described earlier.

Another type of rain-event study was performed along each major stream in both watersheds. In theory, sampling sites were to be placed at the boundaries of "segments" chosen to separate different land-use types. In practice, this proved difficult. Often, different uses occurred on opposite sides of the stream. Also, transitions between uses occurred in isolated places that were too remote for efficient intensive sampling. Therefore, compromise sites were used. All "segment-boundary" sites were sampled under two extremes. First, replicate fecal coliform samples were taken during extended dry conditions in mid-October 1983. Next, rain-event sampling was done at each site on each creek. Minter Watershed streams were sampled in November 1983. Burley streams were sampled in January 1984. Rain-event sampling consisted of fecal coliform sampling at all stations several times during one rainy day. Stream flows were measured once each day. Loading rates for each site were calculated using mean fecal coliform values and flow data.

Supplemental Studies

Supplemental field studies were carried out during the Minter/Burley project to aid in analyzing fecal coliform pathways. These studies address specific questions and are outlined below:

a. Effect of salinity and light on fecal coliform concentrations in waters of the Minter watershed and estuary.

b. Time of travel in Minter and Burley Creeks.

c. Streambed sediment as a reservoir of fecal coliforms.

d. Bacterial speciation in stream water and sediments.

e. The effects of ground water intrusion on water quality in Minter Bay.

f. Distribution of fecal coliform bacteria in estuarine water, sediments, and shellfish.

These studies are found in Appendix A. The results are also discussed in the body of the report where appropriate.

MINTER BAY EVALUATION

Setting

Minter Bay, a long, narrow estuary, is protected from Henderson Bay by a sand spit at its mouth. Total surface area is 80 acres. The volume was estimated to be about 2.5×10^7 cubic feet. This estimate is based on a bathymetric study performed at +15.0 feet above MLLW (Seattle datum, corrected for Wauna). The study was performed on February 2, 1984.

Vacation homes and permanent residences account for most development of the estuary shoreline. The Minterbrook Oyster Company packing plant is located mid-shore on the west side.

Freshwater inputs to the bay originate from Minter Creek and its tributaries. Minter Creek drains along the axis of the estuary in a distinct channel during low tide. The bay also receives water from seeps, springs, and runoff from intermittent streams and ditches. The bay often drains completely during each tidal cycle, leaving the estuary empty. Returning tidal exchange is a freshwater/saltwater mix of Henderson Bay water and a fraction of the contents of Minter Bay from the previous tide. The fraction depends on the size of tidal exchange volume.

Monthly rainfall during the study of both Minter and Burley/Purdy watersheds is shown in Figure 4 together with 30-year monthly averages. The 30-year average annual rainfall was 52.27 inches. The annual total during 1983 (64.17 inches) exceeded this amount by 23 percent. Monthly rainfall in 1983 exceeded the thirty-year averages for 7 out of 12 months. The November total was over 14 inches, nearly twice the 30-year average.

Rainfall was not evenly distributed throughout the year, but tended to be concentrated during short periods. Table 2 shows the distribution of daily rainfall by month during the study. Rainfall of less than 0.1 inch per day occurred two-thirds of the days in the year. Twenty-four-hour rainfall exceeding 1.00 inch occurred on 12 days. The highest daily rainfall occurred on January 5 (2.65 inches) followed by November 4 (2.10 inches). Minimum monthly totals occurred during April and May (1.43 and 1.38 inches, respectively).

Baseline Monitoring

Data collected during routine baseline monitoring in Minter Watershed are shown in Appendix C. Detailed work centered on fecal coliform since it was the most significant problem. Routine sampling sites are shown in Figure 3.

Compliance with Water Quality Standards

Table 3 summarizes the fecal coliform data from Minter Watershed according to compliance with the state water quality standards. The upstream station on Minter Creek (M 4.4) complied fully. However, the upstream sites on both Unnamed Tributary (UN 2.0) and Huge Creek (H 3.5) violated Part 2 of the standard. The upper Unnamed tributary watershed supports extensive animal pasture. The geometric mean at this point was quite high. The upper Huge Creek watershed has recently been clearcut, subdivided, and sold. Failure of the Huge Creek headwaters to comply is the result of several very high FC values obtained during June and July. The flow during the same period was very low. The significance of the high counts is thus probably slight.

The lower, more intensively developed reaches of Minter Watershed streams failed to comply with either one or both parts of the standard. Lower Huge Creek (H 0.1), the Unnamed Tributary, and Minter Creek above the estuary (M 0.0) failed to meet Part 2. Upper Minter Creek (M 1.3) failed both parts.

The mid-Minter Bay station (MES) did not comply with either part of the marine fecal coliform standard. Henderson Bay water flowing into Minter Bay during rising tide (MEX) met Part 1 of the standard. However, an excessive number of samples were higher than the maximum allowed in Part 2.

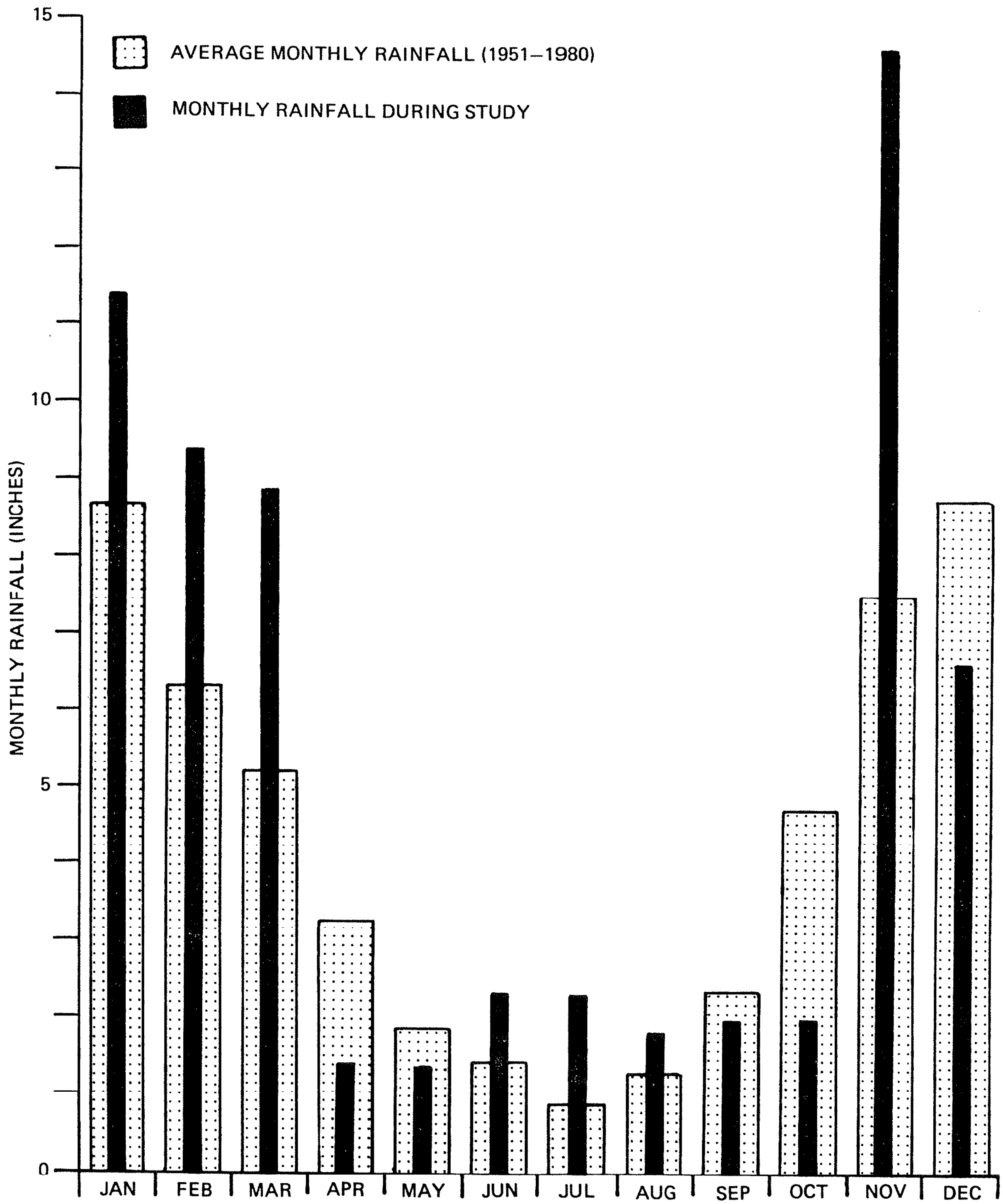


Figure 4. MONTHLY RAINFALL DURING THE MINTER AND BURLEY/PURDY WATERSHED STUDY CONTRASTED WITH 30-YEAR AVERAGE MONTHLY RAINFALL.

Table 2. Rainfall during 1983 at the Minter Creek Salmon Hatchery, Minter Watershed.

	Number of days with 24-hour rainfall (inches) totaling: <0.10	0.10-0.50	0.51-1.00	1.01-1.50	1.51-2.00	2.00-2.50	2.51-3.00
January	13	11	5		1		1
February	11	10	6	1			
March	12	14	3	1	1		
April	25	4	1				
May	27	4					
June	22	7	1				
July	24	6	1				
August	28	1	2				
September	24	6					
October	26	5					
November	9	12	4	3	1	1	
December	19	7	3	2			
Total	240	87	26	7	3	1	1
% of Year	66	24	7	2	1	3	3

Table 3. Summary of compliance with fecal coliform water quality and shellfish marketability standards from all background monitoring stations in Minter Watershed during the period of the WDOE Minter/Burley study.

Station Number	Station Type	No. of Samples	Geometric Mean (FC/100 mL)	Range: Minimum (FC/100 mL)	Range: Maximum (FC/100 mL)	Percent Exceeding Applicable Standards Maximum Limit	Meets Applicable Standards? Part 1[1]	Meets Applicable Standards? Part 2[2]
Minter Creek								
M 4.4	Upstream "control"	24	10	2	86	0	Yes	Yes
M 1.3	Tributary confluence	24	70	4	1350	29	No	No
Huge Creek								
H 3.5	Upstream "control"	24	6	1	1850	12	Yes	No
H 0.1	Tributary confluence	24	30	7	345	12	Yes	No
Unnamed Tributary								
UN 2.0	Upstream site[3]	22	47	2	1150	32	Yes	No
UN 0.0	Tributary confluence	24	50	3	629	25	Yes	No
Minter Mainstem								
M 0.0	Mouth above estuary	24	38	4	323	12	Yes	No
Minter Estuary								
MES	Mid-estuary, falling tide	24	39	9	225	58	No	No
MEX	Estuary mouth, rising tide	23	7	1	103	13	Yes	No
Oyster tissue[4]	Sampled at MES	26	110	5	2400	19	No	N.A.[5]

[1]Part 1: Geometric means not to exceed 14 and 50 FC/100 mL for marine water and freshwater, respectively; 230 FC/100 g for shellfish.

[2]Part 2: Ten percent of samples not to exceed 43 and 100 FC/100 mL for marine water and freshwater, respectively.

[3]Heavy agricultural use upstream from this point; does not fit "control" criteria.

[4]Oyster tissue units are FC/100 g.

[5]N.A. = not applicable.

Saltwater entering the estuary from Henderson Bay had average fecal coliform concentrations of about 7 FC/100 mL. A mid-Henderson station (WDOE ambient station no. CRR 001) located five miles to the south averaged only 1 FC/100 mL. Incoming tidal water is probably returning some of the original fecal coliform load from the watershed contained in the estuary during previous tides. This mechanism was easily seen during daily estuary sampling over the course of a rain event (pages 57 and 103 this report). It is probably erroneous to characterize incoming fecal coliform contamination as a source separate from the watershed. Rather, Henderson Bay serves more as a reservoir of watershed contamination from previous tide cycles.

The mean FC level in shellfish at MEX was within the FDA marketability standard. However, 23 percent of the 26 shellfish samples had FC densities above the limit.

Seasonal Trends in Water Quality.

Fecal coliform data were grouped by two-month periods and transformed to logarithms. This was done to achieve a normal distribution and reduce the biasing effects of very high outlying values (typical of fecal coliform data). The average ($\overline{X}$), "standard deviation" (s), and the quantities ($\overline{X}$ + s) and ($\overline{X}$ - s) were calculated. Then, $\overline{X}$, ($\overline{X}$ + s), and ($\overline{X}$ - s) were retransformed and plotted (Figure 5). The retransformed average is the geometric mean (the height of each thick bar on the graph). The other two values estimate the variation or spread within each two-month period. The values are joined by a vertical "error" line.

All downstream sampling stations showed a rise in mean fecal coliform densities during the summer months followed generally by a dropping off near year's end. The upstream station on Huge Creek (H 3.5) followed a similar seasonal pattern. The Minter Creek upstream site showed a jump in FC densities in July/August, but the data were too variable to show significant seasonality. However, both of these upstream sites exhibit lower mean FC levels than their downstream counterparts. At station UN 2.0 on the Unnamed Tributary, the means were comparable to those at the stream mouth. These results demonstrate the effects of extensive pasturage above UN 2.0. Due to elevated values during November/December, the case for seasonality on the Unnamed Creek is unclear.

Fecal coliform levels in Minter Bay (MES) appear to be somewhat elevated in the warmer months (Figure 5d). This does not appear to be the case for incoming water from Henderson Bay (MEX). However, the variation is too great for a high degree of confidence. Generally, the data suggest that MEX levels are lower than MES due to dilution and die-off of fecal coliform in Henderson Bay.

Fecal Coliform Loading

Geometric means of stream loads by two-month intervals are plotted in Figure 6. The loads generated in the upper reaches of Huge and Minter Creeks were well below those generated in downstream developed stretches. Upper Minter Creek loads (M 4.4) were far greater than those of Huge Creek due to greater stream flow or possibly the presence of a new development of modular housing

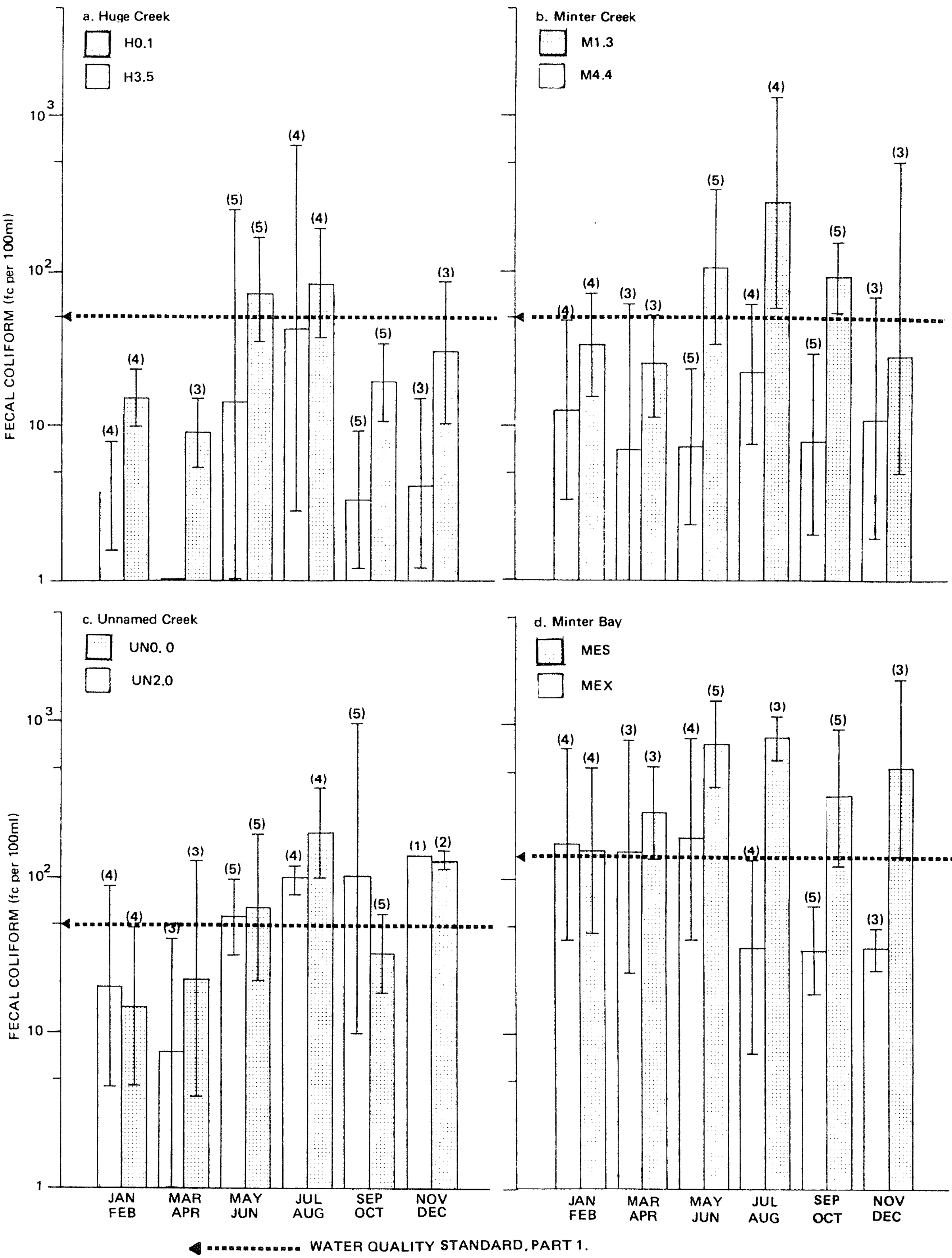


Figure 5. AVERAGE BIMONTHLY FECAL COLIFORM DENSITIES FROM THE MAIN TRIBUTARIES AND THE ESTUARY IN MINTER WATERSHED (GEOMETRIC MEAN ± SD; LOG–TRANSFORMED DATA; (n) = NUMBER OF DATA).

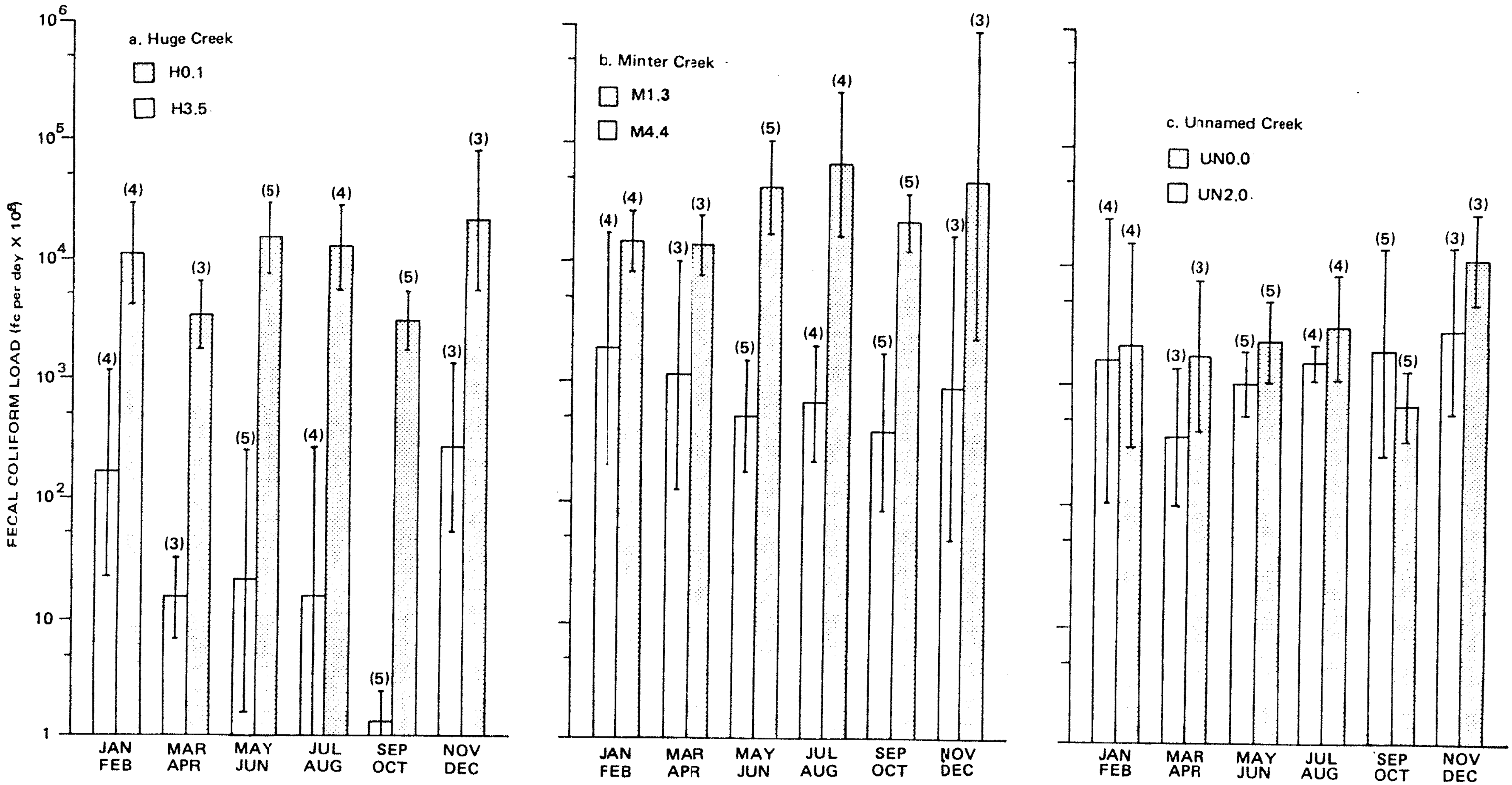


Figure 6. AVERAGE BIMONTHLY FECAL COLIFORM LOADS FROM THE MAIN TRIBUTARIES IN MINTER WATERSHED (GEOMETRIC MEAN ± 1 SD; LOG–TRANSFORMED DATA; (n) = NUMBER OF DATA).

above the station. The loads generated within the upper reach of the Unnamed Tributary (Figure 6c) were similar to loads at the mouth of the stream (UN 0.0). The intensive livestock use upstream of UN 2.0 is a highly significant fecal coliform source on the Unnamed Tributary.

The results shown in Figure 6 illustrate a problem caused by using fecal coliform densities alone in estimating effects watershed-wide. Mean fecal coliform counts at upper Huge Creek (H 3.5, Figure 5a) in July/August are nearly ten times higher than January/February. The implication is that FC loads may be considerably higher in July and August. However, the average stream flow in July/August was about one percent of that of January/February. Therefore, the fecal coliform load (which is proportional to the product of fecal coliform density and stream flow) at H 3.5 in July/August is actually only ten percent that of January/February. This is apparent only when loads are used for making comparisons among different times or places. The use of fecal coliform concentrations are necessary, however, in comparing stream quality with a legally mandated standards and to evaluate the potential for public health problems.

Streamflow at H 3.5 was very low during the summer months. Data from these months were rounded off to zero by the computer (Appendix C). Fecal coliform loads at H 3.5 were calculated from original field data.

Considering the high degree of variability of the data, there is little evidence of significant seasonal trends in fecal coliform loads. Averaged downstream loads from Minter Watershed appear to fluctuate very little seasonally. However, sampling dates during major rain events occurred during January, February, November, and December. If loads associated with those dates are excluded, we find the remaining mean stream loads to be somewhat below those of summer low flow. This suggests that a streamload component exists within developed sections of Minter watershed streams during summer that cannot be explained by rain-generated runoff. One possible explanation is that this component may be derived from survival and regrowth of fecal coliform in stream-bed sediments during the warm months ("Streambed Sediment as a Reservoir...," Appendix A).

Table 4 summarizes fecal coliform loading from Minter Watershed streams. A total annual load was determined for each stream by adding individual bimonthly totals. Bimonthly totals were obained by multiplying the geometric mean daily load (Figure 6) by the number of days in each bimonthly period. The annual load generated from all three creek basins totaled 164,480 x 10^8 FC per year. The upper Minter basin (M 1.3) share was 67 percent of the total. The Huge Creek basin's share was about 24 percent. The Unnamed Tributary contributed about three percent of the total. The pasturage area above UN 2.0 generated about 40 percent of the total load generated within the Unnamed Tributary basin.

The largest load generated per acre was upper Minter Basin which was 2.6 times the basinwide average. The Huge Creek basin generated only 36 percent as much as upper Minter Creek. The Unnamed Tributary generated less than 25 percent of the basinwide value.

Table 4. Fecal coliform load carried by tributaries in Minter Watershed during 1983.

Tributary	Mean Daily Load (FC x 10^8 per day)						Annual Load (FC per year)		
	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec	Total (x 10^8)	Per Acre (x 10^8)	Per River Mile (x 10^8)
Unnamed (UN 0.0)	21.9	17.8	23.4	30.9	6.6	141.2	14,700	3.87	2,040
Upper Minter (M 1.3)	147.9	138.0	323.6	524.8	208.9	457.9	110,050	40.74	28,960
Huge (H 0.1)	107.2	34.7	144.5	125.9	31.6	208.9	39,730	14.52	10,460
Total all Tributaries	277.0	190.5	491.5	681.6	247.1	808.0	164,480	15.65	--
Lower Minter Creek (M 0.0)	418.1	169.6	363.8	224.9	301.6	524.8	118,454	--	--
Relative Load Contribution (%)									
Unknown (UN 0.0)	8	9	5	4	3	17	9		
Minter (M 1.3)	53	72	66	77	84	57	67		
Huge (H 0.1)	39	18	29	18	13	26	24		

The annual FC load carried past Minter Creek mouth (M 0.0) was only 72 percent of the combined load of the three upstream tributaries. During July/August, the load past M 0.0 was one-third that of the combined load of the tributaries. The combined bi-monthly loads from the creek basins tended to be more variable than the observed load at M 0.0 (coefficient of variation = 56.4 and 38.9, respectively). Thus it appears that a load reduction occurs as Minter Creek broadens and deepens in the lower reach. This may be due to die-off in the absence of further input. It may also be due to the adsorption of FC onto suspended material. These then settle out in quiet waters downstream. Water samples were consistently taken from three to four inches beneath the surface of the stream which does not account for streambed load.

Only during January/February did the average daily load at M 0.0 exceed the combined upstream load. Several major storms occurred during this period. The elevated loads may be due in part to entrainment of fecal coliform associated with bottom sediments by high-energy streamflow (McDonald, et al., 1982).

Some evidence for adsorption on sediments was found at M 0.3 during sediment sampling and disturbance experiments ("Streambed Sediments as a Reservoir; Bacterial Speciation", Appendix A). Although FC levels in the sediments were relatively high, virtually no increase in FC in the water resulted from physical disturbance of the sediments. This may indicate that FC adhere strongly to these sediments. We noted that bottom sediments here were coarse in size and settled-out immediately after physical disturbance. Only extremely high flow would be expected to entrain a sediment/FC association.

Correlation Analysis

Correlation analysis was done on several variables that were believed to be directly associated with fecal coliform levels in water and shellfish at the mid-Minter Bay station. The coefficients were calculated with a Hewlett-Packard HP25 programmable calculator and a standardized parametric correlation program (Hewlett-Packard, 1975). The data included those obtained during the Minter rain-event loading study (page 54) in addition to routine background monitoring data. For the purpose of correlation, "rain events" are defined as sampling days preceded by a three-day rainfall event exceeding one inch.

Initial calculations were made with both transformed and untransformed fecal coliform load and concentation data. Since there was little difference in the resulting coefficients, untransformed data were used.

A correlation coefficient, r, ranges in value from -1 to +1. If two variables change in value perfectly in the same direction, r = +1. If two variables change perfectly but in opposite directions, r = -1. If the variables have absolutely no relationship, they change independently and r = 0.

The values in Table 5 were tested for significance by determining a critical r value based on the number of paired variables and the degree of confidence required (Rohlf and Sokal, 1969). If the calculated value of r exceeded the critical r, correlation is significant; if it is less, correlation is statistically unlikely.

Fecal coliform levels at station MES were significantly correlated with fecal coliform loads from Minter Creek. Although significant, the correlation was not large. This suggests that there are other contributing factors.

Table 5. Correlation coefficients (r) from data collected during background monitoring in Minter Watershed.

		Fecal Coliform in water at mid-bay site (MES) (MPN/100 mL)	Fecal Coliform in shellfish at mid-bay site (MES) (MPN/100 g)
Fecal coliform in water at MES (MPN/100 mL)	r	--	0.07
	n	--	23
	test	--	ns
Fecal coliform load from Minter Creek (FC/day)	r	0.50	0.16
	n	22	23
	test	*	ns
Water temp. at MES (°C) including rain events†	r	0.22	-0.22
	n	25	23
	test	ns	ns
Water temp. at MES (°C) excluding rain events	r	0.44	-0.12
	n	21	20
	test	*	ns
One-day rainfall (inches)	r	0.38	-0.05
	n	21	23
	test	ns	ns
Three-day rainfall (inches)	r	0.39	0.23
	n	23	26
	test	ns	ns
Numbers of estuarine birds	r	-0.16	-0.05
	n	18	18
	test	ns	ns

ns = no significant correlation.
 * = significant correlation ($p = 0.05$)
 † = sampling days preceded by three-day rainfall exceeding one inch.

Correlation of fecal coliform levels with water temperature on all sampling dates was insignificant. But correlation with water temperatures recalculated after excluding rain-event dates (on these dates, maximum effects by loading occurred) was significant. Thus fecal coliform levels at the mid-bay site in the absence of rain events were partially linked to seasonal factors.

Creek loading was not significantly correlated with water temperature. That means that loading did not change significantly with season.

These facts suggest that during the summer, elevations in fecal coliform in the estuary may be due in part to factors (FC survivability, regrowth, etc.) within the estuary. There appears to be little evidence that shoreline sources play a major role ("Effects of Groundwater Intrusion," Appendix A).

Fecal coliform levels in the shellfish were not associated with any of the variables, including short-term factors (loading and rainfall) or longer-term factors (season). This may in part be due to variability in the fecal coliform data. Also, bacterial levels in oyster tissue may not always correlate with ambient water concentrations because of physiological influences; e.g., delayed response to fecal coliform loads and residual hold-over.

Correlation analysis provides a time-integrated view of associations among the variables. However, shorter term relationship may appear if we examine individual values over time. Figure 7 shows individual values for fecal coliform loads, three-day total rainfall, estuary fecal coliform concentrations, and water temperature (used as a seasonal factor) plotted over time. Fecal coliforms in shellfish are plotted on each graph to show its relationship with each variable.

Figure 7a shows that routine background monitoring coincided with few major rain events. Such events occurred on January 11, November 15, and December 12. Several minor events occurred in mid-June and September. Shellfish results roughly follow three-day rainfall from January through April. During this period, they would increase immediately during heavy rain events, but would decrease slowly afterward. Until October, fecal coliform levels in shellfish generally increased. During the same period, rain events became less frequent and less intense.

Fecal coliform in shellfish and temperature appear to closely coincide during the late spring and summer (Figure 7b). During November and December, fecal coliform in shellfish remained high, although temperature plummeted. These high values were probably due to increased rainfall.

High fecal coliform values in water and shellfish occurred during major rain events in January, November, and December, and a minor event in late September (Figure 7c). On the other hand, fecal coliform in water and shellfish seemed to increase progressively during summer months when rain events were rare. During the cooler months of the year, except during major episodes of rain, fecal coliform levels in the water were lowest. This finding does not agree with Vasconcelos, et al. (1969) in Burley Lagoon. They found the highest values during winter high runoff and lowest during summer low-runoff conditions.

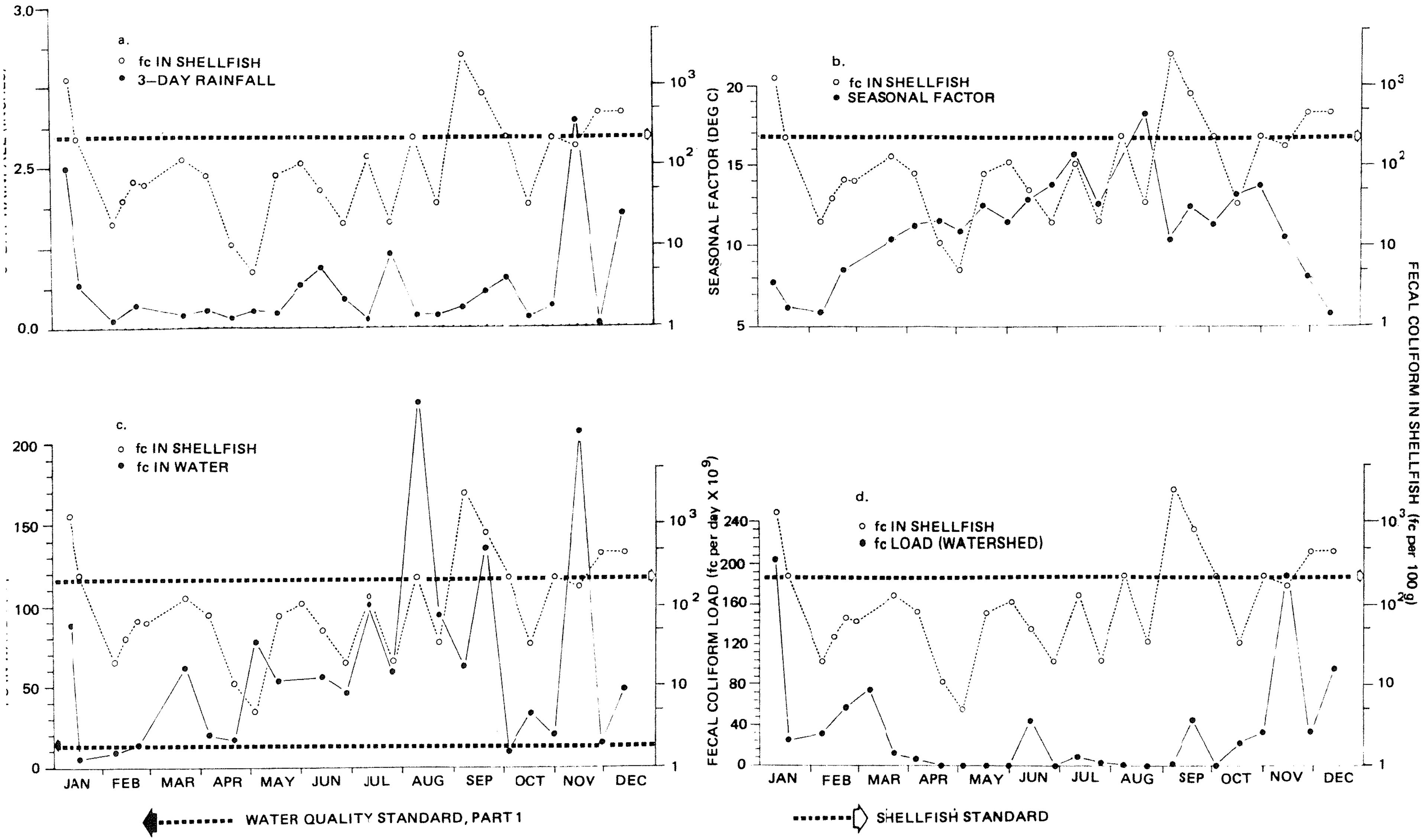


Figure 7. COMPARISON OF SEVERAL VARIABLES IN MINTER BAY COLLECTED DURING ROUTINE BACKGROUND MONITORING.

As expected, maximum fecal coliform loading from Minter Creek (Figure 7d) occurred during major rain events (January, November, and December). At other times, loads and minor rainfall did not coincide. Fecal coliform levels in shellfish seem to respond to loading from April through July. However, through September, shellfish results continued to increase regardless of loads.

The physiology of the oysters may be obscuring simple relationships between the variables. Vasconcelos, et al. (1969) suggest that fecal coliforms in water are readily incorporated into shellfish tissue but die off or are released much more slowly. This may express itself in our data as a lag between fecal coliform results in water and in shellfish. Bernard (1974) found that shellfish filter up to ten times more water at 20°C than at 5°C. Thus, shellfish may accumulate fecal coliform in summer at higher rates. This may explain the net increase in shellfish fecal coliform counts during the summer and early fall. Geldreich (1978) showed that FC concentrations in summer storm water can exceed those in winter storm water by an order of magnitude. Because of these factors, the relatively infrequent rain events during summer may affect oysters more than similar ones in winter.

A summary of waterfowl observations is shown in Table 6. The maximum number of birds and bird species occurred during the winter months when the Burley and Minter estuaries, like other Puget Sound inlets, shelter marine ducks and other birds (Angell and Balcomb, 1982; Steve Herman, Evergreen State College, personal communication). Some species such as gulls and crows seem to be permanent residents in Minter Bay. During the summer, gulls and crows accounted for 70 to 80 percent of the number of birds observed. The relatively large number of these species may be partly explained by the food available at two landfills near Purdy.

Pollution from migrating marine birds is believed by many to be an important problem. However, the analysis shows no significant relationship between the number of birds in Minter Bay and fecal coliform levels in either water or shellfish. This outcome may seem surprising since hundreds of birds can be observed in intimate association with oysters throughout the year. Bernhardt and Yake (1979) summarized densities of fecal coliform in feces from various species of domestic and wild birds and mammals, including humans. Humans from the U.S. discharge 13 million FC per g feces or 117 million FC per day (Fair, et al., 1968). The data suggest that people in India produce a little under two-thirds of the U.S. density. This suggests that diet influences the bacterial flora in the human intestine. Domesticated ducks, chickens, and turkeys produce 33, 1.3, and 0.3 million FC per g feces, respectively (Bernhardt and Yake, 1979). On the other hand, wild birds (robins, English sparrows, starlings, red-winged black birds, pigeons) produced fecal coliform that averaged less than one thousandth the densities produced by domesticated birds. Stated another way, one thousand wild birds may produce less FC than one domesticated bird. Although there is undoubtedly abundant uncertainty in this simple analysis (differences in species, body sizes, and diets), wild birds may have far less effect on background FC levels than first impressions would suggest.

Table 6. Bird counts in Minter Bay taken during background monitoring activities.

Species	Jan		Feb			Mar	Apr		May		June			July		Aug		Sept		Oct			Nov		Dec
	11	18	8	15	22	22	5	20	3	17	1	13	27	11	25	8	22	6	19	3	17	31	15	29	12
Counts not Taken	0	0	0	0										0		0						0			
Common loon *Gavia immer*									X																
Western Grebe *Aechmophorus occidentalis*									X														X		
Double-crested Comorant *Phalacrocorax auritus*					X	X	X		X														X	X	X
Great Blue Heron *Ardea herodias*									X	X	X	X	X		X		X	X	X	X	X		X		X
Mallard *Anas platyrhynchos*						X	X			X	X							X		X			X	X	
Greater Scaup *Aythya marila*								X																X	
Lesser Scaup *Aythya affinis*																							X		
Unidentified Scamp *Aythya sp.*					X	X	X		X																
Common Goldeneye *Bucephala clangula*						X	X																X	X	X
Bufflehead *Bucephala albeola*					X	X	X	X																	X
Harlequin Duck *Histrionicus histrionicus*								X																	
White-Winged Scoter *Melanitta deglandi*								X													X		X	X	
Surf Scoter *Melanitta perspicillata*							X	X	X														X	X	X
Common Scoter *Oidemia nigra*																							X		X
Unidentified Scoter					X	X																			
Hooded Merganser *Lophodytes cucullatus*						X																			
Red-breasted Merganser *Mergus serratus*							X		X												X				
Unidentified duck															X		X								
Bald Eagle *Haliaeetus lencocephalus*																			X		X			X	X
Glaucous-winged Gull *Larus glaucescens*					X	X	X	X	X	X	X	X	X		X		X	X	X	X	X		X	X	X
Bonaparte's Gull *Larus philadelphia*								X	X											X					
Band-tailed pigeon *Columba fasciata*													X												
Belted Kingfisher *Megaceryle alcyon*							X			X			X		X				X		X			X	
Common Crow *Corvus brachyrhychos*					X	X	X	X	X	X	X	X	X		X		X	X	X	X	X			X	
Total Species					6	9	10	8	10	5	4	3	5		5		4	4	5	5	7		10	10	8
Total Count					613	301	226	220	406	66	30	62	50		86		507	154	191	320	446		475	443	757

Intensive Surveys

Land Use and Soils Assessment

The total area of Minter Watershed is about 10,000 acres. One-third is developed to some degree. The remainder is forested (Table 7, Plate 1). The amount of land used for agriculture, mainly animal grazing, is nine percent. Residential land use occupies 11 percent of the watershed. These values compare reasonably well with those of Hoppus (1984).

The term "residential" in Table 7 is applied to all tracts that have a full-time residence. These tracts support a variety of other uses. These include woodlot management through commercial or light-industrial use. The majority are used for small-scale agriculture. The intensity of these uses is highly variable. A resident may maintain gardens and animals one year, but may not the next. Some residents combine agriculture with a business or industry. It is beyond the scope of this work to estimate the relative importance of various other uses on "residential"-sized lots at any particular time. Considering the variability, such an effort would prove to be inaccurate within several years. Since this work was completed, the Pierce/Kitsap County Conservation District has gathered extensive field information on agricultural and wetland (swamps and ponds) acreage. Their information suggests that the figures for these uses in this report may be underestimated (B. McKamey, personal communication). However, the differences relative to the watershed as a whole are probably not significant.

Soils in Minter watershed are generally poor for sewage disposal (Table 8, Plate 2). About half of the watershed is underlain with hardpan which results in saturated surface soils during winter An additional ten percent of the soils are unsuitable because of soil characteristics or topography (category C). The remaining soils are suitable for subsurface disposal.

The northern end of the watershed (upper Minter and Huge Creeks) are dominated by poor soils. Only 17 percent are suitable. In the central part (lower Minter and Huge Creeks), poor soils (categories B and C) cover nearly half of the area. Suitable soils (category A) cover the rest.

The unnamed tributary, the lower end of Minter Creek, and the land surrounding Minter Bay comprise the southern end of the watershed. Good soils cover nearly half of this area. Category B soils cover about a third, and C-type the remainder.

Category D soils are not widespread. These are fine deposits that are generally found along the banks of streams or in stream bottoms; areas that are prone to flooding during peak storm flows. As a consequence, they are usually undeveloped. These soils cover less than one percent of the watershed.

Huge Creek contributed significant fecal coliform loads during routine sampling and rain-event studies. Poor soils probably account for many of the problems here. Most areas near the creek are either poorly drained or underlain by shallow hardpan (Plate 2). This is also where recent large-scale land clearing is occurring. Sixteen percent of the basin has recently been logged. This may affect drainage patterns such that poor soils become saturated faster due to decreased evapotranspiration. This could cause more overland or subsurface flow which, in turn, may affect septic systems and grazing areas.

Table 7. Land Use in Minter Watershed

Land Use	Subbasins					Total
	Unnamed Creek	Huge Creek	Upper Minter Creek	Lower Minter Creek	Estuary Drainage	
Residential						
0 - 2500 ft2 - 0.49 acre	73	0	55	--	15	143
0.5 - 0.99 acre	11	1	6	10	12	40
1.0 - 2.49 acres	23	33	18	3	32	109
2.5 - 4.9 acres	62	197	126	24	39	448
Greater than 5 acres	28	263	78	4	8	381
Subtotal	197	494	283	41	106	1,121
Agricultural	323	294	242	27	48	934
Commercial	7	5	72	--	3	87
Clearcut	7	273	53	--	8	341
Selectively Cut	84	521	166	10	31	812
Scraped	6	--	99	9	12	126
Swamp	--	28	15	--	--	43
Pond	--	11	--	--	--	11
Undesignated	--	217	--	--	1	218
Hatchery	--	--	--	10	--	10
Forest	963	3,234	1,806	417	499	6,819
Total Acreage	1,587	5,077	2,736	514	708	10,522
Percent of Basin Developed	39%	32%	33%	19%	29%	35%
Residential	12%	10%	10%	8%	15%	11%
Agricultural	20%	6%	9%	5%	7%	9%
Other	7%	16%	14%	6%	7%	15%
Percent of Basin Undeveloped	61%	68%	67%	81%	71%	65%

Table 8. Distribution of soils types in Minter Watershed (values are percent ground cover).

Soils Type	Septic System Suitability	Northern (Upper Minter, Huge Creeks)	Central (Lower Minter, Huge Creeks)	Southern (Unnamed trib., south of Minter/Huge Creek Conf., Minter Bay Region)	Total
A	Soils good	17.4	55.2	48.4	40.8
B	Systems do not function well during wet season due to glacial till hardpan	80.2	35.1	33.6	49.2
C	System do not function well during wet season due to soil characteristics and/or topography	2.4	9.7	16.3	9.5
D	Soils not usually developed for residential use	0	0	1.6	0.5

The Minter Creek subbasin above M 1.3 has development proportions very similar to Huge Creek. Upper Minter has about 3 percent more grazing land. Soils are generally good, except close to some parts of the creek. The causes for elevated FC loading may be the presence of many large animals near downstream reaches. Another possibility is that the residential lots south of Pine Road are located on soil not well suited for on-site septic systems.

Agricultural use dominates the Unnamed Creek subbasin. Pastures occupy 20 percent of the area. Residential use takes up 12 percent of the remaining area. The proportion of the watershed that is developed is 39 percent. The Unnamed Creek has the lowest discharge of the three tributaries. In addition, the creek basin has a large proportion of well-drained soils (Plate 2). As a result, this stream was the smallest contributor of fecal loads.

Lower Minter Creek and the estuary drainage has the greatest share of undeveloped land (81 and 71 percent, respectively). Nearly half of the developed component is residential in character. Less than a quarter of the remainder is agricultural. Shoreside residences predominate on the northeast and southwest shores of the estuary. Grazing animals are kept in several fields adjacent to the bay on the east side and on the hilltop above the Minter Creek Hatchery. Minter Creek discharges into the northern end of the bay. Other surface water sources are numerous small seeps and springs and ditch drainage along Creviston Avenue.

In order to quantify the effects of land use on water quality in Minter Watershed streams, correlation analysis was performed on data from the land-use segment studies to be discussed later. A "stream quality index" was calculated for each stream segment in the watershed. This was done by adding the fecal coliform load generated within the segment (positive or negative) to relative fecal coliform level obtained during the dry-period sampling. A "land use index" was determined by ranking soils conditions, housing densities, and animal numbers and adding their ranks. Kendall's Tau (Sokal and Rohlf, 1969) was used to test rank correlation between the "stream quality" and "land use" indices. Correlation was significant (Tau = 0.44, $t_s = 2.93$, $n = 24$, $p = 0.0034$) but not strong. Other interacting factors such as soils type, FC mortality or survivability, degree of sediment in the stream bed, and river flow cloud clear correlations.

Stream Survey Summary

Huge Creek Analysis. The Huge Creek streamwalk took place on March 29 and 30, 1983, during a moderate rain event. Rainfall at the Minter Creek salmon hatchery was nearly an inch per day. During the streamwalk and a few days before, fairly heavy rain fell. A ten-day dry spell preceded this wet period. Rain fell almost every day during the previous two months, so the ground was still quite wet.

Dry-period replicate FC samples were collected on October 4 and 5, 1983, at points in the creek which represented borders between different types of land use. Only a trace of rain was recorded between September 19, and October 4. A trace of rain fell on October 4.

The autumn storm-event study took place on November 3, 1983. The rainfall from 0800 hours on November 2 to 0800 hours on November 3 was 1.66 inches; from November 3 to November 4, 2.10 inches.

These three studies provide information on fecal coliform characteristics of Huge Creek during periods of fairly wet, dry, and very wet conditions, respectively. Huge Creek was divided into five segments. Results are summarized in Table 9 and Figure 8. Three of the five segments contributed net FC loads downstream. Three segments had agricultural, residential, and mixed use, respectively, bordering the stream. Soils were also a factor. Bad or mixed soils were found in three segments, two of which produced loads.

Detailed discussion of each segment follows. Streamwalk observations (Appendix D) are included. Codes for land use and soils types used in the discussion are shown in Plates 1 and 2. Readers not needing a detailed discussion, turn to Unnamed Creek Analysis, page 41.

H 3.5 to 2.5. A large portion of the land near the creek has recently been logged, and is being sold as small agricultural lots. The creek bottom land is a thick, brush-covered bog. North of the creek lies a large section of well-drained Nielton soils with some less favorable Alderwood in the middle of the segment. Two patches of permeable Indianola soil lie south of the creek. They are separated by a large block of Harstine soil which has a hardpan layer starting 24 to 40 inches below the surface.

Fecal coliform results from streamwalk samples were higher at H 3.15 than H 3.5. The source of the violation-level contamination near H 3.15 is not apparent. Only one house was visible from the creek at this point.

Samples at two points downstream also exceeded the standard. At H 2.7 (above a beaver dam) the area is virtual wilderness. No houses are visible. A pasture drain near H 2.45 may have caused the other violation. The soils in the pasture on the east bank have a perched water table in the winter and hardpan layer below. One house is visible at H 2.45, and several horses are pastured here.

During the autumn rain event, fecal bacteria loading was 70 times greater at H 2.5 than at H 3.5. Dry-season samples showed higher values downstream also, though below violation levels. Upstream areas have soils generally unsuited for on-site treatment systems. Grazing land in this stretch is mostly on soils with a perched water table in the winter. Both of these factors become more significant closer to the creek. This segment can be expected to accelerate contamination of the stream as it becomes settled.

Hoppus (1984, Figure 7) shows one septic system failure east of Glenwood Road Southwest and south of Minterbrook Road.

H 2.5 to 1.7. The land bordering the stretch of creek between H 2.5 and H 1.7 is mostly forested with some residential development. Soils on high ground on both sides of the creek are generally good for septic tank drainfields. However, stream bottom land is mucky.

Table 9. Autumn rain-event and dry-period sampling, Huge Creek.

Station	Rain Event (11/3/83) $\bar{X}$ (FC/100 mL)*	Q (cfs)	FC Loading (FC x 10^4/sec)	Dry Period (10/4-5/83) $\bar{X}$ (FC/100 mL)**
H 3.5	24	0.5	0.3	1
H 2.5	132	5.7	21	21
H 1.7	260	8.7	64	3
H 1.3	860	16.0	392	12
H 0.8	720	19.4	398	9
H 0.1	370	21.8	230	3

*Concentration represents the geometric mean of three samples collected over six hours.
**Concentration represents the geometric mean of two replicate samples.

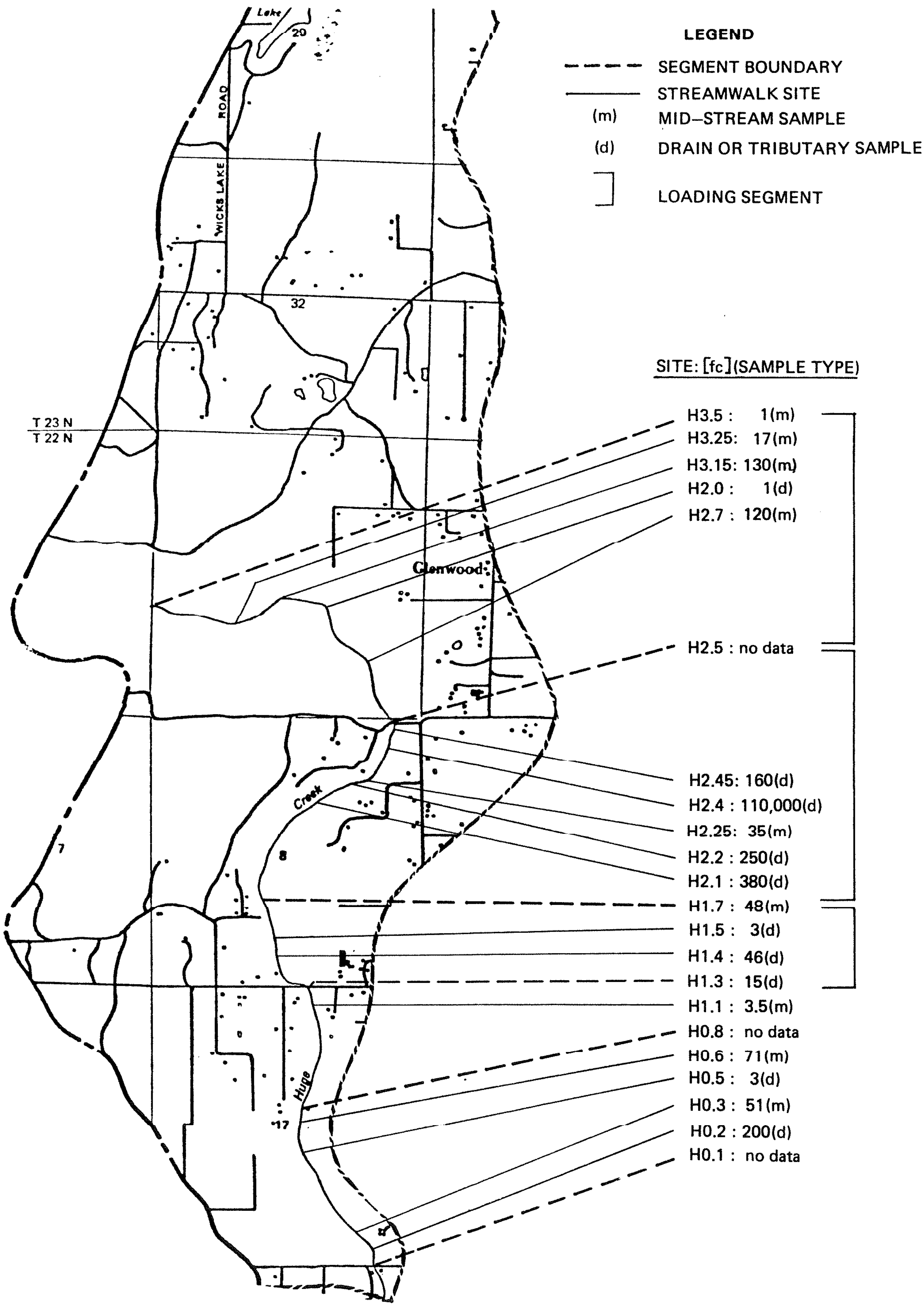


Figure 8. SITES SAMPLED DURING STREAMWALK SURVEYS (MARCH 1983); AND LAND–USE SEGMENTS SAMPLED DURING A NOVEMBER 1983 RAINFALL EVENT ON HUGE CREEK, MINTER WATERSHED.

No houses were seen from the creek during the streamwalk. However, a number of houses line the edge of a high bluff on the east side of the creek. Several drainage inputs in this stretch violated the fecal bacteria standard. One high count (110,000 FC/100 mL) came from a small stream on the forested east side of the creek at H 2.4. There is a cleared area beyond the trees with a small house and an animal pen. A followup sample (taken during an extended dry period) at H 2.4 showed no violation. Two other drainages had fecal concentrations above the standard during the March 1983 streamwalk. The east side seep at H 2.2 had a value of 250 FC/100 mL. There are a few houses 200 to 500 feet from both sides of the creek. The west side input drains a forested area, and had a count of 380 FC/100 mL. A recently built road was observed nearby, but no buildings were visible.

Fecal coliform loading tripled between H 2.5 and H 1.7 during the autumn storm event. In October, samples collected during the dry period showed low FC levels and a slightly decreased downstream concentration. The samples had 21 FC/100 mL and 3 FC/100 mL, respectively. The large FC loading rate in this segment in November 1983 may be related to rapid soil percolation during the wet months (Hagedorn, et al., 1978) such that viable FC bacteria reach the creek from home systems close to the creek. In addition, several homes somewhat removed from the creek on the east side had animal pens.

Hoppus (1984, Figure 7) reports one septic system failure west of Glenwood Road Southwest about 0.6 mile north of Fairview Lake Road Southwest.

H 1.7 to 1.3. A number of scattered homes and a small amount of grazing occur in the stretch of Huge Creek between H 1.7 and H 1.3. The soil quality varies. Some areas have good soil for septic systems, while others, especially near the creek, have poor drainage. No violations were found in streamwalk samples, although Huge Creek at H 1.7 and a stream draining several acres of a west side subsistence farm (H 1.4) had fecal concentrations close to violation levels. Pasture drainage on the west side had a fairly low concentration of 15 FC/100 mL.

During the autumn storm event, fecal loading increased about six-fold from H 1.7 to H 1.3. The dry-period values were only slightly higher at H 1.3 compared to H 1.7, but still very low. Indications are that during wet weather, septic systems in this area (most of which are located on unsuitable soil) add a substantial FC load to the creek.

Analysis of infra-red photographs (Hoppus, personal communication) led to the discovery of two failed septic tank systems (Harriet Ige., Pierce Co. Health Department; Don Miles, Kitsap Co. Health Dept., personal communication). These failures partially affected stream quality within this segment. Although the systems were about 1500 to 2000 feet from the creek, they were close to several drainage patterns which cross pastures and ultimately reach the creek.

H 1.3 to 0.8. Widely spaced houses line the high bank on the west side of the creek between H 1.3 and H 0.8. A small pasture area lies on the east side from about H 1.3 to H 1.1. The soils on both sides of the creek are quite poor for septic tank drainfields.

During the winter wet period, drainfields in this area possibly fail, and fecal bacteria may be transported to the creek. The fecal coliform concentration during the March 1983 streamwalk at H 1.1 was somewhat higher than background levels, possibly due to the slightly elevated levels coming from the large tributary at H 1.4.

Fecal coliform loading during the fall rain event was essentially the same at both H 1.3 and H 0.8. Dry-period samples also had very low FC concentrations at both points. Although this stream segment contributed no additional load at this time, the questionable soils may require some effort in the future to control housing density, maintain adequate distance from the creek, and monitor septic systems.

H 0.8 to 0.1. A vegetated buffer zone, mostly wooded, lines most of the portion of creek from H 0.8 to H 0.12. Extensive pastures lie east of the wooded boundary. Soils near this stretch below H 0.6 are quite good for septic systems.

According to observations made during the March 1983 streamwalk, low-density residential development is taking place on the west side near H 0.6. A log cabin and several mobile homes are nearby. The Harstine soil here has a shallow hardpan. The high FC count at this point may be caused by poorly functioning septic systems which should be tested under wet winter conditions.

Drainage from the pastured east side at H 0.5 had a very low FC concentration. But a sample close to the standard was collected farther downstream at H 0.3 below the large east side grazing area and a few west bank residences. The creek draining east-side fields at H 0.2 also had quite high fecal bacteria concentrations. The creek was fenced in most places between H 0.3 and H 0.2. There were, however, several access points for animals. This area should be investigated for the source of the high FC counts. Fencing the field may decrease loading from such areas as long as other good animal management practices are followed. Direct animal access to the creek should be controlled.

Streamwalk notes from March 1983 indicate that a number of houses are located between H 0.2 and the confluence of Huge Creek with Minter Creek. This lower stretch includes homes and small-scale agriculture. The fecal coliform concentration at the mouth of Huge Creek was below violation level.

Fecal bacteria loading was 42 percent lower at H 0.1 than at H 0.8 during autumn storm monitoring. Dry-season densities were very low at both these points.

Unnamed Creek Analysis. A small amount of rainfall (0.21 inch) fell two days before the Unnamed Creek streamwalk. Four dry days preceded this light shower, but rain had fallen for nine days before this. The soil was probably beginning to dry out after the heavy winter rains, but was still quite wet.

Samples were collected for dry season and autumn rain-event analyses in the Unnamed Creek on the same dates as those in Huge Creek. Weather for these two surveys has been described.

The Unnamed Creek was divided into six segments (Table 10, Figure 9). Three of the six contributed net loads. The uppermost segment (above UN 1.8) is dominated by soggy soils and extensive pasturage. The other two segments have good soils and are residential or light commercial in character.

A detailed description of each segment follows. Readers not needing the detail may advance to Minter Creek Analysis on page 46.

UN 3.1 to 2.0. The land in this boggy headwaters is used for cattle grazing. A chicken ranch is located upstream. The pasture soils are mostly Dupont muck which drain quite slowly. They contain a good nutritional environment for FC bacteria and may allow them greater longevity (Tate, 1978). However, well-drained Indianola loamy sand surrounds the mucky area and includes some pasture land. The pasture is fenced along most of the creek.

A large mobile home court lies above and to the south of the Unnamed Creek on the corner of 94th Avenue NW and Highway 302. The soils in that area are considered suitable for septic systems. However, if a contamination problem occurred, surface flow would probably go toward the creek near UN 2.0 via roadside ditches. Hoppus (1984; Figure 24) reports four probable septic tank failures in this development.

In April 1983 after a relatively dry period, streamwalk fecal concentrations were quite low at UN 2.0 and in a pasture drain at UN 2.15. But the autumn rain-event loading at UN 2.0 was quite high. The samples collected at UN 3.1 were from a drainage ditch which joins several others at about UN 2.15 to form the creek. FC concentrations here were consistently higher than at UN 2.0. The flow at UN 3.1 is typically sluggish. In October 1983, the FC concentration was fairly high at UN 2.0 which indicates fecal loading even when the soil is not saturated. Reports of inadequate manure handling at the chicken farm may partially explain the high FC loading above UN 2.0 (Bea McKamey, personal communication). Despite the well-maintained cattle-raising facilities below the chicken ranch, the muck soils there may sequester FC bacteria which then flow into the creek.

A good site for flow measurements could not be found near UN 3.1. So, net loading from this segment could not be determined and this segment is not included with the three loading segments in Figure 14.

UN 2.0 to 1.8. Several homes with adjoining pastures lie close to the creek between UN 2.0 and UN 1.8. The soils on both sides of the creek are permeable Indianoloa types. However, about a thousand feet north lies another patch of Dupont muck. There are a few homes and some pasture land in this area.

During the April streamwalk, 14 cows and an unknown number of ducks were seen near the creek, and the banks were severely eroded. Fecal bacteria concentrations at UN 1.9 were 66 times higher than at UN 2.0, but the FC concentration at UN 1.8 dropped back to low levels. A subsequent recheck during a dry period did not show unduly high levels in this segment.

Fecal bacteria loading increased by about 14 percent between UN 2.0 and UN 1.8 during the autumn rain event, but an opposite trend is seen in the October samples. The cause of contamination in this segment seems to occur during wet periods.

Table 10. Autumn rain-event and dry-period sampling, Unnamed Creek.

Station	Rain Event (11/3/83) $\bar{X}$ (FC/100 mL)*	Q, (cfs)	FC Loading (FC x 10^4/sec)	Dry Period (10/4-5/83) $\bar{X}$ (FC/100 mL)**
UN 3.1	4555	--	--	--
UN 2.0	1600	5.0	228	45
UN 1.8	1790	5.1	260	30
UN 1.0	900	10.3	264	18
UN 0.4	1100	13.7	429	6
UN 0.3	1130	13.7***	441	13
UN 0.0	780	15.5	344	7

*Concentration represents the geometric mean of three samples collected over six hours.
**Concentration represents the geometric mean of two replicate samples.
***Flow at UN 0.4 used, since stream clogged and out of banks at UN 0.3.

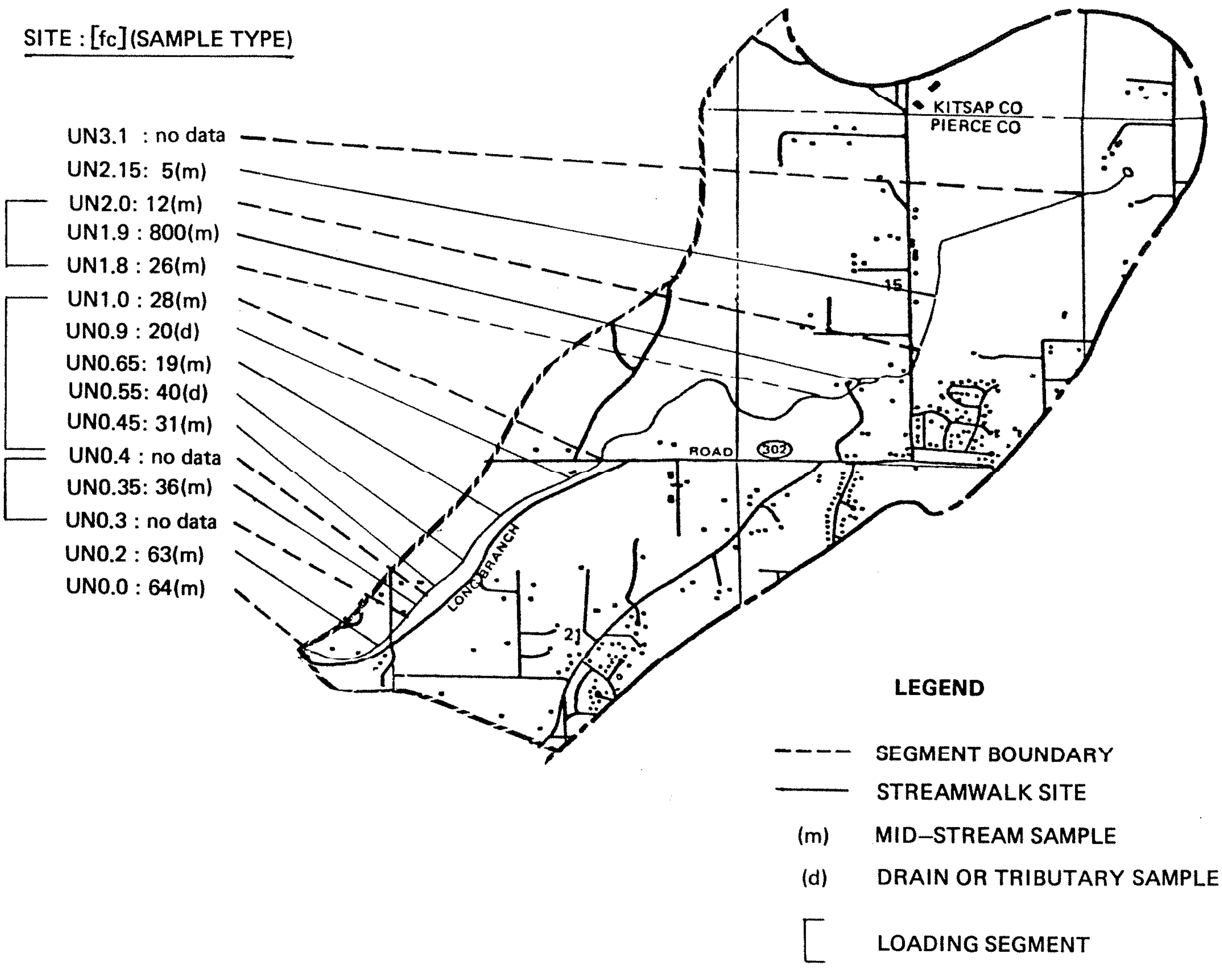


Figure 9. SITES SAMPLED DURING STREAMWALK SURVEYS (MARCH 1983); AND LAND–USE SEGMENTS SAMPLED DURING A NOVEMBER 1983 RAINFALL EVENT ON THE UNNAMED TRIBUTARY, MINTER WATERSHED.

Animal-keeping practices in this reach may be adding to the FC load problem coming from the larger upstream pasture land. Fencing measures and stream bank stabilization may improve the situation.

UN 1.8 to 1.0. The stretch of the Unnamed Creek between UN 1.8 and UN 1.0 is mostly forested along the banks. A short stretch of bog begins at UN 1.8. There are a few homes, some with small pastures. Residential development is located mostly between UN 1.7 and UN 1.5. No animals were sighted during the streamwalk. The soils on both sides of the creek are rated good for septic tank drainfields, and extend quite far from the creek.

Streamwalk fecal samples were taken only at UN 1.8 and UN 1.0. Both were relatively low. No measurable change in fecal loading occurred in the stretch of stream between UN 1.8 and UN 1.0 during the autumn rain event (though all samples were well above violation level). During the October dry-period sampling, fecal bacteria concentration at UN 1.8 and UN 1.0 were within the standard. No noteworthy problems were identified in this stretch. The small pastures require closer examination for good animal management when animals are present.

UN 1.0 to 0.4. The 0.6-mile stretch from UN 1.0 to UN 0.4 is mainly wooded, with several recently built homes near the creek. The soils in the area are classified as generally good for septic tank drainfields. The homes are located rather close to the stream due to constraints imposed by Highway 302 and rather steep relief.

Samples from the creek and from bank drainage during the April 1983 streamwalk were within the water quality standard. Two homes (UN 0.9 - UN 0.45) had chicken coops close to the creek. Fecal loading increased 62 percent in this stretch during the autumn storm sampling, but dry-season samples in October were very low and suggested an opposite pattern.

Although the soils here are well-rated for on-site systems, the drainfields may be too close to the creek for adequate soil treatment during the winter wet season (Hagedorn, et al., 1978). Changes in runoff patterns due to recent development may also affect older drainfield systems. Chickens near the creek may also be a contributing factor.

On March 8, 1984, Harriet Ige, Pierce County Environmental Health Specialist, dye-tested two disposal systems during relatively wet conditions. Dye did not appear in the stream. Three or four disposal systems remain to be checked.

UN 0.4 to 0.3. This stretch of stream includes the Brookside Restaurant and the Minter Veterinary Hospital, both of which lie close to the creek. The soils in the surrounding area are the somewhat excessively drained Indianoloa type, and grassy vegetation covers the bank.

Fecal levels were low and fairly consistent above and below this commercial area during the April streamwalk. But the high FC loading levels found at UN 0.4 carried through to UN 0.3 during the autumn storm sampling. The stream overflowed its banks at UN 0.3 during this storm and flooded the nearby grassy area. On the other hand, October dry-period sampling showed little difference in fecal levels between the two stations. Both were quite low.

A sediment sample collected at UN 0.3 on September 26, 1983 had 5400 FC/100 g, the median concentration of ten samples taken at various locations in the Minter and Burley watersheds ("Streambed Sediment as a Reservoir", Appendix A).

A septic system is shared by both businesses. It was inspected during a rainy period on March 8, 1984 (Harriet Ige, personal communication). On the day before the dye test, 0.98 inch of rain fell at the Minter Creek Hatchery. Rain had fallen every day for 11 days before this, at an average rate of 0.3 inch/day. Ms. Ige's tests showed no failure. Since no other enteric bacterial sources could be identified in this short stretch, upstream sources appear to account for FC loading at both UN 0.4 and UN 0.3.

UN 0.3 to 0.0. The lower 0.3-mile stretch of the Unnamed Creek is mostly wooded. Contrary to most maps, the creek flows under 118th Avenue NW from UN 0.3, along the north side of Highway 302. It then crosses the highway, passes south of Collins Grocery Store, then crosses the highway again to the north side, where there are two houses. It then empties into Minter Creek. Most of the soils in this stretch are good for septic drainfields where the slope is not too great.

During the April 1983 streamwalk sampling, slight violations occurred below Collins Store (UN 0.2) and below the two houses farther downstream.

A 22 percent drop in loading was observed between UN 0.3 and UN 0.0 during the autumn rain event. Dry-period results in October were within the standard. This stretch of creek does not appear to have any major sources of fecal contamination. However, the high counts detected during the streamwalk suggest a need to check the condition of the on-site systems of the houses downstream of UN 0.3.

Minter Creek Analysis. The weather was dry when the Minter Creek streamwalk took place on April 6, 1983. No rain had fallen since April 3, but rainfall for nine days previous to April 3 totaled 3.44 inches. This was preceded by a ten-day dry period which followed a month of near-daily precipitation. Therefore, results obtained during this streamwalk represent fairly wet soil conditions.

The soil was quite dry when dry-period samples were collected on October 4 and 5, 1983, as detailed for Huge Creek. Likewise, the autumn rain-event loading study took place at the same time for all the creeks in the Minter Watershed.

Sediment samples were collected at four locations in Minter Creek on September 26, 1983. The areas were chosen to represent different combinations of factors, such as land use, soil, and distance upstream from the creek mouth ("Bacterial Speciation," Appendix A).

During the autumn rain-event study, Minter Creek was divided into 13 segments along its entire length. Five of 13 segments produced a net load (Table 11, Figure 10). Ten segments showed mixed agricultural or residental use. Seven of the 13 segments had unsuitable or mixed soil types. It is difficult to detect a clear-cut relationship between soils character, land use, and the presence of FC loads. Each segment appears to be unique.

Table 11. Autumn rain-event and dry-period sampling, Minter Creek.

Station	Rain Event (11/3/83) $\bar{X}$ (FC/100 mL)*	Q (cfs)	FC Loading (FC x 10^4/sec)	Dry Period (10/4-5/83) $\bar{X}$ (FC/100 mL)**
M 4.4	640	10.6	193	7
M 4.2	2250	12.5	801	110
M 3.7	2360	18.0	1209	46
M 2.8	1000	20.3	578	31
M 2.2	810	24.0***	553	9
M 2.0	850	24.6	595	5
M 1.9	750	26.4***	564	8
M 1.7	890	28.3	717	51
M 1.6	830	29.4***	695	44
M 1.3	810	32.9	759	51
M 1.0	500	49.2	700	--
M 0.7	630	63.1	1132	50
M 0.3	550	58.5	916	20
M 0.0	550	--	--	8

*Concentration represents the geometric mean of three samples collected over six hours.

**Concentration represents the geometric mean of two replicate samples.

***Flow interpolated from the flow at the next stations upstream and downstream.

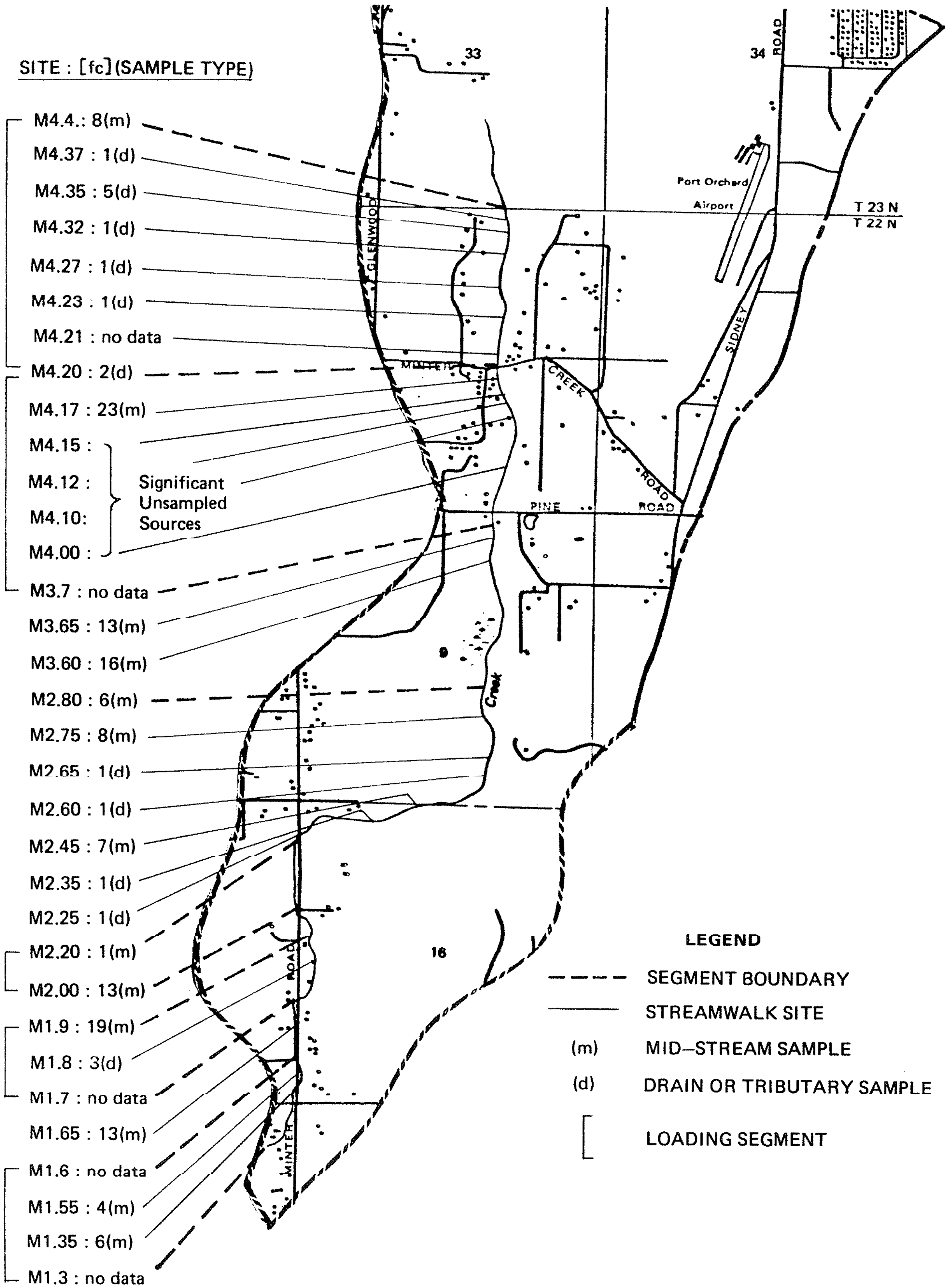


Figure 10. SITES SAMPLED DURING STREAMWALK SURVEYS (MARCH 1983); AND LAND–USE SEGMENTS SAMPLED DURING A NOVEMBER 1983 RAINFALL EVENT ON MINTER CREEK, MINTER WATERSHED.

A detailed discussion of each segment follows. General-interest readers should proceed to Rain-Event Surveys, page 54.

M 4.4 to 4.2. The stream above M 4.4 is wooded and boggy. A modular housing development has appeared over the course of the study near this mucky upper reach. A few houses were seen in June, and there were at least ten by September 1983. The soils are a mixture of types, most of which are classified as unsuitable for septic drainfields. The creek area is wooded around M 4.4, but downstream the surroundings gradually change to predominantly residential and small-scale agricultural.

A few homes were seen along the creek between M 4.4 and M 4.2 during the April streamwalk. The FC concentrations in the creek and from drainages in the stretch were all very low. The soils on the east side near M 4.2, and a narrower band on the west side, are good for on-site waste treatment. Near M 4.4, a similar situation exists, although on opposite sides of the creek. Most of the poorer soils in the area have a shallow hardpan layer.

Sediment samples collected at M 4.2 were three times higher than at M 4.6 ("Streambed Sediment as a Source...," Appendix A). The level at M 4.2 was the second highest found in ten sediment samples collected during the supplemental survey.

Fecal stormwater loading increased four-fold from M 4.4 to M 4.2. The fecal concentration was more than 15 times greater downstream at M 4.2 than at M 4.4 during the October dry season. The residential development between M 4.4 and M 4.2 appears to be related to significant fecal bacteria loading to Minter Creek. All septic systems and barnyard drainages should be further investigated.

Hoppus (1984; Figure 7) reports a septic system failure in this segment between Minter Creek and Westbrook Drive Southwest.

M 4.2 to 3.7. The upper end of this stretch of creek is quite densely settled, with some pasture close to the creek. Excluding the creek bottom, soils in this area are considered suitable for septic drainfields. Slightly elevated fecal concentrations were found in the creek just below M 4.2 during the streamwalk, and can probably be explained by pasture drainage above M 4.2. None of the five ditches which drain home/farmland and enter the creek in this stretch has been sampled. One of these ditches (M 4.0) reportedly drains a farm with pigs and cows on the west side. Another ditch (M 3.8) passes a home with about 40 fowl and a pond which discharges into Minter Creek.

The FC loading rate increased 51 percent from M 4.2 to 3.7 during the November 1983 rain event. The corresponding October 1983 dry-season sampling indicated fecal bacteria levels at M 4.2 that were two times higher than the standard. The sample from M 3.7 was just below the water quality limit.

Soils in the residential areas close to the creek are rated good for septic systems. However, failures due to malfunctions or rapid movement of FC bacteria through the permeable soils may contribute to high loading. Hoppus (1984) identifies three possible on-site system failures at residences along Westbrook Drive and the development south of Pine Road and west of the creek. The duck pond and animal-keeping practices in the area deserve more scrutiny and may also help to explain FC loading. At this time, the effects due to disposal systems cannot be separated from agricultural practice.

M 3.7 to 2.8. The upstream end of this stretch of creek contains two homes which have barnyard animals; goats, sheep, and geese. A quarter mile east lies a gravel pit (Bo-Mac Gravel Co.), and below that a sparsely developed residential area. The creek banks are wooded below M 3.65 and the creek becomes a braided swamp which extends as far as M 2.8. Well-drained soils lie east of the creek where home development is occurring. The patch of soil close to the creek on the east side, however, is not good for drainfields due to seasonal saturation. The mucky soils of the south and west end of the reach are still undeveloped.

Creek samples collected during the April 1983 streamwalk at M 3.65 and M 3.60 had low FC concentrations. At the south end of the bog, M 2.8, the creek had only 6 FC/100 mL.

A 52 percent decrease in rain-event fecal loading was evident from M 3.7 to M 2.8, but the downstream rate was still quite high for an area with so little nearby development. The dry-period samples were similar at the two locations, but within the water quality standard. Fecal coliform bacteria which are carried into this boggy stretch may tend to settle out and survive for long periods. Organic material provides a favorable nutritional habitat for enteric bacterial growth (Tate, 1978). Increased flow probably leads to entrainment of the bacteria and may explain the continued high loading discovered at M 2.8 (McDonald, et al., 1982).

Curtailing animal access in the upstream area of this stretch may cut down FC loading. The two septic systems close to the creek at M 3.7 should also be investigated under wet winter conditions.

It is possible that drainage from the Port Orchard airport and a dense residential development on Sydney Road north of the airport may be causing contamination in Minter Creek (Hoppus, 1984, Figure 20, shows two possible septic system failures within this development). A sample taken from the drain south of the airport (Ferienchick residence, 2/22/83) was 12 times higher than the standard. However, the flow was rather low. The area has a hardpan soil which results in wintertime flooding (Mrs. Ferienchick, personal communication). The drainage appeared to be intercepted in a large pond south of Minter Creek Road. No direct access to Minter Creek has been observed to date. However, it is possible that it drains into the creek by way of the bog.

M 2.8 to 2.2. Forest covers most of the area between M 2.8 and M 2.4 except for a recently logged area just below M 2.8. Small farms are found below the woods, and a small logged area lies just upstream on the south side of the creek. Several homes with pastureland lie north of the creek east of 118th Avenue. The pastures appear to drain into the creek. A roadside ditch drains about a half mile of 118th and Fairview Lake Road Southwest near its juncture with 118th Avenue. The ditch empties into Minter Creek near M 2.25.

Along the upper part, the surrounding soils are considered well-suited for septic drainfields. Near the Pierce/Kitsap county line, the soil north of the creek changes to types that are seasonally saturated and unsuited to septic drainfields. This is the same area where farm and residential land uses begin. Ponded water was visible in cleared lowlands well into spring.

Several small drains in this stretch had very low FC densities during the April streamwalk. No apparent change in FC loading between M 2.8 and M 2.2 was measured during the fall rain event. However, the loading rate remained relatively high. Samples taken during the October dry season had a somewhat lower FC concentration at M 2.2 than upstream at M 2.8. Both samples were below the water quality limit.

Since the soils in the lower part of this stretch are ponded in winter or are underlain by hardpan, existing septic tank drainfields should be inspected during the wet season. Likewise, pasture drainage and animal management practices in this area should be monitored for changes in populations of grazing animals.

M 2.2 to 2.0. The upper and lower ends of the stretch between M 2.2 and M 2.1 are pasturelands, while the middle section is mostly alder swamp. East of the creek, soils are well-drained, but the water table near the creek bottom and west of the creek is perched in places during the winter. Hardpan underlies most of the rest of the area. There is evidence of bank erosion.

The streamwalk fecal concentration at M 2.2 was quite low.

Storm-event FC loading remained at the fairly high level at both M 2.2 and M 2.1. Comparative dry-season results were both well below the standard.

Fecal contamination from grazing cattle are a likely source of fecal bacteria in this stretch, although this is not apparent from the data. It is possible that eroded bank soils contribute to enhanced survivability and downstream transport of fecal coliform. Thus, the creek should be fenced and the banks checked for vegetated buffer (Young, *et al.*, 1980).

M 2.0 to 1.9. Large pastures line both sides of the creek between M 2.1 and M 1.9. A few houses are set back about 200 to 500 feet from the creek. One of these houses was identified by Hoppus (personal communication) as having a failed septic system. A subsequent inspection by health authorities, however, revealed no problem (Harriet Ige, personal communication). The local soils are mostly well-drained except for the creek bed. Streamwalk fecal concentrations were below the standard in both places. About 20 cows were seen grazing along this unfenced creek section. Rain-event fecal loadings were about the same at both M 2.1 and 1.9. Low values were reported at both stations during the dry October sampled.

The cow pasture near M 2.1 appears to be the largest potential source in this stretch. The relatively good water quality seems to be evidence of the benefits of frequent rotation of herds back away from the stream. Eventually, however, the stream banks should be fenced.

M 1.9 to 1.7. A few residences on narrow five-acre tracts lie on the west bank of the reach from M 1.9 to M 1.7, and extensive pastureland west of 118th Avenue. A vegetated buffer fronts most of this stretch. The east side is mostly wooded. Three homes are located close to the creek where the soils are classified as poorly drained and unsuitable for septic tank drainfields. The soils beyond the creek bed area, on the other hand, are mostly well-drained.

Streamwalk notes indicate there were a few ducks in a pond near M 1.8, but the nearby east side tributary had negligible fecal concentrations.

Despite the lack of obvious surface sources in this 0.2-mile stretch, fecal bacteria loading increased about 27 percent during the fall rain sampling. Dry-period FC concentrations were six times greater at M 1.7 than at M 1.9. The downstream value violates the FC standard. Attention should be given to this stretch, especially during wet weather. Septic systems close to the creek and pasture drainage should be investigated. It is also possible that the "loading" increase is derived from disturbance of streambed sediments derived from upstream.

M 1.7 to 1.6. Pastures and a few houses occupy the segment between M 1.7 to M 1.6. The creek passes through a horse farm to the west of 118th Avenue with about 10 to 15 horses. The horses have access to the creek along the entire section, and the banks are heavily eroded. The farm residence is located directly next to the creek. Horses have been seen in the creek on several occasions. Soils in this reach have good drainage except near the creek.

The streamwalk creek sample (M 1.65) in April, like most of the Minter Creek results, was quite low. The FC loading remained at the fairly high level during the fall rain monitoring, but no additional load was added. Dry-season FC concentrations were very similar at the two stations and in the violation range.

The concentration of FC bacteria in the sediments just below the horse farm, at M 1.6, was fairly low compared to other sites sampled ("Streambed Sediment as a Reservoir...," Appendix A). Substrate particle size and flow characteristics are among the many factors that influence the density of fecal bacteria inhabiting stream sediments. This section of the creek may not be easily colonized by bacteria, but FCs which enter this stretch may survive to reproduce in sediments farther downstream.

The well-drained soils in this area may, in part, account for the decreased storm-event loading. As mentioned previously, cattle are frequently rotated among different pastures, and one storm event may not represent year-round trends. Stream bank erosion due to creek access by horses should be reduced by fencing, however. Erosion control also prevents sediment from accumulating downstream and thus eliminates favorable habitat for FC survival.

M 1.6 to 1.3. The section from M 1.6 to M 1.3 is surrounded by pasturelands with a few houses fairly close to the creek. Most of the soils are categorized as somewhat excessively drained, yet suitable for on-site waste treatment. A patch of soil southeast of the creek has a high winter water table and slow permeability.

No animals were observed during the April streamwalk, and FC concentrations were very low at both M 1.6 and M 1.3. This was the farthest downstream the surveyors reached during the April streamwalk.

A 19 percent increase in FC loading occurred during the rain-event in November, 1983. No major difference between the two stations was observed in samples collected during the October 1983 dry season. However, both samples were almost water quality violations. Septic systems in the permeable soil close to the creek may again explain the high October counts.

M 1.3 to 1.0. Pasture and residential land uses occupy most of the area around this stretch of creek where Minter and Huge creeks converge. Soils which lie between Huge and Minter Creeks are classified as somewhat excessively drained. The patch of poorly drained soil mentioned in the above stretch east of the creek extends into this section.

The only experimental results available for this stretch are from the rain-event study. Fecal loading at M 1.0 was less than the sum of Huge Creek (H 0.1) and upper Minter Creek (M 1.3). One possible explanation is that FC bacteria settle out in the deeper, calmer downstream areas. The bacteria may survive in the bottom sediments and can be transported with the bedload to the mouth of the creek. (Some evidence for this is found in "Streambed Sediment...," Appendix A) Samples collected from surface waters do not reflect this mechanism. This phenomenon is also evident in mean annual loading rates calculated from routine monitoring data for Minter and Burley/Purdy watersheds (see pages 27 and 63, respectively). On the other hand, reduced counts downstream may also be mortality of FC in the water.

M 1.0 to 0.7. Minter Creek flows through a steep, wooded canyon in this stretch which ends just above the Unnamed Creek confluence. The soil is excessively drained and too steep for development. Two residential areas lie on the west side of this stretch. The upper end residences are quite far from the creek (about 300 to 500 feet). Those in the lower end are quite close to the stream (roughly 100 to 300 feet). Several small Department of Fisheries hatchery ponds lie on the east side of the creek near downstream residences. Soils in the residential areas are mostly poor for septic drainfield systems.

Soils east of and above the creek are used mostly for pasture-land. Those nearest the stream are good although too steep for development. Those beyond are subject to seasonal dampness.

Fall storm sampling showed a 62 percent increase in FC loading between M 1.0 and M 0.7. The October 1983 dry-season sample was just at violation level, 50 FC/100 mL. The most likely fecal source appears to be the homes near the creek at M 0.7.

M 0.7 to 0.3. A few houses in the upper part of this stretch are the only development evident. Forest land covers most of the area. The west side soils on which a few homes have been built are generally considered unsuitable for drainfield systems. Soils east of the steep, excessively drained creek area are well-drained, but not yet developed.

Despite the increased FC bacteria entering this stretch from the Unnamed Creek, the rate of loading was 18 percent lower at M 0.3 than at M 0.7. Dry-season results likewise showed a lower value at M 0.3 (20 FC/100 mL) than at M 0.7 (50 FC/100 mL).

The FC concentration of a sediment sample at M 0.3 was quite high compared to the other nine areas sampled ("Streambed Sediment...," Appendix A), especially since the surrounding land is relatively undeveloped. Apparently conditions upstream allowed the survival of FC bacteria which were transported to this area in large numbers, or the bacteria reproduced to the level observed (Hendricks, 1972; Hendricks and Morrison, 1967). These conditions may be controlled by instituting erosion control measurements in the watershed.

The septic systems in the upper part of this stretch present a water quality risk considering the proximity of the estuary. They should be inspected under wet winter conditions.

M 0.3 to 0.0. Forests occupy most of the near-creek area in the upper half of the stretch from M 0.3 to M 0.0. The Minter Creek Salmon Hatchery, operated by the Washington State Department of Fisheries, has a large facility along the lower half of the stretch. Septic system dye tests were carried out in winter of 1980 at the Minter hatchery. No trace of dye appeared in the creek after monitoring for two days (Dale Clark, WDOE, personal communication).

The dry-period FC concentration was somewhat lower at M 0.0 than at M 0.3. The mean concentration of fecal bacteria was the same at the two stations during the autumn rain sampling. High tide prevented taking a flow measurement at M 0.0. Therefore, loading cannot be quantified here. However, no major inflow occurs in this stretch. It therefore seems safe to conclude no significant FC loading occurs.

Rain-Event Surveys

A rainfall event was monitored during February 8, 9, and 10 at the sampling stations shown in Figure 2. The results are shown in Figure 11. Streamflows in the Minter Watershed exhibited a one-day lag relative to rainfall. Streamflows observed on February 8 reflected the lack of rainfall the previous day. On February 9, flows jumped substantially in the three tributaries and the lower Minter Creek combined flow. This occurred despite a 50 percent reduction in rainfall the same day. On February 10, streamflow dropped, apparently in response to the reduction of rainfall on February 9.

The streamflow from Huge Creek ranged from 74 to 94 percent of upper Minter Creek. The greater share that occurred on the third day of the study may have been due to delayed release of runoff from the more heavily forested Huge Creek subbasin. The Unnamed Tributary contributed only one-fifth to one-third as much water as either of the two larger streams.

On February 8, following a period of relative dryness, the observed flow at the mouth of the lower Minter Creek (M 0.0) nearly equaled the sum of flows of the three tributaries. On February 9, the average observed flow (104 cfs) exceeded the sum of the tributary flows (92 cfs). This gap was also present on the final day. Thus a significant flow is added to the stream below the confluence of the Unnamed tributary during extended periods of heavy rain. This added flow may come from roadside drainage from SR 103 and Creviston Avenue.

Fecal coliform concentrations were similar in the three tributaries and the lower Minter section (Figure 12). All four sampling sites met the water quality standard on February 8. All sites exceeded it on the following day, and only Huge Creek returned to compliance levels on the third. Fecal coliform levels in each stream generally responded to changes in streamflow.

It is unclear, by applying FC counts alone, which of the two larger streams contributes the greatest contamination potential to the estuary. Streamflows must be considered. A highly polluted stream (high FC densities) with a very

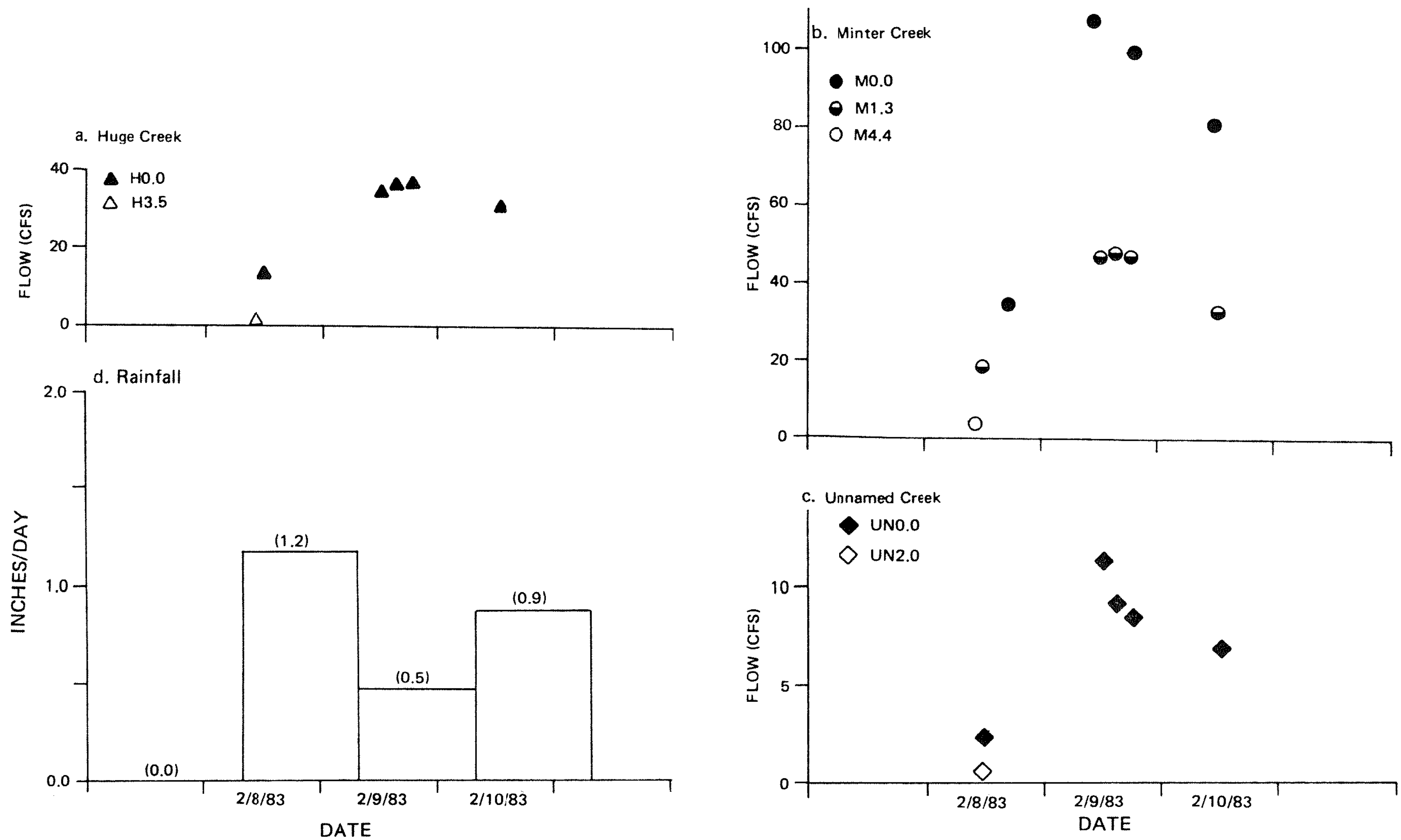


Figure 11 DAILY RAINFALL AND STREAMFLOWS IN SEVERAL MINTER WATERSHED STREAMS DURING A RAIN EVENT (FEB. 8–10, 1983).

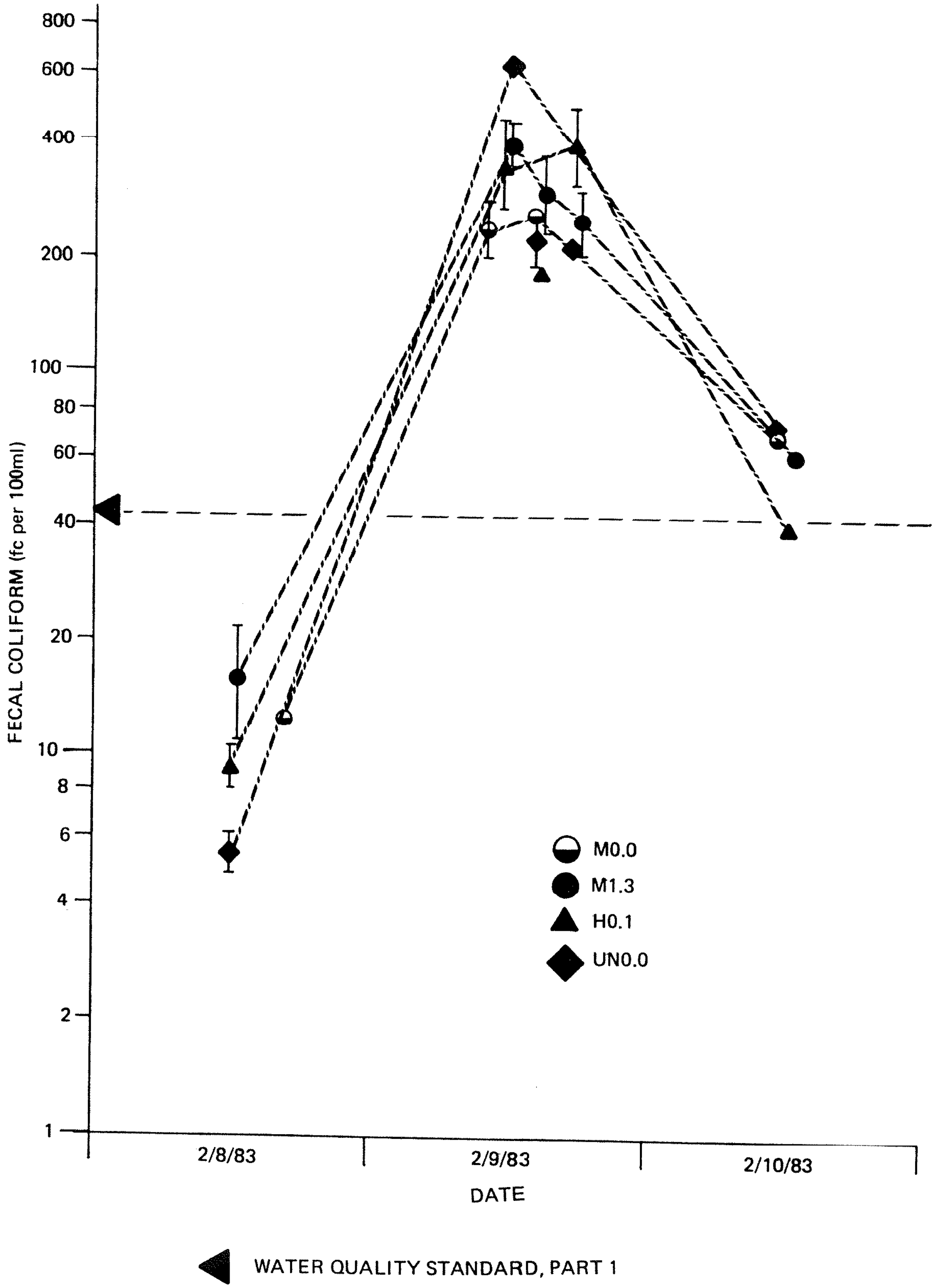


Figure 12. FECAL COLIFORM DENSITIES FROM MINTER WATERSHED STREAMS DURING A RAIN EVENT FROM FEBRUARY 8–10, 1983 (GEOMETRIC MEANS ± 1 SD; LOG–TRANSFORMED DATA; n=2).

small flow may be as important a source as a slightly polluted river of much larger flow. To account for the different flows of the creeks, instantaneous FC loads were calculated by the method from Kittrell (1969), as discussed previously.

Loads generated in the Unnamed Tributary basin during the study were well below those of the other basins at all times (Figure 13). On February 9, the Huge Creek load equaled 40 percent of upper Minter Creek. This was somewhat higher proportionally to conditions during routine monitoring (Table 3). During the rest of the rain event, Huge Creek discharged loads that averaged 65 percent of the Minter load. This suggests that during periods of heavy rain, the importance of Huge Creek increases somewhat over relatively dry times.

The observed load at the mouth of Minter Creek (M 0.0) during each run was compared to a "theoretical total load" estimated by adding the loads from the three upstream tributaries. This was done to determine if a significant load was generated in the lower Minter Creek segment. The observed load was nearly equal or somewhat lower than the theoretical load during most of the study. This suggests that a significant load is not contributed below the Unnamed Creek confluence. However, on February 10, the observed load was about 60 percent higher than the theoretical load. This added load may come from grazing areas along Creviston Avenue on the higher elevations to the east of M 0.0. A significant number of cattle and horses are found here.

Figure 14 shows a method of ranking streams in which the loads are divided by stream length. In this way, stream loads can be compared according to a common standard. As before, the Unnamed Tributary is least important. Huge Creek generally appears to contribute less load per river mile than the upper Minter Creek basin.

Fecal coliform densities in water and shellfish at the estuarine sites are shown in Figure 15. On the first day of the event, samples at both mid-bay and mouth sites had FC levels well below the marine water quality standard. During the following two days, all samples at both sites were well above the standard. Incoming tidal flow carried higher fecal coliform values than initially. There is correlation between values at mid-bay and at the estuary entrance. Rain-generated loads from the watershed directly affect water quality in Minter bay, and indirectly by returning a fraction of partially mixed Minter Bay waters on subsequent tides.

A shellfish sample was taken on the first day of the study and again a week later. Fecal coliform levels were doubled in the second sample although the result was still within marketability limits. Wintertime rain events probably have less effect on shellfish sanitation than similar events in summer (page 31).

BURLEY LAGOON EVALUATION

Setting

Burley Lagoon is located at the north end of Henderson Bay on Carr Inlet (Figure 3). The lagoon is approximately two miles long by one-quarter mile

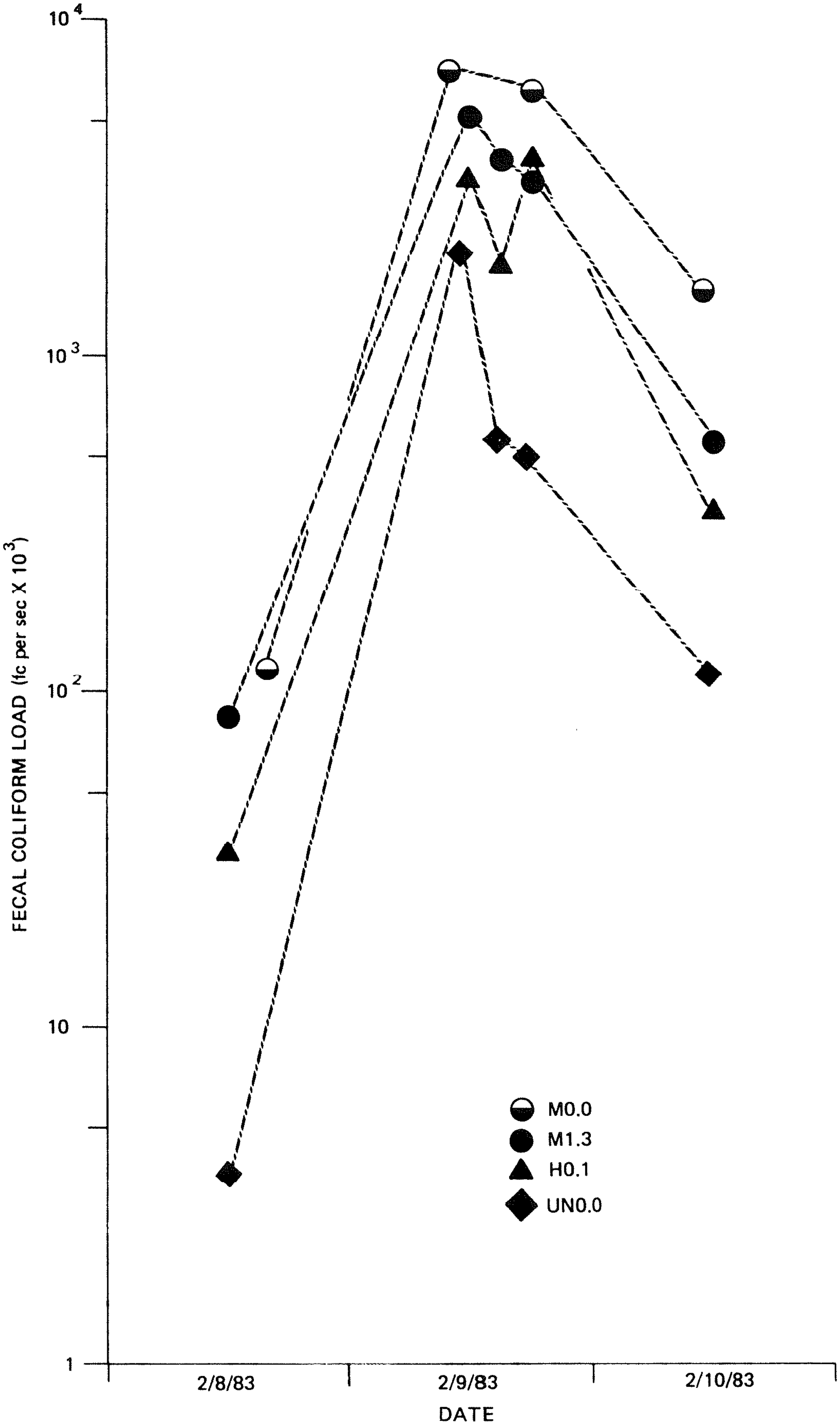


Figure 13. **INSTANTANEOUS FECAL COLIFORM LOADS FOR SEVERAL MINTER WATERSHED STREAMS DURING RAIN–EVENT STUDIES FROM FEBRUARY 8–10, 1983.**

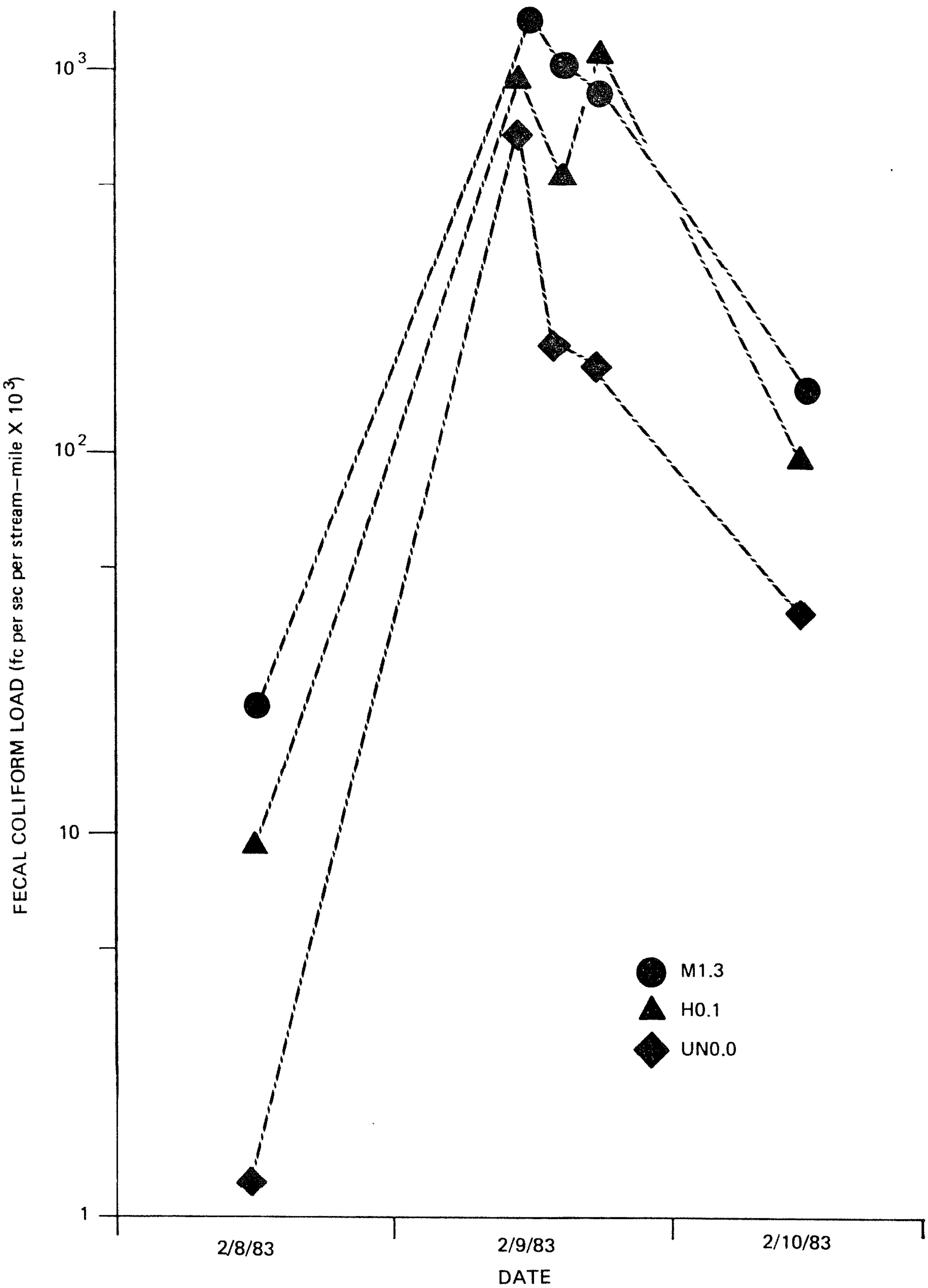


Figure 14. INSTANTANEOUS FECAL COLIFORM LOADS PER STREAM MILE FOR SEVERAL MINTER WATERSHED STREAMS DURING RAIN–EVENT STUDIES FROM FEBRUARY 8–10, 1983.

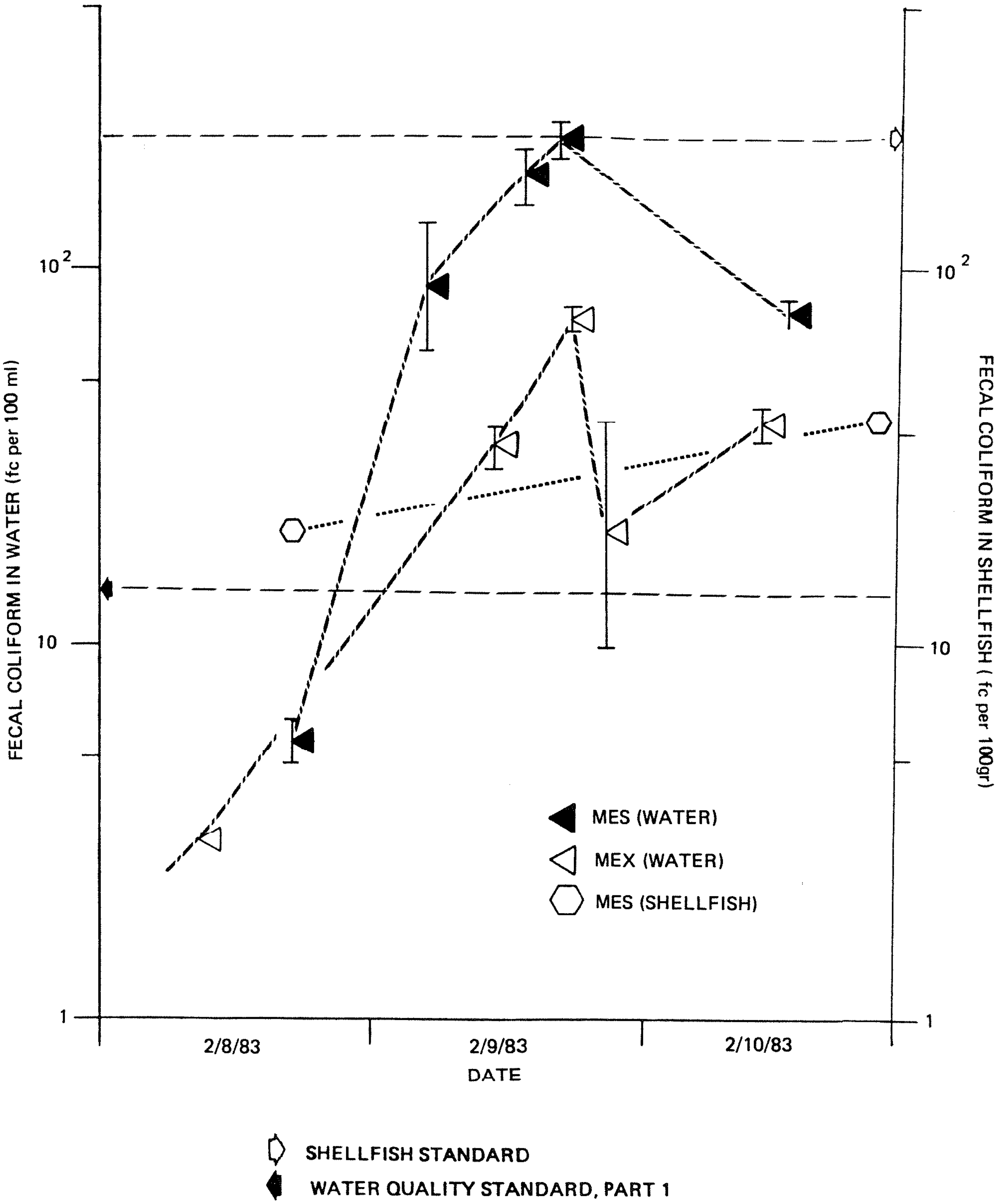


Figure 15. FECAL COLIFORM DENSITIES IN WATER AND SHELLFISH FROM MINTER BAY DURING A RAIN—EVENT STUDY FROM FEBRUARY 8–10, 1983 (GEOMETRIC MEAN ± 1 SD; LOG–TRANSFORMED DATA; n=2).

wide. It covers 370 acres of surface area and has a volume of 19.0×10^7 ft^3 (Kelley, 1963). Except for a narrow passage to Henderson Bay, the lagoon is enclosed by a sand spit along the south end. Shoreline is used for permanent residences, a small shopping center, and an oyster plant. The northern shallow end of the lagoon flushes completely during each tidal cycle. The southern deeper end retains water during low tides.

The main freshwater inputs to the lagoon are Burley and Purdy Creeks, located at the northern end and southeast corner, respectively. Additionally, numerous small streams and drains contribute runoff to the lagoon, particularly during periods of heavy rainfall. Some streamwater inputs directly outside the lagoon mouth may also be drawn in with incoming tide water. Salinity measurements of lagoon water show little vertical stratification during dry periods, while a freshwater layer is present during rainfall events. The thickness of the layer is related to the intensity of rainfall. Rainfall characteristics during the study year were discussed on page 18.

Baseline Monitoring

Data collected during routine background monitoring in Burley Watershed are shown in Appendix C. Figure 3 shows locations of routine sampling sites.

Compliance with Water Quality Standards

Table 12 relates the fecal coliform data to the state water quality standards. Both "control" tributaries (X 0.2; V 0.0) complied fully. The undeveloped Purdy tributary (V 0.0) occasionally experienced higher values than X 0.2 in Burley basin. This was probably due to a slightly higher level of development. The upstream stations on Burley Creek and Purdy Creek (BU 5.2, P 3.6) also complied fully. However, the upper end of Bear Creek (BR 1.8) violated the second part of the fecal coliform standard.

None of the lower stretches of streams draining developed zones complied with the FC standard. Burley Creek (BU 0.3) had a mean FC level intermediate between Bear Creek (BR 0.0) and upper Burley Creek (BU 0.6) which drain into the mainstem. Results at Purdy Creek mouth (P 0.1) are similar to Burley Creek (BU 0.3).

The Burley Lagoon mid-bay station (BES) failed to comply with either part of the marine fecal coliform standard. Henderson Bay water coming into Burley Lagoon (BEX) complied fully. Conditions at both sites were better than the same sites in Minter Bay. Shellfish samples from BES show less contamination than Minter Bay samples on the average. The monitoring results suggest that the quality of the incoming tidal flow is correlated with water quality within Burley Lagoon. It appears that some contaminated water is returned to Burley Lagoon after partially mixing with Henderson Bay waters. It is possible that inflowing Henderson Bay waters become contaminated by sources outside Burley Lagoon and Minter Bay (shoreside residences, etc.). This is not likely, however. If the tidal return was contaminated outside the estuaries, fecal coliform concentrations coming into Burley Lagoon should be higher than those entering Minter Bay because the shoreline around Burley Lagoon is far more developed. Yet, Minter results are higher. Thus the quality of incoming Henderson Bay water into either estuary reflects water quality within the estuary during previous tide cycles. Direct evidence for this phenomenon is discussed elsewhere in this report (page 103).

Table 12. Summary of compliance with fecal coliform water quality and shellfish marketability standards from all background monitoring stations in Burley Watershed during the period of the WDOE Minter/Burley study.

Station Number	Station Type	No. of Samples	Geometric Mean (FC/100 mL)	Range Minimum (FC/100 mL)	Range Maximum (FC/100 mL)	Percent Exceeding Applicable Standards Maximum Limit	Meets Applicable Standards? Part 1[1]	Meets Applicable Standards? Part 2[2]
Burley Creek								
BU 5.2	Upstream "control"	21	15	1	1284	5	Yes	Yes
BU 0.6	Tributary confluence	22	106	17	2179	45	No	No
X 0.2	Undeveloped "control"	22	3	0	29	0	Yes	Yes
Bear Creek								
BR 1.8	Upstream "control"	20	43	2	5250	20	Yes	No
BR 0.0	Tributary confluence	23	90	7	870	48	No	No
Burley Mainstem								
BU 0.3	Mouth above estuary	24	97	18	400	46	No	No
Purdy Creek								
P 3.6	Upstream "control"	22	6	1	250	5	Yes	Yes
P 0.1	Stream mouth	25	106	6	3246	55	No	No
V 0.0	Undeveloped "control"	22	5	0	170	5	Yes	Yes
Burley Estuary								
BES	Mid-estuary; falling tide	25	13	2	278	20	Yes	No
BEX	Estuary mouth; rising tide	25	6	2	49	4	Yes	Yes
Oyster tissue[3]	Sampled at BES	23	98	11	440	9	No	N.A.[4]

[1]Part 1: Geometric means not to exceed 14 and 50 FC/100 mL for marine water and freshwater, respectively; 230 FC/100 g for shellfish.

[2]Part 2: Ten percent of samples not to exceed 43 and 100 FC/100 mL for marine water and freshwater, respectively.

[3]Oyster tissue units are FC/100 g.

[4]N.A. = not applicable.

Seasonal Trends in Water Quality

Figure 16 demonstrates seasonal fluctuations in fecal coliform levels. Data were pooled into groups of two months. Geometric means and standard deviations of logarithms were calculated. All downstream sampling stations showed a rise in mean fecal coliform densities during the summer months followed generally by a dropping off near year's end. This pattern also occurred in "control" streams that drain undeveloped subbasins. Like Minter Watershed, the apparent increase in FC concentrations during summer may be due to reduced stream flow, rather than a change in loading from sources.

Minter and Burley Watersheds are comparable in area. However, Minter Bay is considerably more shallow and smaller in area than Burley Lagoon. The ratios of estuary volume (ft^3) to watershed area (ft^2) for Minter and Burley Watersheds are 0.05 and 0.42, respectively, or eight times greater for Burley Lagoon. This fact may make Minter Bay more sensitive to FC loads. Burley Lagoon may be able to absorb more watershed input without substantial change in water quality due to greater dilution from Henderson Bay. The seasonal response suggested in Minter Bay was not apparent in Burley Lagoon.

Fecal Coliform Loading

Figure 17 shows geometric means of stream loads for bimonthly intervals. Both upper and lower reach stations are shown for each stream.

The upland loads in each stream were well below those from developed zones downstream during the period of study. Stations P 3.6 and BR 1.8 produced fecal coliform loads that were similar to those produced in the undeveloped control areas (V 0.0, X 0.2). Station BU 5.2 showed loads as high as ten times the load of the control sites. Among the undeveloped subbasins, V 0.0 loads appear to be about ten times higher than those of X 0.2.

Seasonal variations in stream loading are not as apparent in Burley Watershed as they are in Minter. Downstream Purdy Creek (P 0.1) and the two control sites (X 0.2, V 0.0) suggest high loads in July and August.

Estimates of total annual loading for Burley, Bear, and Purdy Creeks are shown in Table 13. The total annual load entering Burley Lagoon from Burley and Purdy Creeks was 313,000 x 10^8 FC/year. Burley Creek produced 82 percent and Purdy Creek 18 percent of the total.

Burley Creek and Bear Creek are the major tributaries draining Burley basin. The total annual load from both streams (BU 0.6, BR 0.0) is 440,000 x 10^8 FC/year. This sum is about 40 percent higher than the observed load downstream at the mouth of Burley Creek (BU 0.3). This reduction may be due to die-off or settling-out with sediments of bacteria, or both. The Bear Creek load was 14 percent of upper Burley Creek and almost equal to Purdy Creek.

Bear Creek contributes 10 percent, Burley Creek 78 percent, and Purdy Creek 12 percent of the total annual load from all three tributaries.

The annual load generated within the undeveloped subbasin in Burley basin (X 0.2) was 0.05 percent of the load at BU 0.6. The undeveloped control in Purdy Basin (V 0.0) produced about 1 percent of the load at Purdy Creek mouth. Station V 0.0 produced four times the load as did X 0.2. This may be due to a slightly higher level of development near V 0.0.

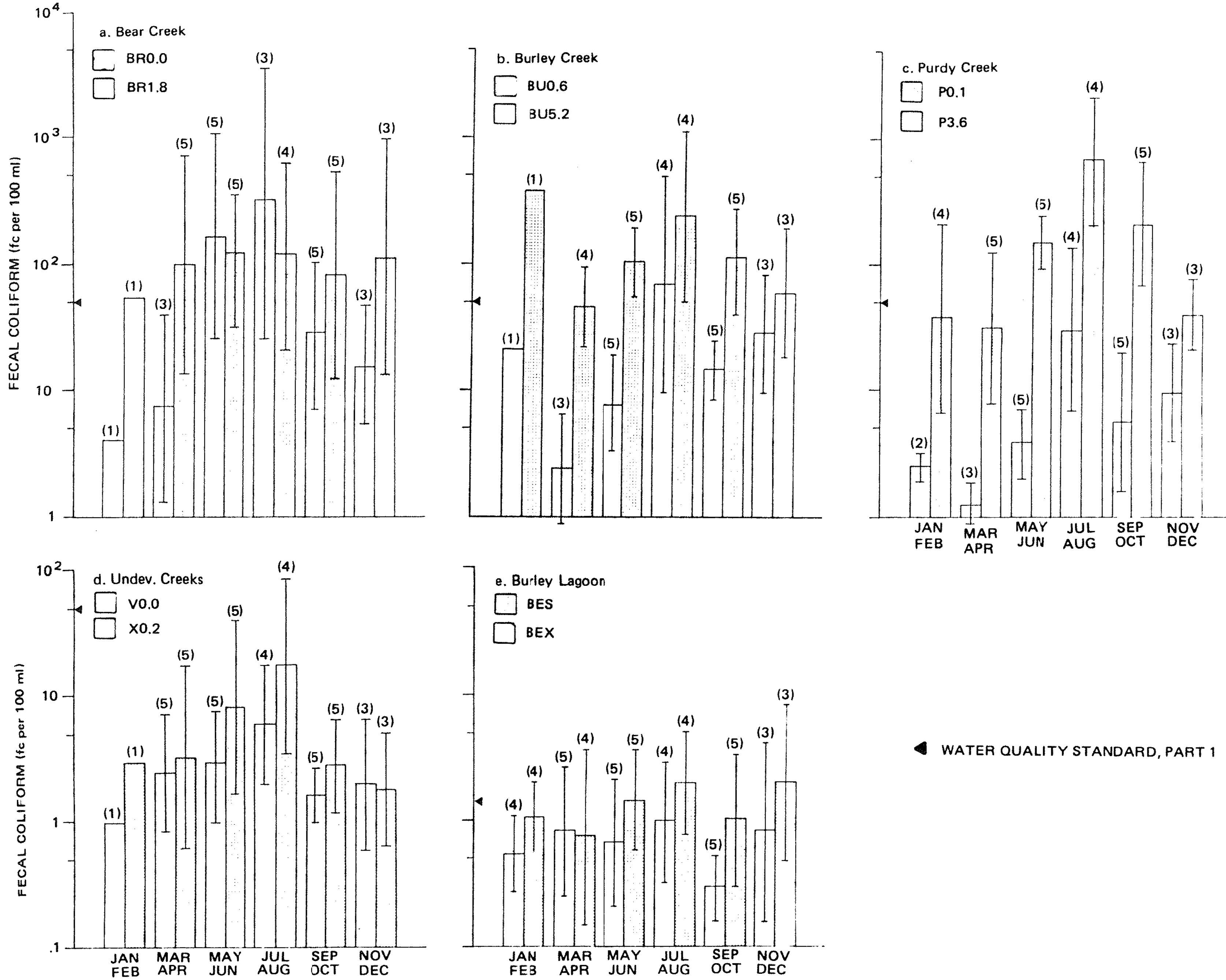


Figure 16. AVERAGE BIMONTHLY FECAL COLIFORM DENSITIES FROM THE MAIN TRIBUTARIES, SEVERAL UNDEVELOPED STREAMS AND THE ESTUARY IN BURLEY/PURDY WATERSHED (GEOMETERIC [illegible]AN [illegible] SD; [illegible]—T[illegible]SFC[illegible]ED [illegible]A; ([illegible] NUM[illegible]R OF [illegible]TA)

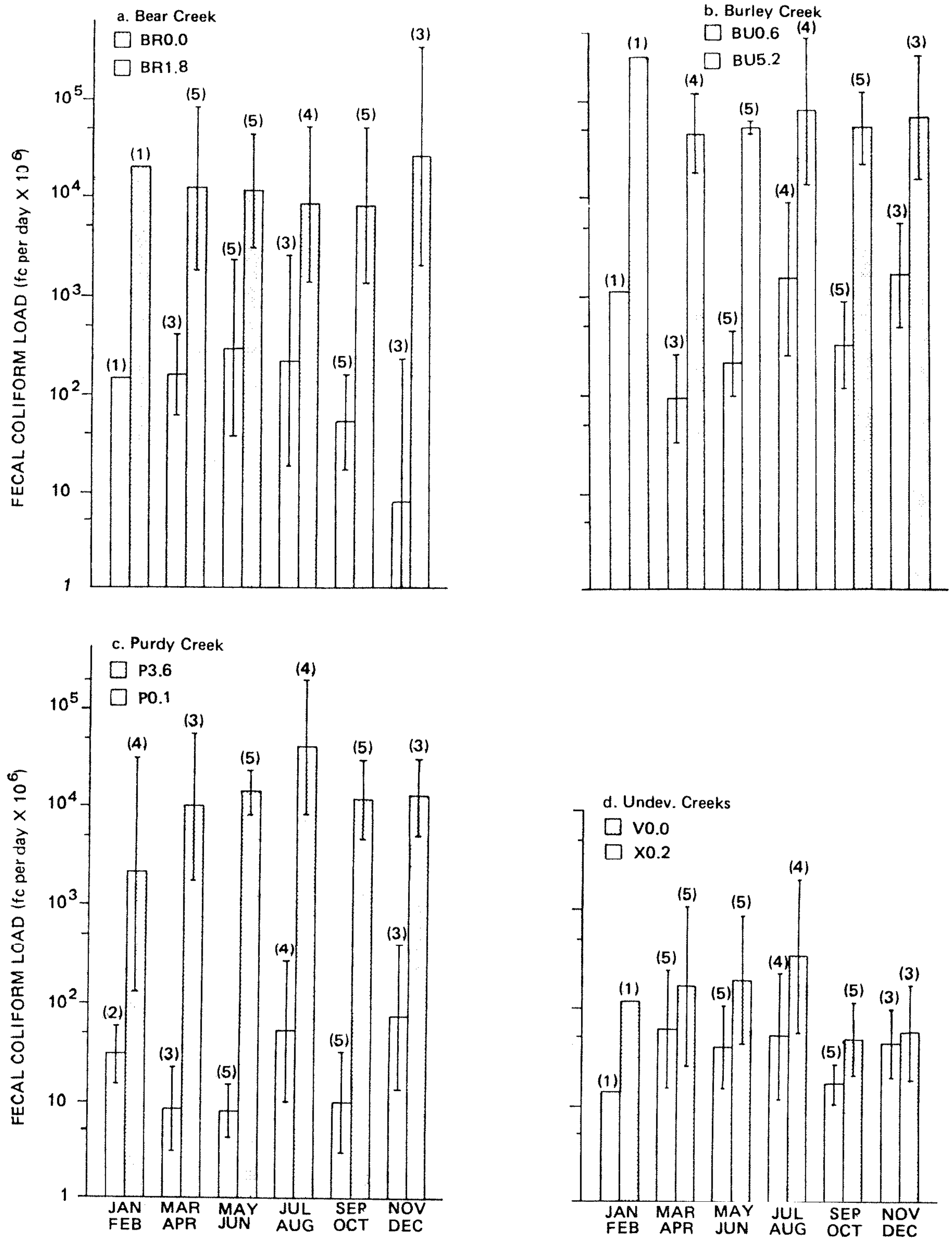


Figure 17. AVERAGE BIMONTHLY FECAL COLIFORM LOADS FROM THE MAIN TRIBUTARIES IN BURLEY/PURDY WATERSHED (GEOMETRIC MEAN ± 1SD; LOG–TRANSFORMED DATA; (n) = NUMBER OF DATA.

Table 13. Fecal coliform load carried by streams in Burley/Purdy Watershed during 1983.

Stream	Mean Daily Load (FC x 10^8 per day)						Annual Load (FC per year)	
	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec	Total (x 10^8)	Per Acre (x 10^8)
Bear Creek (BR 0.0)	195.0	120.2	117.5	85.1	81.3	263.0	52,280	29.57
Upper Burley Creek (BU 0.6)	3467.4	446.7	524.8	812.8	537.0	660.7	387,299	81.78
Total Bear & Burley Creeks	3662.4	566.9	642.3	897.9	618.3	923.7	439,580	
Lower Burley Creek (BU 0.3)	426.6	911.0	478.6	1174.9	575.4	616.6	255,560	--
Purdy Creek (P 0.1)	21.4	100.0	141.2	416.9	120.2	134.9	57,390	25.74
Total Burley & Purdy Creeks	448.0	1012.0	620.0	1591.8	695.7	751.5	312,950	
Control Tributary (X 0.2)	0.1	0.6	0.4	0.5	0.2	0.4	140	0.49
Control Tributary (V0.0)	1.2	1.7	2.0	3.4	0.5	0.6	.570	0.88
Relative Load Contribution (%)								
Bear Creek (BR 0.0)	5.3	18	15	6	11	25	10	
Upper Burley Creek (BR 0.6)	94.1	67	67	62	73	62	78	
Purdy Creek (P 0.1)	0.6	15	18	32	16	13	12	

On the basis of acreage, upper Burley Creek Subbasin generated 82 x 10^8 FC/acre/year. The annual areal load from X 0.2, the Burley Basin control site, was less than 1 percent of the load. The areal load from Bear Creek was slightly more than a third that of upper Burley and similar to that of Purdy Creek. The areal load from V 0.0, the Purdy Basin control was 3 percent that of Purdy Creek mouth and twice the load of its Burley basin counterpart (X 0.2).

Correlation Analysis

Correlation analyses were performed on variables thought to be directly associated with fecal coliform levels in water and shellfish (Table 14). The data include those obtained during the rain-event loading study in addition to routine monitoring data. For analyses, "rain events" are defined as dates preceded by three-day rainfall exceeding one inch.

There was a significant (if not particularly strong) relationship between fecal coliform levels in shellfish and the overlying water. This was not the case in Minter Bay. There was also a highly significant relationship between fecal coliform levels in shellfish and water and one-day and three-day rainfall.

It appears that major rainfall events trigger contamination incidents in Burley Lagoon. Regression analysis was performed on these data using a Hewlett-Packard HP25 programmable calculator. The resulting relationship follows:

$$FC = (140.6)\ R + 12.98\ (n = 26)$$

where FC = fecal coliform concentration (MPN/100 mL)
R = one-day rainfall (in)

However, since the background monitoring data rarely intersected signficant rain events, the usefulness of this relationship is questionable as a management tool. A different approach based on estuarine surface salinity may be appropriate (see "A Tool for Predicting...," Appendix A).

Table 14 suggests that Burley Creek loads may be an important factor in fecal coliform concentrations in the water at BES, while Purdy Creek (P 0.1) loads are not. (The surface waters were typically a partially mixed freshwater layer that is primarily Burley Creek water based on river flow.) However, neither Purdy nor Burley Creek loads are significantly correlated with shellfish fecal coliform levels.

There is no significant relationship between water temperature (a factor related to seasonality) and fecal coliform levels, even when data from rain events are excluded. Thus, unlike Minter Bay, seasonal variation in fecal coliform levels was undetected.

Figure 18 shows some relationships between individual fecal coliform values in Burley Lagoon oysters and several other parameters plotted over time. This was done to detect short-term relationships not readily apparent through correlation analysis. The other parameters were fecal coliform loads, three-day rainfall, fecal coliform levels in the estuary, and water temperature (used as a seasonal factor).

Table 14. Correlation coefficients (r) from data collected during background monitoring in Burley Lagoon.

		Fecal Coliform in water at mid-bay site (BES) (MPN/100 mL)	Fecal Coliform in shellfish at mid-bay site (BES) (MPN/100 g)
Fecal coliform in water at BES (MPN/100 mL)	r	--	0.50
	n	--	18
	test	--	*
Fecal coliform load from Burley Creek (FC x 10^6 per day)	r	0.53	0.13
	n	23	22
	test	*	ns
Fecal coliform load from Purdy Creek (FC x 10^6 per day)	r	0.25	0.15
	n	24	22
	test	ns	ns
Water temp. at BES (°C) including rain events	r	-0.15	-0.12
	n	26	20
	test	ns	ns
Water temp. at BES (°C) excluding rain-event study (inches)	r	0.19	
	n	21	
	test	ns	
One-day rainfall (inches)	r	0.82	0.58
	n	27	23
	test	**	**
Three-day rainfall (inches)	r	0.71	0.39
	n	27	23
	test	**	ns
Numbers of estuarine birds	r	0.03	--
	n	18	--
	test	ns	--

* = significant correlation (p = 0.05)
ns = no significant correlation.
** = signficant at p = 0.01.

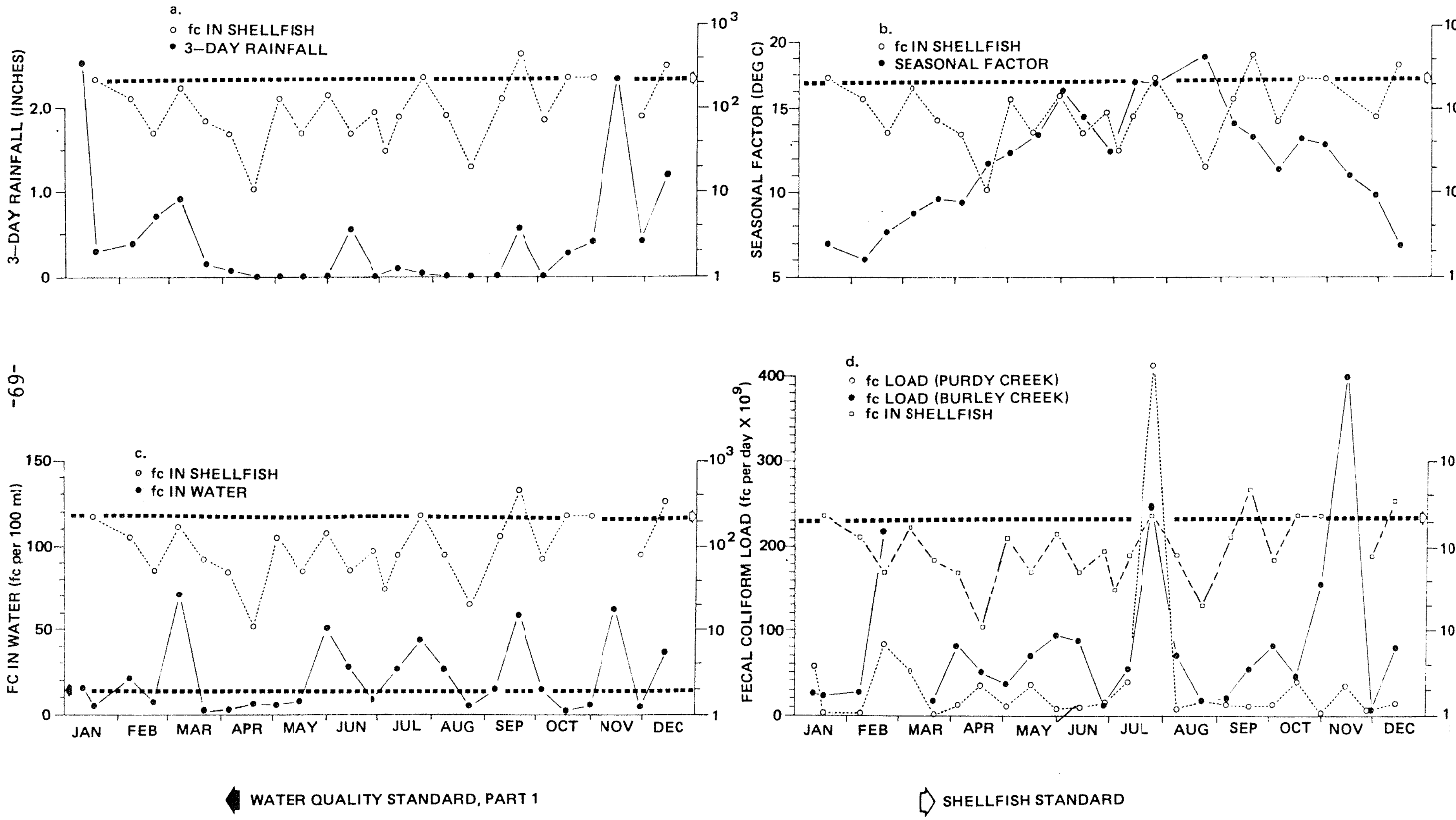


Figure 18. COMARISON OF SEVERAL VARIABLES IN BURLEY LAGOON COLLECTED DURING ROUTINE BACKGROUND MONITORING.

Three-day rainfall totals appear to be linked to fecal coliform levels in shellfish from mid-February through mid-April and again from mid-July through December (Figure 18a). Fecal coliform in shellfish seemed to increase gradually from mid-April through mid-September independently of rainfall.

Two violations in marketability standards occurred from mid-September to mid-December. Generally, the fecal coliform values in shellfish from Burley Lagoon were seasonally less variable and the numbers of shellfish violations less numerous than those from Minter Bay.

Figure 18c suggests a relationship between fecal coliform densities in water and shellfish. Both variables changed together in February and March, from mid-July through September, and in December. During June through September, fecal coliform levels in estuarine water were generally higher although rainfall was low and watershed loading remained relatively constant.

Fecal coliform loads from Burley and Purdy Creeks (Figure 18d) behaved similarly relative to rain events. But Purdy loads were generally substantially below those of Burley Creek. Both fecal coliform loads and shellfish densities rose substantially in late July due to a series of intense daily rain squalls that occurred in the area. Loads and fecal coliform in shellfish are linked from that time until mid-September. In general, however, the behavior of these two variables were not strongly linked during most of the year.

Few major rain events were sampled during the period from April through October. However, very heavy squalls happened during routine sampling on July 25. Samples from most Burley Watershed stations were taken in the afternoon. These samples showed fecal coliform levels far above normal. In addition, the lower Burley Watershed stations showed high turbidity and suspended materials levels (Appendix C). Despite a lack of rain during the previous ten days and unsaturated watershed soils, stream flows at BU 0.6, BU 0.3, and P 0.1 jumped 50 to 100 percent higher than typical of the period. This rain event may have created some pollutant loading from runoff. However, it is also possible that a part of the high fecal coliform and turbidity levels may be explained by the disturbance of bottom sediments by increased streamflow (Matson, et al., 1978; McDonald, et al., 1982).

As in Minter Bay, marine birds in Burley Lagoon appeared to have no relationship to fecal coliform levels in water or shellfish. Table 15 summarizes observations on bird species and numbers during the study. Comments on seasonal variation in bird species are essentially those made for Minter Bay.

Intensive Surveys

Land Use and Soils Assessment

The percentage of developed land in the Burley/Purdy Watershed is 27 percent. Six percent is agriculture, and 17 percent is occupied by residential or residential/light agricultural mixed use (Table 16).

The areas of both Minter and Burley/Purdy Watersheds are nearly equal, although the latter is eight percent less developed. Residential use here is more important and agricultural use less important than in Minter Watershed.

Table 15. Bird counts in Burley Lagoon taken during background monitoring activities.

Species	Jan 11	Jan 17	Feb 7	Feb 21	Mar 7	Mar 21	Apr 4	Apr 18	May 2	May 16	May 31	June 13	June 27	July 11	July 25	Aug 8	Aug 22	Sept 6	Sept 19	Oct 3	Oct 17	Oct 31	Nov 14	Nov 29	Dec 12
Counts not Taken	0	0	0		0									0		0						0			
Horned Grebe *Podiceps auritus*																			X				X	X	X
Eared Grebe *Podiceps caspicus*				X		X																			
Western Grebe *Aechmophorus occidentalis*							X	X	X	X										X	X		X	X	
Double-crested Comorant *Phalacrocorax auritus*				X		X	X	X	X	X	X							X	X	X	X		X	X	X
Great Blue Heron *Ardea herodias*								X		X	X	X	X		X		X	X	X	X	X			X	
Mallard *Anas platyrhynchos*										X									X	X	X		X	X	
American Widgeon *Mareca americana*																		X			X			X	
Shoveler *Spatula clypeata*																	X								
Greater Scaup *Aythya marila*				X			X						X												
Unidentified Scaup *Aythya sp.*						X		X			X	X			X										X
Common Goldeneye *Bucephala clangula*				X			X		X														X	X	X
Barrow's Goldeneye *Bucephala islandica*							X																		
Bufflehead *Bucephala albeola*				X		X	X	X	X														X	X	X
White-Winged Scoter *Melanitta deglandi*				X			X	X	X	X		X					X	X	X	X			X		X
Surf Scoter *Melanitta perspicillata*							X	X															X		X
Common Scoter *Oidemia nigra*							X				X												X	X	X
Unidentified Scoter						X							X												
Hooded Merganser *Lophodytes cucullatus*																			X	X	X		X		
Red-breasted Merganser *Mergus serratus*							X										X	X	X				X		X
Common Merganser *Mergus merganser*															X					X					
Glaucous-winged Gull *Larus glaucescens*				X		X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X
Ring-billed Gull *Larus delawarensis*				X																					
Bonaparte's Gull *Larus philadelphia*													X												
Pigeon Guillemot *Cepphus columba*													X												
Belted Kingfisher *Megaceryle alcyon*						X				X			X		X		X			X					
Common Crow *Corvus brachyrhychos*				X		X	X	X		X		X	X		X		X	X	X	X	X		X	X	X
Total Species				9		8	12	9	6	8	5	5	8		6		7	7	8	10	8		13	11	11
Total Count				343		528	339	368	148	131	36	139	190		109		158	642	381	271	560		751	1040	1050

Table 16. Land use in Burley/Purdy Watershed.

Land Use	Purdy Creek	Bear Creek	Burley Creek	Estuary Drainage	Total
	Subbasins				
Residential					
0 - 2500 ft^2 - 0.49 acre	10	15	41	55	121
0.5 - 0.99 acre	11	26	79	62	180
1.0 - 2.49 acres	53	91	279	112	535
2.5 - 4.9 acres	75	75	296	41	488
Greater than 5 acres	79	82	217	32	410
Subtotal	228	289	912	302	1,734
Agricultural	83	155	311	44	588
Commercial	--	--	11	10	21
Clearcut	--	6	10	--	16
Selectively Cut	43	105	163	10	321
Scraped	5	16	56	--	77
Swamp	--	7	6	10	23
Undesignated	5	15	7	41	68
Forest	1,855	1,161	3,237	1,166	7,424
Park	--	14	--	--	14
School	10	--	23	--	33
Total Acreage	2,229	1,768	4,736	1,583	10,319
Percent of Basin Developed	16%	33%	31%	22%	27%
Residential	10%	16%	19%	19%	17%
Agricultural	4%	9%	6%	3%	6%
Other	2%	8%	6%	0%	4%
Percent of Basin Undeveloped	84%	67%	69%	78%	73%

Soils in Burley/Purdy Watershed are generally poor for subsurface sewage disposal (Table 17, Plate 4). Nearly 75 percent of the watershed is covered with categories B and C soils (nearly 25 percent more area than in Minter watershed). Most of these soils are dry in the summer, but become saturated during winter rains due to glacial-till hardpan. In the central and south ends of the watershed (Lower Burley Creek, Bear and Purdy Creeks, and around the estuary), satisfactory soils are available in only 15 to 19 percent of the area. A larger proportion of good (caregory A) soils are found in the north end of the watershed (40 percent). The alluvial D-soils are rare. These tend to be concentrated in the north and central parts of the watershed.

The Bear Creek Subbasin is the most developed of the three. Thirty-three percent of its area is currently in use.

The agricultural component, mostly animal husbandry, is higher than in the other creeks, occupying 9 percent of the area. A severe feedlot problem exists in the upper end of the creek and may contribute much to FC contamination as far downstream as the mouth.

The 16 percent that is residentially developed is less than that in Burley Basin and higher than that in Purdy Subbasin. The predominantly poor soils and coincident wide-spread development presumably act together to produce contamination of Bear Creek.

The Burley Subbasin is the most residentially developed. Nineteen percent of the area is housed. A total of 31 percent is developed. Agricultural use is about average for the watershed, 6 percent.

A wide band of poor soils lies along most of Burley Creek. Many animals and homes close to the creek, especially in downstream areas, appear to contribute to the high FC loading at BU 0.6.

Bear Creek joins the mainstem of Burley Creek below BU 0.6. The town of Burley is situated on poorly drained soils. The town is small but rather densely populated. In addition, 10 to 20 acres of land in mid-town is used for cattle grazing. Drainage from the town occurs via five roadside ditches into Burley Creek (below BU 0.6) and directly into Burley Lagoon.

A landfill is located south of the Burley-Ollala Road about one-half mile east of Burley Creek. Hoppus (1984) suggests that surface drainage from the landfill toward Burley Creek may be possible. A specific investigation of this possiblity has not been done. Data obtained during the streamwalk survey did not show any streams or drains entering Burley Creek at this point. However, further inspections may be in order.

Of the three major watersheds which drain into Burley Lagoon, Purdy Creek is the least developed (16 percent). About 10 percent of the Purdy Subbasin is developed for homes, and 4 percent for agriculture.

The poor soils which cover most of the subbasin make the area particularly susceptible to FC contamination if sufficient precautions are not taken.

Table 17. Distribution of soils types in Burley/Purdy Watershed (values are percent ground cover).

Soils Type	Septic System Suitability	North (Upper Burley Creek)	Central (Bear, Lower Burley, Purdy Creeks)	South (Purdy Creek estuary)	Total
A	Soils good	38.6	14.7	18.8	23.8
B	Systems do not function well during wet season due to glacial till hardpan	33.9	65.4	70.8	56.2
C	System do not function well during wet season due to soil characteristics and/or topography	25.2	18.6	10.4	18.7
D	Soils not usually developed for residential use	2.4	1.3	0	1.3

Pierce County maintains a landfill just outside the Purdy Creek watershed on the north side of the Purdy Crescent Road east of Purdy. This landfill was the subject of a special survey ("The Effects of the Purdy Landfill on Fecal Coliform Levels...," Appendix A). The results indicated that the landfill contributes a small but measurable FC load to Purdy Creek and Burley Lagoon.

In addition to Burley and Purdy Creeks, several small creeks and numerous seeps and small springs flow into Burley Lagoon. Roadside ditches in Burley and Purdy villages contribute flow during rainy periods. Soils on the northeast shore are wet. Few houses are found there. The west-central shore is dominated by low-density residential use. The northwest shoreline is relatively unpopulated. The east-central through the southeast shoreline to the Highway 302 Bridge is densely settled with residences.

EPA (Region X) has recently undertaken investigation and cleanup of a site on the northwest shore that is contaminated with PCBs. The effects are considered to be minimal and PCB migration stabilized at this time. Further discussion of this problem is beyond the scope of this study.

Statistical analysis was used to determine if a relationship between water quality violations and streamside land use exists in the Burley/Purdy watershed. Fecal coliform data from the streamwalks and the stream loading analysis were used. Each of the 88 fecal coliform results was sorted into two groups--violations or non-violations. Each sample was also scored according to the presence or absence of animals and houses close to the streams. Streamwalk notes were used for scoring.

A chi-square test for independence (Sokal and Rohlf, 1969) was used to test the hypothesis that the presence of houses or animals has nothing to do with fecal coliform violations in nearby streams. This hypothesis would mean that there would be an equal chance of either violation or compliance levels of fecal coliform in any sample. On the other hand, if fecal coliform levels are linked in some way to the houses or animals, the probability would not be equal. The second hypothesis was rejected at the 99.5 percent confidence level. We conclude that both housing and animals are related to fecal coliform violations in the creeks.

Stream Survey Summary

Bear Creek Analysis. The Bear Creek streamwalk was done on April 27, 1983, following a light four-day rain which totaled 0.36 inch. The rainfall for April, recorded at the Minter Creek Salmon Hatchery, was only 1.43 inches. Most of this fell early in the month. Therefore, streamwalk observations represent fairly dry conditions and a lowered water table.

On October 10, only trace amounts of precipitation had fallen three weeks prior to the dry-period sampling. The water table was also at its lowest annual level following the warm dry summer.

The rain-event segment loading analysis was done on January 24 and 25, 1984, under less than ideal study conditions. Slightly more than one inch of rain fell on January 24. No rain was recorded on January 25. The total rainfall during the previous five days was only 1.74 inches. Both December 1983 and January 1984 were dry, cold months, and a nine-day dry period preceded the late January storm samplings.

On January 24, stream flow was not measured, and only one sample was analyzed from each station. On January 25, stream flows were measured, and three samples were analyzed at several sites. The average of the three samples was used with the stream flow to calculate fecal coliform loading. A comparison was drawn between the FC concentration at the start of a winter rain (January 24) with that after a substantial rain has fallen (January 25). Extended freezing temperatures during late December and early January, however, may have reduced the fecal bacteria population in or on the ground.

Six segments were set up on Bear Creek. Four of the six segments showed significant loading, including one that was predominantly undeveloped forest (Table 18, Figure 19). Four segments had mixed agriculture/residential use. Three of these showed significant loading. The segment near the mouth of the stream, predominantly residential, produced a net load. Soils are generally marginal in all segments.

The evidence indicates that the greatest source of contamination is a pasture near the head of the creek. Eroded soils and fecal coliform enter the creek at this point. The clogged streambed probably has caused the failure of nearby septic systems during heavy rains. Fecal coliforms are transported downstream as a slug with fine sediments at the onset of heavy rain.

More detailed information follows. Land use and soils codes are from Plates 3 and 4 (inside rear cover). Streamwalk data are in Appendix D. Readers with only general interest should advance to Burley Creek Analysis (page 81).

BR 1.8 to 1.5. A wooded residential area lies about 1000 feet above the routine monitoring station at BR 1.8, although the immediate vicinity of the station is an undeveloped swamp-forest. Pastures with grazing cattle and a few homes occupy the near-creek areas between BR 1.8 and 1.5. Very intensive cattle grazing of the pasture at the corner of Madrona and Pine roads appeared to cause heavy erosion and stream siltation. This led to flooding of homes and septic systems downstream. Cattle graze on the west side of Madrona Road, but not as intensely as on the east side. Hoppus (1984) identifies two probable septic system failures on either side of Pine Road to the west of BR 1.8 and one more near the corner of Pine and Madrona Roads.

Some soils with good drainage are located upstream of BR 1.8 west of the creek. The pasture soils are mostly Kitsap with low permeability and high water table during the winter. Most of the soils near the creek (where several homes are located) have a hardpan sublayer.

Ducks and geese were seen around BR 1.7 during the April streamwalk. Cows were seen at BR 1.6. Heavy bank erosion extends almost to BR 1.5. The only stream fencing seen was near BR 1.5.

All four of the creek samples collected in this stretch during the streamwalk violated the FC water quality standard. The highest FC concentration occurred a short distance downstream of the heavily grazed pasture (BR 1.6 and BR 1.5).

During the January 24, 1984, winter storm sampling, the FC concentration was almost four times higher at BR 1.5 than at BR 1.7, but both readings were very high. After the rain had stopped the following day, the FC concentration was still twice as high at BR 1.5 as at BR 1.7, but much lower than the day before.

Table 18. Winter rain-event and dry-period sampling, Bear Creek.

Station	Rain Event (1/24/84) (FC/100 mL)*	Rain Event (1/25/84) $\overline{X}$ (FC/100 mL)**	Q (cfs)	FC Loading (FC x 10^4/sec)	Dry Period (10/10/83) $\overline{X}$ (FC/100 mL)***
BR 1.8	7	12	0.8	0.3	1
BR 1.79	--	--	--	--	41
BR 1.7	1200	187	N/A	N/A	24
BR 1.5	4600	389	1.2	15.1	37
BR 1.1	200, 320	229	1.5	10.3	5
BR 0.9	120	277	1.7	12.9	31
BR 0.7	--	--	--	--	17
BR 0.5	100	226	7.2	47.5	21
BR 0.2	80	216	7.1	45.7	8
BR 0.0	69	248	10.0	75.6	16

*Concentration represents one sample.
**Concentration represents the geometric mean of three samples collected over six hours.
***Concentration represents the geometric mean of two replicate samples.

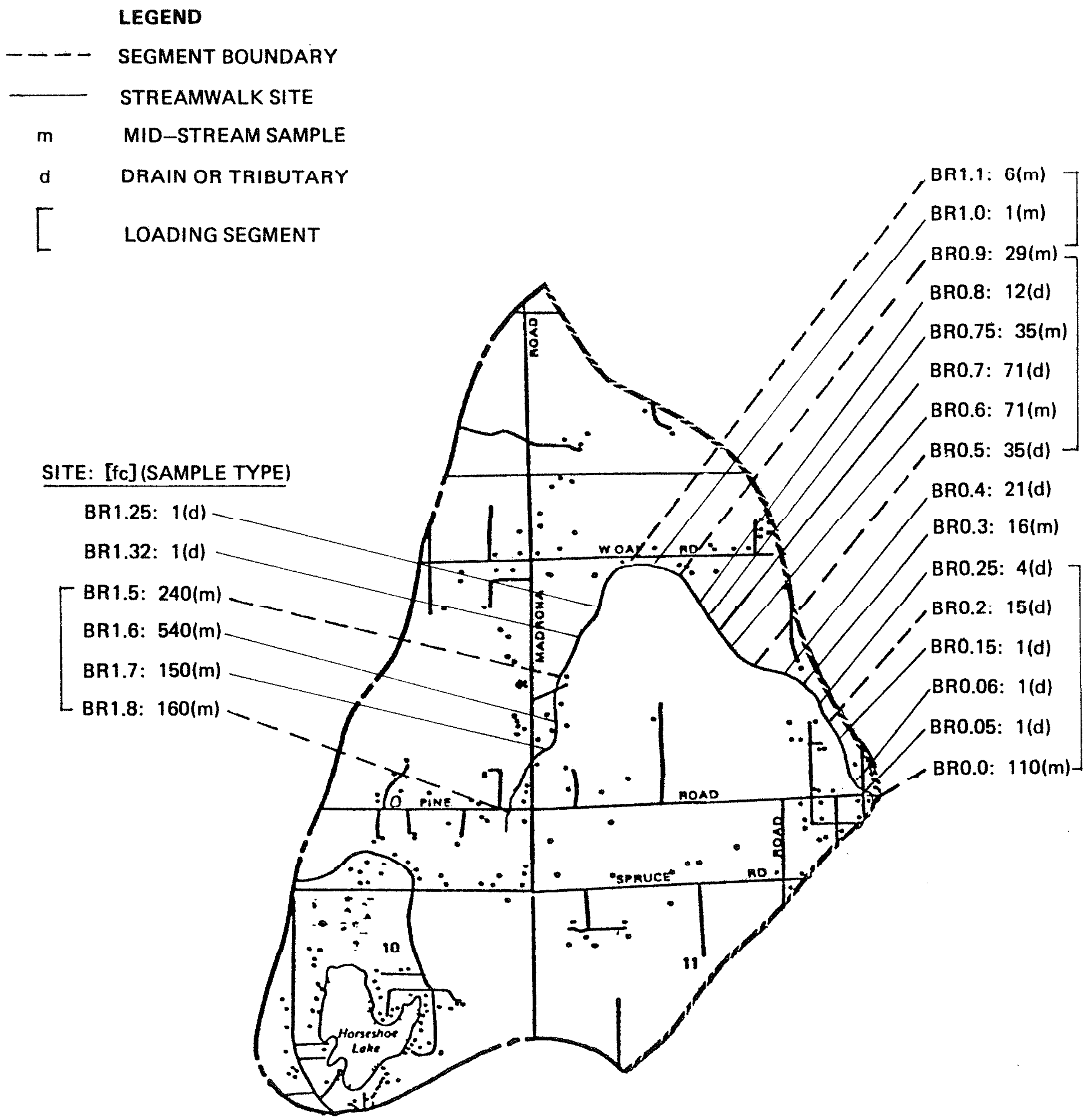


Figure 19. SITES SAMPLED DURING STREAMWALK SURVEYS (APRIL 1983); AND LAND-USE SEGMENTS SAMPLED DURING A JANUARY 1984 RAINFALL EVENT ON BEAR CREEK, BURLEY WATERSHED.

During the winter storm sampling, both the fecal loading and concentration were much lower at BR 1.8 than at any of the downstream stations. Dry-period October samples were likewise very low at BR 1.8 (1 FC/100 mL), but increased between BR 1.79 and BR 1.5. The stream bottom at BR 1.7 was so mucky that flow measurements could not be taken, and loads could not be computed here.

A major problem in this stretch appeared to be year-round flooding resulting from extreme siltation and bank erosion caused by the farm at the corner of Pine and Madrona Roads. Septic systems downstream of the farm obviously did not function, and ponded conditions provide an ideal habitat for harboring fecal bacteria. At the time, manure from the overgrazed farm was not handled in the manner suggested by the Kitsap County Soil Conservation District, and contamination from here was also a substantial source of the downstream high levels. Ducks, geese, and cows in the flooded area added to the problem.

The high nutrient loading from the dairy and silty stagnant conditions support high levels of FC in sediments. A sample taken on September 26, 1983 had 240,000 FC/100 g at BR 1.6 which was the highest of ten sediment smaples taken in both watersheds ("Streambed Sediment, etc.," Appendix A). Upon disturbance, such as that caused by increased flow, bottom sediments are probably carried downstream. This sediment transport mechanism is another possible explanation for the elevated FC concentrations for considerable distance downstream (McDonald, et al., 1982; Berkeley, et al., 1980).

Since the time of our surveys, the Washington Conservation Corps has assisted local landowners in stream channelization. In addition, the farmer primarily responsible for the problem has reduced the size of his herd and followed SCS recommendations. A re-check of conditions should be made during a wet season.

BR 1.5 to 1.1. The major land use in this stretch is undeveloped forest with a few residences and a sheep farm near BR 1.1. Soils throughout the area are rated poor for septic drainfields because of a shallow underlying hardpan layer.

The creek near the sheep ranch is not fenced. There are about 30 sheep on a small pasturage. The FC concentration in two tributaries above BR 1.1 were both very low and drain the west side. Besides the sheep ranch on the west side, a new home lies near the creek at BR 1.1. Streamwalk notes (Appendix D) show several small pipes near the creek below this house. It is not clear which possible source is responsible for the high FC concentration found at BR 1.1 during the streamwalk.

The FC loading rate dropped by about one-third from BR 1.5 to BR 1.1 during the winter storm monitoring. Likewise, the dry-period FC concentration at BR 1.1 was one-seventh that found at BR 1.5.

Although not a major problem, the developed area around BR 1.1, including the sheep ranch and nearby septic systems, should be inspected during winter wet-weather conditions.

BR 1.1 to 0.9. Between BR 1.1 and BR 0.9, there are a few residences and pastures north of the creek. The soils north of the creek are the slowly permeable Kitsap soil which has a high winter water table. The homes on the south side of the creek are mostly on Kapowsin soils with a hardpan layer starting between 20 and 32 inches below the surface.

No violations were found during the streamwalk below BR 1.1 of this stretch. During the winter wet-period sampling on January 25, fecal loading increased about 25 percent from BR 1.1 to BR 0.9, while flow increased only 13 percent. A comparison of the FC levels on the previous day shows a higher concentration at BR 1.1 than at BR 0.9. Thus, the "loading" in this stretch may be a case of a slug of bacteria washing into the stream at BR 1.1 and moving downstream, causing elevated levels at BR 0.9 later in the storm.

The October dry-period FC concentration at BR 0.9, on the other hand, was six times higher than that at BR 1.1, but both were below the standard. Septic system failures may explain the elevated fecal bacteria levels found here under both wet and dry conditions. This segment deserves further attention.

BR 0.9 to 0.5. Much logging and clearing has recently occurred between BR 0.9 and 0.5. Residential development is gradually taking place. According to streamwalk notes, houses are visible along most of the creek below BR 0.75. The soils on both sides of the creek are a mixture of types classified as unsuitable for septic drainfields.

During the streamwalk between BR 0.9 and BR 0.7, no fecal bacteria problems were apparent. A pond which drains into the creek at BR 0.7 was slightly above the FC standard, although no animals were seen nearby. Another minor violation occurred below a group of houses near BR 0.6. A tributary enters Bear Creek below the group of houses. The stream drains pasture and swamp land on the north side of West Oak Road. The Kitsap County Conservation District, together with the landowner, is preparing to fence the small tributary. Other improvements are also planned for this farm.

A 270 percent increase in FC loading occurred during the second day of the winter storm event between BR 0.9 to 0.5. The flow increased 330 percent in the same stretch. However, the October dry-period results show no downstream FC increase.

During the streamwalk, several cattle and chickens were seen at BR 0.5 about 200 feet above the creek. There is also a home with a pond close to the creek. Discharge from the pond produced no violation.

BR 0.5 to 0.2. The section of Bear Creek between BR 0.5 and BR 0.2 is mostly wooded. Residences are located on the east bank. The land along the upper two-thirds (BR 0.5 to BR 0.3) of this stretch has mostly good Indianola soil. The lower third of the reach has mainly Norma soil which is typically ponded in winter.

During the April 1983 streamwalk, the FC level in the creek was quite low at BR 0.3 immediately downstream from a home close to the creek. Both of the tributaries sampled near BR 0.2 had low FC concentrations. There were no streamwalk reports of animals visible from the creek.

The winter rain-event monitoring (January 25) indicated no major change in loading between BR 0.5 and BR 0.2. However, the FC concentration at both stations increased over 2 1/2 times between January 24 and 25, demonstrating the magnitude of the rain effect on FC loading. On the other hand, there was a slight downstream decrease in FC concentration during dry-period sampling in October.

Despite the denser residential development along this stretch of creek, the data do not indicate a definite fecal contamination problem. Interpretation of the wet-weather sampling is open to question. The origin of the bacteria sampled cannot be definitely established. The presence of mostly well-drained soil, however, suggests that septic systems should not fail if properly installed and maintained. It is possible that soils are too well-drained considering the proximity of the houses to the stream.

There may be another explanation. Upstream stations (BR 1.8 - BR 0.5) tended to be lower in FC on the second day of the rain event while downstream sites (BR 0.5-BR 0.0) were higher. This may be evidence of downstream transport of FC in a slug from the upper end of Bear Creek. Thus during a prolonged storm event, problems in the upper end of the tributary affect water quality throughout Bear Creek.

BR 0.2 to 0.0. The lower 0.2-mile of Bear Creek is mostly residential, with some wooded areas. The two major soil types are rated as poor: Norma which is ponded during the winter; and Kapowsin which has a hardpan layer starting 20 to 32 inches below the surface.

Streamwalk samples of a pipe and two drainage ditches which discharge into the creek along this reach had trace FC concentrations. A spring which enters just below BR 0.2 was not sampled. Subsurface flow was emerging from the banks, but was not sampled. However, the streamwalk sample collected from the creek itself at BR 0.0 was over twice the water quality limit.

Winter storm event fecal bacteria loading increased more than 50 percent from BR 0.2 to BR 0.0. As witnessed in the stretch above, the concentration of FC increased 2 1/2 to 3 1/2 times at both stations between January 24 and 25, 1984, following the 1-inch rain. The flow in this stretch, unlike the above reach, increased 41 percent while FC loading increased a somewhat higher 65 percent. Samples from the same locations taken in October showed a slight increase in concentration going from BR 0.2 to BR 0.0.

The FC bacteria density in late-summer sediment samples was about the median level of ten samples collected in both Minter and Burley watersheds ("Streambed Sediment...," Appendix A). Since the soils in this segment are mostly unsuitable for septic tank drainfields, it seems probable that some of the systems in the densely populated area may fail when soils are saturated.

Burley Creek Analysis. The Burley streamwalk took place on May 10 and 11, 1983, following a five-day rain which totaled 0.97 inch. An eight-day dry period preceded this rain, and the total rainfall in April 1983 recorded at the Minter Creek Hatchery was 1.43 inches. The ground, therefore, was probably not saturated, but flows may have been somewhat higher than normal for the season.

The dry-period sampling in Burley Creek took place on October 11, 1983. The winter rain-event loading study was done on January 24 and 25. Fecal coliform samples and flow measurements were taken on each day. Thus loads are available for two days with different rainfall characteristics. Details of the weather patterns during these surveys are the same as those for Bear Creek.

Table 19 and Figure 20 summarize study results. Burley Creek was divided into seven segments. All segments had generally marginal soils. Six segments produced loads. Two segments were predominantly agricultural. Loading tended to be high initially after onset of rain and lower later, which suggests a "first flush" from surface runoff. Two other segments were predominantly residential. Loads tended to be minimum at first and higher later, which suggests loading from contaminated ground water. The other loading segments had mixed agriculture and residential use.

The following detailed discussion may be bypassed by turning to Purdy Creek Analysis (page 90).

BU 5.0 to 4.5. The hilly section of Burley Creek between BU 5.0 and BU 4.5 is mostly pasture. There are several homes in the upper area above BU 5.0.

The soil permeability here is low, and the water table is high during the winter in many places. There is a small section of good Indianola soil in the north end of the pasture. Slopes in the pasture range between 8 and 15 percent.

Based on streamwalk notes and frequent observations during routine monitoring trips, this farm is well-managed, and the fields are not overgrazed. Nevertheless, samples from the May 1983 streamwalk showed increased FC concentrations in the creek of up to 150 FC/100 mL at M 4.5. The high FC levels may be due to the steep gradient and lack of a well-developed vegetative buffer.

This segment demonstrated a "first flush" effect in FC loading during the winter storm event. This effect was observed in other segments where there is animal grazing. Fecal bacteria lying near the ground surface adjacent to the creek caused a high initial FC loading increase (300 percent on January 24, 1984) out of proportion to the increase in flow from runoff (52 percent) going downstream from BU 5.0 to BU 4.5. As the rainfall subsided, the increase in FC loading between the two points (123 percent on January 25, 1984) was two times the flow increase (77 percent). Apparently the fecal bacteria closest to the creek had been washed out to some extent over the 24-hour rain.

Dry-period sampling in October yielded a ten-fold increase in FC concentration at BU 4.5 over that at BU 5.0, although this is far below the FC standard.

A landowner and the Kitsap County Conservation District constructed a fence along the creek during summer 1984. Prior to that time, cattle had unlimited access to the stream. Some improvement in creek conditions should result from fencing. However, the steepness of the grazing areas requires care in manure management. Otherwise, some wastes will probably still enter the creek, especially under saturated winter ground conditions.

BU 4.5 to 4.3. A small livestock-grazing area lies below BU 4.5. After passing through the pasture, Burley Creek crosses under Highway 16 just below BU 4.4, then passes through a swampy wooded area close to a few homes. Septic systems are not recommended for most of the soils here. The authors reported high FC counts at BU 4.3 to the Bremerton/ Kitsap County Health Department. An investigation revealed that one of the septic tanks close to the creek above BU 4.3 had a septic tank, but no drainfield. Corrective action was undertaken (Russell Carr, Environmental Health Technician, personal communication). This same system failure was identified by Hoppus (1984).

Table 19. Winter rain-event and dry-period sampling, Burley Creek.

Station	Rain Event (1/24/84) (FC/100 mL)*	Q (cfs)	FC Loading (FC x 10^4/sec)	Rain Event (1/25/84) $\overline{X}$ (FC/100 mL)**	Q (cfs)	FC Loading (FC x 10^4/sec)	Dry Period 10/11/83 $\overline{X}$ (FC/100 mL)***
BU 5.0	47	2.3	1.2	42	3.0	3.0	2
BU 4.5	49	3.5	4.9	46	5.3	6.7	20
BU 4.3	45	4.5	5.7	49	6.7	10.1	1300
BU 3.7	21	8.2	4.9	94	11.7	56.5	12
BU 3.5		--	--	--	--	--	15
BU 3.2		--	--	--	--	--	12
BU 2.6	37	14.4	15.1	92	22.4	114.8	16
BU 2.2							12
BU 1.6	18	23.6	12.1	77	30.2	72.2	14
BU 1.3	43	26.4	32.2	84	37.8	80.7	13
BU 0.9		--	--	--	--	--	23
BU 0.6	20	33.4	19.0	103	48.9	181.1	26
BU 0.3							35

*Concentration represents one sample.
**Concentration represents the geometric mean of three samples collected over six hours.
***Concentration represents the geometric mean of two replicate samples.

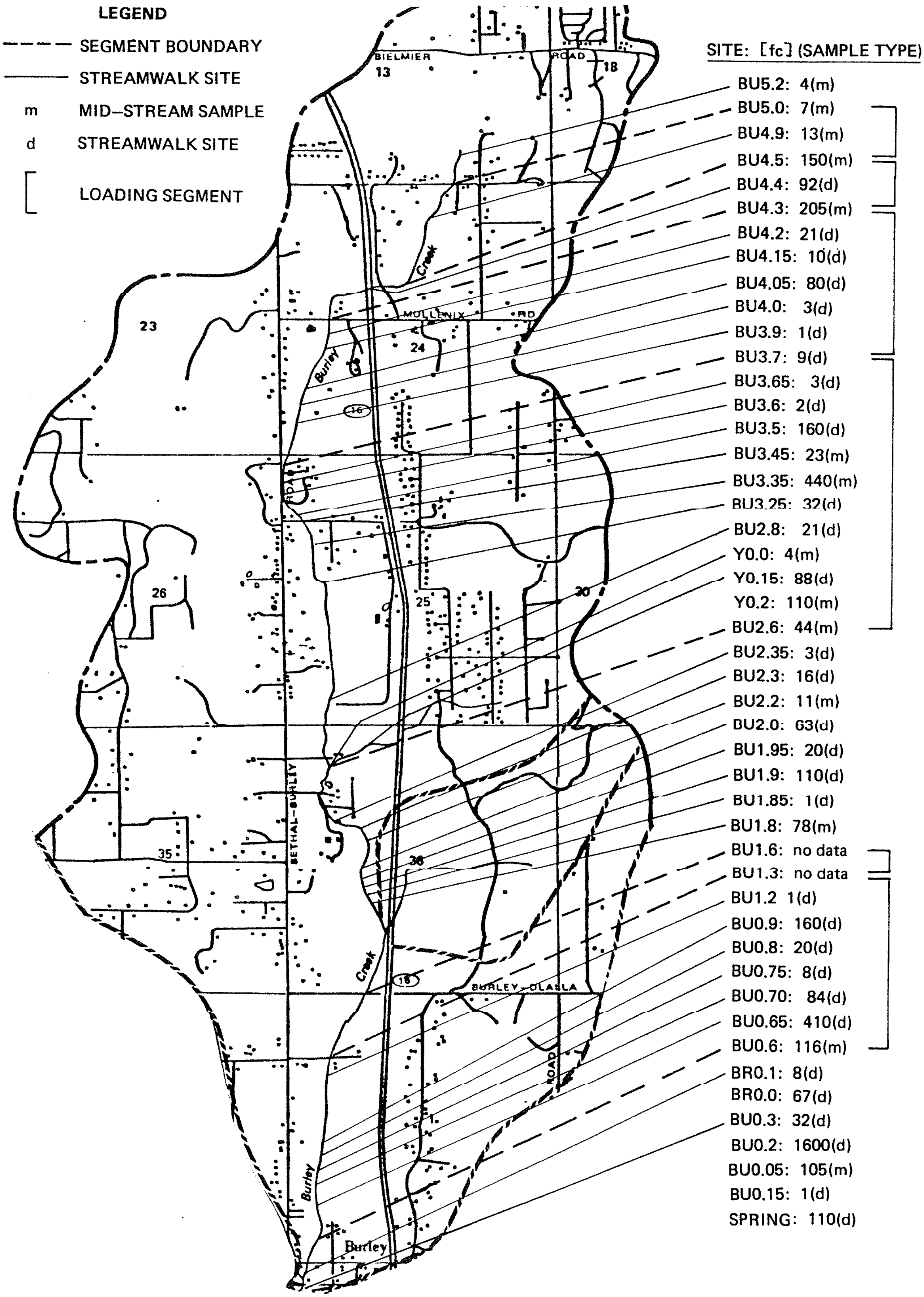


Figure 20. SITES SAMPLED DURING STREAMWALK SURVEYS (MAY 1983); AND LAND–USE SEGMENTS SAMPLED DURING A JANUARY 1984 RAINFALL EVENT ON BURLEY

This segment demonstrated a delayed loading response relative to stream flow. At the beginning of the rain, loading increased only 16 percent going from Bu 4.5 to BU 4.3, while the flow increased 28 percent. But after a day of quite heavy rain, the loading increased 50 percent while the flow increased only 26 percent. Septic tank effluent may be the cause of contamination. Subsurface movement of FC may occur after the ground becomes saturated, producing a delay in stream loading (Hagedorn, et al., 1978).

BU 4.3 to 3.7. Burley Creek bottom land from BU 4.3 to BU 3.7 is mostly wooded with light residential development 200 to 800 feet beyond. Soils along the creek are described as the poorly drained Norma type with some very steep areas. However, most of the soils more than 500 feet from the creek are good for septic drainfields.

Out of five drainage inflows sampled during the May streamwalk, only a two-foot-wide tributary on the west side (BU 4.05) violated the FC standard. Several houses were reportedly visible near BU 3.9 on the west side of the creek. No animals were seen during this streamwalk. Hoppus (1984; Figure 38) reports a poultry farm on the west side of the creek near here.

During the winter rain event, the stream load at BU 3.7 was 11.5 times higher when the storm was subsiding on January 25 than when the rain was just beginning on January 24. The loading rate at the upstream station, BU 4.3, increased about 1.8 times in the same period. This area is another example of the delayed response in FC loading from on-site systems. The flow increased 82 percent going downstream from BU 4.3 to BU 3.7 on the first day of rain, while the FC load dropped 14 percent. However, immediately following the storm, FC loading increased 460 percent and the flow rate increased only 74 percent within the segment. Further investigation of the septic systems in this area, especially during the rainy winter season, is strongly recommended.

BU 3.7 to 2.6. Grazed pastures line the banks along most of the creek between BU 3.7 and BU 2.6. Grazing is quite heavy in some places. Burley-Bethel and Holman roads, within about 500 feet of this stretch, are lined with relatively dense housing. With one exception, the soils within 1000 feet of the creek have a high water table and/or low permeability. Around the lower 0.3 mile of the stretch, the soils are classified as Muck, and the area is used mainly for pasture land.

The stream is fenced along most of this reach, although streamwalk notes report livestock access to the creek 200 yards downstream of Holman Road. Samples of inflows were low above the pasture area (BU 3.65, BU 3.6). However, below the grazing area, an FC density three times the standard occurred in the ditch at BU 3.5. Another creek sample at BU 3.35 was nearly ten times the FC standard. A small, heavily grazed horse pasture on the west side of the creek above BU 3.35, could be responsible for the high FC density there.

The Pierce County Conservation District discovered an additional unfenced pasture near BU 2.9 (Bea McKamey, personal communication, 1984). The section from about BU 2.7 to BU 2.6 was reported to have grazing animals on the west side which were fenced from the creek.

During moderate rainfall (January 24), loading in this segment tripled while flow nearly doubled. After the rainfall subsided (January 25), loads at the lower end of the segment were twice that of the upper end. However, stream flow between the two points was only slightly higher proportionally than the previous day. These results are similar to the "first flush" phenomenon found in the actively grazed segment between B 5.0 and BU 4.5. Tate (1978) found that fecal coliform survive much longer in organic muck soils than in sand, especially when flooded. The mucky soils in this segment may provide a good nutritional habitat which allows FC bacteria to survive much longer than in other areas with comparable grazing intensity. During moderate to heavy rainfall, muck soils may introduce geater numbers of fecal coliform to a stream than can be explained by the number of sources.

BU 2.6 to 1.6. Poor soils surround most of the creek mainstem here. They include the wintertime ponded Norma type, very poorly drained Semiahmoo muck, and Kitsap which has low permeability and high winter water table. The lower 0.3 mile of this stretch is mostly wooded and has good Indianola and Nielton soils.

This stretch of Burley Creek is characterized as pastureland, with grazing cattle and a few scattered homes. Two substantial tributaries flow into Burley Creek in this stretch. The first drains a large housing development on Horizon Drive east of Highway 16. The second drains the undeveloped subbasin used as a control during several sampling programs (Station X 0.2).

Samples collected along the "Horizon Drive" tributary in May 1983 indicate an FC source or sources. A sample twice the standard occurred just east of Highway 16 (Y 0.2). Hoppus (1984; Figure 38) reports three probable septic tank failures in the housing development. The soils on the west side of the development, where most of the homes lie, are classified as suitable for on-site sewage systems. However, on the east side, an impermeable layer of glacial till lies between 25 and 40 inches below the surface.

A high FC concentration was also found downstream at Y 0.15 just below a dairy barn and two houses west of S.R. 16. The soils are mostly muck and Norma, both of which are poorly drained, especially in the winter. Hoppus (1984; Figure 38) shows a failure here also.

Streamwalk reports indicate that large fields between Y 0.15 and the highway drain into this stretch. The creek was strongly colored at both sampling sites, and foamy at Y 0.15. The fecal content diminished drastically at the mouth of the "Y" tributary, to only trace densities of FC. Under wetter soil conditions and higher flows, the upstream contamination would be likely to reach Burley Creek.

Below the "Horizon Drive" tributary confluence, three east bank ditches draining undeveloped woods had very low FC concentrations during the May 1983 streamwalk. Cows and horses were reported at BU 2.0, 1.95, and 1.9. Details of fencing were not specified. The two ditches at BU 2.0 and Bu 1.9 both exceeded the FC standard. The sample from a pond outlet on the undeveloped east side at BU 1.95 had only 20 FC/100 mL. A small metal pipe with a discharge into the east side at BU 1.85 had trace levels.

Fecal bacteria concentrations were measured only at BU 2.6 and BU 1.8 during the May 1983 streamwalk. The upstream site, BU 2.6, was below the standard, while near the cattle- and horse-grazing area at BU 1.8, the density was above.

Reports by the Kitsap County Conservation District indicate that horses graze on the west side of the creek between BU 2.6 and BU 2.55. They are not fenced from the creek, but have only limited access (Bea McKamey, personal communication). The stretch of creek from BU 2.45 to BU 2.35 has been fenced since the study. A ditch which joins the creek at BU 2.35 passes through a cattle-grazing area that is not fenced, and cattle gain access freely. The Conservation District also noted that the creek is fenced from BU 2.35 to BU 2.0.

Winter rain-event FC loading increased by about the same factor (6 to 7.5 times) at both segment boundaries (BU 2.6 and BU 1.6) between the beginning and end of the January 1984 rain. However, the loading rate was lower on both days at the downstream location (BU 1.6) than upstream at BU 2.6. A possible explanation for the load loss is that loading from upstream settles out along the one-mile stretch. Bacterial loading within the BU 2.6-1.6 section may also settle out, especially in the undeveloped one-third on this stretch.

Dry-period samples taken in October 1983 at BU 2.6, 2.2, and 1.6 were all within the acceptable limit.

Hoppus (1984, Figure 38) shows three possible septic system failures far to the east of Burley Creek and another to the west. All are near the boundaries of the watershed. The effect of these systems given their remoteness is probably low.

BU 1.6 to 1.3. The short stretch of Burley Creek between BU 1.6 and BU 1.3 is forested. The only nearby development seems to be one house which lies about 500 feet east of BU 1.2, and a narrow field along Bethel-Burley Road 200 to 1000 feet from the creek which may be used for grazing livestock.

The soils near the house are either Harstine or Norma, neither of which are considered suitable for septic tank drainfield systems. The field near Burley-Bethel Road is mostly Norma soil.

A landfill is located a half-mile east of Burley Creek and south of Burley-Olalla Road. Hoppus (1984; Figure 44) suggests that surface drainage from the landfill is directed toward Burley Creek. However, the stream looked very clean with a gravel bottom during the May 1983 streamwalk. No inflows were reported, and no FC samples taken then.

The January 1984 rain sampling initially nearly doubled FC loading between BU 1.3 and BU 1.6. But by the end of the rain on January 25, the net loading increase was only 12 percent. Despite the lack of major development here, there seems to be a quick-responding surface source. This may implicate the pasture area. However, it is possible that the landfill may have had a heretofore undetected effect.

Samples collected at the upper and lower boundary of this stretch during the October 1983 dry season were within acceptable FC limits.

Recent excavation and clearing next to the creek began during January 1984, near BU 1.3. The soil appears to be Norma type which has drainage problems, especially during the winter.

It may be worthwhile to inspect the septic system at the home located east of the creek and verify the presence of animals. The field along Burley-Bethel Road would not appear to cause a fecal bacteria problem since it is buffered by a relatively wide wooded strip and no inflows were found during the May 1983 streamwalk. A winter inspection of the field including animal census and drainage patterns would answer many of the questions about this stream segment. An investigation of landfill drainage patterns would also be in order. However, the landfill is scheduled for closure soon.

BU 1.3 to 0.6. The section of Burley Creek from Oak Road to the Bear Creek confluence is the most densely populated area in the upper Burley Creek Subbasin. A wide forest buffer lines the creek from about BU 1.3 to BU 0.8. A few houses are visible from the creek. There are, however, quite a few houses with small pastures along Burley-Bethel Road 300 to 500 feet to the west. Streamwalk reports indicate an erosion problem starting about 1/2 mile south of Oak Road. Relatively dense housing is found from BU 0.9 to BU 0.6, with the density increasing downstream.

The upper end of this stream reach has poor soils near the creek. The residential areas in the lower end of this section have mostly Norma or Kapowsin soils, and houses are very close to the creek.

Notes from the May 1983 streamwalk describe the banks of the creek as vegetated along at least the upper half of this stretch, although some bank erosion exists. Two tributaries which drain the undeveloped east side had very low FC concentrations in May 1983. Two out of three tributaries draining the lower west side had quite high concentrations of fecal bacteria. These tributaries drain areas of pasturage and residences. Both of the creek samples collected in May 1983 at BU 0.9 and BU 0.6 violated the FC standard. Several houses are especially close to the creek just above BU 0.6. One mobile home lies within 15 feet of the creek. The only animals noted during the streamwalk in this area were two goats at BU 0.9; however, horses and cows are scattered through the area.

The January 1984 storm event results seem quite comparable to those obtained from the residentially developed stretch between Bu 4.3 and BU 3.7. On the first day, FC loading was 41 percent lower at the downstream site (BU 0.6) than upstream (BU 1.3). As the rain subsided the next day, loading was 124 percent higher at the downstream station than at the upstream site. On both days, the flow at BU 0.6 was about 28 percent higher than at BU 1.3. A "delayed response" occurred between onset of the rain and arrival of the FC in the stream. The lag suggests a ground-water pathway (rather than direct runoff) for the FC load. The nearly ten-fold increase in loading over two days is similar to the segment between BU 4.3 and BU 3.7. A "first flush" would be expected if the major FC sources were animal wastes washed off nearby pastures.

Dry-season samples collected between BU 1.3 and BU 0.6 demonstrate an increase in downstream FC concentration, though these were not violations.

Sediment samples collected at BU 0.6 in September 1983 had a relatively high concentration of fecal coliforms, 9200 FC/100 g ("Streambed Sediment...," Appendix A).

Septic systems which lie in this segment, especially those adjacent to the creek, may be contributing loads, although there are few obvious failures. Most of the systems are old and are likely to have lacked periodic maintenance. Upgrading to more advanced systems may be necessary due to the poorly drained soils.

BU 0.6 to 0.05. Lower Burley Creek from BU 0.6 to BU 0.05 passes through Burley village, one of the most densely populated areas in the Burley Watershed. Many homes, most more than 30 years old, have small pastures with animals. There are also large areas used strictly for pasturing large animals.

The low-lying Norma soil is the major soil type in this area. There are also large patches of poorly drained Kapowsin which have a hardpan layer below the surface. There are two patches of Nielton which is classified as suitable for dense residential development.

Streamwalk notes describe some erosion between BU 0.6 and the Bear Creek confluence. We have noticed that infrequent storms have aggravated the subsidence. The situation will probably worsen if no remedial action is taken.

Bear Creek joins Burley Creek about 0.1 mile below BU 0.6 and increases the flow 12 to 25 percent. This added flow also contributes a large quantity of FC bacteria. Out of 30 samples collected at BR 0.1 during all programs, 23 violated the FC water quality standard.

Three inflows below Bear Creek were sampled during the May streamwalk. Pastureland occupies the area near BU 0.3, although no animals were seen. The FC concentration was within the FC standard. Two horses, ten cows, and two residences were seen near the ditch draining the swampy area near BU 0.2. The ditch had an FC concentration nearly 30 times the standard. A short distance downstream at BU 0.15, a marshland drainage had only trace levels.

The final Burley Creek FC sample taken within the estuary at BU 0.05 in May exceeded the standard. A number of residences lie on the east side of the creek. The FC result may be an underestimate because of dilution by tidal action.

This segment was not included in the winter storm event survey due to complications from the addition of Bear Creek loading. Dry-season samples collected at BU 0.3 were within the standard, but were the second highest dry-season sample collected in Burley Creek.

The intensive human and animal development in this area during the winter makes it an ideal candidate for fecal bacteria problems, especially when the water table is high. The age of the septic systems and proximity to Burley Lagoon make this an area worthy of closer scrutiny. Subsurface fecal bacteria movement from septic drainfields during winter saturated-soil conditions should be examined in this area, especially homes near the creek (Hagedorn, *et al.*, 1978). Numerous roadside ditches within Burley village also flow into lower Burley Creek or into the lagoon directly. Despite the problems posed by soils within this segment, Hoppus (1984) shows no septic system failures.

Details of animal populations and their access to the creek have been addressed more fully by McKamey (1984).

Purdy Creek Analysis. The streamwalk survey of Purdy Creek took place on April 25, 1983. At the Minter Creek Hatchery 0.04 inch of rain was recorded. During the two preceding days, 0.1 and 0.2 inch of rain fell. However, no rain was recorded from April 13 through April 22. April's total rainfall was half the 30-year average (Figure 4). The ground was becoming fairly dry after the heavy winter rains.

The dry-period sampling took place on October 12, 1983 at Purdy Creek. No appreciable rain had fallen for three weeks, and the water table was near its lowest level for the year.

The rain-event segment loading study was carried out on December 5, 1983. Despite National Weather Service rainfall predictions, only about 0.1 inch of rain fell at the Minter Creek Hatchery between 0800 hours and 1300 hours, most of that before 0930 hours. The previous day, however, 0.49 inch of rain was recorded. Only slight precipitation occurred during the week before. Thus, surface runoff was probably negligible. In addition, flow measurements could be taken only at the lower four sampling sites due to an equipment malfunction. For these reasons, the following comparisons among segments are qualitative, and loading figures are probably underestimates of worst-case conditions.

Three of seven segments in Purdy Creek produced net loads (Table 20 and Figure 21. Agricultural or mixed use prevail in these segments. Two other mixed-use segments generated no net loading, but field observations and past data suggest further work is needed. This includes the segment at the mouth which contains Purdy Village and the Purdy Landfill. Soils appear to be marginal in all Purdy segments. In general, soils are poor in bottom lands, flat areas, and along the streams. Much of the development seems to be occurring in these areas.

More detailed analysis follows. General-interest readers can proceed to Rain-Event Surveys on page 97.

P 3.6 to 2.8. The land draining into Purdy Creek above P 3.6 is mostly undeveloped forest. However, several homes lie near P 3.6 within about 500 feet of the creek with cleared areas for horses and chickens. A barbed-wire fence stretches along the west side of the creek here. The area lining the creek from P 3.6 to 2.8 is rapidly developing into a small farm/residential area of two- to five-acre lots. Horses, cows, and fowl occupy many of the home sites, sometimes close to the creek. According to streamwalk reports, there were signs of cattle walking in the creek just above P 3.3. Two houses were visible from the creek. A sample collected from a small pond inflow near P 3.3 had a density of 200 FC/100 mL.

Routine background monitoring samples collected at P 3.6 were below the fecal coliform standard throughout the year except on July 25 during a very heavy rainstorm. During the December 1983 storm sampling, none of three samples exceeded the standard. Storm samples were not collected at P 2.8. Therefore, no loading information is available there.

Thick brush covers the east side of the creek around P 2.9. Several houses lie about 700 feet east of the creek. No major clearing has begun there. A tributary from the east enters Purdy Creek at P 2.9. The FC density (34 FC/100 mL) was below the standard, yet above background levels. Dry-period samples collected at P 3.6 and P 2.8 were both very low.

Table 20. Winter rain-event and dry-period sampling, Purdy Creek.

Station	Rain Event (12/5/83) $\bar{X}$ (FC/100 mL)*	Q (cfs relative)	FC Loading (FC x 10^4/sec relative)	Dry Period (10/12/83) $\bar{X}$ (FC/100 mL)**
P 3.6	19	--	--	7
P 2.8	--	--	--	5
P 2.3	33	--	--	155
P 1.8	110	--	--	100
V 0.0	1	0.7	0	2
P 1.4	84	2.8	6.6	21
P 1.3	70	5.0	9.9	33
P 0.8	210	9.0	53.9	39
P 0.2	--	--	--	17
P 0.1	180	8.9	46.3	17

*Concentration represents the geometric mean of three samples collected over four hours.
**Concentration represents the geometric mean of two replicate samples.

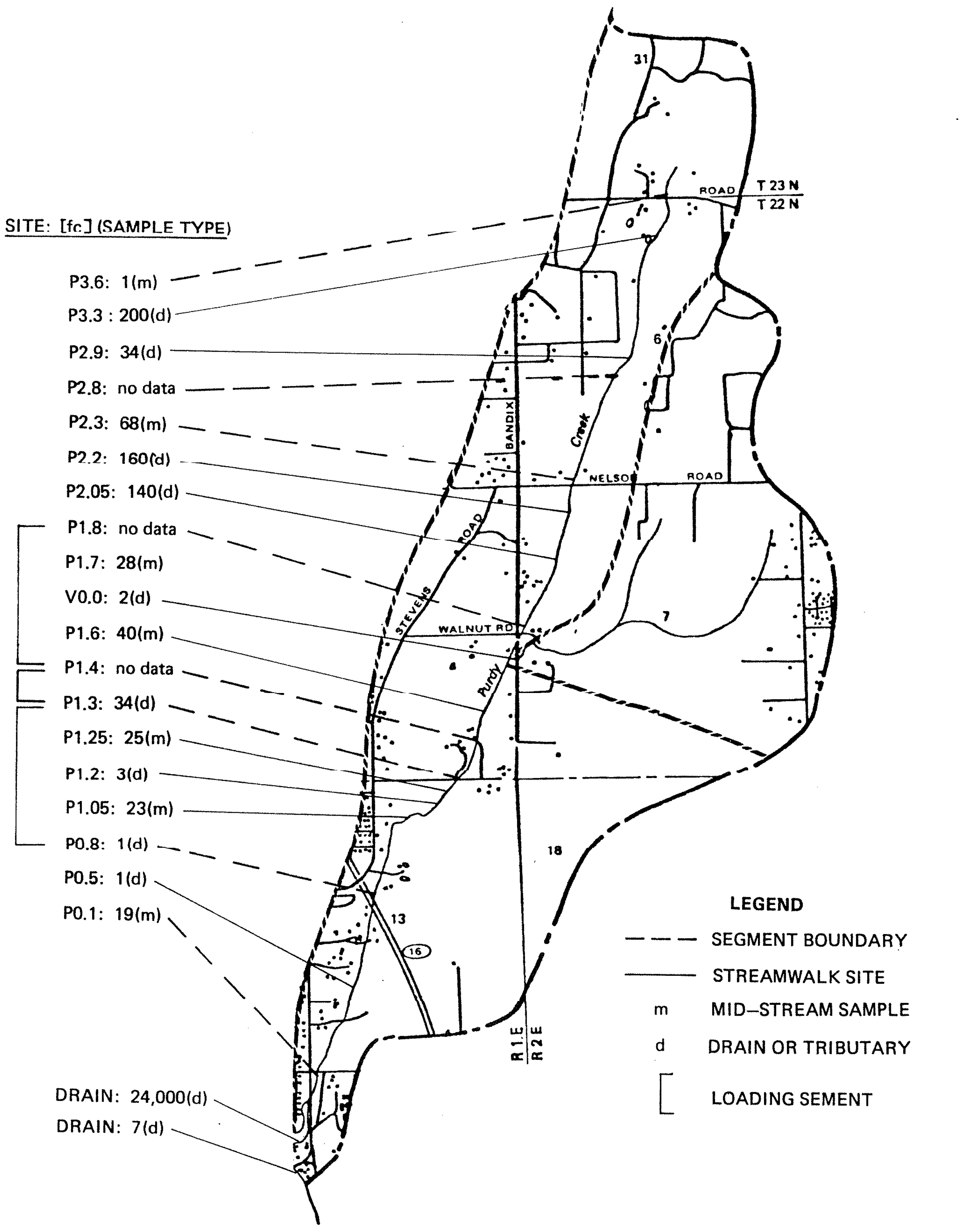


Figure 21. SITES SAMPLED DURING STREAMWALK SURVEYS (APRIL 1983); AND LAND–USE SEGMENTS SAMPLED DURING A DECEMBER 1983 RAINFALL EVENT ON PURDY CREEK, PURDY WATERSHED.

The soils along this stretch are quite patchy. Near the creek Harstine soils lie with a glacial till underlayer mixed with poorly drained Norma. Areas of well-drained soils, such as Indianola are occasionally found in this drainage area.

Special attention should be given to construction of septic systems in developing areas of this stretch. Existing systems should be periodically serviced and inspected, and those already present scrutinized. Inadequate animal management may also be causing problems in this stretch.

P 2.8 to 2.3. Land bordering Purdy Creek between P 2.8 and P 2.3 is mainly undeveloped forest with some areas cleared for horse pastures. There are a few houses near P 2.3 with cleared areas for animals, one of which had various fowl and goats. A large, densely housed area lies along Bandix Road north of Nelson Road where P 2.3 is located. Most of the homes in this area are not visible from the road, but one wooded 2.5-acre lot had four cows penned in a very small area in August 1983.

According to the 1979 Kitsap County Land Use Planning map, several small undeveloped lots line the creek between P 2.6 and P 2.5. Most of the other lots in the undeveloped area are at least 2.5 acres.

Most soils along the creek in this segment have a hardpan layer 20 to 40 inches below the ground surface or a perched water table during the winter. Two small patches of Indianola soil lie quite far from the creek. The populated areas lie in Harstine soils. About half of the pasture areas occupy the well-drained Indianola soil, and about half lie in Harstine.

Streamwalk notes from April describe pasturage just downstream of P 2.9. The only sample collected in this stretch at P 2.3 slightly exceeded the standard.

The geometric mean of three samples taken here during rain-event sampling was below the standard for freshwater. During the October 1983 dry-period sampling, however, the mean of two samples from P 2.3 was three times the limit (compared to trace levels upstream at P 2.8).

The winter rain event was not representative of a typical winter storm, and the results probably underestimate the effect of rain on FC loading in the creek. The 0.49-inch rain which fell the day before sampling may have caused a semi-washout of fecal bacteria. Violations of the FC standard at P 2.3 in April and October 1983 (when soils were not saturated) seem to indicate a problem with animal wastes in this stretch, although septic systems near the creek should also be inspected.

P 2.3 to 1.8. The upper quarter of the stretch of Purdy Creek between P 2.3 and P 1.8 is undeveloped forest. Below the wooded area lie mostly large residential/farm acreages (5 to 10 acres).

No soils in the area surrounding this reach could be classified as suitable for conventional septic tank drainfields. East of the creek lie mostly steep Alderwood soils with a weak hardpan layer about 38 inches below the surface. A perched water table is likely during the winter. On the west side, Harstine soils cover most of the area. The soils in and near the creek bed are mainly McKenna type, which are typically associated with slow permeability, ponding, and subsidence.

Two inflows enter Purdy Creek in this stretch: a spring drainage from the swampy west side at P 2.2; the other, one of many pasture seeps in the area east of the creek at P 2.05. Both inputs had violation-level FC concentrations during the April 1983 streamwalk. Livestock reportedly have access to the creek in places near P 2.05, but the east side is mostly fenced. A horse, two cows, and a chicken coop were seen on the west side. The sample collected from the creek at P 2.3 in April was slightly above the FC standard. The lower part of this creek section was not sampled.

During the December rain event, the FC concentration at P 1.8 reached 200 FC/100 mL in the morning when the rain was heaviest. The geometric mean of three samples at P 1.8 was twice the FC standard, while P 2.3 was within the standard. The samples collected in October at both P 1.8 and P 2.3 exceeded the limit two- to three-fold.

The increased FC concentrations in this stretch during the light winter rain and the October dry period suggest that this segment is a significant source of FC loading. Livestock grazing and access to the creek may account for most of the problem. Proximity of chickens to the creek should also be investigated. On-site sewage facilities located on poor soil may also make a significant contribution. Hoppus (1984, Figure 48) shows a possible failed septic system east of Purdy Creek just above P 1.8.

P 1.8 to 1.4. Trees line the creek banks from P 1.8 to about P 1.6. A major undeveloped tributary (V 0.0) flows into Purdy Creek just above P 1.7. The contribution of water to Purdy Creek ranges from 25 percent during winter to 50 percent during summer. The land which drains into the tributary is mostly undeveloped forest except for a couple of houses near the mouth, one of which lies directly on the creek about 0.1 mile upsteam of V 0.0. This tributary was used during this study as an undeveloped control subbasin.

The creek area is wooded below the V 0.0 tributary confluence to about P 1.6. The vegetation alternates between forest and brushy thickets from about P 1.6 to P 1.45. Pastureland begins upstream from P 1.4 and extends into the next reach.

Areas very near the creek have mostly McKenna soils. Harstine soils cover most of the other nearby areas. The "V" tributary drainage basin has mainly Alderwood soils. These soil types may produce saturated soils or perched water tables seasonally.

A streamwalk sample collected in April 1983 at V 0.0 had only 2 FC/100 mL. This site was a routine sampling station, and out of 25 bi-weekly replicate samples only three water quality violations occurred. Most of the values were less than 10 FC/100 mL. The other streamwalk sample from this stretch was below the violation level yet above background at P 1.6.

A small group of homes lies within 200 to 500 feet east of the creek near P 1.6, but a steep wooded area separates the houses from the creek. There are several large animals near these homes, including a llama, horse, goat, and a Shetland pony. Streamwalk notes report livestock prints in the creek downstream of P 1.6.

During the winter light rain event, the average of three samples exceeded the allowable limit by about 60 percent. This level appears lower than that upstream at P 1.8, but the added uncontaminated flow from V 0.0 should have diluted the load more than it did if no other sources were present.

Replicate samples collected during the October 1983 dry period had a much lower FC density at P 1.4 than at P 1.8. The FC level at P 1.8 was twice the FC standard. At this time of year, dilution from the large, clean input at V 0.0 was more effective in lowering the concentration of FC bacteria.

No human sources of fecal contamination were observed from the ground in this segment. However, Hoppus (1984, Figure 48) shows two septic system failures below P 1.8 south of Walnut Road Southeast. Since the soils are mostly unsuitable for septic tank drainfield systems, home systems close to the creek should be inspected under winter wet-weather conditions.

P 1.4 to 1.3. The short stretch of creek between P 1.4 and P 1.3 is bordered by pastures on both sides. No animals were seen grazing in these fields. A short distance east of the creek, however, there is a small farm with about 100 chickens and geese. A small drainage appears to flow near this farm and empties into Purdy Creek on the north side of 160th Street, just above P 1.3.

The local soils are mostly Norma which have moderately rapid permeability during the dry season but a high water table and probability of ponding during the wet months.

A sample of drainage from the chicken farm entering Purdy Creek was below violation levels when sampled during the April 1983 streamwalk.

Samples collected during the winter mild rain event had very similar concentrations at the two stations, P 1.4 and P 1.3. However, a higher flow measured downstream suggests a net loading occurred in the segment. Dry-period samples in October indicated a higher FC concentration at P 1.3 than at P 1.4.

The chicken farm is the probable cause of the net fecal loading. The Soil Conservation District technician for the area has contacted the farm owners, and they have agreed to make corrections.

P 1.3 to 0.8. The area along Purdy Creek between P 1.3 and P 0.8 is used mainly for pasturing cows and horses. There are several homes close to the creek and along 62nd Street Northwest. Part of a very densely packed trailer park on the west side of 62nd also lies in this creek drainage.

Soils surrounding this area are not generally suited for individual septic systems. The upper part of the section has Norma type soils, and the mid-to-lower part has mostly Harstine.

Two drainage inflows sampled along this reach during the April streamwalk had fecal levels below 5 FC/100 mL. Two other sites within the segment had values below the standard. The creek is partially fenced between P 1.2 and P 1.05.

Under wet December conditions, this stretch appears to contribute a large load of FC bacteria. The concentration at the upstream station, P 1.3, was slightly above the FC standard. The sample downstream at P 0.8 was three times higher. Flow measurements (relative values only) doubled in this stretch. FC loading, therefore, probably increased six-fold between P 1.3 and P 0.8.

Replicate October dry-period samples were comparable and rather low at each segment boundary and somewhat higher than sites farther downstream.

The Conservation District is working with at least one of the farmers who raises animals in this stretch, and is planning a fencing project on both sides of the creek. This may alleviate part of the problem, but access will probably continue until special bridges are constructed in these grazing areas. The SCS is working on designs for bridges, but implementation may not occur for some time.

P 0.8 to 0.1. The area around Purdy Creek between P 0.8 and P 0.1 has fairly dense residential development with patches of pastureland and woods.

The soils bordering the upper stretch are Harstine which are not considered suitable for septic systems. Farther west and south lies a relatively steep, wide stretch of well-drained Nielton soil.

The results of the April 1983 streamwalk indicate a possible problem pasture near P 0.5. No animals were observed in the mucky-looking field, although it was apparent that livestock had been grazing in or near the creek. A sample collected at P 0.1 at the same time had a low FC concentration.

This segment showed little change in mild winter storm loading. The three samples collected during the December 1983 survey had very similar FC concentrations (all well above the FC standard). The flow measurements, only useful in a relative sense, were nearly the same at P 0.8 and P 0.1, which suggests no net increase in FC loading.

Samples collected in October 1983 following a dry period had lower FC counts at P 0.2 and P 0.1 than above at P 0.8.

Wintertime FC sources in this stretch need further evaluation. The densely housed trailer park located on the south bend of 62nd Avenue Northwest is built on soils unable to adequately treat on-site waste effluent (B-3), especially in the winter. The east side of the trailer park is within 500 feet of the creek near P 0.7. Hoppus (1984, Figure 48) shows one possible septic system failure near this park. Houses located close to the creek on both sides, and the gas station above P 0.1, are also built on poor soil for septic systems (B-2), and are susceptible to failure, especially during wet weather.

Although a large increase in FC loading was not evident from the comparison in December of P 0.8 and P 0.1, this area should not be rated problem-free. The winter storm dropped only 0.1 inch of rain during the sampling, and gives little indication of what occurs during the frequent heavy winter rain here. The close proximity of this section of the creek to the shellfish-growing area in Burley Lagoon make it high priority to assure that no major bacterial inputs occur here.

Part of Purdy Township (including two schools, restaurant, and several businesses) lies along and drains into the stretch of Purdy Creek below P 0.1. Routine monitoring data at P 0.1 show mean FC levels at 106 FC/100 mL far higher than those shown during the streamwalk survey or the dry- and wet-weather surveys. A drain sampled behind the Purdy shopping center in April 1983 had more than 240,000 FC/100 mL. Time constraints and complexity prohibited further investigations of wastewater problems in Purdy. However, the problems there require further detailed investigation. Hoppus (1984) found one possible septic system failure east of Purdy Drive Northwest and north of the Westwynd Motel.

A supplementary rain-event survey was carried out in March 1985 to measure the efects of the Purdy Landfill on fecal coliform loading in Purdy Creek and Burley Lagoon ("The Effects of the Purdy Landfill...," Appendix A). The results show that the landfill is relatively far removed from Purdy Creek and overland runoff did not reach existing drainage. However, the landfill contributed a small but measurable FC load to Purdy Creek. One source of the fecal coliform was probably thousands of resident crows and gulls that forage on the uncovered solid waste in the landfill disposal pit. The pathway appears to be contaminated ground water that intersects nearly roadside drainage and ultimately discharges into Purdy Creek upstream of SR 16. The mechanism may be similar to that described by Hagedorn, et al., (1978).

Rain-Event Surveys

Figure 3 shows the location of stations at tributary mouths and in the estuary. Figure 22 summarizes rainfall data and streamflows during the rain event. In all cases, a correlation of stream flows with rainfall is apparent. There is little evidence of a lag time between peak rainfall and streamflows, although there are substantial daily variations at higher streamflows in Purdy and Burley creeks.

Elevated flows are associated with increased levels of FC bacteria in both developed and undeveloped streams. The undeveloped Burley tributary (X 0.2) reached peak fecal coliform levels very early and achieved lower FC densities than its undeveloped Purdy counterpart (V 0.0, Figures 23 - 25). This may be due to smaller size and lesser degree of development. Both undeveloped tributaries showed decreasing FC densities as the rain event continued. In all cases, FC levels were well within the state water quality freshwater standards.

Samples taken from streams draining developed stream reaches showed substantial violation of the standard. Fecal coliform levels seemed to be linked to stream flow. The geometric means for Burley Creek and Bear Creek were 346 FC/100 mL and 758 FC/100 mL, respectively. All samples from both creeks exceeded the fecal coliform standard. However, on March 21, a period with little rainfall, all of the main streams complied with the Part 1 standard. Purdy Creek contributed less FC contamination than either Burley or Bear creeks. Burley Creek reached maximum levels of about 1700 FC/100 mL, but values at other times were substantially less. Maximum Bear Creek values were somewhat lower than Burley Creek, but consistently higher at other times during the study.

In order to compare the contamination potential of the three streams, instantaneous FC loads were calculated (Figure 26) using the method of Kittrell (1969).

Among the developed creeks, Burley Creek generally contributed the greatest load during any particular sampling run, Purdy Creek contributed the least, and Bear Creek roughly intermediate. Bear Creek's contribution averaged about 50 percent that of Burley Creek. The annual load estimated from routine monitoring data was only 14 percent that of Burley Creek (page 63), but routine monitoring generally missed important rain events. This suggests that Bear Creek's role in loading becomes proportionally greater during rainfall.

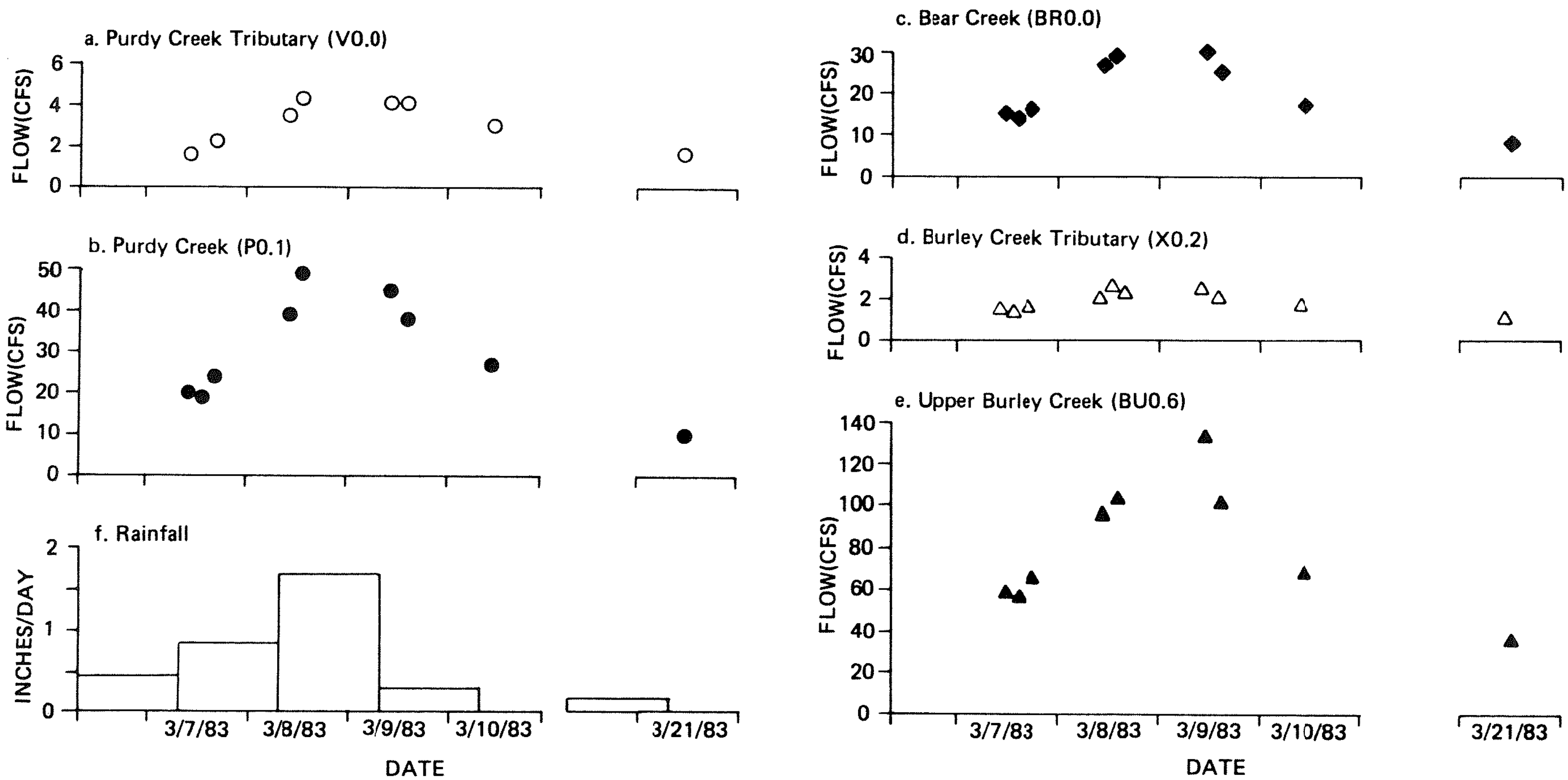


Figure 22. DAILY FAINFALL AND STREAMFLOW IN SEVERAL BURLEY/PURDY WATERSHED STREAMS DURING A RAIN EVENT (MARCH 7–10, 1983). DATA FROM MARCH 21, 1983, ARE INCLUDED FOR A DRY–PERIOD COMPARISON.

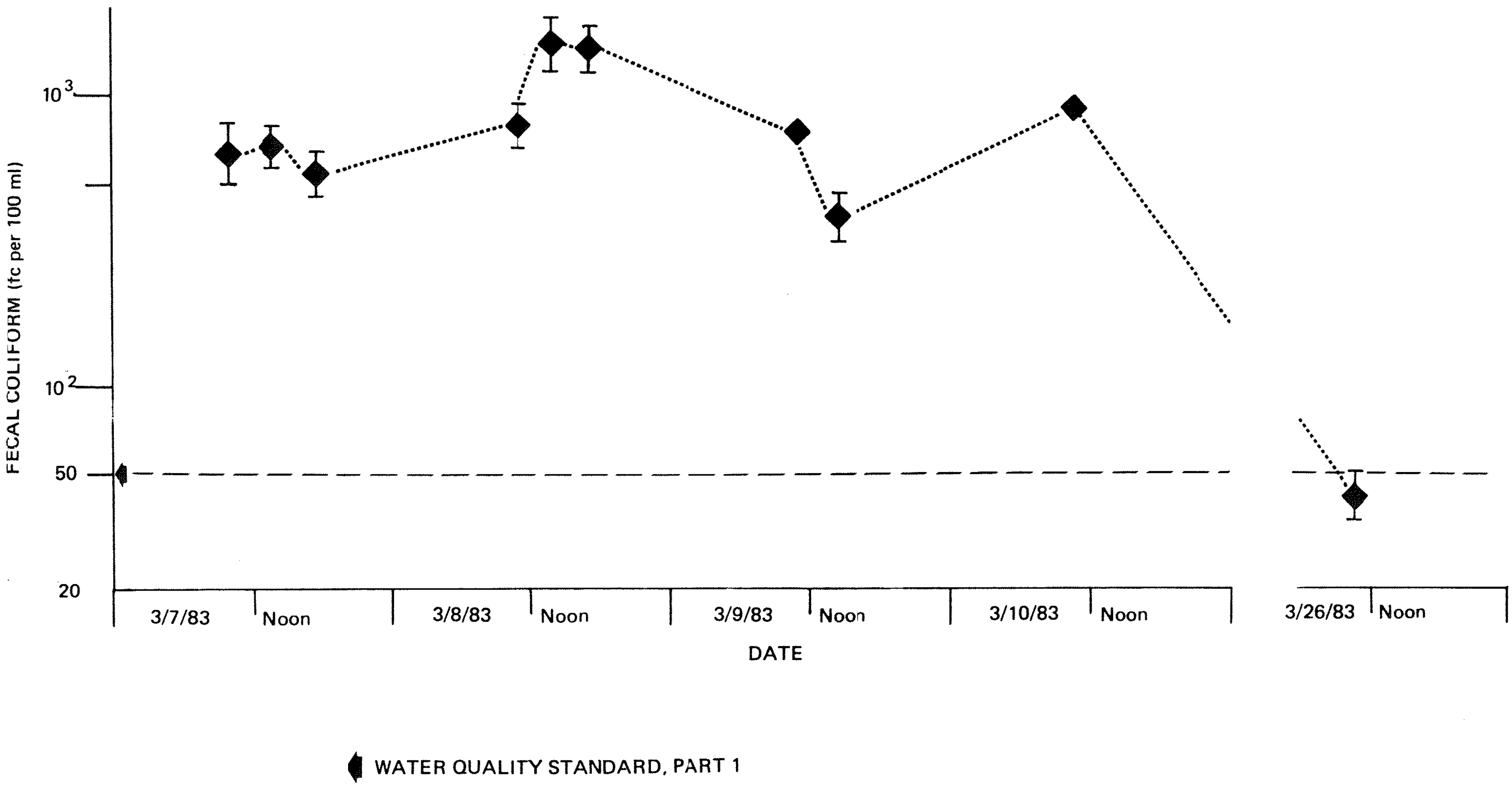


Figure 23. FECAL COLIFORM DENSITIES IN BEAR CREEK, BURLEY WATERSHED DURING RAIN–EVENT STUDIES FROM MARCH 7–10, 1983. DATA FROM A DRY PERIOD (MARCH 26, 1983) IS PROVIDED FOR COMPARISON (GEOMETRIC MEAN ± 1 SD; LOG–TRANSFORMED DATA; n = 2).

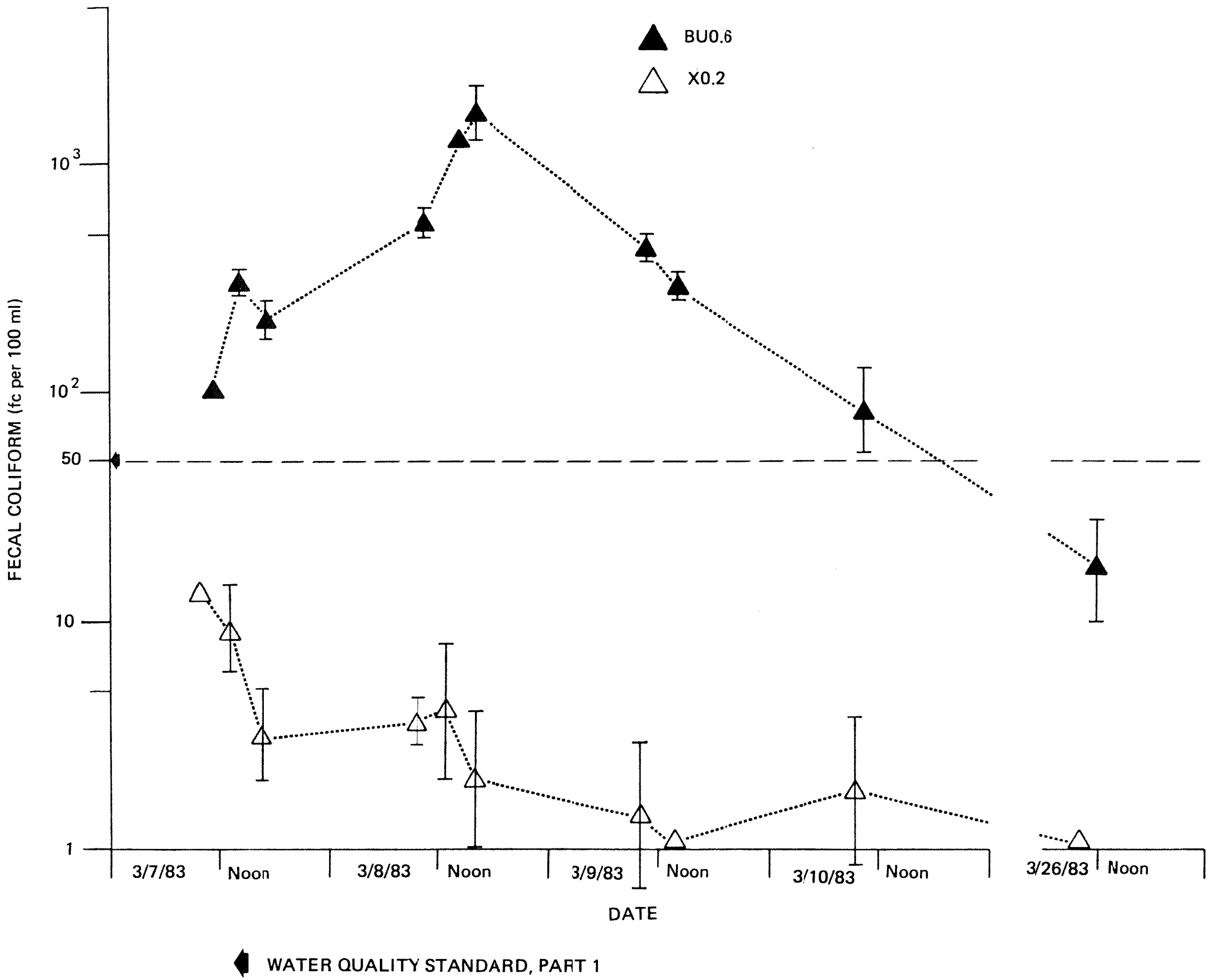


Figure 24. FECAL COLIFORM DENSITIES IN BURLEY CREEK AND AN UNDEVELOPED TRIBUTARY IN BURLEY WATERSHED DURING RAIN –EVENT STUDIES FROM MARCH 7–10, 1983. DATA FROM A DRY PERIOD (MARCH 26, 1983) IS PROVIDED FOR COMPARISON (GEOMETRIC MEAN ± 1 SD; LOG–TRANSFORMED DATA; n = 2).

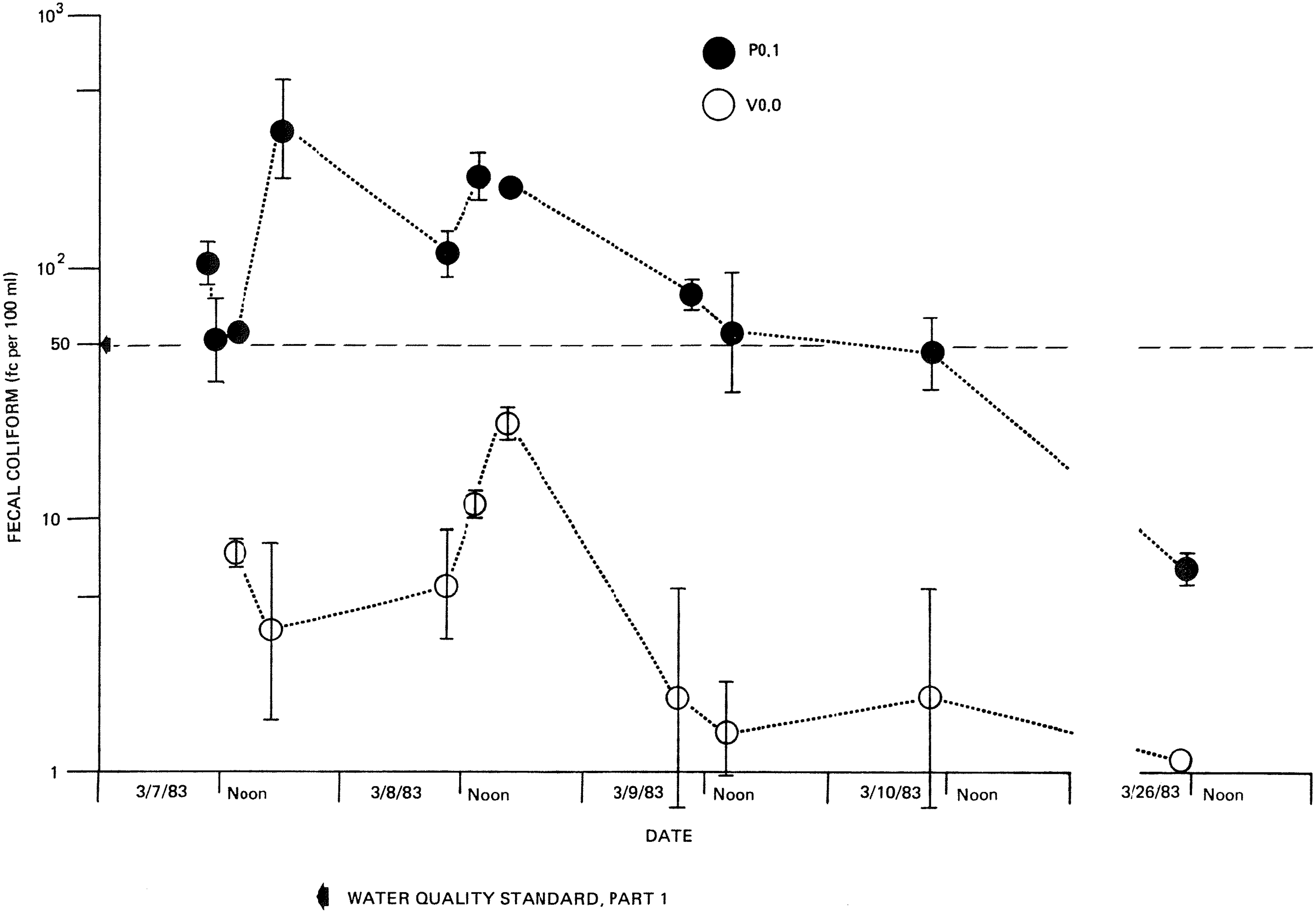


Figure 25. FECAL COLIFORM DENSITIES IN PURDY CREEK AND AN UNDEVELOPED TRIBUTARY IN PURDY WATERSHED FROM MARCH 7–10, 1983. DATA FROM A DRY PERIOD (MARCH 26, 1983) IS PROVIDED FOR COMPARISON (GEOMETRIC MEAN ± 1 SD; LOG–TRANSFORMED DATA; n = 2).

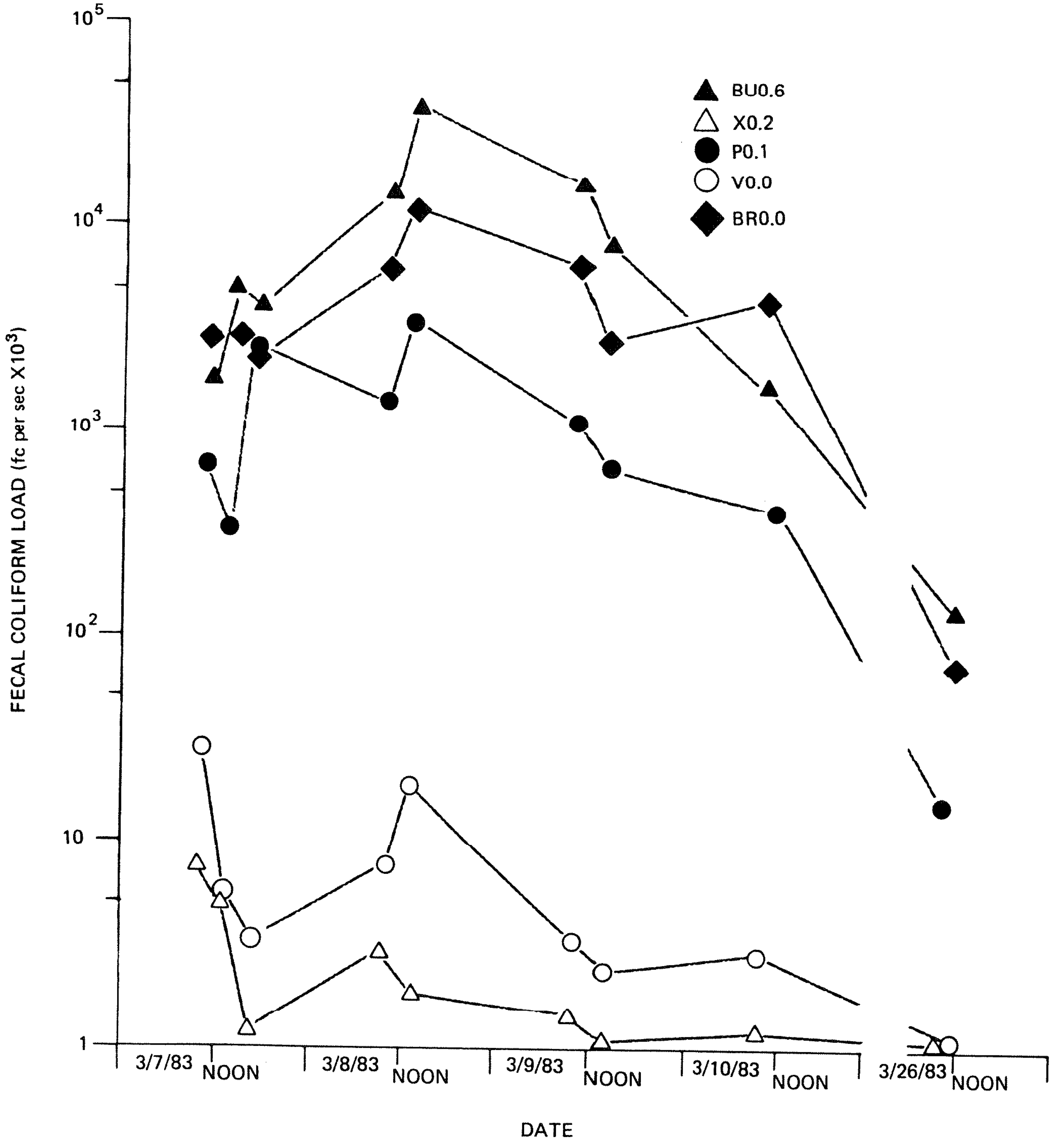


Figure 26. INSTANTANEOUS FECAL COLIFORM LOADS FOR SEVERAL BURLEY/PURDY WATERSHED STREAMS AND UNDEVELOPED TRIBUTARIES DURUNG RAIN–EVENT STUDIES FROM MARCH 7–10, 1983. DATA FROM A DRY PERIOD (MARCH 26,1983) ARE PROVIDED FOR COMPARISON.

Loads per stream mile are shown in Figure 27. Bear Creek Basin exceeded Burley Creek Basin in six of nine runs during the rain event and again during dry weather (March 21).

Fecal coliform patterns at both estuary sites reflected responses in the watershed during the rain event (Figure 28). Each day, the FC level in waters coming into the estuary during rising tide was substantially lower than estuarine water over the shellfish beds sampled during dropping tide. Violations of the water quality standards for marine waters occurred during peak rainfall periods. Values at both estuarine sites are strongly linked to rainfall. It is clear that samples taken at the mid-bay site (BES) respond to watershed loading. The fact that results at Burley Lagoon mouth behave similarly is evidence that the quality of the incoming tide is influenced by Burley Lagoon water from previous tide cycles. On the other hand, tissue analysis before and after the rain-event study did not violate the marketability standard.

A REGIONAL PERSPECTIVE

Table 21 compares Minter, Burley, and Purdy Creeks with several others in the Pacific Northwest. Some streams were sampled at the same time as this study; however, some care must be used in comparisons between studies as there were differences in sampling dates and methods.

Minter Creek bacterial quality compared favorably with an agricultural stretch of the Chehalis River. However, the results were considerably higher than similarly developed areas of the Skokomish River and urbanized Deschutes River. The results were quite comparable to the North and South Nemah Rivers in Willapa Bay, but considerably lower than a heavily contaminated agricultural zone in Tillamook Bay. Thus Minter Creek seemed to be about average in degree of contamination compared to other northwest streams with similar land use.

Burley and Purdy Creeks, on the other hand, exceeded other Puget Sound streams cited except heavily urbanized Chambers Creek (near Steilacoom). The results were somewhat below Tillamook Creek levels. Thus, these two creeks probably rank relatively high in contamination levels compared to other northwest streams.

RECOMMENDATIONS

We have attempted to identify general sources of bacterial contamination in Minter/Burley Watersheds. Individual segment loads were determined and combined with observations on land use. Further work should be directed toward follow-up and specific problems. Some suggestions follow.

Future Work

Rain-event studies should be repeated in problem segments identified earlier. This effort would serve two purposes. First, it should document the effects of agricultural improvements made recently by landowners and the Washington Conservation Corps (Bea McKamey, personal communication). These improvements include fencing, bridging, and streambank stabilization. Second, additional specific sources may be identified.

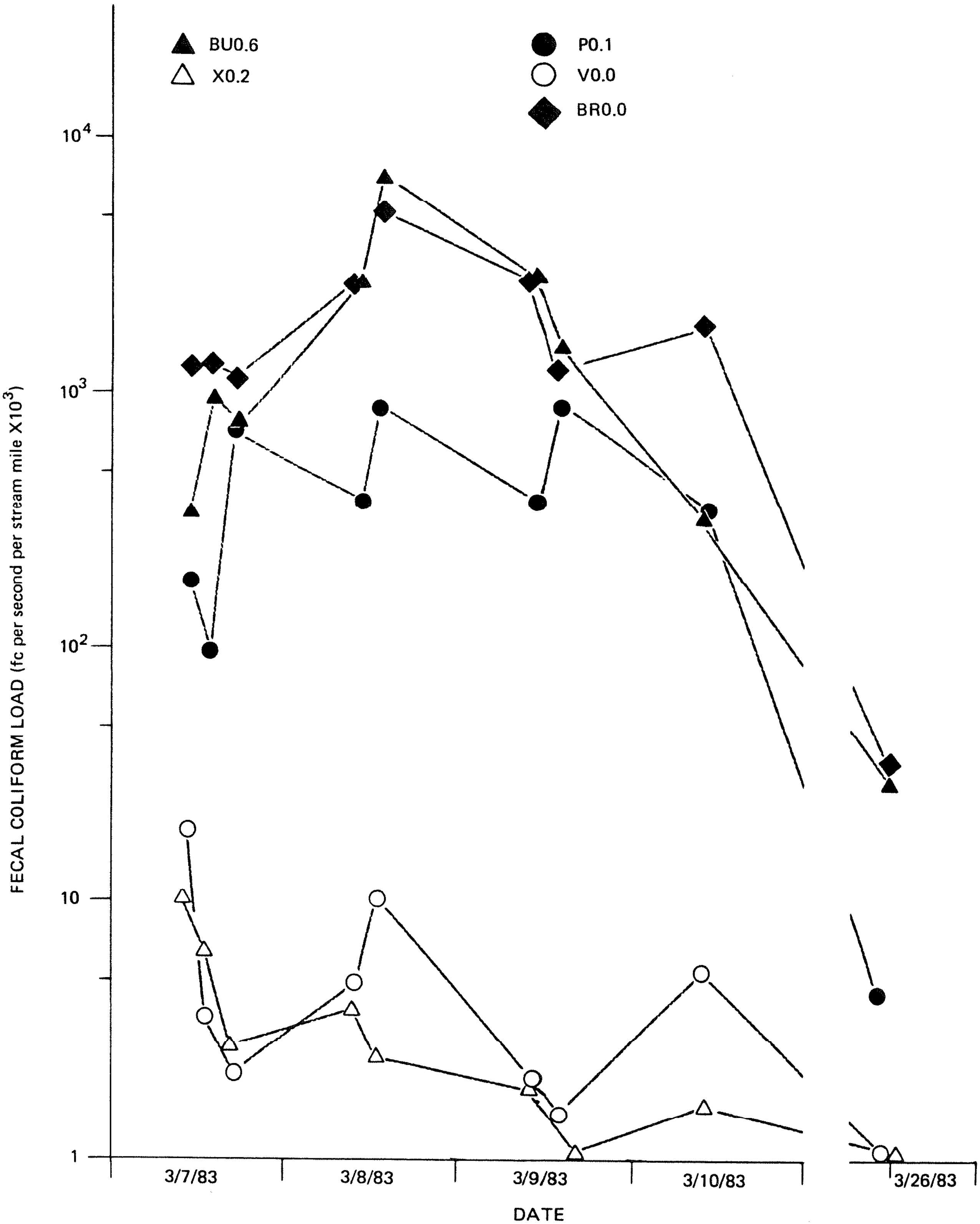


Figure 27. INSTANTANEOUS FECAL COLIFORM LOADS PER STREAM MILE FOR SEVERAL BURLEY/PURDY WATERSHED STREAMS AND UNDEVELOPED TRIBUTARIES DURING RAIN–EVENT STUDIES FROM MARCH 7–10, 1983. DATA FROM A DRY PERIOD (MARCH 26, 1983) ARE PROVIDED FOR COMPARISON.

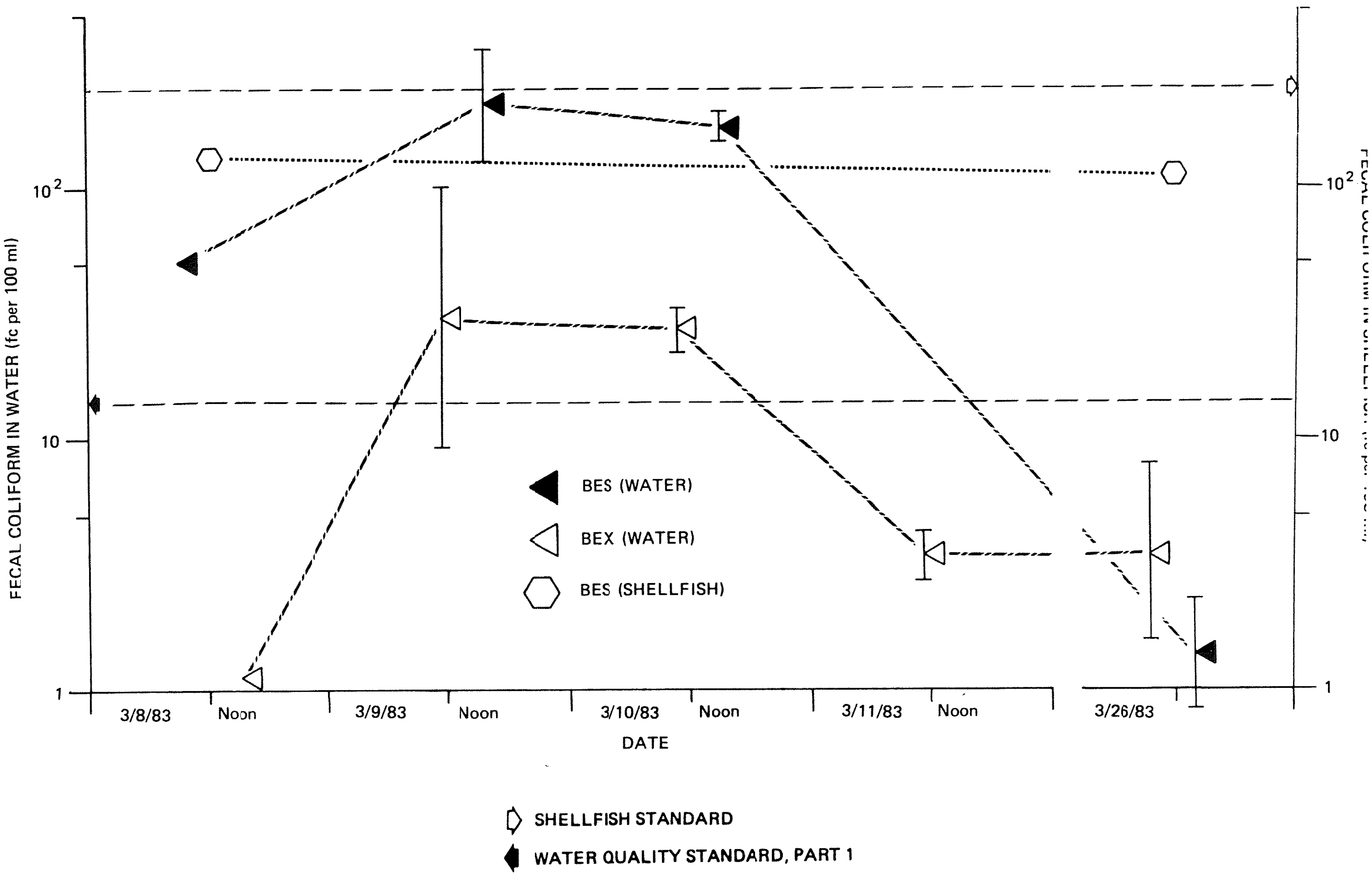


Figure 28. FECAL COLIFORM DENSITIES IN WATER AND SHELLFISH FROM BURLEY LAGOON DURING A RAIN– EVENT STUDY FROM MARCH 7–10, 1983 (GEOMETRIC MEAN ± 1 SD, LOG–TRANSFORMED DATA; n = 2).

Table 21. Comparison of Minter and Burley Creeks with several other Pacific Northwest streams.

Stream	Relative Size	Number of Samples	Geometric Mean (FC/100 mL)	Median (FC/100 mL)	Range: Minimum (FC/100 mL)	Range: Maximum (FC/10 mL)	Land use (vicinity of sampling site)
Minter Creek (M 0.0)[1]	Small	24	38	--	4	323	Residential, agricultural
Burley Creek (BU 0.3)[1]	Small	24	97	--	18	400	Residential, agricultural
Purdy Creek (P 0.1)[1]	Small	25	106	--	6	3,246	Residential, agricultural
Chehalis River (Porter)[2]	Large	11	37	--	5	210	Agricultural
Skokomish River (Potlatch)[2]	Medium	3	8	--	1	53	Agricultural
Deschutes River (Olympia)[2]	Medium	12	18	--	1	240	Urban-residential, commercial, agricultural
Chambers Creek (Steilacoom)[3]	Small	3	117	--	27	920	Urban-residential, commercial
North Nemah R. (Willapa Bay)[4]	Medium	21	--	8	--	--	Light agricultural
South Nemah R. (Willapa Bay)[4]	Medium	23	--	58	--	--	Light agricultural
Tillamook Cr. (Tillamook Bay, Oregon)[5]	Small	11	144	--	<30	4,600	Residential, agricultural

[1]Background monitoring program; Jan.-Dec. 1983; membrane filter (MF) analysis; this study.

[2]WDOE ambient water quality network; Jan.-Dec. 1983; MF analysis.

[3]WDOE ambient water quality network; Nov.-Dec. 1983; MF analysis.

[4]Routine bacterial survey, 1980; MF analysis (CH$_2$M Hill, 1981).

[5]Ambient water quality data; October 1979-zJuly 1980; most probably number (MPN) anlaysis (Jackson and Glendening, 1982a).

Intensive investigations should be carried out within the villages of Burley and Purdy in order to locate sources and problems. Other candidates for special evaluation are the Kitsap County landfill located on Burley-Ollala Road, and drainage from the Port Orchard Airport. Community concerns about Pierce County landfill (east of Purdy) were addressed in this study (Appendix A).

Much of this study has been directed toward sources along streams. Some effort should be directed toward sources draining directly into the estuaries.

On-Site Sewage Disposal Systems

Waste disposal systems should be designed for particular sites. Alternatives are required where soils or depth of water table are inadequate. Along with these two factors, proximity to the creek or estuary should be carefully considered. Under saturated conditions, fecal coliform bacteria can travel considerable distances from the point of disposal (Gerba, 1984).

Hoppus (1984) has identified nearly 40 possible septic tank failures in Minter and Burley Watersheds. Field checks of these systems should be conducted during saturated soil conditions. Additionally, many appear clumped together, probably due to poor soils. Some nearby systems were shaded during aerial photography and should be inspected.

There is a controversy concerning the usefulness of percolation testing. Many jurisdictions are adopting the alternative of detailed field soils analyses. Some practitioners use plant assemblages in conjunction with soils data (Richard McNicholas, Mason County Water Quality Program, personal communication). The analysis can be applied any time of year. If this option is exercized, it is essential that reliable soils data are available, that the skills of the sanitarian or health worker are adequate to perform the analysis, and that criteria are sufficiently sound to ensure adequate enforcement.

Fluorescent dyes will not always trace bacterial movement through ground water. Yeasts or marked bacteria (i.e., antibiotic-resistant E. coli.) might be used to test for failing septic systems (Gerba, 1984; Rahe, et al., 1978). If fluorescent dyes are used, sequential samplers and fluorometry should be used instead of visual observations.

Conventional septic systems located in unsuitable or marginal soils within the watersheds should be inspected periodically and failed systems replaced. Maintenance should occur at adequate intervals. King County successfully uses this approach.

In addition to stringent requirements for septic system disposal in marginal areas, homeowners should be encouraged to obtain water-saving devices on faucets and toilets.

Agricultural Practices

A number of publications are available providing detailed analyses of agricultural waste management alternatives. (URS, 1977; Robbins, 1978; WDOE, 1979; McKamey, 1983). These should be used in any future public awareness program. Other issues to consider might include the following.

Both this study and the literature strongly suggest stream bed sediments and elevated fecal coliform concentrations are related, especially in agricultural areas. Erosion and sedimentation controls are therefore important and rightfully linked to water quality improvements.

Farmers must consider the cost of handling waste accumulations and long-term land productivity as well as animal caring and feeding costs when identifying herd size. If information is needed, the county extension agent of the Soil Conservation Service (SCS) can provide valuable assistance to local residents. Adequate funding for the SCS is necessary to ensure their success at the local level. Financial and/or labor assistance to landowners also has merit and should be encouraged through identified funding programs.

Education may be as effective as enforcement of existing or future land-use ordinances. Existing handbooks and guidelines should be integrated into a general reference source for prospective rural residents. These could be placed in assessors' offices, realtors' offices, and with extension agents. The pamphlet should stress the importance of soil characteristics, slope, vegetative cover, runoff control, and herd size. In this way, problems may be averted.

Future Work in Shellfish-Growing Areas

The background monitoring program in Minter and Burley/Purdy Watersheds was a major component of the survey. This was undertaken to understand the role of environmental factors in fecal coliform contamination. Although some useful information was obtained, background variations tended to obscure significant relationships. Future survey design should favor replicated multi-seasonal intensive surveys during rainy periods.

The present effort was hampered by the limited number of microbiological analyses that could be completed each day. This was especially true of MPN samples for water and shellfish. In the future, we must either increase the WDOE laboratory capacity for these analyses or make arrangements with another laboratory.