DEPARTMENT OF ENVIRONMENT
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC REGION

SHELLFISH GROWING WATER BACTERIOLOGICAL AND SANITARY SURVEY OF LADYSMITH HARBOUR, DAVIS LAGOON, BOULDER POINT, AND SHARPE POINT TO YELLOW POINT, BRITISH COLUMBIA, 1983-1984

Regional Program Report 84-18

By

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ABSTRACT

During 1983 and 1984, bacteriological and sanitary surveys were conducted by the Environmental Protection Service in Ladysmith Harbour and the surrounding areas of Davis Lagoon, Boulder Point, Sharpe Point, Kulleet Bay and Yellow Point.

Shellfish growing water bacteriological standards were exceeded in portions of the open shellfish harvesting area in the inner Ladysmith Harbour. The contamination resulted from extremely heavy rains and from fecally contaminated agricultural runoff in Thomas Creek.

The shellfish growing waters of Sibell Bay and Dunsmuir Island in the closed portion of the outer harbour were not contaminated during any of the studies despite the bypass of up to 9,480 $m^3.day^{-1}$ of untreated combined sanitary and storm wastewater through the newly constructed bypass outfall in the outer harbour. Dilution and dispersion patterns of the sewage effluent are discussed.

Water quality in Davis Lagoon continues to exceed approved growing water standards due to local contamination sources. All other areas sampled met the approved growing water standard.

Recommendations are made to change the Schedule I shellfish closures in the inner and outer portions of Ladysmith Harbour.

RÉSUMÉ

En 1983 et 1984, des études bactériologiques et sanitaires furent conduites par le service de la protection de l'environnement dans le port de Ladysmith et aux environs du lagune Davis, de la pointe Sharpe, de la baie Kulleet et de la pointe Yellow.

Les standards bactériologiques des eaux convenables à la culture des mollusques et crustacés furent excédés dans des portions de la région ouverte à la culture des mollusques dans la partie intérieure du port de Ladysmith. La contamination fut provoguée par d'extrêmes précipitations, et par l'écoulement d'averse contaminé fécalement par les régions agricoles du ruisseau Thomas.

Les eaux de culture de mollusques à la baie Sibell et à l'île Dunsmuir dans la portion fermée de la section extérieure de port ne furent pas contaminés pendant toutes le études malgré une dérivation de plus de 9,480 $m^3 \cdot jour^{-1}$ d'eaux usées combinées sanitaires et pluviales d'un émissaire marin nouvellement construit dans la partie extérieure de port. Les modèles de dilution et de dispersion de l'effluent sont discutés dans le rapport.

La qualité de l'eau dans le lagune Davis continue d'excéder les standards d'eau approuvés pour la culture attribuable à des sources locales de contamination. Toutes les autres régions échantillonnées ont satisfait le standard d'eau de culture approuvé.

Des recommendations furent apportées afin de changer les fermetures incluses dans l'Annexe 1 regardant les portions intérieures et extérieures du port de Ladysmith.

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LIST OF ABBREVIATIONS

cm/s	centimeters per second
DFO	Department of Fisheries and Oceans
EPS	Environmental Protection Service
FC	Fecal Coliform
FS	Fecal Streptcocci
>	"greater than"
<	"less than"
Ipgd	Imperial gallons per day
kg	kilogram
m	metres
mL	millilitres
mm	millimetres
$m^3 \cdot m^2 \cdot day^{-1}$	cubic meter per square meter·day
$m^3 \cdot day^{-1}$	cubic meter per day
$m^3.sec^{-1}$	cubic meters per second
MF	Membrane Filtration
mg/kg	milligram per kilogram
MPN	Most Probable Number
PCB	polychlorinated biphenyl
PCP	pentachlorophenol
PPB	parts per billion
ppt	parts per thousand
STP	Sewage Treatment Plant
SVR	sediment volatile residue
TCP	tetrachlorophenol
$ug.g^{-1}$	micrograms per gram
USgpd	U.S. gallons per day

CONCLUSIONS

1. The bacteriological quality of the waters lying within the Area 17-1A closure at the head of Ladysmith Harbour continues to exceed the shellfish growing water standard. Contamination is attributable to the numerous creeks entering the harbour, with Thomas Creek being the most significant contributor of fecal pollution.

2. During prolonged periods of heavy rainfall, the bacteriological quality of the approved growing area in the inner harbour can exceed the shellfish growing water standard. Further, pollution in Thomas Creek can contaminate the approved growing area along the eastern shoreline of Ladysmith Harbour in the absence of significant rainfall accumulations.

3. The bacteriological quality of the growing waters in the closed outer harbour area met the approved growing water standard under all sampling conditions, with the exception of one station at the head of Burleith Arm. Growing water quality at this one station exceeded the standard during February, as a consequence of rain-induced agricultural runoff.

4. Discharges of untreated combined storm and sanitary effluent by way of the newly constructed bypass outfall into the outer harbour did not exert a negative impact on the water quality in the Sibell Bay and Dunsmuir Island areas. This is contrary to previous data collected in 1970 which suggested that the discharge of unchlorinated effluent from the Ladysmith sewage treatment plant was causing unacceptable fecal pollution in Sibell Bay. The differences between the present data and the 1970 data may be due to (i) documented improvements in the on-site sewage disposal systems in Sibell Bay, (ii) differing tidal, wind and current conditions between the two studies, (iii) differing behaviour of the two plumes resulting from discharge volumes, conditions of

receiving water stratification and so on. Further sampling is required to determine the basis for these differences.

5. The discharge of sludge through the sewage treatment plant outfall had a measurable effect on water quality in the Sibell Bay area. During periods of minimal stratification of the water column, sludge will surface and be subject to wind-directed dispersion.

6. The water quality of Davis Lagoon continues to exceed the approved growing water standard due to septic tank tile field seepage entering the local drainage systems.

7. The water quality of the Boulder Point, and Sharpe Point to Yellow Point areas met the approved growing water standard during these surveys. Sampling of Kulleet Bay should continue periodically due to potential problems associated with the failure of on-site disposal systems.

8. Oyster samples collected for chemical analysis in the inner harbour and Davis Lagoon were below detection limits for PCBs, chlorophenols and resin acids. Levels of trace metals were similar to those observed in other shellfish areas of British Columbia.

9. Chlorophenol contamination resulting from spraying practices at the Schon Timber Mill was noted in the yard area and in a creek flowing through the plant site. Although levels of chlorophenols were reduced at the creek mouth, the poor practices at the mill pose a significant health and environmental concern.

SCHEDULE I CLOSURES

It is recommended that Schedule I closure 17-1A at the head of Ladysmith Harbour be expanded to include the northern shoreline to Wedge Point.

Due to the occasional contamination of the open area of the inner harbour during periods of extreme rainfall, it is recommended that seasonal closures of all or part of the open area be considered.

Due to the acceptable water quality observed at Sibell Bay and Dunsmuir Island (despite the large volume of untreated sewage discharged through the Ladysmith sewage treatment plant bypass outfall), it is recommended this area be reclassified as conditionally approved. This reclassification would be contingent upon the installation of specific alarm controls at the sewage treatment plant (bypass overflow, chlorine failure, power failure) and restrictions in sludge dumping frequencies.

The recommended changes in Schedule I closures are shown in Figure 1.

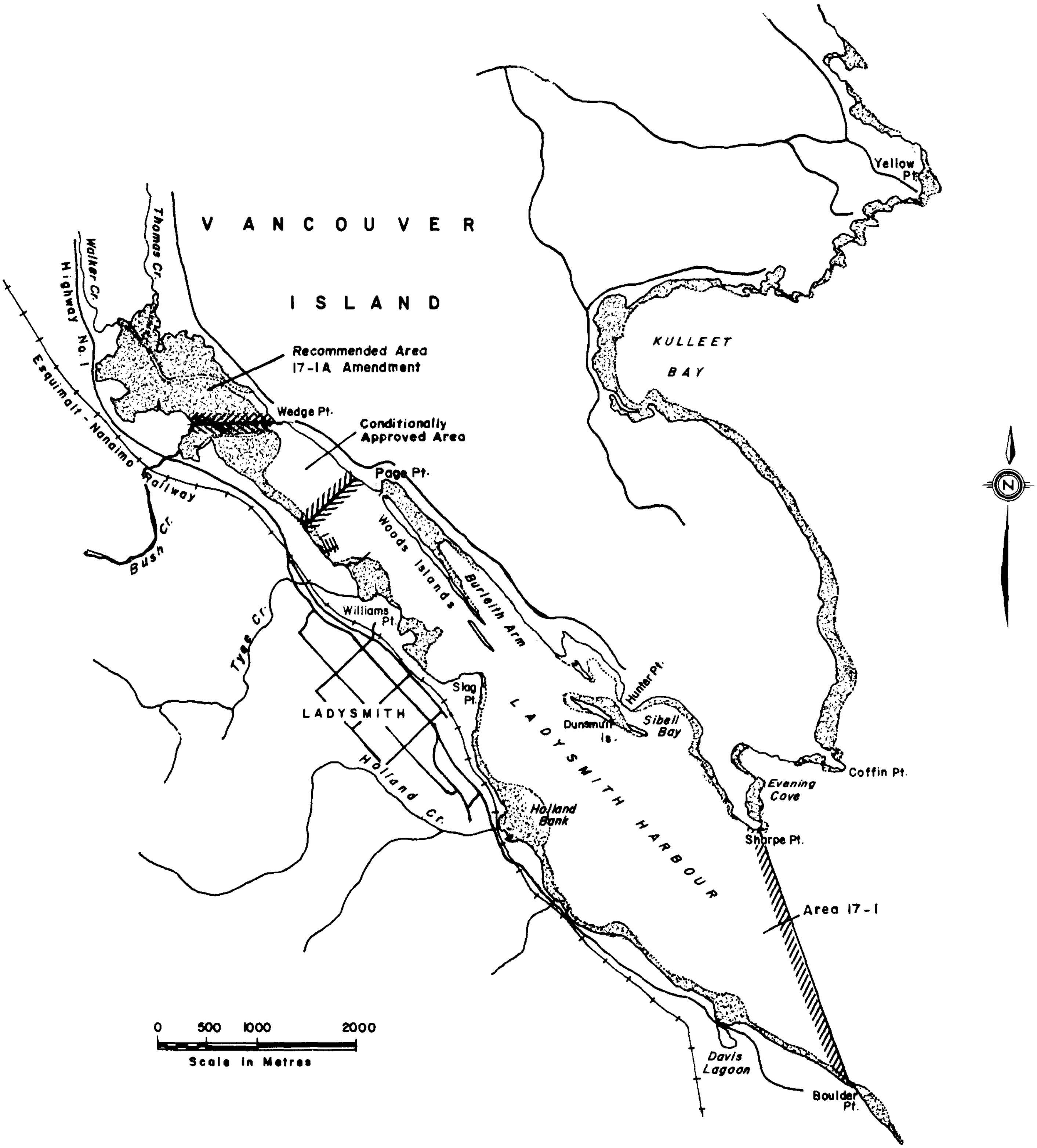


FIGURE 1 RECOMMENDED SCHEDULE 1 CLOSURES

1.0 INTRODUCTION

Ladysmith Harbour has historically been a major oyster production area in British Columbia. However, with its closure in 1965, oyster production was effectively halted. The closure was imposed after surveys conducted by the Department of National Health and Welfare in 1962 and 1964 revealed significant pollution of the oyster beds was occurring as a result of the discharge of 1590 $m^3.day^{-1}$ of raw sewage from the Town of Ladysmith to the inner harbour.

In 1965 the town constructed an Imhoff type sewage treatment plant at Holland Bank, with an outfall extending 876 m into the outer harbour to a depth of 19 m. The previous outfall to the inner harbour was retained as an emergency overflow. A survey conducted in 1970 (Tevendale, 1973a) concluded that sewage effluent from the relocated outfall was causing a deterioration of water quality in the outer harbour and presented a significant health risk to consumers of shellfish harvested from the Holland Bank and Sibell Bay areas. This resulted in the expansion of the closure in the outer harbour. However, the inner harbour water quality had improved to the extent that many of the oyster leases could be re-opened to direct harvesting provided there was a complete elimination of the overflow of sanitary sewage via the old sewer outfall and improvements were made in septic tank ground absorption disposal fields.

In 1974 the Town of Ladysmith installed a flow-metering system and chlorination equipment to continuously record and proportionally disinfect primary-treated sewage leaving the treatment plant. A subsequent survey conducted by Cooper and Kay (1975) concluded that the outer harbour water quality had improved due to the effluent chlorination to the extent that the shellfish growing water standard was being met. However, the area was not re-opened since there were inadequate controls in place at the sewage treatment plant to guard against the discharge of unchlorinated effluent resulting from operational failures at the plant. Further, the practice of de-sludging the sewage treatment plant through the outfall was considered a significant contamination source. The opening of the inner harbour remained contingent on the elimination of the sanitary sewer storm overflow. Following discussions with the Town of Ladysmith, it was agreed that the inner harbour could be re-opened provided a monitoring and warning system was put in place to permit closure of the oyster leases in the event of a sanitary sewer overflow.

Despite the re-opening of much of the oyster growing area of the inner harbour, oyster production from the harbour continued to decline. Oyster larval bioassays conducted by Bourne et al (1981) in 1979 showed water quality to be poorer in Ladysmith Harbour than in control water at the Pacific Biological Station in Nanaimo. A gradient of water quality from best at the mouth, to poorest at the head of the harbour was indicated. Chemical analysis of harbour water showed evidence of wood extractives, chlorophenols, fuel additives and dimethyl sulfide. Levels of copper, mercury and arsenic in the water were too low to explain the poor water quality reflected by the bioassay results.

Studies to examine the plume dispersion and dilution characteristics of the Ladysmith outfall were undertaken by Shepherd (1982) in 1981. The study concluded the initial dilution of the plume ranged from 150:1 to 250:1, but was unable to determine the subsequent dilution due to dispersion. Bacteriological sampling of the sediments around the outfall showed fecal coliform levels dropped to less than 200/100 g within 400 m of the outfall, suggesting the disinfected effluent was having a minimal bacteriological effect on the benthos (Kay, 1984). However, bacteriological tracking of sludge discharged through the outfall demonstrated fecal coliform levels approaching the shellfish growing water standard were detected up to 1400 m from the discharge point (Kay, 1984).

On August 20, 1981 the Town of Ladysmith was issued an amended permit by the provincial Waste Management Branch allowing the construction of a new outfall parallel to the existing sewage treatment plant discharge and terminating in approximately the same depth. The outfall was designed to accommodate up to 54,000 $m^3.day^{-1}$ of untreated combined storm and sanitary waste which had bypassed the sewage treatment plant. As a result of the installation of this outfall, which was completed in January of 1983, all overflows of sewage to the inner harbour ceased.

Concerns over the impact of this volume of untreated sewage on the bacteriological quality of Ladysmith Harbour resulted in a sanitary and bacteriological survey of Ladysmith Harbour being conducted by the Environmental Protection Service in February, 1983. Follow-up sampling was conducted in March, June, July and October of 1983 and March of 1984. Effluent tracer studies using fluorometry and bacteriology were conducted to determine the dilution and dispersion characteristics of the outfall plumes.

In addition to the assessment of water quality in Ladysmith Harbour, comprehensive surveys of Kulleet Bay, Coffin Point, Yellow Point, Davis Lagoon and Boulder Point were undertaken to ensure the areas were classified correctly for shellfish harvesting. These areas had previously been surveyed in 1975 (Cooper and Kay, 1975) with the exception of Davis Lagoon, which was surveyed in 1973 (Tevendale, 1973b). The previous surveys had shown Davis Lagoon to be contaminated from local sources, primarily septic tank seepage. The other areas were all classified as approved.

The EPS survey of Ladysmith Harbour also provided complementary data and some sampling assistance to a comprehensive water quality study of the harbour conducted by the provincial Ministry of Environment (McDougall and Boyd, 1984). This study was undertaken in response to a recommendation from the Ladysmith Harbour Crown Foreshore Plan (Lands, Parks and Housing, 1981) and was designed by the Resource Quality Section of the Waste Management Branch in collaboration with other federal and provincial agencies. In their report, McDougall and Boyd (1984) concluded the water quality in Ladysmith Harbour was suitable for successful oyster culture and spawning, with the sewage discharge exerting only a minor impact on the outer harbour water quality in terms of oyster culture. Chlorophenols were detected in several marine freshwater and sediment samples and bioaccumulation of chlorophenols was noted in liver tissues of Pacific staghorn sculpins collected near lumber mills. Oyster tissues sampled from the inner harbour oyster leases showed no detectable levels of chlorophenols.

The results of the EPS sanitary and bacteriological surveys of Ladysmith Harbour and surrounding waters conducted in 1983 and 1984 are discussed in the following sections. For additional information on the water quality of Ladysmith Harbour, the reader is referred to McDougall and Boyd (1984).

2.0 SAMPLE STATION LOCATIONS

Marine sample stations were located in commercially harvested oyster and clam areas, including provincially-registered oyster leases. Oyster lease locations in the study area are shown in Figure 2. Resource information was obtained from the Department of Fisheries and Oceans and Marine Resources Branch.

All major freshwater and effluent discharges to the study area were sampled to determine the significance of their bacterial contributions to the receivng waters.

Samples of sediment and shellstock were periodically collected as an adjunct to the water sampling program.

Marine sample stations are shown in Figure 3 and freshwater sample stations are shown in Figure 4.

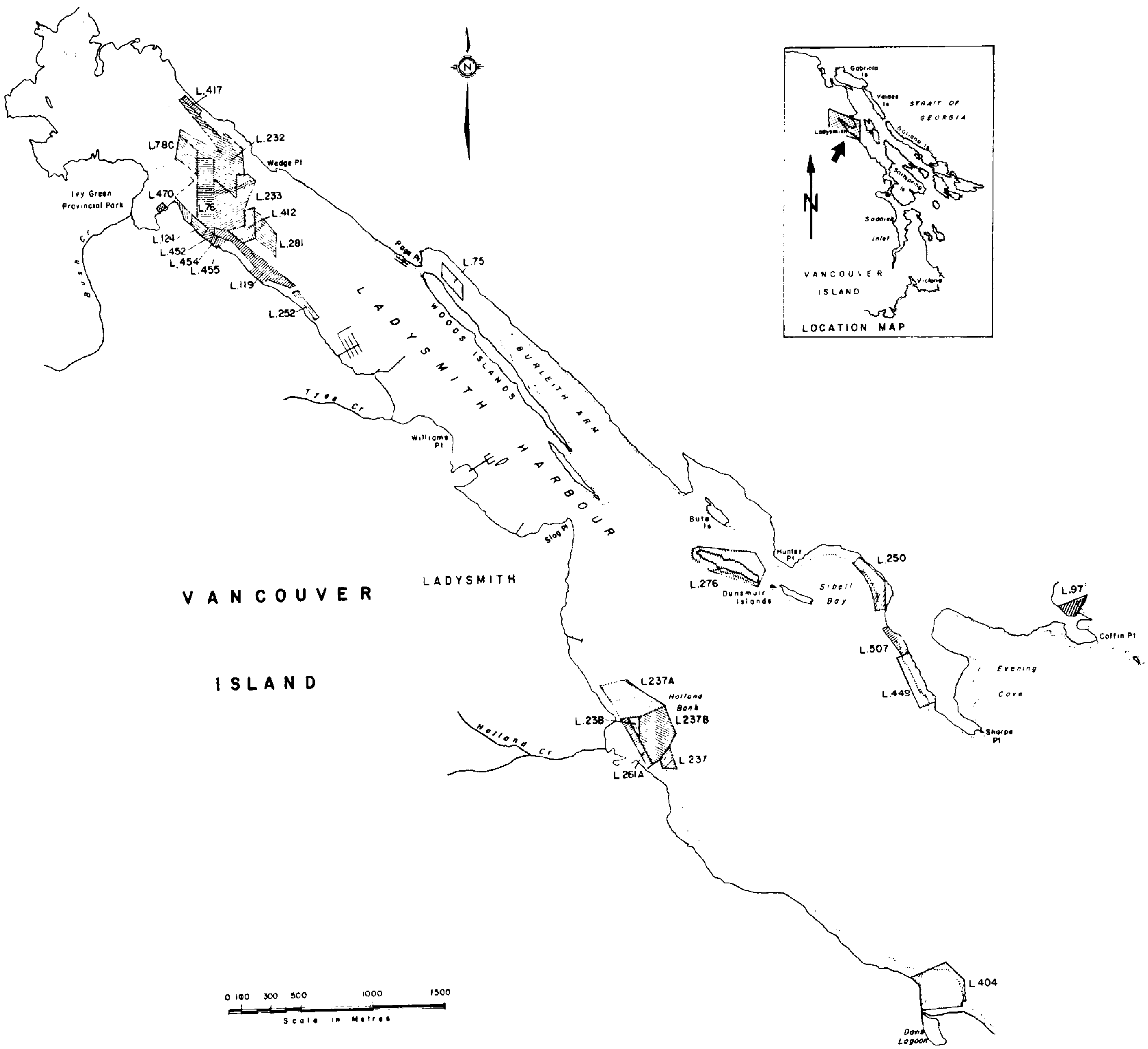


FIGURE 2 LOCATION OF OYSTER LEASES IN STUDY AREA

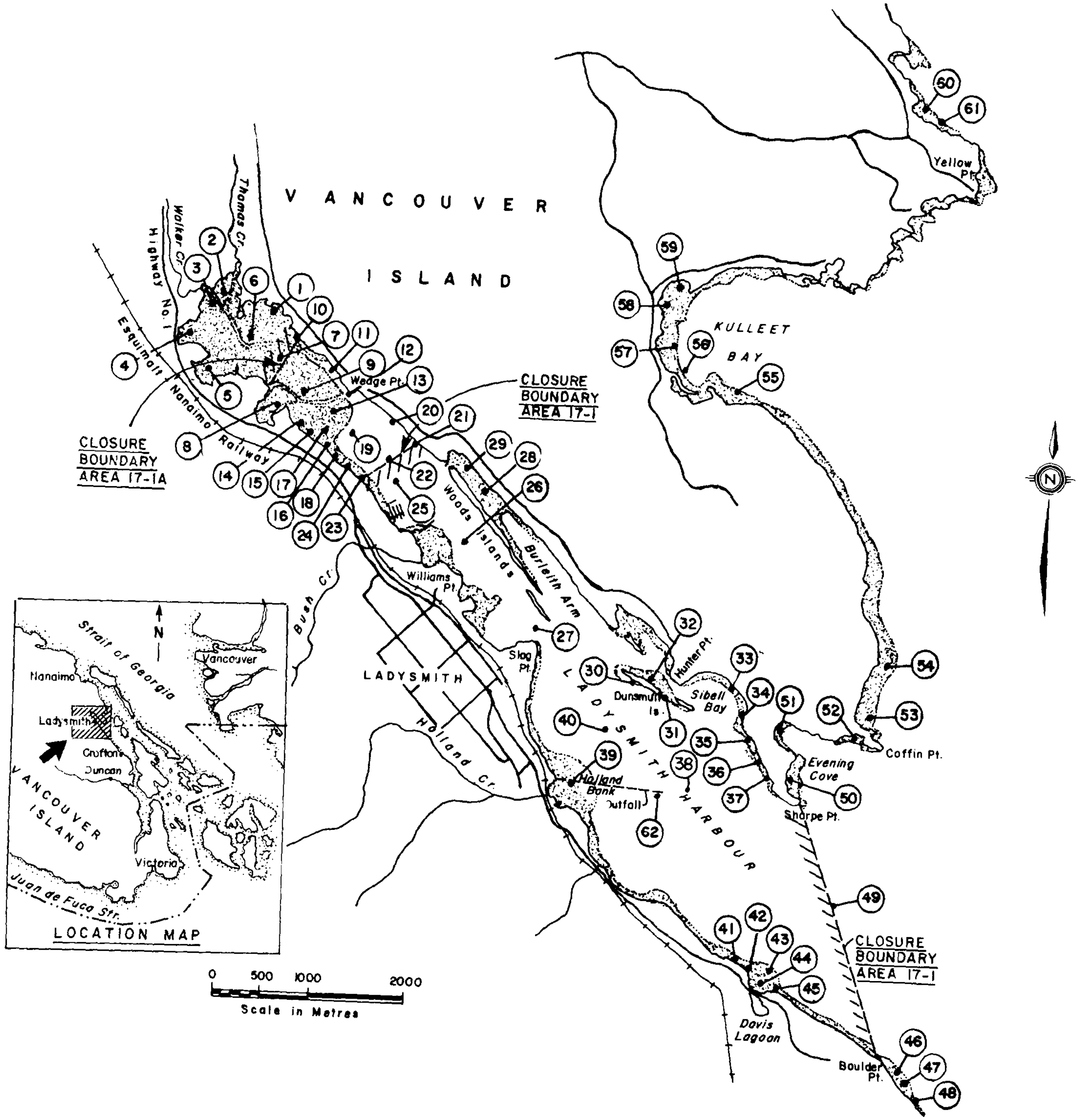


FIGURE 3 LADYSMITH HARBOUR AND SURROUNDING AREA - MARINE SAMPLE STATION LOCATIONS

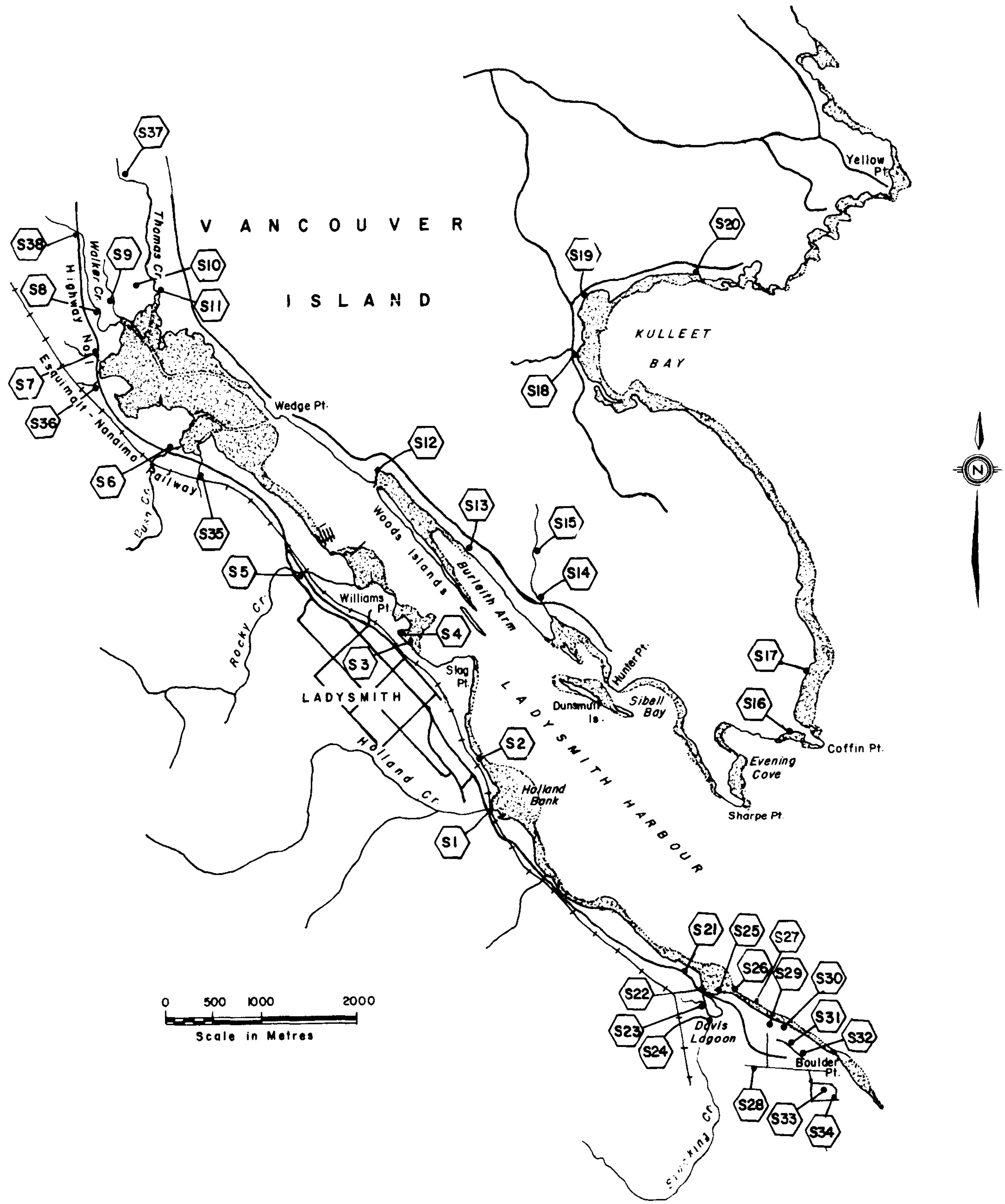


FIGURE 4 LADYSMITH HARBOUR SHELLFISH GROWING WATER QUALITY SURVEY FRESHWATER STATION LOCATIONS - February - March, 1983

3.0 FIELD PROCEDURES

3.1 Bacteriological Sampling and Analyses

All marine water samples for bacteriological analyses were collected in sterile wide-mouth glass bottles, approximately 15-30 cm below the water surface. The water depth at collection points over shellfish beds did not usually exceed 1.5 m. Samples were stored in coolers at temperatures not exceeding 10°C until processed. All analyses were conducted on site in the EPS mobile microbiology laboratory, generally within five hours of collection.

The fecal coliform MPN per 100 ml was determined using the multiple tube fermentation technique (three decimal dilutions of five tubes each) as described in Part 908 of the 15th edition of Standard Methods for the Examination of Water and Wastewater (APHA, 1980). The culture medium used was the A-1 medium as described by Andrews and Presnell (1972) and further evaluated by Kay (1978). A-1 medium was prepared in this laboratory.

All freshwater samples were collected in sterile wide mouth glass bottles and were tested for fecal coliform and fecal streptococci using the membrane filtration method described in Part 909 and 910 of the 15th edition of Standard Methods. Media used were mFC and KF Streptococcus Agars obtained from Difco Laboratories, Detroit, for the fecal coliform and fecal coliform streptococci tests respectively. The membrane filters used were Millipore HC, obtained from Millipore Limited, Mississauga, Ontario.

Biochemical confirmation of fecal coliform isolates obtained from the MPN procedure was performed on a percentage of all samples collected. These results are presented in Appendix X.

3.2 Physical Testing Analyses and Equipment

Salinity measurements were made on all marine samples using an American Optical Refractometer (Catalogue No. 10413) which has a resolution to the nearest 0.5 ppt. Salinity data and tide information are presented in Appendix I.

4.0 RESULTS

The daily data record for marine sample stations, which includes station location, salinity, fecal coliform MPN/100 mL, time of collection and state of tide is presented in Appendix I. Summaries of bacteriological data for marine and freshwater sample stations are given in Appendices II and V, respectively, and freshwater station descriptions and daily bacteriological results are presented in Appendices III and IV, respectively.

Canadian bivalve molluscan shellfish growing areas are classified as approved or prohibited according to the following bacteriological criteria:

> In order that an area be considered bacteriologically safe for the harvesting of shellfish, the fecal coliform median MPN of the water must not exceed 14 per 100 mL, and not more than 10% of the samples ordinarily exceed an MPN of 43 per 100 mL, in those portions of the area most probably exposed to fecal contamination during the most unfavourable pollution conditions.*

Based on these criteria, 24 of the 66 sample stations did not meet the approved growing water standard during some or all of the sampling periods. This data is presented in both Appendix II and Figures 5 and 6 and is discussed in detail in subsequent sections.

Shellfish growing areas can also be closed on the basis of known or potential pollution sources which may or may not be reflected in the bacteriological water quality results. All major freshwater inputs to the study area were therefore sampled and fecal coliform levels were measured. In addition, fecal streptococci analyses were performed on selected sample stations when high fecal coliform levels were observed or when animal fecal pollution was suspected. The fecal coliform:fecal streptococci (FC:FS) ratio of each input was calculated when one or both of the parameters

*This report expresses the 10% limit in terms of a 90 percentile which must not exceed 43/10 mL

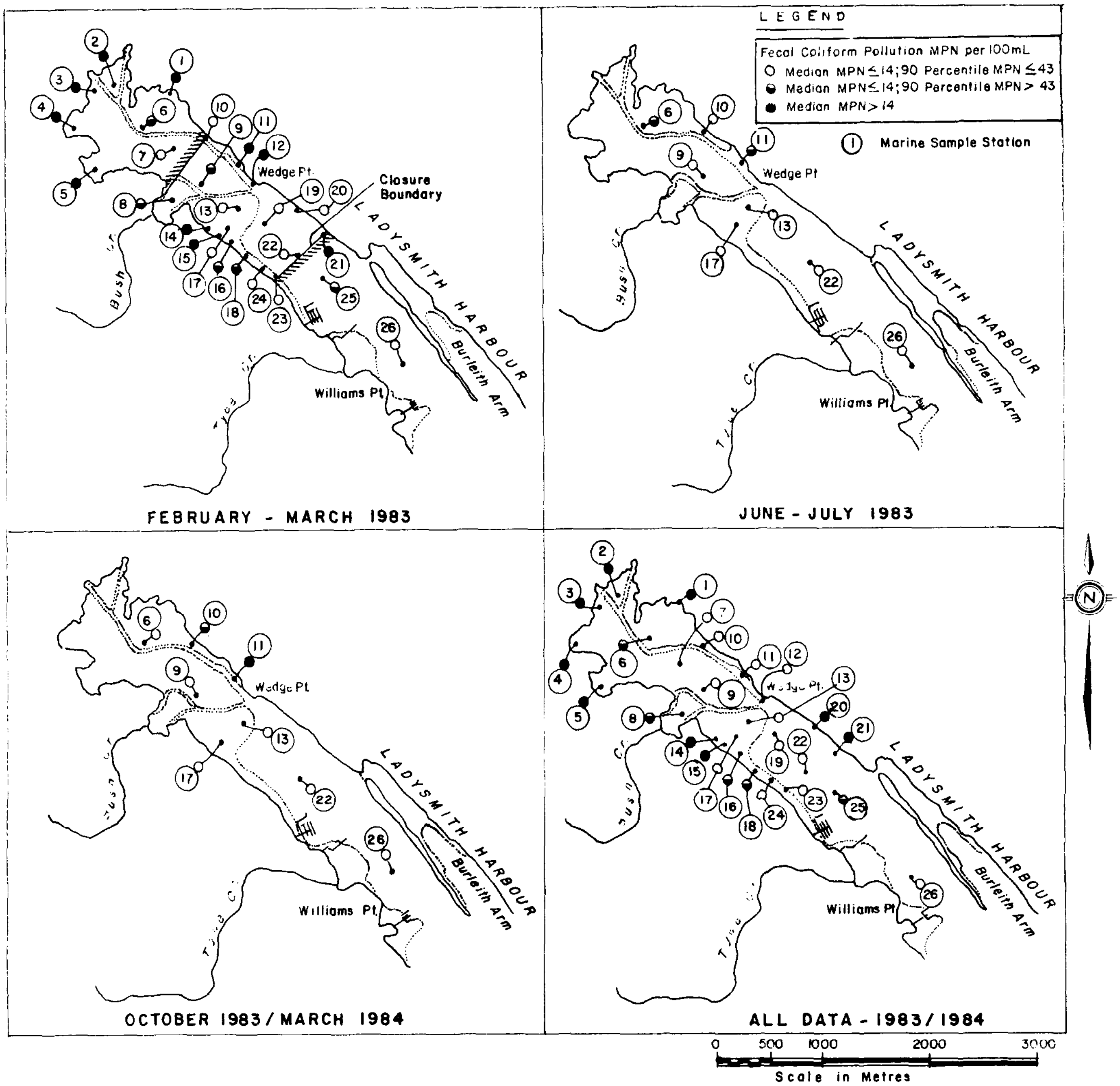


FIGURE 5 INNER HARBOUR MARINE SAMPLE STATION LOCATIONS - BY SURVEY PERIOD

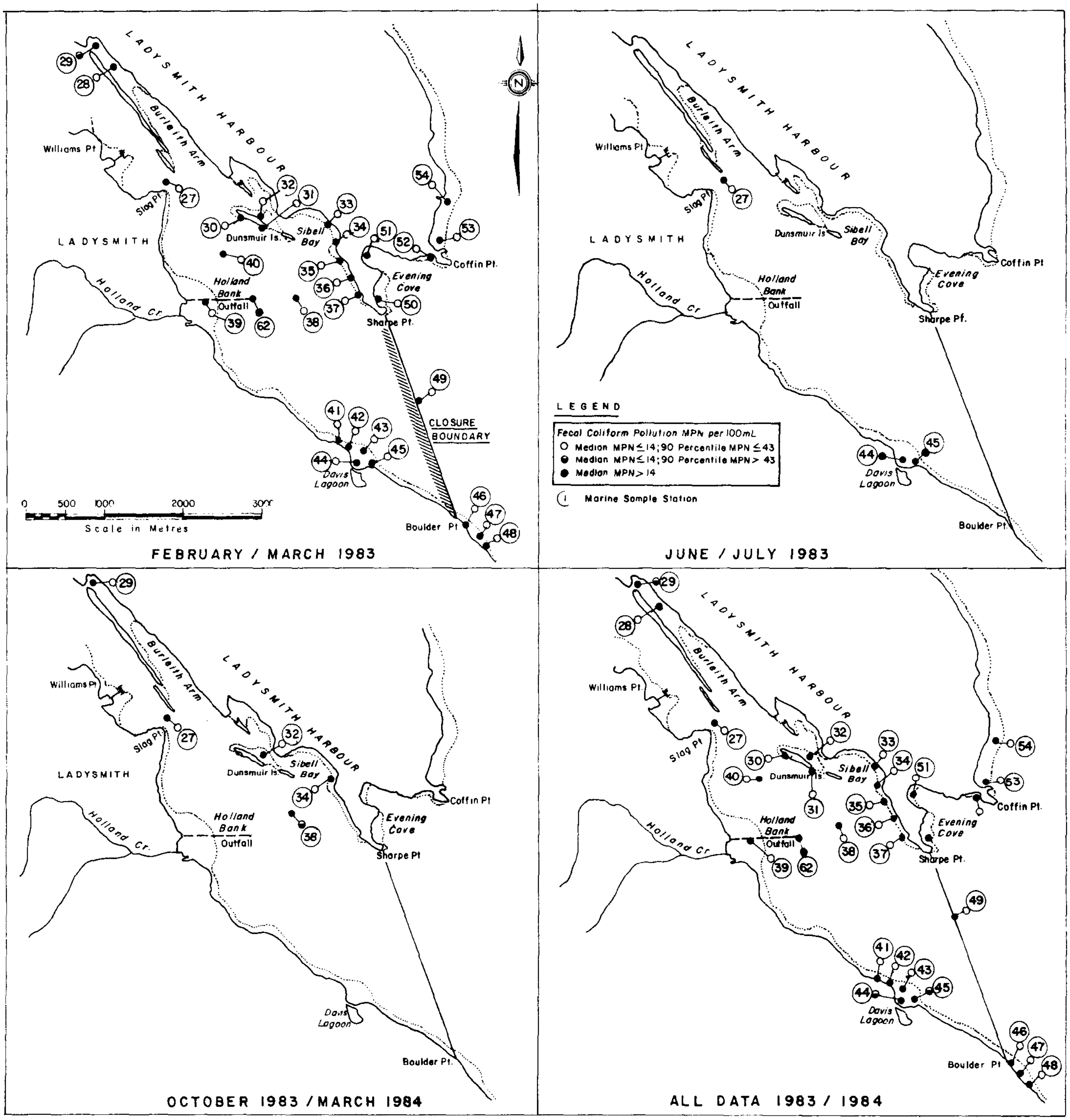


FIGURE 6 OUTER HARBOUR MARINE SAMPLE STATION LOCATIONS BY SURVEY PERIOD

exceeded 100/100 mL. Geldreich and Kenner (1969) have reported higher FS than FC levels in all warm-blooded animal feces except for humans. The FC:FS ratio in humans was 4.4 whereas in other warm-blooded animals the ratio was less than 0.7. Care must be taken in the interpretation of FC:FS ratios and in this report they are presented as supporting data for sanitary investigations. The daily calculated FC:FS ratios are presented in Appendix IV.

In addition to FC:FS ratio determinations, population equivalents were also calculated for selected freshwater sampling stations. The concept of population equivalents takes into account both the fecal coliform concentration and the flow of contaminated water and is useful in comparing relative bacteriological impacts of freshwater inputs. The population equivalent of a source of fecal contamination may be calculated using an average value for the fecal coliform contribution per capita to a sewage system. The average per capita daily discharge of coliforms has been estimated at 1.6×10^{11} total coliforms. The fecal coliform concentration in domestic sewage has been estimated at 20% of the total concentration (Water Quality Studies, 1968). This yields a value of 3.2×10^{10} fecal coliforms per person per day. The equation for population equivalent becomes:

$$\text{Population equivalents} = \frac{\text{Fecal coliforms discharged per day}}{\text{Fecal coliforms/person/day}}$$

$$= \frac{\text{Flow} \times \text{Fecal coliform concentration}}{3.2 \times 10^{10}}$$

Population equivalents for selected stations are presented in Table 1 and discussed in subsequent sections.

During the survey periods, rainfall was observed to have a significant impact on water quality in some of the study areas. In particular, rainfall accumulations during February 1983 were extraordinarily high, exceeding the 30 year monthly average by slightly less than three times. Daily rainfall data for the survey months are presented in Table 2.

TABLE 1 FLOW MEASUREMENTS AND POPULATION EQUIVALENT CALCULATIONS FOR SELECTED SAMPLING STATIONS

SAMPLE STATION	DATE OF MEASUREMENT	FLOW ($m^3.sec^{-1}$)	FECAL COLIFORM PER 100 mL	POPULATION EQUIVALENT
S5	Feb. 17/83	4.4	27*	3.2
S6	Feb. 16/83	3.27	21*	1.9
S8	Feb. 16/83	0.53	40	0.57
S9	Feb. 16/83	0.04	< 10	< 0.01
S10	Feb. 16/83	0.058	20	0.03
S11	Feb. 16/83	0.22	1500	8.91
	Feb. 17/83	0.57	532*	8.2
S12	Feb. 16/83	0.11	280	0.83
S24	Feb. 17/83	5.0	14	1.89
S26	Feb. 17/83	0.07	1780*	3.36

*Average FC value for February

TABLE 2 DAILY RAINFALL DATA FOR SAMPLING PERIODS (mm)

DAY	FEBRUARY 1983	MARCH 1983	JUNE 1983	JULY 1983	OCTOBER 1983	MARCH 1984
1	0.0	0.2	2.4	4.3	trace	0.8
2	0.0	0.0	1.6*	0.0	1.4	0.0
3	0.0	trace	0.0*	0.0	1.0	0.0
4	0.0	trace	0.0	0.0	0.0	0.0
5	trace	6.6	0.0*	0.0	0.0	0.0
6	4.0	18.2	0.0	trace	0.0	0.0
7	0.0	5.0	0.0*	0.9	0.0	0.0
8	22.0*	46.2	1.8*	1.1	0.0	0.0
9	9.9*	21.6	6.4*	trace	0.0	4.2
10	66.5*	10.6	0.4	2.1	0.0	2.2
11	36.0*	1.8	8.1	9.0	0.0	7.8
12	14.4	14.8	0.0	4.4*	0.0	4.0
13	1.2	33.4	0.0	1.0*	0.0	6.8
14	3.8*	0.6	1.6	8.4	0.0	7.6
15	17.0	0.0	trace	0.0	0.0	2.0
16	31.4*	0.0	13.5	0.0	5.6	6.8
17	14.7	0.0	10.1	0.0	0.0	3.2
18	0.4	0.0	2.8	0.0	2.2	1.4
19	55.2	0.0	2.3	1.9	2.2	16.6
20	0.0	0.0	trace	1.5	4.2	18.0*
21	19.6*	0.8*	0.0	0.0	14.0	1.3*
22	20.6*	1.0*	1.4	0.0	3.8	6.8*
23	2.2*	0.8*	7.0	0.0	0.0	1.0*
24	1.1	0.0*	0.6	0.4	8.6*	2.6
25	3.4	0.0	1.2	1.0	0.0*	5.8
26	1.8	1.8	trace	5.5	0.7*	0.0
27	0.0	0.8	0.0	0.3	0.0	0.8
28	0.4	16.8	1.4	0.0	0.0	5.2
29	-	12.4	2.8	0.0	8.4	0.0
30	-	3.2	2.9	0.0	2.0	0.0
31	-	2.4	-	0.0	0.2	0.0
	325.6	199.0	68.3	41.8	54.3	104.9
30 yr avg. 1951-1980	117.1	108.4	39.7	22.6	101.2	108.4

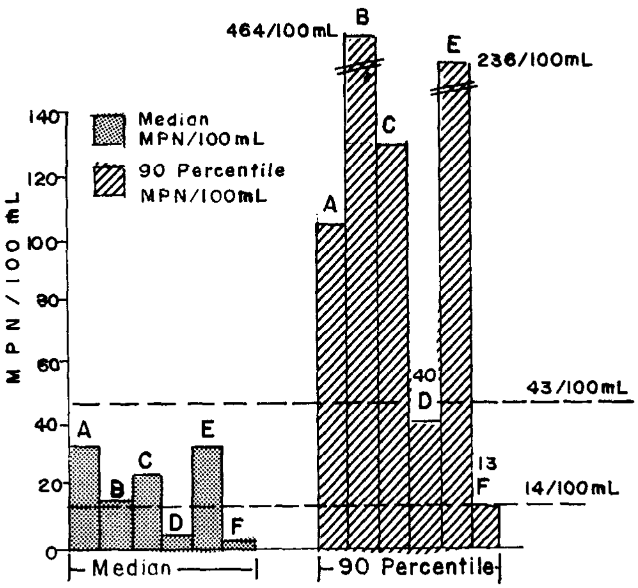
*Denotes sampling day

4.1 Ladysmith Harbour (LH001-LH040)

The discussion of Ladysmith Harbour results has arbitrarily been divided into three sections, namely (i) the closed area at the head of the harbour, Area 17-1A; (ii) the area where shellfish harvesting is permitted, between closed areas 17-1A and 17-1; and (iii) the outer harbour closed area, Area 17-1.

Forty marine sampling stations were established in Ladysmith Harbour and all were sampled a minimum of six times during the initial survey in February 1983. In addition, most of the stations were sampled again in March 1983 and further sampling was undertaken at selected monitoring stations during June, July and October of 1983 and March of 1984. The monitoring stations were chosen to provide additional water quality data since it was felt the February 1983 data may not have been representative due to the abnormally high amount of rainfall. The monitoring stations included stations 6, 9, 10, 11, 13, 17, 22, 26, 27, 29, 32, 34 and 38.

4.1.1 Inner Harbour Closure. Marine sample stations 1-7 were established in this area, and all except station 7 exceeded the shellfish growing water standard during February 1983. Median and 90 percentile values were calculated from combined data for all seven sampling stations. These values were calculated for a variety of situations, including differing tidal conditions, collection dates and rainfall conditions and are presented graphically in Figure 7. The impact of the February 1983 data on the classification of the growing waters is readily evident. Using all data collected from the seven stations, both the median and 90 percentile standards are exceeded, with values of 23/100 mL and 130/100 mL respectively. However, if February 1983 data are excluded from these calculations, the growing water standard is met (median = 5/100 mL; 90 percentile = 40/100 mL). The bias imparted by the February data was likely the result of heavy rainfall and the resultant landwash effects. This is supported by the median and 90 percentile calculations under wet (i.e. $\geq$ 5 mm during preceding 5 days) and dry (i.e. < 5 mm of rainfall during preceding 5 days) conditions. In this analysis, median and 90 percentile data exceeded the standard during wet conditions but were well within approved levels during dry conditions.



DATA TREATMENT	Number of OBS.	MPN/100 mL		
		RANGE	MEDIAN	90 PERCENTILE
EBB TIDE				
(A) - All Data	25	<2 - 280	33.0	104.5
HIGH SLACK				
(B) - All Data	38	<2->1600	15.0	464.0
ALL TIDES				
(C) - All Data	65	<2->1600	23.0	130.0
(D) - Excluding Feb. 1983	23	<2 - 130	5.0	40.0
PRECEDING 5-DAY RAINFALL				
(E) ≥ 5mm	54	<2 ->1600	33.0	236.0
(F) <5mm	11	<2 - 13	2.0	13.0

FIGURE 7. BACTERIOLOGICAL DATA SUMMARY - STATIONS 1-7

Salinity values for stations 1-7 ranged from 2.0 ppt to 26.0 ppt with a mean of 11.8 ppt for February. Salinities were notably higher at stations 6 and 7 during the March sampling program, with a range of 23.5 ppt to 26.0 ppt and a mean of 24.5 ppt. The increased salinity values correspond with reduced rainfall accumulations and reduced fecal coliform levels.

Several creeks enter the head of Ladysmith Harbour of which six were sampled, as shown in Figure 4. Fecal coliform levels ranged from < 10/100 mL to 7300/100 mL with the highest levels being recorded in Walker

Creek (S8; mean FC = 345/100 mL) and Thomas (Kuuista) Creek (S11; mean FC = 1360/100 mL). Four other unnamed creeks (S7, S9, S10 and S36) were sampled, each with generally low levels of fecal coliforms. The highest fecal coliform concentrations in S7, S9 and S10 occurred on February 11, following heavy rainfall. These creeks drain rural areas and the higher coliform counts may have resulted from animal sources or sewage tile field leachate. No pollution sources were identified during the sanitary survey and the bacterial contribution from these creeks was considered insignificant based on population equivalent calculations (Table 1).

Thomas Creek (S11) was the most significant contributor of fecal coliforms, with population equivalent values of 8.9 and 8.2 on February 16 and 17 respectively. The creek drains a farming area and at one farm 30-40 cattle had direct access to the creek. Samples collected upstream of the farming activity on Thomas Creek (S37) during March 1983 had low fecal coliform levels ($\leq$ 30/100 mL) as compared with levels at the mouth (140/100 mL - 760/100 mL) thereby further implicating animal fecal matter as the pollution source.

Although fecal streptococci measurements were taken on Thomas Creek, the FC:FS ratios were not indicative of animal pollution despite the sanitary survey observations. The reasons for this are not clear but may be related to the differential die off rates of fecal coliforms and fecal streptococci. Geldreich (1976) has reported rapid die-off rates for *S. bovis*, a biotype specific to cattle, as compared to fecal coliforms. The high FC:FS ratio may also be due to sources of human sewage which were not identified during the sanitary survey.

Fecal coliforms were noted in a sediment sample collected at the mouth of the creek (FC = 490/100 g) indicating resuspended bottom sediments may be an additional source of contamination in this area.

The impact of rainfall on FC levels in the creek was not obvious, and there was no significant correlation between FC and daily rainfall or 24 hour antecedent rainfall accumulations. Further flow measuring work would have to be undertaken to establish the relationship between rainfall and coliform levels as expressed by population equivalents. It is interesting to note that the highest FC level recorded (June 5/83 = 7300/100 mL) occurred during a period of no rainfall. This likely was due to the absence of a dilution effect which which would be expected from the rain.

Fecal contamination encountered in Thomas Creek during previous surveys of Ladysmith Harbour (Tevendale, 1973; Cooper and Kay, 1975) was at a lower level than that reported here, suggesting a worsening pollution condition exists in the drainage area of the creek.

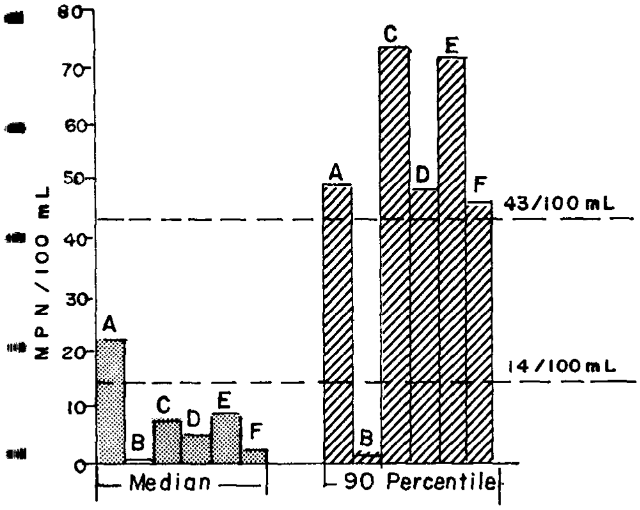
4.1.2 Inner Harbour - Open Area. Marine sample stations 8-24 were established in this area to assess growing water quality over commercially active oyster leases. Lease locations are shown in Figure 2. In addition to intensive sampling at all stations during February and March 1983, stations 9, 10, 11, 13, 17 and 22 were sampled during June, July and October of 1983 and March of 1984, as shown in Figure 5.

The impact of the heavy February rains on water quality in the open area was very pronounced, with most of the sampling stations exceeding the growing water standard. Table 3 presents a comparative analysis of February and March data. For interpretive purposes, the data have been grouped according to the sample station location in the open area, namely (i) western shoreline, (ii) centre line, or (iii) eastern shoreline. Reductions in fecal contamination during March were most dramatic along the western shoreline and centre line, although cumulative data show the growing water standard continues to be exceeded at the 90 percentile level for the western shoreline. The eastern shoreline stations did not demonstrate this same reduction in fecal coliform levels, with both the median and 90 percentile value remaining high.

Median and 90 percentile calculations for the western, centre and eastern zones of the open area are presented graphically in Figure 8. The values have been calculated using all data collected between February 1983 and March 1984 under differing tidal and/or rainfall conditions. The

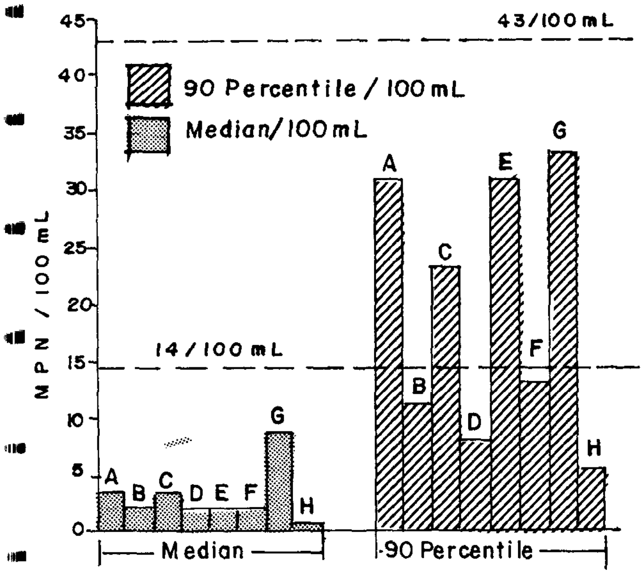
TABLE 3 COMPARATIVE DATA ANALYSIS FOR OPEN AREA MARINE STATIONS - February and March 1983

STATION NUMBER(S)	FEBRUARY 1983 MPN/100 mL		MARCH 1983 MPN/100 mL	
	Median	90 Percentile	Median	90 Percentile
combined data (8, 9, 13-18)	23	79	2	31.6
9	23	49	2	4.4
13	17	33	< 2	< 2
19	17	26	2	2.6
10, 11, 12, 20, 21				
combined data (east)	17	59.5	14	49
8, 14, 15, 16, 18, 23, 24				
combined data (west)	23	79	2	46.6
9, 13, 19, 22				
combined data (centre)	17	33	< 2	2.3



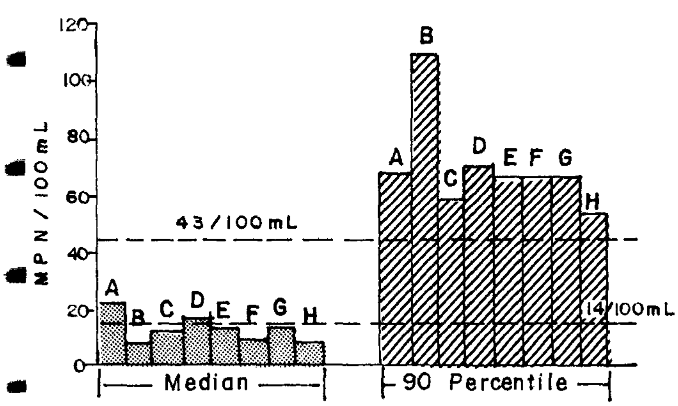
DATA TREATMENT	Number of OBS.	MPN/100 mL		
		RANGE	MEDIAN	90 PERCENTILE
EBB TIDE				
(A) - All Data	21	< 2 - 79	22.0	49.0
(B) - Excluding Feb. 1983	7	< 2 - 2	< 2.0	2.0
HIGH SLACK				
(C) - All Data	56	< 2 - 130	8.0	73.6
(D) - Excluding Feb. 1983	21	< 2 - 110	5.0	48.7
ALL TIDES				
(E) - All Data	77	< 2 - 130	9.0	72.7
(F) - Excluding Feb. 1983	28	< 2 - 110	2.0	46.6

INNER HARBOUR OPEN AREA - WEST SIDE (STATIONS 8, 14, 15, 16, 18, 23, 24)



DATA TREATMENT	Number of OBS.	MPN/100 mL		
		RANGE	MEDIAN	90 PERCENTILE
EBB TIDE				
(A) - All Data	42	< 2 - 49	3.0	31.0
(B) - Excluding Feb. 1983	30	< 2 - 33	2.0	11.4
HIGH SLACK				
(C) - All Data	44	< 2 - 49	3.0	23.0
(D) - Excluding Feb. 1983	24	< 2 - 17	2.0	7.6
ALL TIDES				
(E) - All Data	92	< 2 - 49	2.0	31.0
(F) - Excluding Feb. 1983	72	< 2 - 43	2.0	12.6
PRECEDING 5-DAY RAINFALL				
(G) - ≥ 5 mm	56	< 2 - 49	8.5	33.0
(H) - < 5 mm	36	< 2 - 11	< 2.0	5.5

INNER HARBOUR OPEN AREA - CENTRE LINE (STATIONS 9, 13, 19, 22)



DATA TREATMENT	Number of OBS.	MPN/100 mL		
		RANGE	MEDIAN	90 PERCENTILE
EBB TIDE				
(A) - All Data	33	< 2 - 1100	21.0	70.0
(B) - Excluding Feb. 1983	23	< 2 - 1100	9.0	110.9
HIGH SLACK				
(C) - All Data	49	< 2 - 79	11.0	51.1
(D) - Excluding Feb. 1983	22	< 2 - 94	15.0	73.0
ALL TIDES				
(E) - All Data	85	< 2 - 1100	13.0	70.0
(F) - Excluding Feb. 1983	50	< 2 - 1100	10.0	70.0
PRECEDING 5-DAY RAINFALL				
(G) - ≥ 5 mm	59	< 2 - 1100	13.0	70.0
(H) - < 5 mm	26	< 2 - 79	10.0	57.4

INNER HARBOUR OPEN AREA - EAST SIDE (STATIONS 10, 11, 12, 20, 21)

FIGURE 8 BACTERIOLOGICAL DATA SUMMARY - STATIONS 8 - 24 impact of February rainfall is again evident for the western shoreline and centre stations, since exclusion of February data in each calculation resulted in significantly lower median and 90 percentile values. In the case of the eastern shoreline, 90 percentile value exceeded the growing water standard under all conditions. The highest median values for both eastern and western shorelines were recorded on the ebb tide, suggesting the contamination was from a local source rather than having been introduced from outside. The generally good water quality in the centre of the open area further supports the contention of localized land-based sources being responsible.

The association between fecal coliform values, salinity, and rainfall was investigated for February data. Correlation coefficients were not considered significant, although a trend of higher FC values with lower salinity was noted. During February, mean salinity values in the lease area dropped from 25 ppt to 10 ppt during the heavy rainfall. Salinities recorded during the March survey had returned to levels ranging from 22-26 ppt and remained typical for surface waters during subsequent monitoring.

Historical data for the three sampling zones in the open area are depicted in Figure 9. In this analysis, median and 90 percentile values from representative sampling stations were calculated from this study and previous studies (Tevendale, 1983, Cooper and Kay, 1975) and averaged using both the median and arithmetic mean. The data shows that water quality has worsened since 1970 in all zones although the centre line data show the least change. Contamination of the east side was evident in 1970 at the 90 percentile level while west side water quality has been acceptable until this study.

Bacteriological data for shellfish tissue samples collected in the open area during 1983 are presented in Table 4. These data include samples collected during the EPS surveys and samples drawn from commercial lots by the Fish Inspection Branch of DFO. Forty-six percent (12/26) of these samples exceeded the wholesale market guideline of 230 FC/100 g. The

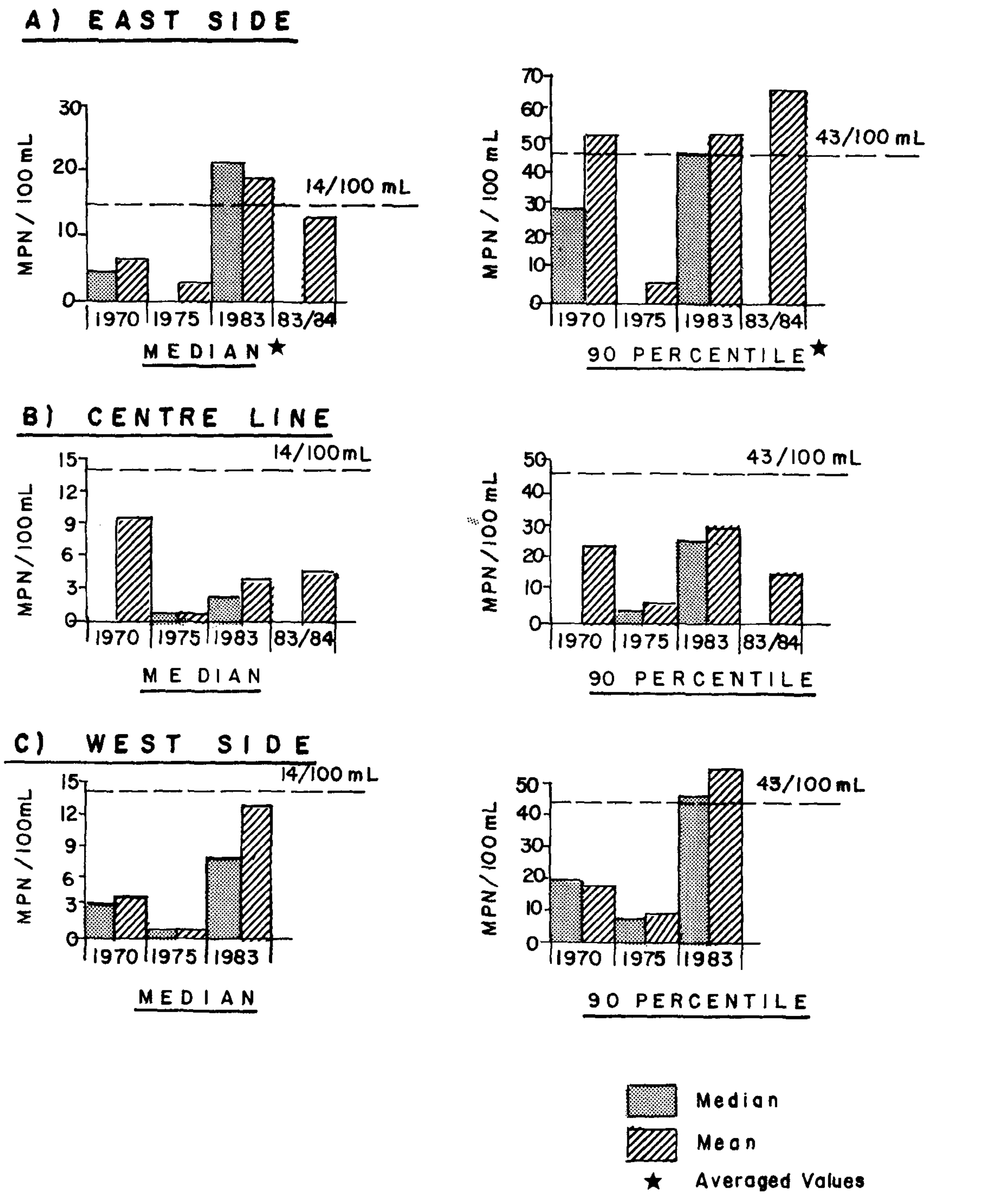


FIGURE 9 COMPARISON OF FECAL COLIFORM MEDIAN AND 90 PERCENTILE VALUES - 1970-1984 (OPEN AREA)

TABLE 4 SHELLSTOCK BACTERIOLOGICAL DATA FOR LADYSMITH HARBOUR OPEN AREA

HARVEST DATE	HARVEST LOCATION	FC PER 100 g	SPECIES	(mm) PRECEDING 24 HR. RAINFALL	PRECEDING 48 HR. RAINFALL	PRECEDING 5 DAY RAINFALL
Feb. 22/83	L.452**	< 20	whole oysters	19.6	19.6	89.9
Feb. 27/83	L.452**	50	whole oysters	1.8	5.2	29.1
Mar. 22/83	LH013	40	whole oysters	0	trace	15.2
Mar. 22/83	LH018	< 20	whole oysters	0	trace	15.2
Oct. 3/83	L.455	20	whole oysters	1.4	1.4	29.0
Oct. 4/83	L.328	< 20	whole oysters	1.0	2.4	22.3
Oct. 5/83	L.232	50, 20,< 20	shucked oysters	0	1.0	12.6
Nov. 5/83	Ladysmith	1100	whole oysters	0.3	29.7	65.6
Nov. 7/83	L.455	700	whole oysters	4.9	22.3	78.5
Nov. 14/83	L.455	70	whole oysters	24.2	30.2	83.8
Nov. 28/83	L.455	1300, 1700	shucked oysters	1.8	14.0	81.5
29		330				
Dec. 5/83	L.455	5400	shucked oysters	13.8	13.8	18.1
		3500	" "			
		9200	" "			
		24000	" "			
		16000	" "			
		16000	whole oysters			
		> 24000	whole oysters			
Dec. 12/83	L.76	< 20	whole oysters	0	8.8	39.8
Dec. 20/83	L.76	< 20, < 20 < 20	whole oysters	0	0	0

**relayed from L.404 (Davis Lagoon)

fecal coliform levels in the shellfish could not be correlated with rainfall accumulations.

The major identified sources of fecal contamination to the open area include (i) the freshwater inflow at the head of the harbours, of which Thomas Creek has been implicated as a major contributor, (ii) Bush Creek (S6) on the western shore, and (iii) general landwash.

The outflow of Thomas Creek was observed to remain along the eastern shoreline of Ladysmith during a dye release in July (Appendix VI), confirming the creek as a major pollution source in this zone. The influence on the centre and western zones (as determined by dye dispersion) was limited during this dry period but may be significant during high creek flows.

Bush Creek (S6) is the largest freshwater input along the western shore of the open area. During February, FC levels were low, ranging from 4/100 mL to 50/100 mL, while during October FC levels increased, ranging from 33/100 mL to 1600/100 mL. A single population equivalent value of 1.9 was calculated for February 16. The creek drains a sparsely populated area, and no sewage or fecal pollution sources were evident. A second unnamed creek (S35) enters Ladysmith Harbour immediately south of Bush Creek but was not considered a significant source.

In addition to these creeks, it was likely that fecal pollution from numerous diffuse sources was washed into the harbour during heavy February rains. Although sewage disposal within the Ladysmith townsite is via a central collection and treatment system (Figure 10), sewage treatment around the foreshore of the open area is primarily by ground disposal, i.e. septic tank and tile field. The sanitary survey did not identify any malfunctioning tile fields; however, failure of such systems is not uncommon during periods of heavy rainfall and resulting high water table.

4.1.3 Outer Harbour Closure. Marine sample stations 25-40 were established in the closed area between the northern boundary of Area 17-1

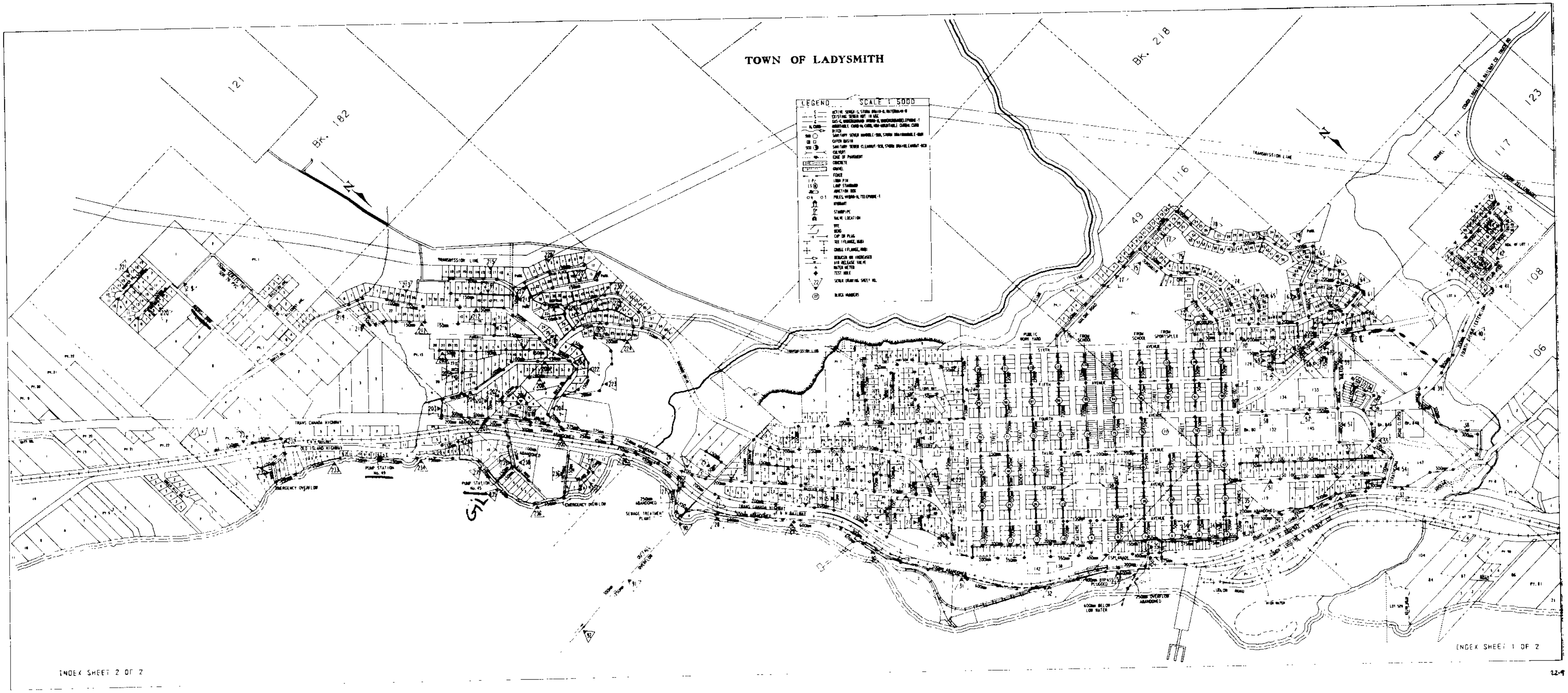
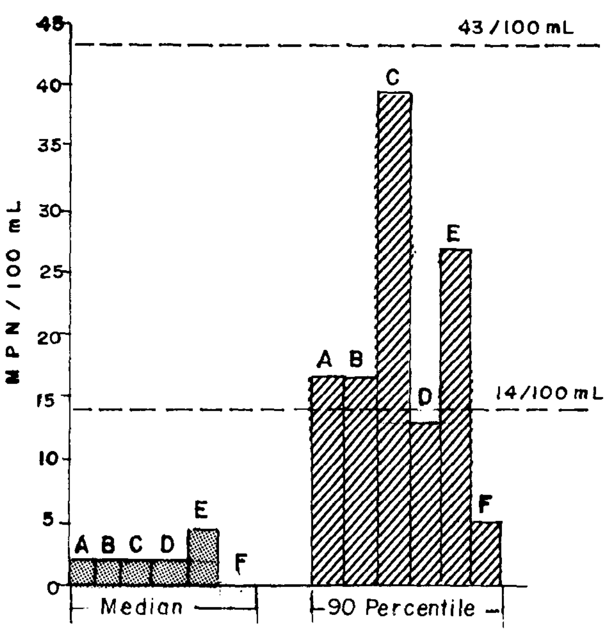


FIGURE 10 BOUNDARIES OF LADYSMITH SEWAGE COLLECTION SYSTEM

and a line drawn from Holland Creek to Sharpe Point. Sample station 62 was located over the outfall plume from the Ladysmith sewage treatment plant. Sampling of all stations was conducted during the February and March (1983) surveys and was continued at stations 26, 27, 29, 32, 34 and 38 during the monitoring program (Figure 6).

Water quality in the closed area was generally within the approved growing water standard, even during the heavy February rains. Fecal coliform levels exceeding the standard were recorded at stations 25 and 29 during February and at station 38 during March 1984; however, all other stations were acceptable. Median and 90 percentile values were calculated from combined data from stations 25-40 for differing tidal and rainfall conditions and are presented graphically in Figure 11. As this analysis demonstrates, the median FC levels remained at the same low levels regardless of the data treatment. Variations were most pronounced in the 90 percentile levels, with the highest values being recorded in samples collected on high slack tides (all data). Rainfall (≥ 5 mm in 5 days) was shown to affect water quality although the growing water standard was not violated. The impact of February data, although observable in the high slack tide analysis, was not nearly as significant as for the open area.



DATA TREATMENT	Number of OBS.	MPN/100 mL		
		RANGE	MEDIAN	90 PERCENTILE
EBB TIDE				
(A) - All Data	147	<2 - 93	2.0	17.0
(B) - Excluding Feb. 1983	100	<2 - 93	2.0	17.0
HIGH SLACK				
(C) - All Data	95	<2 - 110	2.0	39.5
(D) - Excluding Feb. 1983	28	<2 - 33	2.0	13.8
PRECEDING 5-DAY RAINFALL				
(E) ≥ 5 mm	164	<2 - 110	4.5	27.0
(F) < 5 mm	86	<2 - 33	< 2.0	5.0

FIGURE 11 BACTERIOLOGICAL DATA SUMMARY - STATIONS 25 - 40

Oyster leases in the outer harbour are located at the head of Burleith Arm and in the Dunsmuir Island and Sibell Bay to Sharpe Point areas. With the exception of L.75 (marine station 29) in Burleith Arm, these leases were of approved water quality. The highest fecal coliform levels were noted on February 23 at stations 32-38. All samples were collected on a high tide. The high FC levels were observed following a sludge dump at the sewage treatment plant which occurred on February 22 (1230-1630 h).

Salinity levels ranged from 4 ppt to 29 ppt with a mean of 22.1 ppt during February, and from 22 ppt to 30.5 ppt with a mean of 26 ppt during March reflecting the impact of the heavy February rains.

Several creeks enter this portion of the harbour, of which 8 were sampled. In addition, the discharge rates and fecal coliform densities of the Ladysmith sewage treatment plant and overflow bypass were recorded during the February and March surveys and the results are discussed in Section 4.1.3.1. Appendix VII presents data on the treatment efficiency of the STP and Appendix VIII describes results of dye studies to determine the dilution and dispersion patterns of the sewage plume.

The major freshwater input to the outer harbour is Holland Creek (S1) which enters the harbour at Holland Bank. Fecal coliform levels were low ($\leq$ 30/100 mL) during the February and March surveys but increased to a high of 920/100 mL during October sampling. Flows could not be obtained during February; however, the influence of the creek could be seen to extend across the harbour. Samples collected at the closest marine station (LH039) during ebb tides had fecal coliform values ranging from 2/100 mL - 8/100 mL. Previous sampling of this creek (Cooper and Kay, 1975) showed it to have low FC levels, even during periods of rainfall. The source(s) of the high coliform levels recorded in October was not determined but was likely storm drainage containing animal fecal matter, since the Holland Creek drainage area is sewered.

Three creeks (S2, S3 and S4) were sampled between Holland Creek and Rocky Creek during February. Fecal contamination was minimal in S2 (mean FC = 17/100 mL) but was higher in S3 (mean FC = 110/100 mL) and S4 (mean FC = 145/100 mL). The latter two creeks are storm drains for the Ladysmith townsite and likely contain fecal matter from domestic animals.

Rocky Creek (S5) was sampled at the Highway and exhibited relatively low FC values in February (10-50/100 mL). A population equivalent of 3.2 was calculated using a single flow measurement and the average FC count for February. Fecal coliform levels increased significantly during October (170 - > 2400/100 mL); however, as flows were not recorded, a population equivalent could not be calculated. Fecal contamination in Rocky Creek has not been observed in previous surveys (Tevendale, 1973a; Cooper and Kay, 1975) and the source(s) of pollution noted in October was not determined.

Although the townsite area is sewered, a number of commercial operations along the western shoreline of the closed area are not connected and are serviced by on-site ground disposal systems. These systems are described in Table 5. No evidence of seepage or malfunctioning was observed during the sanitary survey; however, both the Doman Forest Products and Pacific Forest Products tile fields are under asphalt paving. This problem was noted during the previous survey (Cooper and Kay, 1975) at the then Ladysmith Forest Products and Saltair Lumber Mills sawmills.

Three creeks (S12-S14) were sampled along the eastern shoreline and of these, S12 was the most highly contaminated. Fecal coliform levels ranged from 10-1440/100 mL during February but dropped to levels ≤ 10/100 mL in March. Two farms occupy the drainage area of the creek and landwash contaminated with fecal matter from cows and horses was likely the coliform source. A single FC:FS ratio of 0.01 on February 16 further implicates animal pollution as the cause. The high FC levels in the creek during February correlate well with the water quality at marine station 29, which did not meet the growing water standard. Fecal coliform levels in the marine station also decreased in March. The remaining two creeks (S13 and S14) were not considered significant.

TABLE 5 SEWAGE DISPOSAL FACILITIES IN UNSEWERED AREAS

FACILITY	METHOD OF DISPOSAL
Ivy Green Restaurant	Septic tank and pump - tile field absorption
Shower, Laundry Washrooms Mobile Home Park	Septic tank - tile field absorption Serviced monthly Individual septic tank - tile field absorption - some on package STP and tile-field absorption system
Domans Forest Products Ltd.	Office - septic tank - tile field absorption Mill - septic tank tile field absorption Shop - septic tank tile field absorption
Pacific Forest Products Ltd.	Office - septic tank - tile field absorption Mill - septic tank - tile field absorption
Schon Timber	Office - septic tank - tile field absorption
Ivy Green Park	Holding tank - sani station
Mañana Lodge	Lodge - septic tank and tile field absorption Shower - septic tank and tile field absorption Total of 3 x 700 Gal septic tank

4.1.3.1 Ladysmith sewage treatment plant. Combined raw sewage and stormwater bypasses occurred through the newly installed outfall during the entire February survey, with bypasses equalling or exceeding the plant flow on 15 of the 28 days in February. Population equivalents for the unchlorinated bypass ranged from 12 to 6,517 as shown in Table 6. The highest P.E.s and flows were consistent with the greatest rainfall accumulations, as shown in Figure 12. Treated effluent was not considered a significant source of fecal coliforms as sufficient chlorine was added to reduce fecal coliforms to < 10/100 mL.

Sludge was dumped through the outfall on February 22, 1983 and samples were collected in the receiving waters at the conclusion of the discharge. Only one station showed counts (FC = 130/100 mL) coincident with visible evidence of sludge.

Receiving water monitoring in the vicinity of the outfall (station 62) usually detected fecal coliforms at the boil but within a short distance fecal coliform levels dropped to near background. Median levels dropped to 2/100 mL at the surface within 550 m of the outfall.

Additional bacteriological sampling in the vicinity of the outfall was conducted in conjunction with effluent dispersion studies in July 1983 and March 1984. These studies are discussed in detail in Appendix VIII. Briefly, data collected during July showed the effluent to be trapped at a level approximately 15 m below the surface. This trapping was the result of density stratification in the water column and consequently made effluent tracing difficult. During March 1984 effluent was visible at the surface plume; however, intensive surface water sampling around the outfall was unable to demonstrate a significant zone of influence. Further sampling indicated the effluent had sunk, with the highest fecal coliform levels measured at a depth of 1 m below the surface.

In addition to the receiving water sampling, an operational assessment of the sewage treatment plant was performed during February. Twenty-four hour composite samples of influent and effluent were collected for 3 separate days and analyzed for nutrients, BOD, NFR, mercury and total

TABLE 6 DAILY FLOWS AND POPULATION EQUIVALENTS FOR LADYSMITH SEWAGE TREATMENT PLANT BYPASS - February 1983

DATE (1983)	PLANT FLOW ($m^3.day^{-1}$)	BYPASS FLOW ($m^3.day^{-1}$)	POPULATION[1] EQUIVALENT	FECAL COLIFORM PER 100 mL
Feb. 1	1730	202	90	
2	1855	205	91	
3	1625	70	31	
4	1616	45	20	
*5	1349	27	12	
*6	1349	27	12	
7	1349	27	12	
8	1442	144	64	
9	1710	761	340	
10	2860	2668	1334	1.6×10^6
11	2998	9480	6517	2.2×10^6
*12	3544	12439	5558	
*13	3544	6785	2120	
14	3544	3392	1060	
15	2676	1985	887	
16	2497	2230	996	
17	2928	4510	2015	
18	3347	6125	2737	
*19	3245	6334	2830	
*20	3245	6984	3120	
21	3245	2923	1306	
22	2929	3701	1272	1.1×10^5
23	2177	5158	2305	
24	2876	454	203	
25	2542	2607	1165	
*26	1810	1643	734	
*27	1810	1036	463	
28	1810	893	399	

*Bypass flows estimated for weekend.

[1]Population equivalent calculation based on the mean FC density of 1.4×10^6/100 mL except where sample data was available.

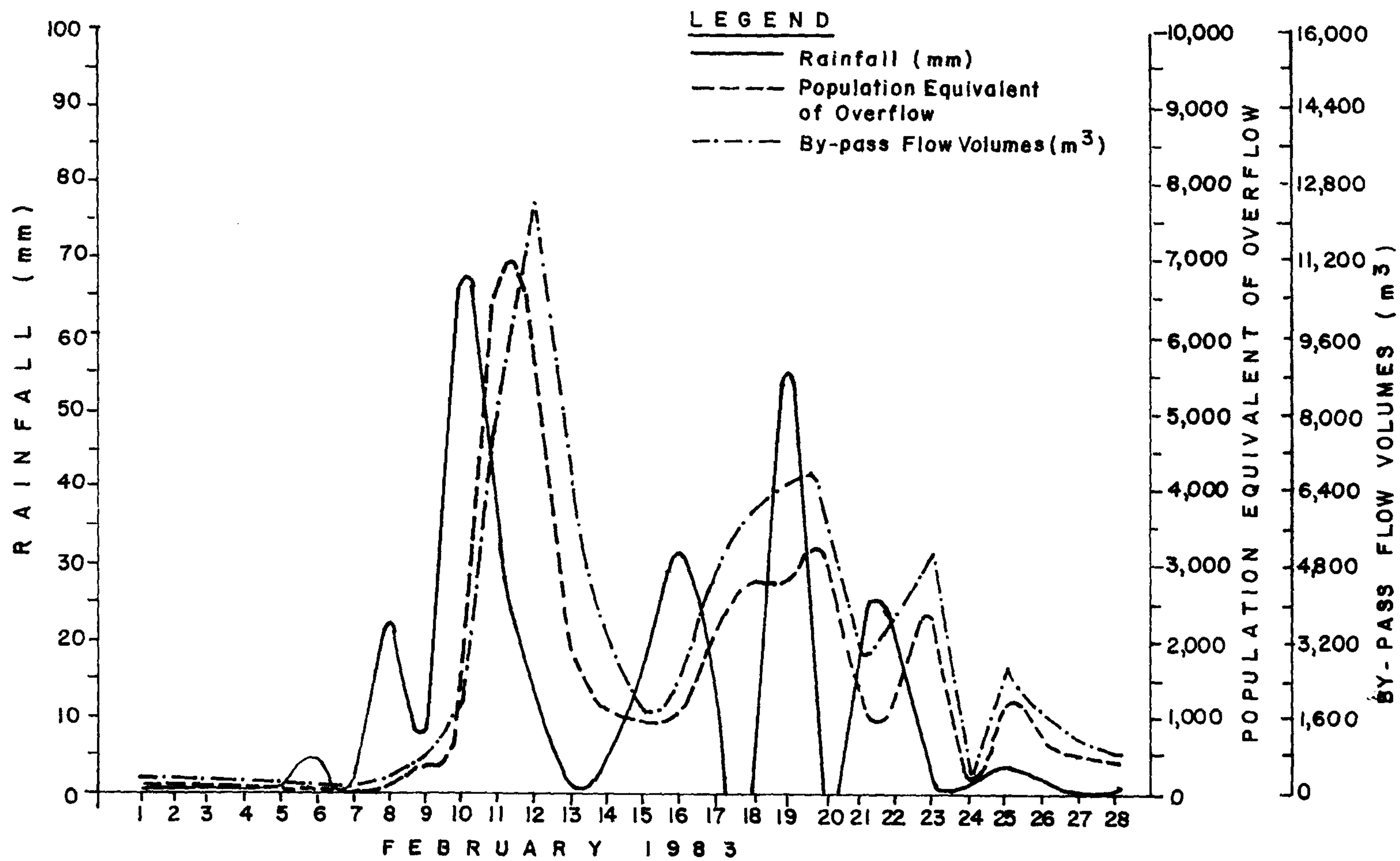


FIGURE 12 LADYSMITH SEWAGE TREATMENT PLANT FLOW RECORD, FEBRUARY, 1983

metals. The final effluent BOD and NFR values for the three days were well within the provincial permit requirements of 130 $mg.L^{-1}$ although the large flows through the plant during the heavy rains resulted in an increase, rather than reduction in BOD and NFR. A full discussion of the results is presented in Appendix VII.

4.2 Davis Lagoon

Marine stations 41-45 were sampled during February and March with additional sampling at stations 44 and 45 during June and July. Stations 43-45 are located on commercial oyster lease L.404.

Station 45 exceeded the growing water standard during the February sampling period however combined data for each station for February and March met the standard. Salinity values were slightly higher in March, with station 44 having the lowest salinities in both February and March due to the influence of Stocking Creek (S24).

During March, sampling of Davis Lagoon was repeated twice daily on ebb and high slack tides. Comparison of medians and 90 percentiles for the two tide conditions shows slightly higher 90 percentile values on the ebb tide but water quality on both tidal conditions was acceptable for shellfish harvesting.

Previous sampling of Davis Lagoon (Tevendale, 1973b) found the shellfish growing areas to be highly contaminated and attributed the pollution to seepage from faulty on-site ground disposal systems and possibly effluent from the Ladysmith STP. Since the low fecal coliform levels encountered during February and March 1983 were not consistent with the previous data, additional sampling was conducted in June and July. The results were similar to the 1973 data, with stations 44 and 45 exceeding the growing water standard at both the median and 90 percentile levels.

The major freshwater input to Davis Lagoon is Stocking Creek (S24). Fecal coliform levels were low (mean FC = 16/100 mL) during the survey, with a population equivalent of 1.89 (February 17, 1983 flow data). Additional samples were collected at five other creeks (S21-S23, S25, S26) to assess the bacteriological quality of the local drainage. None of these discharges had large flows although all showed evidence of fecal contamination. The highest FC levels were noted in S26 (mean FC = 1380/100 mL; P.E. = 3.36, Feb. 17/83), which enters the marine waters near station 45. The contamination source continues to be septic tank ground disposal seepage as previously reported (Tevendale, 1973b). This is corroborated by local reports that the area has a very shallow soil layer which is insufficient for ground disposal on the small lots (S. Chan, personal communication). Additional sampling (S28-S34) of drainage ditches in the residential area immediately south of Davis Lagoon also showed evidence of sewage contamination.

Direct shellfish harvesting is not permitted from Davis Lagoon (L.404) since it is included in the Area 17-1 closure. A single oyster sample collected on March 22, 1983 at station 44 showed minimal fecal contamination (20/100 g).

4.3 Boulder Point

Boulder Point is the southern boundary of closure Area 17-1 and the open area immediately south has been established as a recreational shellfish reserve by the Provincial Government. Fecal contamination at the three marine stations (46-48) was minimal, the highest value being 26/100 mL.

No sources of sewage contamination were identified during the survey.

4.4 Sharpe Point, Evening Cove and Coffin Point

This coastline is harvested for manila clams, and a commercial oyster lease (L.97) is located at Coffin Point.

During the February sampling program, marine stations 50-54 were of approved growing water quality although the median value of 14/100 mL for station 51 indicates a possible sewage pollution source. Highest FC counts were observed on flood and high slack tides. There was no observable correlation between FC levels and rainfall and no onshore pollution sources noted.

Freshwater sampling stations were established on two creeks (S16 and S17) which enter near marine stations 52 and 54. Both showed evidence of fecal contamination, with mean FC densities of 93/100 mL and 97/100 mL respectively. Drainage in S16 originates from a low, flat area occupied by a housing subdivision. Sewage treatment is by septic tank tile field ground disposal. A trailer park located south of S17 is serviced by a septic tank and tile field and has a communal pit privy. No sewage disposal problems were identified in either of these drainage areas and the low flows exerted a minimal impact on marine water quality.

Commercial shellfish product bacteriological records obtained from the Fish Inspection Branch of DFO are presented in Table 7. During 1983 and 1984 one clam sample harvested from the Coffin Point area exceeded the 230/100 g fecal coliform wholesale market guideline. Oysters harvested from oyster lease L.97 had FC levels ranging from < 20-50/100 g.

4.5 Kulleet Bay

Kulleet Bay was sampled during both February and March 1983 at marine stations 55-59. Station 58 exceeded the growing water standard as a result of contamination during February. All other stations were classified as approved and combined data for stations 55-59 show water quality to meet approved standards (February: median = 8/100 mL; 90 pct = 33/100 mL: March: median = < 2/100 mL; 90 pct = 5/100 mL). All stations showed elevated fecal coliform levels and reduced salinities on February 23, 1983, following heavy rainfall on February 21 and 22. Mean salinities were slightly lower in February than in March.

Three creeks (S18-S20) were sampled; however, only S18 had a significant flow. FC values ranged from 10-180/100 mL with a mean of 60/100 mL. The contamination in this creek may have been responsible for the fecal coliform levels noted in marine station 58. The creek drains part of the Kulleet Bay Indian Reserve and contamination may be resulting from on-site sewage disposal systems. Previous studies of Kulleet Bay (Cooper and Kay, 1975) have identified numerous malfunctioning sewage disposal systems on the reserve. Most of the homes have now been upgraded with new tile fields.

TABLE 7 SHELLFISH TISSUE BACTERIOLOGICAL RESULTS
Sharpe Point to Yellow Point - January 1983 to September 1984

LOCATION	SAMPLE DATE	SPECIES	FECAL COLIFORM /100 g
Kulleet Bay	January 5/83	manila clams	490
"	February 9/83	manila clams	< 20
"	February 23/83	littleneck clams	20
"	March 22/83	cockles	20*
Yellow Point	May 30/83	manila clams	80
Coffin Point (L.97)	June 24/83	oysters, shucked	50
"	June 24/83	oysters, shucked	20
"	June 24/83	oysters, shucked	< 20
Yellow Point	June 24/83	manila clams	< 20
Kulleet Bay	July 6/83	manila clams	170
Yellow Point	July 6/83	manila clams	790
"	July 12/83	manila clams	170
Kulleet Bay	July 12/83	manila clams	790
Coffin Point	July 12/83	manila clams	460
Yellow Point	October 3/83	manila clams	1100
Coffin Point (L.97)	October 3/83	oysters, shucked	50
"	October 3/83	oysters, shucked	< 20
"	October 3/83	oysters, shucked	20
Yellow Point	October 11/83	littleneck clams	< 20
Coffin Point (L.97)	October 12/83	oysters, whole	< 20
"	December 12/83	oysters, whole	20
"	January 24/84	oysters, shucked	< 20,< 20, 50
"	February 4/84	oysters, shucked	< 20,< 20,< 20
"	April 4/84	littleneck clams	70
"	May 29/84	oysters, shucked	< 20
Kulleet Bay	May 30/84	littleneck clams	< 20
"	June 6/84	manila clams	130

*(EPS sample)

Commercial clam lots harvested from Kullet Bay during 1983 and 1984 showed sporadic contamination with 2 of 8 samples exceeding the market guideline (Table 7). The cause of this contamination was not determined since an exact harvest location was unknown. A single sample of cockles collected by EPS at station 59 showed minimal (FC = 20/100 g) contamination.

4.6 Yellow Point

Marine stations 60 and 61 were located at the Provincial Goverment Recreational Oyster Reserve at Yellow Point and both were of approved water quality. No sewage pollution sources were evident and it appears water quality has not changed since the previous study (Cooper and Kay, 1975). Sewage disposal at the Inn of the Sea development located immediately north of the oyster reserve is by means of a secondary treatment plant with subsequent sand filtration disinfection and disposal to ground (Waste Management Branch permit No. PE-5435). A recent (November 6, 1984) site inspection of the facility revealed the plant was not operating properly and the UV disinfection equipment had not been installed. Evidence of possible tile field seepage was noted but not confirmed.

Commercial clam lots harvested from the Yellow Point area during 1983 exceeded the fecal coliform market guideline in 2 of 6 samplings (Table 7). The water quality and sanitary survey results could not explain these high FC results.

4.7 Chemical Analysis of Shellfish Tissues

Oysters were collected on May 17 and July 11, 1983 by the Marine Resources Branch from two locations and analyzed by EPS for trace metals, PCB, PCP, TCP and resin acids. The samples were collected from the Marine Resources Branch growth experiment site in the inner harbour and the control site at Davis Lagoon. Samples of both mature, bottom-cultured oysters and immature, off-bottom cultured (stake culture) oysters were collected.

Results are summarized in Table 8 for selected metals as well as PCB, PCP, TCP and resin acids. Appendix IX presents all trace metal data.

Levels of organic contaminants were below detection limits for all samples as were levels for lead. Cadmium levels ranged from 0.46 $ug.g^{-1}$ to 1.55 $ug.g^{-1}$ wet weight, with the highest value being observed in mature, bottom-cultured oysters from Davis Lagoon. The lowest cadmium values were in mature bottom-cultured oysters from the inner harbour.

Copper values ranged from 8.3 $ug.g^{-1}$ (wet weight) to 44.4 $ug.g^{-1}$ (wet weight) with the highest levels recorded in bottom-cultured mature oysters from the inner harbour. Lowest levels were in off-bottom cultured immature oysters from Davis Lagoon.

Zinc values ranged from 146 $ug.g^{-1}$ (wet weight) to 338 $ug.g^{-1}$ (wet weight) with the highest levels recorded in bottom-cultured immature oysters from Davis Lagoon.

4.8 Chlorophenol Sampling Program - Schon Timber

On February 8 and 11, 1983 samples of water and sediment were collected at the Schon Timber Mill, located at the head of Ladysmith Harbour, and analyzed for total chlorophenols. The sampling program was initiated due to concern over the lack of environmental controls in the chlorophenol spraying operation. (Chlorophenol is used by the sawmill to treat wood products for sapstain control.) The hand spraying technique in use at the time of the survey resulted in the deposition of 230-450 litres per day of chlorophenate solution (1-2%) directly onto the yard soil surface. During periods of rainfall the chlorophenols were washed off the yard and discharged into a small stream (S10) which flows through the plant site and subsequently into Ladysmith Harbour.

Samples collected on February 8 and 11 indicated 27 $ug.g^{-1}$ total chlorophenols in the soil near the treatment area and 181 $ug.L^{-1}$ total chlorophenols in the creek water. Levels in the creek were reduced to 0.27 $ug.L^{-1}$ at the mouth. Sampling locations are shown in Figure 13.

TABLE 8 SUMMARY OF CHEMICAL DATA FOR SHELLFISH TISSUE (*C. gigas*) SAMPLES

PARAMETER	SAMPLE STATION							
	1		2		3		4	
	wet wt. $ug.g^{-1}$	dry wt. $ug.g^{-1}$	wet wt. $ug.g^{-1}$	dry wt. $ug.g^{-1}$	wet wt. $ug.g^{-1}$	dry wt. $ug.g^{-1}$	wet wt. $ug.g^{-1}$	dry wt. $ug.g^{-1}$
Mercury								
No. of samples	1	1	1	1	1	1	1	1
No. of replicates	2	2	2	2	2	2	2	2
Range	0.03-0.03	0.16-0.18	0.03-0.03	0.12-0.16	0.03-0.03	0.16-0.18	0.04-0.04	0.32-0.37
Mean	0.03	0.17	0.03	0.14	0.03	0.17	0.04	0.35
Cadmium								
No. of samples	2	2	2	2	2	2	2	2
No. of replicates	5	5	5	5	8	8	5	5
Range	0.76-1.37	4.2-7.5	4.7-7.4	4.7-7.4	0.85-1.55	4.3-8.1	0.46-1.28	4.2-8.1
Mean	0.98	5.5	5.6	5.6	1.19	6.1	0.81	6.2
Lead								
No. of samples	2	2	2	2	2	2	2	2
No. of replicates	5	5	5	5	8	8	5	5
Range	< 0.2-0.2	< 1.0-< 1.0	< 0.2-< 0.2	< 1.0-< 1.0	< 0.2-< 0.2	< 1.0-< 1.0	< 0.2-< 0.2	< 1.0-< 1.0
Mean	< 0.2	< 1.0	< 0.2	< 1.0	< 0.2	< 1.0	< 0.2	< 1.0
Copper								
No. of samples	2	2	2	2	2	2	2	2
No. of replicates	5	5	5	5	8	8	5	5
Range	13.6-20.4	75.3-112.0	8.31-11.5	39.9-56.2	13.6-20.2	69.9-109	18.7-44.4	69.3-279
Mean	16.4	93.8	9.74	46.8	16.5	84.2	23.5	172.1

TABLE 8 SUMMARY OF CHEMICAL DATA FOR SHELLFISH TISSUE (C. gigas) SAMPLES (Continued)

PARAMETER	SAMPLE STATION							
	1		2		3		4	
	wet wt. $ug.g^{-1}$	dry wt. $ug.g^{-1}$	wet wt. $ug.g^{-1}$	dry wt. $ug.g^{-1}$	wet wt. $ug.g^{-1}$	dry wt. $ug.g^{-1}$	wet wt. $ug.g^{-1}$	dry wt. $ug.g^{-1}$
Zinc								
No. of samples	2	2	2	2	2	2	2	2
No. of replicates	5	5	5	5	8	8	5	5
Range	160-210	885-1150	146-149	689-716	200-257	963-1390	112-338	1020-2400
Mean	186	1068	147	707	219	1118	239	1850
PCB								
No. of samples	1		1		1		1	
No. of replicates	1		1		1		1	
Range	-		-		-		-	
Mean	< 0.05		< 0.05		< 0.05		< 0.05	
Chlorophenols								
No. of samples	1		1		1		1	
No. of replicates	1		1		1		1	
Range	-		-		-		-	
Mean	< 0.001		< 0.001		< 0.001		< 0.001	
Resin Acids								
No. of samples	1		1		1		1	
No. of replicates	1		1		1		1	
Range	-		-		-		-	
Mean	< 2.0		< 2.0		< 2.0		< 2.0	

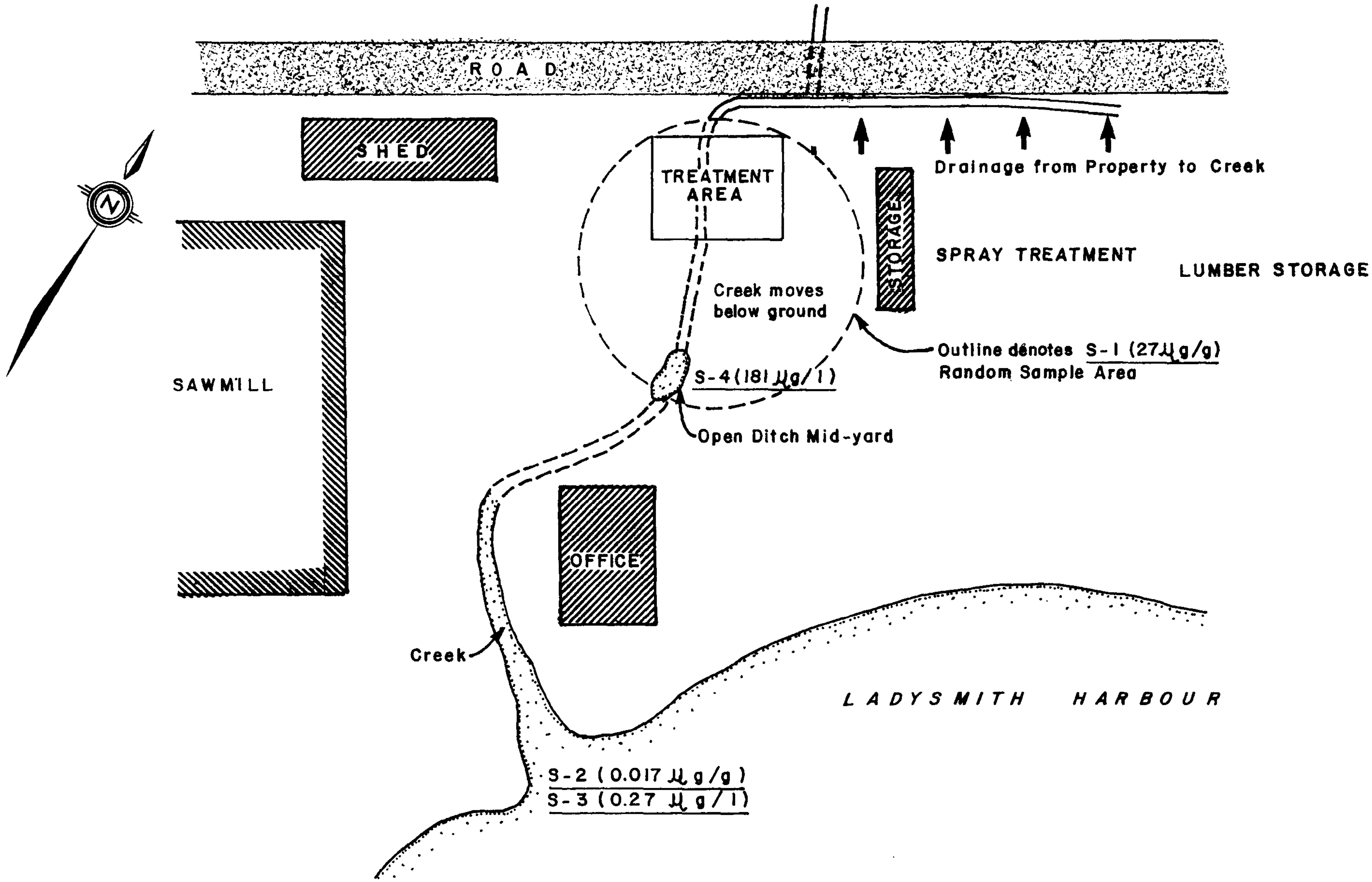


FIGURE 13 SCHON TIMBER

5.0 DISCUSSION

5.1 Ladysmith Harbour

The water quality of the shellfish growing areas in Ladysmith Harbour has shown significant changes since the 1970 survey which was conducted following the installation of the Ladysmith sewage treatment plant and outfall. These changes, as reflected in median, mean, and 90 percentile fecal coliform values, are presented in Table 9 for representative marine sampling stations as shown in Figure 14. A review of the median fecal coliform values together with the percentage of individual results exceeding 14 FC/100 mL indicates worsening water quality at inner harbour stations A, B and E whereas outer harbour stations F and G have shown significant improvement during the period 1970-1984. Water quality at stations C and D has remained relatively constant.

During the 1983/84 surveys the contamination of the inner harbour was due, in part, to the exceptionally high level of precipitation encountered during February 1983 and the resultant landwash effect. Under such conditions, animal fecal matter in surface runoff together with seepage from failed ground disposal systems caused widespread pollution of the approved growing area. Fecal coliform levels returned to acceptable levels at most stations during subsequent sampling in drier weather; however, contamination persisted along the eastern shoreline. The source of contamination was identified as Thomas Creek (S11) as confirmed by bacteriological sampling and a dye tracer study conducted during low flow conditions on July 13, 1983. The dilution factors of the creek water and the observed fecal coliform densities in the creek would cause the growing water standard to be exceeded. The degree of dilution afforded to the creek during high flow conditions is unknown but would likely be less than that observed in July, since the volume of contaminated water entering the dilution water (i.e. salt water) would be greater.

Flushing of the inner harbour area is considered to be poor, since it is dependent almost exclusively on the exchanging of water by the

TABLE 9 SUMMARY OF BACTERIOLOGICAL DATA FOR REPRESENTATIVE MARINE STATIONS: 1970-1984

SAMPLE STATION	No. of Samples	F.C. MPN/100 mL					
		Range	Median	Mean	90 PCT	S.D.	% > 14
1970							
A	15	< 3-43	3	7.1	23.5	14.1	(2/15) 13
B	14	< 3-93	8	16.1	35.0	25.4	(5/14) 36
C	15	< 3-43	4	10.1	33.0	15.4	(4/15) 27
D	15	< 3-93	7	12.3	18.5	23.2	(2/15) 13
E	15	< 3-23	4	5.8	9.0	6.1	(1/15) 7
F	14	< 3-240	27	53.1	127.2	69.9	(8/14) 57
G	14	< 3-240	22	42.3	107.2	68.5	(8/14) 57
1975							
A	6	< 2-5	< 2	2	5.0	2.4	0
B	11	< 2-46	2	5.3	3.8	13.6	(1/11) 9
C	14	< 2-70	< 2	6.3	8.6	18.6	(1/14) 7
D	12	< 2-7	< 2	< 2	4.4	2.3	0
E	13	< 2-350	< 2	30.3	15.2	96.2	(2/13) 15
F	10	< 2-33	< 2	3.5	2.0	10.4	(1/10) 10
G	14	< 2-23	< 2	3.8	13.4	7.4	(2/14) 14
1983/84							
A	26	< 2-1100	17	69.7	79.0	212.7	(14/26) 54
B	10	< 2-130	14	33.6	79.0	41.7	(5/10) 50
C	28	< 2-49	5.5	11.5	33.0	14.1	(8/28) 29
D	29	< 2-33	2	7.1	24.0	10.6	(5/29) 17
E	11	< 2-49	8	17.5	44.7	18.3	(5/11) 45
F	18	< 2-27	2	5.4	14.2	8.5	(2/18) 11
G	18	< 2-23	3	6.6	22.2	8.5	(4/18) 22

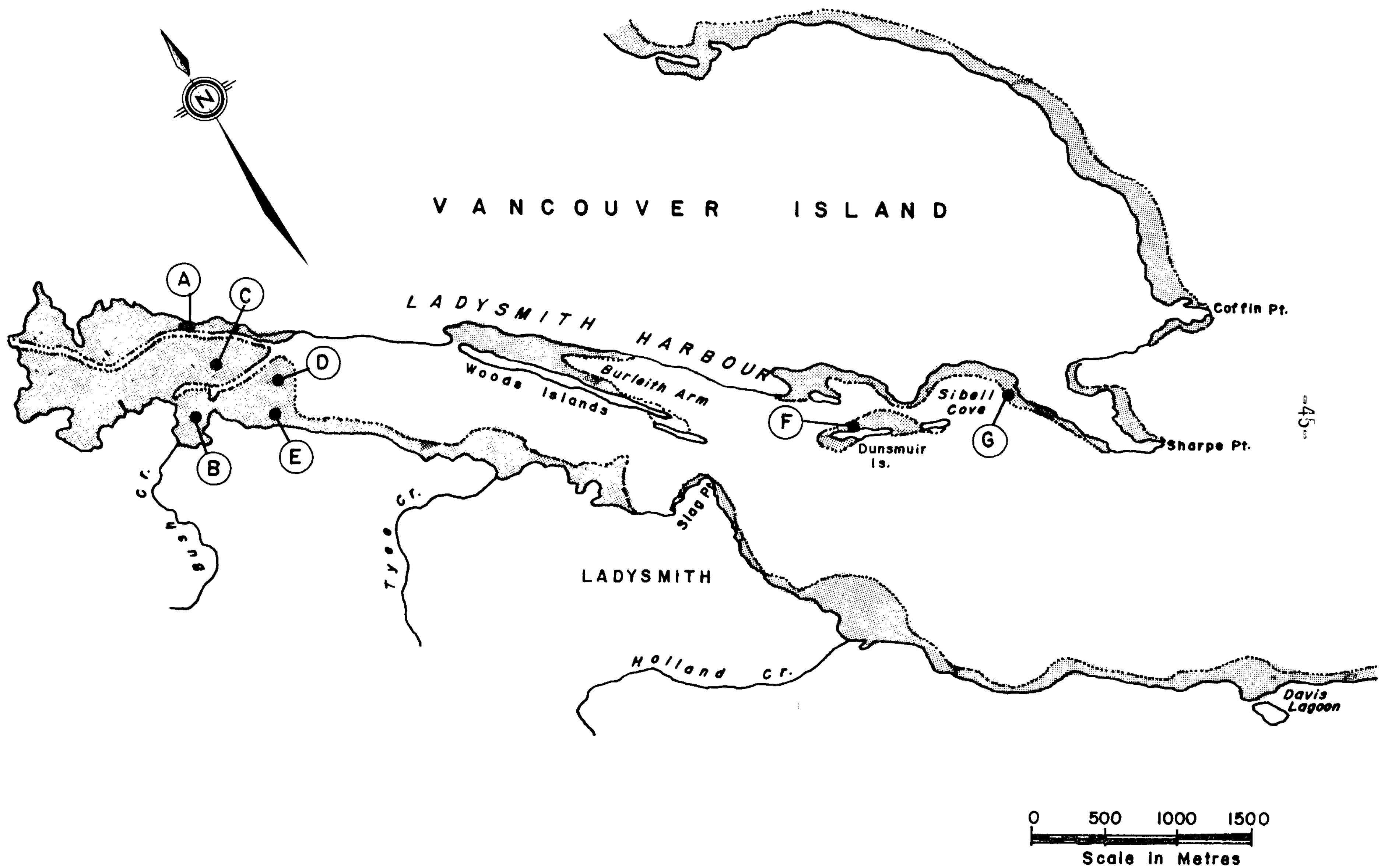


FIGURE 14 REPRESENTATIVE MARINE SAMPLE STATIONS - 1970 - 1984

tide with some assistance from wind mixing (Lands, Parks and Housing, 1981). Thus although the head of the harbour will experience almost 100% water exchange during a tidal cycle, much of the same water may return and recontaminate the growing areas.

The polluton of the inner harbour growing area may also have been due, in part, to the introduction of sewage-contaminated outer harbour water. Pommen and Holden (1981) have shown that surface droques deployed at the Ladysmith STP outfall plume can move into the inner harbour. This movement is accelerated by southeast winds, which tend to blow surfaced effluent towards the head of the harbour. However, based on the surface water bacteriological results obtained during 1983/84 for outer harbour stations, there would appear to be significant dilution of the sewage effluent so as not to contaminate the inner harbour growing waters.

Fecal coliform levels in shellfish samples collected in the inner harbour showed significant contamination in 1983, particularly from L.455. This lease is located on the west side of the inner harbour and was being used as an approved relay site for contaminated oysters. The FC levels in these oysters may have been the result of contamination from sources in the inner harbour. However, it is possible that the relayed oysters were unable to purify themselves due to reduced salinities resulting from heavy rains. Hopkins (1936) has shown that water transport through the gills of Crassostrea gigas is significantly reduced at salinity levels of 13 ppt or below and that adaptation to reduced salinities takes several days.

Levels of trace metals in oysters harvested from the inner harbour open area are within the range of those reported elsewhere in British Columbia (Duncan, 1984). The higher copper levels noted in the harbour oysters as compared with Davis Lagoon likely results from the urban runoff entering the harbour. Levels of metals in Thomas, Walker, Bush, and Rocky Creeks have not been found to be sufficient to warrant concern (McDougall and Boyd, 1984).

The absence of organic contaminants in oyster tissue collected during this study suggests that the oyster leases are far enough removed from potential contamination sources not to be a concern at this time. McDougall and Boyd (1984) were unable to detect organic compounds in Thomas, Walker or Bush Creeks except for low levels ($\leq$ 0.05 ug.L^{-1} TCP, $\leq$ 0.03 ug.L^{-1} PCP) of chlorophenols. Results of organic analyses for Rocky Creek were noticeably different and revealed high concentrations of chlorophenols (30 ug.L^{-1} PCP and 62 ug.L^{-1} TCP). The source(s) of chlorophenols to the creek was not determined.

The impact of the new overflow bypass outfall on the water quality of the outer harbour was negligible during the 1983/84 sampling program. During 1983, 128[1] bypasses were recorded at the treatment plant. In addition, sludge was discharged through the STP outfall on two occasions. The monthly total bypass volumes for 1983 are presented graphically in Figure 15 with details given in Appendix VII. The total bypass volume for February 1983 was 83,594 m^3 as compared with 67,352 m^3 for the treated effluent from the STP. Despite these excessive bypass volumes, water quality at all stations in the outer harbour met the approved shellfish growing standards.

5.2 Davis Lagoon and Boulder Point

Water quality data collected during June and July of 1983 support data collected previously (Tevendale, 1973b) and indicate significant contamination problems continue to exist in Davis Lagoon. The generally good water quality observed during February and March appears anomalous, since the greatest pollution from septic seepage would be expected during conditions of heavy rainfall and subsequent land wash. However, it is possible that the seepage was diluted to such an extent by the excessive rainfall as to make it non-detectable in the marine samples.

Growing waters at the Boulder Point recreational shellfish reserve were of approved quality during the February and March surveys.

[1]The number of bypasses may be greater since records are not kept 7 days/week.

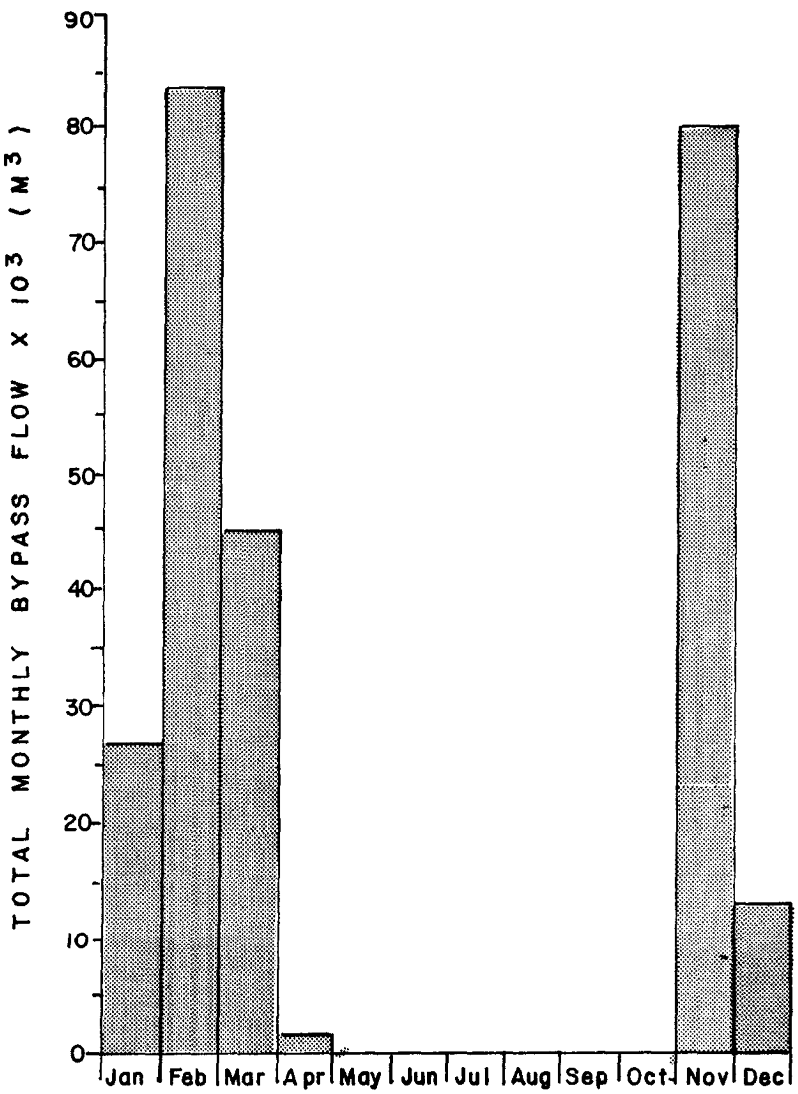


FIGURE 15 LADYSMITH SEWAGE TREATMENT PLANT - TOTAL MONTHLY OVERFLOW BYPASS VOLUMES, 1983

5.3 Sharpe Point to Yellow Point

Low level contamination of the shellfish growing waters at Kulleet Bay is likely the result of septic tank seepage entering the main creek draining the village. Although considerable upgrading of the tile fields has occurred during the past several years, proper maintenance of the disposal systems is lacking. For example, some of the tile fields were being used as parking areas which will ultimately lead to failure. The occasional incidence of contaminated shellfish reportedly harvested from Kulleet Bay may be a symptom of this problem.

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APPENDIX I

DAILY DATA RECORD
FOR MARINE SAMPLE STATIONS

APPENDIX I

TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH001	49 01.30	123 50.42	83/02/08	0900	High Slack	2	26.0
			83/02/10	0905	High Slack	11	23.0
			83/02/11	0930	High Slack	79	16.0
			83/02/14	0940	Ebb	79	5.0
			83/02/16	0905	Ebb	49	9.5
			83/02/21	1000	High Slack	33	11.5
LH002	49 01.35	123 51.08	83/02/08	0905	High Slack	2	24.5
			83/02/10	0910	High Slack	130	17.0
			83/02/11	0935	High Slack	>1600	6.0
			83/02/14	0940	Ebb	79	5.0
			83/02/16	0905	Ebb	280	5.5
			83/02/21	1005	High Slack	49	7.0
LH003	49 01.35	123 51.17	83/02/08	0910	High Slack	<2	25.0
			83/02/10	0910	High Slack	110	10.0
			83/02/11	0935	High Slack	920	2.0
			83/02/14	0945	Ebb	22	4.0
			83/02/16	0905	Ebb	130	6.0
			83/02/21	1010	High Slack	49	4.0
LH004	49 01.19	123 51.28	83/02/08	0915	High Slack	5	26.0
			83/02/10	0915	High Slack	19	15.5
			83/02/11	0940	High Slack	>1600	4.5
			83/02/14	0945	Ebb	23	4.0
			83/02/16	0910	Ebb	79	8.0
			83/02/21	1010	High Slack	33	6.5
LH005	49 01.07	123 51.17	83/02/08	0920	High Slack	5	25.0
			83/02/10	0915	High Slack	350	17.5
			83/02/11	0940	High Slack	170	5.5
			83/02/14	0950	Ebb	33	5.0
			83/02/16	0910	Ebb	46	8.0
			83/02/21	1010	High Slack	23	4.5
LH006	49 01.06	123 50.44	83/02/08	0925	High Slack	8	22.5
			83/02/10	0920	High Slack	23	21.5
			83/02/11	0945	High Slack	920	12.0
			83/02/14	0950	Ebb	49	5.5
			83/02/16	0910	Ebb	11	9.0
			83/02/21	1015	High Slack	13	11.0
			83/03/21	1125	Ebb	<2	24.5
			83/03/22	0855	High Slack	13	23.5
			83/03/23	0845	High Slack	13	23.5
			83/03/24	0845	High Slack	<2	25.5
			83/06/02	1105	Ebb	22	27.0
			83/06/03	1100	High Slack	5	26.5
			83/06/05	1030	High Slack	2	26.0

APPENDIX I

TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity	
LH006	continued...		83/06/07	1020	Flood	13	25.0	
			83/06/08	1110	Flood	4	26.5	
			83/06/09	0835	Ebb	33	26.0	
			83/07/12	0710	Ebb	130	24.0	
			83/07/13	0855	Ebb	13	24.0	
			83/10/24	0955	Ebb	9	23.5	
			83/10/24	1030	Ebb	<3	25.5	*
			83/10/25	0835	High Slack	3		
			83/10/25	0835	High Slack	<3		*
			83/10/26	0830	High Slack	<3	23.0	
			83/10/26	0835	High Slack	<3	24.0	*
			84/03/20	0730	Ebb	7	19.5	
			84/03/21	0805	Ebb	43	27.0	
			84/03/22	0830	Ebb	43	12.5	
			84/03/23	0905	Ebb	4	16.0	
LH007	49 01.11	123 50.39	83/02/08	0925	High Slack	4	25.0	
			83/02/10	0920	High Slack	17	22.5	
			83/02/11	0945	High Slack	33	7.5	
			83/02/14	0955	Ebb	33	6.5	
			83/02/16	0915	Ebb	49	9.5	
			83/02/21	1015	High Slack	33	8.5	
			83/03/21	1125	Ebb	<2	25.0	
			83/03/22	0855	High Slack	2	24.0	
			83/03/23	0845	High Slack	2	24.5	
			83/03/24	0845	High Slack	<2	26.0	
LH008	49 00.55	123 50.41	83/02/08	0930	High Slack	<2	25.0	
			83/02/10	0925	High Slack	9	12.0	
			83/02/11	0950	High Slack	79	4.0	
			83/02/14	0955	Ebb	9	3.0	
			83/02/16	0915	Ebb	33	11.5	
			83/02/21	1020	High Slack	130	6.0	
			83/02/23	0950	High Slack	17	3.5	
			83/03/22	0900	High Slack	11	24.0	
			83/03/23	0850	High Slack	46	21.5	
			83/03/24	0850	High Slack	2	24.5	
LH009	49 01.02	123 50.27	83/02/08	0935	High Slack	7	25.0	
			83/02/10	0925	High Slack	8	25.5	
			83/02/11	0950	High Slack	33	5.0	
			83/02/14	1000	Ebb	49	8.5	
			83/02/16	0915	Ebb	17	9.0	
			83/02/21	1020	High Slack	23	8.5	
			83/02/23	0945	High Slack	49	5.0	
			83/03/21	1130	Ebb	2	23.0	
			83/03/22	0900	High Slack	<2	22.0	

* depth sample

APPENDIX I

TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity	
LH009	continued...		83/03/23	0850	High Slack	2	25.0	
			83/03/23	1440	Ebb	8	20.5	
			83/03/24	0850	High Slack	2	24.0	
			83/03/24	1340	Ebb	<2	25.5	
			83/06/02	1115	Ebb	2	28.0	
			83/06/03	1100	High Slack	17	26.5	
			83/06/05	1040	High Slack	7	26.0	
			83/06/07	1025	Flood	2	26.0	
			83/06/08	1130	Flood	2	28.0	
			83/06/09	0830	Ebb	2	27.0	
			83/07/12	0720	Ebb	33	24.0	
			83/07/13	0900	Ebb	23	23.5	
			83/10/24	1005	Ebb	9	24.5	
			83/10/24	1010	High Slack	<3	28.0	*
			83/10/25	0850	High Slack	4		
			83/10/25	0850	High Slack	7		*
			83/10/26	0840	High Slack	4	28.0	
			83/10/26	0840	High Slack	<3	25.0	*
			84/03/20	0735	Ebb	<3	24.0	
			84/03/20	0735	Ebb	<3	25.0	*
			84/03/21	0810	Ebb	4	24.5	
			84/03/21	0815	Ebb	<3	25.0	*
			84/03/22	0835	Ebb	4	12.0	
			84/03/22	0840	Ebb	<3	27.5	*
			84/03/23	0910	Ebb	9	18.0	
			84/03/23	0915	Ebb	<3	23.5	*
LH010	49 01.16	123 50.26	83/02/08	0940	High Slack	2	25.0	
			83/02/10	0930	High Slack	5	25.0	
			83/02/11	0955	High Slack	70	11.5	
			83/02/14	1000	Ebb	33	5.5	
			83/02/16	0920	Ebb	13	10.0	
			83/02/21	1020	High Slack	13	13.0	
			83/02/23	0945	High Slack	11		
			83/03/21	1130	Ebb	<2	24.5	
			83/03/22	0900	High Slack	<2	23.0	
			83/03/23	0855	High Slack	17	24.0	
			83/03/24	0855	High Slack	<2	25.0	
			83/06/02	1110	Ebb	2	28.0	
			83/06/03	1105	High Slack	13	26.0	
			83/06/05	1050	High Slack	<2	26.0	
			83/06/07	1020	Flood	13	25.5	
			83/06/08	1120	Flood	5	27.0	
			83/06/09	0835	Ebb	8	27.0	
			83/07/12	0715	Ebb	33	24.0	
			83/07/13	0855	Ebb	8	24.0	
			83/10/24	1015	Ebb	<3	27.0	

APPENDIX I
TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH010	continued...		83/10/25	0850	High Slack	11	
			83/10/26	0845	High Slack	9	23.5
			84/03/20	0740	Ebb	4	22.0
			84/03/21	0820	Ebb	240	21.0
			84/03/22	0845	Ebb	4	11.0
			84/03/23	0920	Ebb	23	16.0
LH011	49 01.09	123 50.13	83/02/08	0940	High Slack	<2	25.5
			83/02/10	0930	High Slack	11	25.0
			83/02/11	1000	High Slack	17	14.0
			83/02/14	1000	Ebb	11	6.5
			83/02/16	0920	Ebb	79	10.0
			83/02/21	1020	High Slack	49	5.5
			83/02/23	0945	High Slack	11	4.0
			83/03/21	1135	Ebb	<2	24.5
			83/03/22	0905	High Slack	33	24.0
			83/03/23	0855	High Slack	49	25.5
			83/03/24	0855	High Slack	79	25.0
			83/06/02	1115	Ebb	17	28.0
			83/06/03	1110	High Slack	17	26.0
			83/06/05	1040	High Slack	<2	26.0
			83/06/07	1025	Flood	70	26.0
			83/06/08	1120	Flood	9	27.5
			83/06/09	0830	Ebb	5	17.0
			83/07/12	0715	Ebb	140	24.5
			83/07/13	0900	Ebb	5	25.0
			83/10/24	1020	Ebb	23	29.5
			83/10/25	0855	High Slack	9	
			83/10/26	0845	High Slack	4	29.0
			84/03/20	0740	Ebb	9	23.0
			84/03/21	0820	Ebb	43	22.0
			84/03/22	0845	Ebb	23	16.0
			84/03/23	0920	Ebb	1100	14.0
LH012	49 01.02	123 50.02	83/02/08	0940	High Slack	<2	27.0
			83/02/10	0930	High Slack	11	26.0
			83/02/11	1000	High Slack	33	18.0
			83/02/14	1000	Ebb	33	8.0
			83/02/16	0920	Ebb	23	12.0
			83/02/21	1020	High Slack	22	8.5
			83/02/23	0940	High Slack	17	6.5
			83/03/21	1135	Ebb	5	24.5
			83/03/22	0905	High Slack	2	25.0
			83/03/23	0900	High Slack	22	25.5
			83/03/24	0855	High Slack	23	25.0
LH013	49 00.56	123 50.10	83/02/08	0945	High Slack	2	26.0

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TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity	
LH013	continued...		83/02/10	0935	High Slack	2	26.5	
			83/02/11	1005	High Slack	33	13.5	
			83/02/14	1005	Ebb	33	7.5	
			83/02/16	0920	Ebb	11	12.5	
			83/02/21	1025	High Slack	17	10.0	
			83/02/23	1000	High Slack	23	9.5	
			83/03/21	1135	Ebb	<2	25.5	
			83/03/22	0905	High Slack	<2	22.5	
			83/03/22	1440	Ebb	<2	22.0	
			83/03/23	0900	High Slack	2	25.0	
			83/03/23	1440	Ebb	<2	24.5	
			83/03/24	0855	High Slack	<2	25.0	
			83/03/24	1530	Ebb	<2	26.0	
			83/06/02	1120	Ebb	5	28.0	
			83/06/03	1110	High Slack	2	26.0	
			83/06/05	1045	High Slack	2	26.5	
			83/06/07	1030	Flood	<2	26.0	
			83/06/08	1125	Flood	2	26.5	
			83/06/09	0825	Ebb	<2	26.0	
			83/07/12	0720	Ebb	33	24.0	
			83/07/13	0905	Ebb	2	24.5	
			83/10/24	1025	Ebb	<3	28.5	
			83/10/24	1030	Ebb	<3	27.5	*
			83/10/25	0900	High Slack	<3		
			83/10/25	0900	High Slack	4		*
			83/10/26	0850	High Slack	<3	28.0	
			83/10/26	0850	High Slack	<3	26.0	*
			84/03/20	0745	Ebb	4	23.0	
			84/03/20	0745	Ebb	<3	25.0	*
			84/03/21	0825	Ebb	9	24.5	
			84/03/21	0830	Ebb	4	24.5	*
			84/03/22	0850	Ebb	14	10.0	
			84/03/22	0855	Ebb	<3	27.5	*
			84/03/23	0925	Ebb	9	16.0	
			84/03/23	0930	Ebb	4	24.0	*
LH014	49 00.51	123 50.27	83/02/08	0945	High Slack	<2	27.5	
			83/02/10	0935	High Slack	2	26.0	
			83/02/11	1005	High Slack	70	4.0	
			83/02/14	1005	Ebb	23	7.5	
			83/02/16	0925	Ebb	49	11.0	
			83/02/21	1025	High Slack	79	3.5	
			83/02/23	0955	High Slack	23	8.0	
			83/03/21	1140	Ebb	2	24.5	
			83/03/22	0910	High Slack	49	22.5	
			83/03/23	0905	High Slack	110	23.5	
			83/03/23	1540	Ebb	2		

APPENDIX I

TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH014	continued...		83/03/24	0855	High Slack	5	22.5
LH015	49 00.49	123 50.26	83/02/08	0950	High Slack	2	28.0
			83/02/10	0935	High Slack	23	26.5
			83/02/11	1010	High Slack	70	6.5
			83/02/14	1010	Ebb	79	10.0
			83/02/16	0925	Ebb	17	11.0
			83/02/21	1025	High Slack	34	3.5
			83/02/23	0955	High Slack	94	9.5
			83/03/21	1140	Ebb	2	23.5
			83/03/22	0910	High Slack	110	22.0
			83/03/23	0905	High Slack	5	24.5
			83/03/24	0900	High Slack	5	22.0
LH016	49 00.45	123 50.15	83/02/08	0955	High Slack	<2	27.5
			83/02/10	0940	High Slack	5	27.0
			83/02/11	1010	High Slack	49	10.5
			83/02/14	1010	Ebb	22	11.5
			83/02/16	0925	Ebb	33	10.5
			83/02/21	1030	High Slack	8	3.5
			83/02/23	0955	High Slack	46	10.0
			83/03/21	1145	Ebb	<2	21.5
			83/03/22	0910	High Slack	2	22.0
			83/03/23	0905	High Slack	22	22.5
			83/03/24	0900	High Slack	5	24.0
LH017	49 00.48	123 50.15	83/02/08	1000	High Slack	<2	22.5
			83/02/10	0940	High Slack	2	26.0
			83/02/11	1015	High Slack	110	16.5
			83/02/14	1010	Ebb	17	11.5
			83/02/16	0925	Ebb	33	8.0
			83/02/21	1030	High Slack	21	4.0
			83/02/23	0955	High Slack	10	10.0
			83/03/21	1145	Ebb	<2	23.5
			83/03/22	0915	High Slack	2	23.0
			83/03/23	0910	High Slack	<2	24.5
			83/03/24	0900	High Slack	<2	26.0
			83/06/02	1115	Ebb	2	28.0
			83/06/03	1110	High Slack	5	26.0
			83/06/05	1050	High Slack	<2	26.0
			83/06/07	1035	Flood	2	26.0
			83/06/08	1130	Flood	11	26.5
			83/06/09	0825	Ebb	2	26.5
			83/07/12	0720	Ebb	13	25.0
			83/07/13	0905	Ebb	2	25.0
			83/10/24	1030	Ebb	4	29.0
			83/10/25	0905	High Slack	4	

APPENDIX I
TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity	
LH017	continued...		83/10/26	0855	High Slack	<3	27.5	
			84/03/20	0750	Ebb	4		
			84/03/20	0750	Ebb		22.0	*
			84/03/21	0835	Ebb	23	24.0	
			84/03/22	0900	Ebb	23	9.0	
			84/03/23	0935	Ebb	9	16.0	
LH018	49 00.39	123 50.04	83/02/08	1000	High Slack	5	23.5	
			83/02/10	0940	High Slack	4	25.0	
			83/02/11	1015	High Slack	7	23.0	
			83/02/14	1015	Ebb	33	11.5	
			83/02/16	0930	Ebb	79	9.0	
			83/02/21	1030	High Slack	46	3.5	
			83/02/23	1005	High Slack	33	11.0	
			83/03/21	1145	Ebb	<2	23.0	
			83/03/22	0915	High Slack	<2	22.0	
			83/03/23	0910	High Slack	7	21.5	
			83/03/24	0900	High Slack	<2	25.5	
LH019	49 00.48	123 50.00	83/02/08	1000	High Slack	5	23.5	
			83/02/10	0945	High Slack	<2	26.0	
			83/02/11	1015	High Slack	14	24.5	
			83/02/14	1015	Ebb	23	13.5	
			83/02/16	0930	Ebb	33	7.5	
			83/02/21	1030	High Slack	23	5.0	
			83/02/23	1000	High Slack	17	15.0	
			83/03/21	1150	Ebb	2	24.0	
			83/03/22	0915	High Slack	<2	23.0	
			83/03/22	1450	Ebb	2	23.5	
			83/03/23	0915	High Slack	2		
			83/03/23	1445	Ebb	4	25.0	
			83/03/24	0905	High Slack	2	25.5	
			83/03/24	1530	Ebb	<2	26.0	
LH020	49 00.55	123 49.43	83/02/08	1000	High Slack	2	24.0	
			83/02/10	0945	High Slack	8	25.5	
			83/02/11	1015	High Slack	21	25.0	
			83/02/14	1015	Ebb	33	10.0	
			83/02/16	0930	Ebb	49	12.5	
			83/02/21	1035	High Slack	33	6.5	
			83/02/23	1005	High Slack	33	14.0	
			83/03/21	1150	Ebb	21	23.5	
			83/03/22	0920	High Slack	2	25.0	
			83/03/23	0915	High Slack	8	25.0	
			83/03/24	0905	High Slack	49	25.5	
LH021	49 00.46	123 49.25	83/02/08	1005	High Slack	5	23.5	

APPENDIX I
TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity	
LH021	continued...		83/02/10	0945	High Slack	2	26.5	
			83/02/11	1020	High Slack	8	25.5	
			83/02/14	1020	Ebb	27	12.0	
			83/02/16	0935	Ebb	23	10.5	
			83/02/21	1035	High Slack	70	7.0	
			83/02/23	1010	High Slack	70	14.5	
			83/03/21	1150	Ebb	11	23.0	
			83/03/22	0920	High Slack	8	25.0	
			83/03/23	0920	High Slack	79	24.5	
			83/03/24	0905	High Slack	23	26.0	
LH022	49 00.38	123 49.35	83/02/08	1010	High Slack	<2	23.5	
			83/02/10	0945	High Slack	5	28.0	
			83/02/11	1020	High Slack	33	24.0	
			83/02/14	1020	Ebb	11	13.5	
			83/02/16	0935	Ebb	23	12.0	
			83/02/21	1035	High Slack	17	7.0	
			83/02/23	1010	High Slack	13	16.0	
			83/03/21	1150	Ebb	<2	22.5	
			83/03/22	0920	High Slack	<2	22.5	
			83/03/22	1500	Ebb	<2	22.0	
			83/03/23	0920	High Slack	8	25.5	
			83/03/23	1445	Ebb	<2	26.0	
			83/03/24	0910	High Slack	<2	26.0	
			83/03/24	1530	Ebb	<2	26.5	
			83/06/02	1120	Ebb	8	28.0	
			83/06/03	1115	High Slack	13	26.5	
			83/06/05	1055	High Slack	2	26.0	
			83/06/07	1035	Flood	11	26.0	
			83/06/08	1135	Flood	<2	27.0	
			83/06/09	0825	Ebb	<2	27.5	
			83/07/12	0720	Ebb	13	25.0	
			83/07/13	0910	Ebb	2	25.5	
			83/10/24	1035	Ebb	4	28.0	
			83/10/25	0910	High Slack	<3		
			83/10/26	0900	High Slack	<3	28.0	
			84/03/20	0755	Ebb	9	24.0	
			84/03/20	0800	Ebb	<3	28.0	*
			84/03/21	0840	Ebb	9	24.0	
			84/03/21	0845	Ebb	<3	28.0	*
			84/03/22	0910	Ebb	43	11.5	
			84/03/23	0940	Ebb	9	15.0	
			84/03/23	0945	Ebb	<3	28.0	*
LH023	49 00.29	123 49.47	83/02/08	1015	High Slack	4	21.5	
			83/02/10	0950	High Slack	5	26.0	
			83/02/11	1025	High Slack	33	24.0	

APPENDIX I

TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH023	continued...		83/02/14	1020	Ebb	49	11.5
			83/02/16	0935	Ebb	7	13.0
			83/02/21	1040	High Slack	22	14.0
			83/02/23	1015	High Slack	23	16.0
			83/03/21	1155	Ebb	<2	22.5
			83/03/22	0925	High Slack	2	22.0
			83/03/23	0920	High Slack	5	24.5
			83/03/24	0910	High Slack	<2	25.5
LH024	49 00.33	123 49.52	83/02/08	1015	High Slack	5	21.0
			83/02/10	0950	High Slack	2	27.0
			83/02/11	1025	High Slack	49	25.5
			83/02/14	1020	Ebb	23	13.5
			83/02/16	0940	Ebb	33	12.0
			83/02/21	1040	High Slack	8	9.5
			83/02/23	1015	High Slack	33	26.0
			83/03/21	1155	Ebb	<2	23.0
			83/03/22	0935	High Slack	2	22.0
			83/03/23	0925	High Slack	14	24.0
			83/03/24	0910	High Slack	2	25.0
LH025	49 00.31	123 49.26	83/02/08	1040	High Slack	2	27.0
			83/02/10	0955	High Slack	8	26.5
			83/02/11	1030	High Slack	110	17.5
			83/02/14	1025	Ebb	14	13.0
			83/02/16	0940	Ebb	22	13.5
			83/02/21	1040	High Slack	79	4.0
			83/02/23	1015	High Slack	13	26.0
			83/03/21	1200	Ebb	<2	24.0
			83/03/22	0925	High Slack	17	24.0
			83/03/22	1500	Ebb	<2	23.5
			83/03/23	0925	High Slack	2	25.5
			83/03/23	1450	Ebb	<2	26.0
			83/03/24	0915	High Slack	<2	26.0
			83/03/24	1525	Ebb	<2	27.5
LH026	49 00.14	123 48.59	83/02/08	1050	High Slack	2	26.0
			83/02/10	0955	High Slack	7	26.5
			83/02/11	1030	High Slack	49	20.0
			83/02/14	1045	Ebb	11	15.0
			83/02/16	0940	Ebb	11	15.0
			83/02/21	1045	High Slack	5	9.0
			83/02/23	1020	High Slack	17	19.5
			83/03/21	1200	Ebb	<2	25.5
			83/03/22	0930	High Slack	33	24.0
			83/03/22	1500	Ebb	<2	24.0
			83/03/23	0930	High Slack	13	25.5

APPENDIX I

TABLE 1 : Daily Data Record for Marine Sample Stations (Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH026	continued...		83/03/23	1450	Ebb	5	26.0
			83/03/24	0915	High Slack	<2	25.5
			83/03/24	1520	Ebb	<2	27.0
			83/06/02	1125	Ebb	17	28.0
			83/06/03	1120	High Slack	2	26.5
			83/06/05	1055	High Slack	2	26.0
			83/06/07	1040	Flood	<2	25.5
			83/06/08	1140	Flood	<2	27.0
			83/07/12	0725	Ebb	17	25.0
			83/07/13	0920	Ebb	7	25.5
			83/10/24	1040	Ebb	<3	26.0
			83/10/25	0910	High Slack	<3	
			83/10/26	0940	High Slack	<3	28.0
			84/03/20	0810	Ebb	4	24.0
			84/03/21	0855	Ebb	4	22.0
			84/03/22	0915	Ebb	21	8.0
			84/03/23	0950	Ebb	9	15.5
LH027	48 59.42	123 48.20	83/02/08	1050	High Slack	<2	27.0
			83/02/10	1015	High Slack	<2	27.5
			83/02/11	1035	High Slack	46	24.5
			83/02/14	1050	Ebb	13	15.0
			83/02/16	0945	Ebb	8	17.5
			83/02/21	1045	High Slack	17	17.0
			83/02/23	1020	High Slack	22	18.0
			83/03/21	1200	Ebb	<2	25.5
			83/03/22	0930	High Slack	2	26.0
			83/03/22	1500	Ebb	<2	25.0
			83/03/23	0930	High Slack	5	25.5
			83/03/23	1455	Ebb	2	26.0
			83/03/24	0915	High Slack	<2	26.0
			83/06/02	1125	Ebb	2	28.0
			83/06/03	1120	High Slack	2	27.0
			83/06/05	1100	High Slack	<2	26.0
			83/06/07	1045	Flood	<2	25.5
			83/06/08	1145	Flood	5	27.0
			83/07/12	0725	Ebb	4	25.0
			83/07/13	0925	Ebb	23	26.0
			83/10/24	1045	Ebb	<3	27.5
			83/10/25	0915	High Slack	4	
			83/10/26	0935	High Slack	<3	28.0
			84/03/20	0815	Ebb	15	24.0
			84/03/21	0900	Ebb	4	22.0
			84/03/22	0920	Ebb	23	18.5
			84/03/23	0955	Ebb	4	22.0
LH028	49 00.34	123 48.55	83/02/08	1100	High Slack	<2	28.0

APPENDIX I

TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH028	continued...		83/02/10	1020	High Slack	<2	28.0
			83/02/11	1035	High Slack	11	23.0
			83/02/14	1055	Ebb	70	10.5
			83/02/16	0950	Ebb	17	13.5
			83/02/21	1050	Ebb	21	17.0
			83/02/23	1025	High Slack	13	15.5
			83/03/21	1205	Ebb	2	25.0
			83/03/22	1510	Ebb	23	22.0
			83/03/23	1500	Ebb	2	25.5
			83/03/24	1510	Ebb	<2	27.0
LH029	49 00.39	123 49.02	83/02/08	1100	High Slack	<2	28.0
			83/02/10	1020	High Slack	11	27.0
			83/02/11	1040	High Slack	110	20.5
			83/02/14	1055	Ebb	33	9.0
			83/02/16	0950	Ebb	46	14.0
			83/02/21	1050	Ebb	8	20.0
			83/02/23	1025	High Slack	49	12.0
			83/03/21	1210	Ebb	5	24.5
			83/03/23	1500	Ebb	5	25.5
			83/03/24	1515	Ebb	<2	26.5
			83/10/24	1055	Ebb	15	27.5
			83/10/25	0925	Ebb	<3	
			83/10/26	0910	High Slack	<3	29.0
			84/03/21	0910	Ebb	43	21.0
			84/03/22	0930	Ebb	9	24.0
			84/03/23	1005	Ebb	23	22.0
LH030	48 59.33	123 47.38	83/02/08	1110	High Slack	2	28.0
			83/02/10	1025	High Slack	2	27.0
			83/02/11	1050	High Slack	17	24.0
			83/02/14	1050	Ebb	14	16.5
			83/02/21	1055	Ebb	<2	24.5
			83/02/23	1035	High Slack	13	20.5
			83/03/21	1215	Ebb	<2	26.5
			83/03/22	1520	Ebb	2	26.0
			83/03/23	1510	Ebb	2	26.0
			83/03/24	1505	Ebb	<2	27.0
LH031	48 59.29	123 47.19	83/02/08	1110	High Slack	<2	28.5
			83/02/10	1025	High Slack	<2	28.0
			83/02/11	1050	High Slack	33	22.0
			83/02/14	1105	Ebb	13	21.0
			83/02/16	0955	Ebb	13	20.5
			83/02/21	1055	Ebb	<2	27.0
			83/02/23	1035	High Slack	13	22.0
			83/03/21	1215	Ebb	<2	27.0

APPENDIX I

TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH031	continued...		83/03/22	1520	Ebb	<2	26.0
			83/03/23	1510	Ebb	2	26.5
			83/03/24	1505	Ebb	<2	27.0
LH032	48 59.34	123 47.22	83/02/08	1115	High Slack	2	29.0
			83/02/10	1030	High Slack	<2	27.5
			83/02/11	1050	High Slack	27	24.0
			83/02/14	1105	Ebb	5	14.0
			83/02/16	0955	Ebb	2	21.0
			83/02/21	1055	Ebb	11	25.5
			83/02/23	1035	High Slack	27	21.5
			83/03/21	1235	Ebb	2	27.0
			83/03/22	1525	Ebb	<2	25.5
			83/03/23	1515	Ebb	<2	26.0
			83/03/24	1500	Ebb	<2	27.0
			83/10/24	1105	Ebb	<3	29.0
			83/10/25	0945	Ebb	<3	
			83/10/26	0920	High Slack	4	29.0
			84/03/20	0825	Ebb	4	26.0
			84/03/21	0920	Ebb	<3	26.0
			84/03/22	0940	Ebb	9	26.0
			84/03/23	1015	Ebb	4	25.0
LH033	48 59.30	123 46.38	83/02/08	1120	High Slack	<2	24.5
			83/02/10	1035	High Slack	2	28.0
			83/02/11	1050	High Slack	5	27.5
			83/02/14	1110	Ebb	8	19.0
			83/02/16	1000	Ebb	5	24.5
			83/02/21	1100	Ebb	5	26.5
			83/02/23	1040	High Slack	13	23.0
			83/03/21	1240	Ebb	<2	27.0
			83/03/22	1535	Ebb	<2	26.0
			83/03/23	1520	Ebb	<2	26.5
			83/03/24	1500	Ebb	<2	27.0
LH034	48 59.21	123 46.36	83/02/08	1125	High Slack	<2	24.5
			83/02/10	1035	High Slack	<2	28.0
			83/02/11	1055	High Slack	22	29.0
			83/02/14	1110	Ebb	4	18.0
			83/02/16	1000	Ebb	7	25.0
			83/02/21	1100	Ebb	<2	26.0
			83/02/23	1045	High Slack	23	23.0
			83/03/21	1240	Ebb	<2	27.5
			83/03/22	1535	Ebb	2	26.0
			83/03/23	1520	Ebb	<2	30.5
			83/03/24	1500	Ebb	5	27.0
			83/10/24	1110	Ebb	<3	25.5

APPENDIX I
TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH034	continued...		83/10/25	0950	Ebb	<3	
			83/10/26	0925	High Slack	<3	28.0
			84/03/20	0835	Ebb	9	26.0
			84/03/21	0930	Ebb	23	26.0
			84/03/22	0950	Ebb	9	22.0
			84/03/23	1025	Ebb	15	25.0
LH035	48 59.15	123 46.30	83/02/08	1130	High Slack	<2	24.5
			83/02/10	1035	High Slack	<2	28.0
			83/02/11	1055	High Slack	<2	27.5
			83/02/14	1115	Ebb	4	22.0
			83/02/16	1000	Ebb	<2	26.0
			83/02/21	1100	Ebb	<2	27.0
			83/02/23	1045	High Slack	79	24.0
			83/03/21	1245	Ebb	<2	27.0
			83/03/22	1540	Ebb	<2	25.5
			83/03/23	1525	Ebb	<2	27.0
			83/03/24	1455	Ebb	<2	27.0
LH036	48 59.08	123 46.24	83/02/08	1130	High Slack	<2	26.0
			83/02/10	1040	High Slack	<2	27.5
			83/02/11	1100	High Slack	4	27.0
			83/02/14	1115	Ebb	11	21.0
			83/02/16	1005	Ebb	2	26.0
			83/02/21	1105	Ebb	2	27.0
			83/02/23	1050	High Slack	49	24.0
			83/03/21	1245	Ebb	<2	27.5
			83/03/22	1540	Ebb	<2	25.5
			83/03/23	1530	Ebb	<2	26.5
			83/03/24	1455	Ebb	<2	27.0
LH037	48 59.02	123 46.20	83/02/08	1135	High Slack	<2	24.5
			83/02/10	1040	High Slack	<2	28.0
			83/02/11	1100	High Slack	2	26.5
			83/02/14	1115	Ebb	5	21.5
			83/02/16	1005	Ebb	<2	26.0
			83/02/21	1105	Ebb	<2	27.5
			83/02/22	1655	Ebb	2	24.5
			83/02/23	1050	High Slack	22	24.0
			83/03/21	1250	Ebb	<2	27.5
			83/03/22	1540	Ebb	<2	25.5
			83/03/23	1530	Ebb	<2	26.5
			83/03/24	1455	Ebb	<2	26.5
LH038	48 58.59	123 46.58	83/02/08	1135	High Slack	<2	24.5
			83/02/10	1045	High Slack	<2	27.5
			83/02/11	1105	High Slack	2	28.0

APPENDIX I
TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH038	continued...		83/02/14	1120	Ebb	6	22.0
			83/02/16	1010	Ebb	2	26.0
			83/02/21	1105	Ebb	<2	25.5
			83/02/22	1635	Ebb	5	22.5
			83/02/23	1050	High Slack	49	24.0
			83/03/21	1250	Ebb	2	26.0
			83/03/22	0940	High Slack	<2	26.5
			83/03/22	1545	Ebb	5	26.0
			83/03/23	0945	High Slack	3	
			83/03/23	1530	Ebb	2	27.0
			83/03/24	0925	High Slack	17	26.5
			83/03/24	1455	Ebb	5	26.5
			83/10/24	1120	Ebb	43	29.0
			83/10/25	0955	High Slack	4	
			83/10/26	0930	High Slack	<3	29.0
			84/03/20	0845	Ebb	<3	26.5
			84/03/21	0940	Ebb	93	27.0
			84/03/22	1000	Ebb	4	26.0
			84/03/23	1035	Ebb	4	25.0
LH039	48 58.59	123 48.01	83/02/08	1145	High Slack	5	21.5
			83/02/10	1050	High Slack	<2	27.5
			83/02/11	1110	High Slack	17	11.5
			83/02/14	1125	Ebb	8	16.0
			83/02/16	1015	Ebb	7	20.0
			83/02/21	1110	Ebb	2	21.5
			83/02/22	1620	Ebb	8	9.5
			83/02/23	1100	High Slack	49	13.5
			83/03/21	1255	Ebb	2	23.0
			83/03/22	1550	Ebb	4	25.0
			83/03/23	1535	Ebb	<2	26.5
			83/03/24	1450	Ebb	<2	26.0
LH040	48 59.17	123 47.43	83/02/08	1150	High Slack	2	24.5
			83/02/10	1055	High Slack	<2	27.5
			83/02/11	1110	High Slack	31	18.0
			83/02/14	1125	Low Slack	23	11.5
			83/02/16	1015	Ebb	2	22.0
			83/02/21	1110	Ebb	4	16.5
			83/02/22	1620	Ebb	8	18.5
			83/02/23	1105	High Slack	2	22.0
			83/03/21	1255	Ebb	2	24.5
			83/03/22	0930	High Slack	11	26.0
			83/03/22	1555	Ebb	2	26.0
			83/03/23	0950	High Slack	2	26.5
			83/03/23	1535	Ebb	2	26.0
			83/03/24	0915	High Slack	2	26.0

APPENDIX I
TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH040	continued...		83/03/24	1450	Ebb	2	26.5
LH041	48 58.02	123 46.36	83/02/08	1305	High Slack	8	26.5
			83/02/10	1105	High Slack	22	27.0
			83/02/11	1120	High Slack	12	27.0
			83/02/14	1310	Low Slack	<2	26.0
			83/02/16	1110	Ebb	33	25.5
			83/02/21	1340	Ebb	8	22.0
			83/02/23	1345	Ebb	13	25.0
			83/03/21	1300	Ebb	5	25.5
			83/03/22	0945	High Slack	2	22.0
			83/03/22	1600	Ebb	<2	26.0
			83/03/23	1000	High Slack	<2	26.5
			83/03/23	1540	Ebb	2	27.0
			83/03/24	0930	High Slack	5	26.5
			83/03/24	1445	Ebb	<2	26.0
LH042	48 57.59	123 46.27	83/02/08	1310	High Slack	<2	23.0
			83/02/10	1105	High Slack	<2	26.5
			83/02/11	1120	High Slack	4	27.5
			83/02/14	1315	Low Slack	<2	26.0
			83/02/16	1115	Ebb	2	25.0
			83/02/21	1335	Ebb	<2	24.0
			83/02/23	1340	Ebb	33	22.5
			83/03/21	1300	Ebb	8	24.5
			83/03/22	0945	High Slack	<2	24.0
			83/03/22	1600	Ebb	<2	25.5
			83/03/23	1000	High Slack	2	26.5
			83/03/23	1540	Ebb	17	27.0
			83/03/24	0930	High Slack	23	26.0
			83/03/24	1440	Ebb	<2	22.5
LH043	48 57.59	123 46.16	83/02/08	1310	High Slack	<2	24.0
			83/02/10	1110	High Slack	<2	26.0
			83/02/11	1125	High Slack	8	22.0
			83/02/14	1315	Low Slack	2	25.0
			83/02/16	1115	Ebb	2	22.0
			83/02/21	1335	Ebb	<2	23.5
			83/02/23	1340	Ebb	22	18.0
			83/03/21	1305	Ebb	2	15.0
			83/03/22	0945	High Slack	<2	23.5
			83/03/22	1605	Ebb	<2	26.5
			83/03/23	1005	High Slack	<2	26.0
			83/03/23	1545	Ebb	79	27.0
			83/03/24	0930	High Slack	2	26.0
			83/03/24	1440	Ebb	<2	21.0

APPENDIX I
TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH044	48 57.54	123 46.22	83/02/08	1310	High Slack	<2	25.0
			83/02/10	1110	High Slack	4	13.0
			83/02/11	1125	High Slack	49	8.0
			83/02/14	1315	Low Slack	2	24.0
			83/02/16	1115	Ebb	4	13.5
			83/02/21	1330	Ebb	2	22.5
			83/02/23	1340	Ebb	23	10.0
			83/03/21	1305	Ebb	<2	20.5
			83/03/22	0950	High Slack	2	22.5
			83/03/22	1605	Ebb	<2	25.5
			83/03/23	1005	High Slack	<2	25.5
			83/03/23	1550	Ebb	<2	26.0
			83/03/24	0935	High Slack	<2	20.0
			83/03/24	1440	Ebb	<2	19.5
			83/06/02	1000	High Slack	110	7.0
			83/06/03	1005	High Slack	240	24.5
			83/06/04	1025	High Slack	49	22.0
			83/06/05	0920	High Slack	33	25.0
			83/06/06	0930	Low Slack	79	5.0
			83/06/07	0925	Low Slack	33	6.0
			83/06/08	0950	Low Slack	23	8.0
			83/06/09	0920	Ebb	23	10.0
			83/07/12	0805	Ebb	240	20.0
			83/07/13	1015	Ebb	240	12.0
LH045	48 57.53	123 46.12	83/02/08	1315	High Slack	<2	26.0
			83/02/10	1110	High Slack	<2	25.5
			83/02/11	1125	High Slack	2	25.0
			83/02/14	1315	Low Slack	79	24.0
			83/02/16	1115	Ebb	17	26.0
			83/02/21	1330	Ebb	<2	22.5
			83/02/23	1335	Ebb	33	23.0
			83/03/21	1310	Ebb	4	23.5
			83/03/22	0950	High Slack	<2	23.5
			83/03/22	1610	Ebb	<2	23.5
			83/03/23	1010	High Slack	<2	26.5
			83/03/23	1555	Ebb	<2	27.0
			83/03/24	0935	High Slack	<2	24.0
			83/03/24	1435	Ebb	<2	23.5
			83/06/02	1005	High Slack	33	22.0
			83/06/03	1010	High Slack	79	26.0
			83/06/04	1030	High Slack	33	25.5
			83/06/05	0925	High Slack	5	26.0
			83/06/06	0935	High Slack	11	25.0
			83/06/07	0930	High Slack	21	25.0
			83/06/08	0955	High Slack	49	25.0
			83/06/09	0920	Ebb	49	26.0
			83/07/12	0805	Ebb	94	24.0

APPENDIX I
TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH045	continued...		83/07/13	1025	Ebb	130	25.5
LH046	48 57.30	123 45.12	83/02/08	1320	High Slack	<2	27.5
			83/02/10	1120	High Slack	<2	28.0
			83/02/11	1130	High Slack	12	29.5
			83/02/14	1325	Low Slack	2	27.0
			83/02/16	1125	Ebb	<2	28.0
			83/02/21	1325	Ebb	4	21.0
			83/02/23	1330	Ebb	17	25.5
			83/03/21	1315	Ebb	2	25.5
			83/03/22	1620	Ebb	<2	24.5
			83/03/23	1500	Ebb	5	27.5
			83/03/24	1425	Ebb	<2	27.0
LH047	48 57.24	123 45.05	83/02/08	1325	High Slack	<2	28.0
			83/02/10	1120	High Slack	<2	28.0
			83/02/11	1135	High Slack	8	26.5
			83/02/14	1325	Low Slack	<2	26.5
			83/02/16	1125	Ebb	<2	27.5
			83/02/21	1320	Ebb	5	21.5
			83/02/23	1330	Ebb	5	26.0
			83/03/21	1315	Ebb	<2	26.5
			83/03/22	1620	Ebb	<2	24.5
			83/03/23	1600	Ebb	<2	27.0
			83/03/24	1430	Ebb	26	
LH048	48 57.17	123 44.58	83/02/08	1325	High Slack	<2	28.0
			83/02/10	1120	High Slack	<2	28.0
			83/02/11	1135	High Slack	2	29.5
			83/02/14	1330	Flood	<2	27.0
			83/02/16	1125	Ebb	<2	28.0
			83/02/21	1320	Ebb	2	22.5
			83/02/23	1325	Ebb	13	27.0
			83/03/21	1320	Ebb	<2	25.5
			83/03/22	1620	Ebb	2	24.0
			83/03/23	1605	Ebb	<2	27.5
			83/03/24	1430	Ebb	<2	27.0
LH049	48 58.17	123 45.40	83/02/08	1330	High Slack	<2	26.0
			83/02/10	1125	High Slack	<2	27.5
			83/02/11	1140	High Slack	6	30.0
			83/02/14	1330	Flood	<2	25.0
			83/02/16	1130	Ebb	<2	27.5
			83/02/21	1315	Ebb	2	24.0
			83/02/22	1700	Flood	5	22.0
			83/02/23	1335	Ebb	22	24.0
			83/03/21	1325	Ebb	5	25.5

APPENDIX I

TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH049	continued...		83/03/22	0940	High Slack	2	26.5
			83/03/22	1555	Ebb	<2	25.0
			83/03/23	1020	High Slack	<2	26.5
			83/03/23	1615	Ebb	<2	27.0
			83/03/24	0930	High Slack	9	27.0
			83/03/24	1420	Ebb	<2	26.5
LH050	48 59.01	123 46.09	83/02/08	1335	High Slack	<2	29.0
			83/02/10	1130	High Slack	<2	28.0
			83/02/11	1145	High Slack	9	27.5
			83/02/14	1340	Flood	23	15.0
			83/02/16	1140	Ebb	2	25.5
			83/02/21	1310	Ebb	<2	24.5
			83/02/23	1105	High Slack	33	21.0
LH051	48 59.18	123 46.16	83/02/07	1340	High Slack	<2	28.0
			83/02/10	1135	High Slack	17	26.0
			83/02/11	1150	High Slack	14	25.0
			83/02/14	1345	Flood	17	20.0
			83/02/16	1140	Ebb	2	24.0
			83/02/21	1310	Ebb	2	24.0
			83/02/23	1110	High Slack	22	18.0
LH052	48 59.16	123 45.36	83/02/08	1345	Ebb	11	26.5
			83/02/10	1140	High Slack	<2	26.0
			83/02/11	1150	High Slack	49	24.0
			83/02/14	1350	Flood	21	20.0
			83/02/16	1145	Ebb	8	23.5
			83/02/21	1305	Ebb	13	25.0
			83/02/23	1115	High Slack	8	23.0
LH053	48 59.21	123 45.31	83/02/08	1400	Ebb	<2	28.0
			83/02/10	1145	High Slack	2	27.5
			83/02/11	1155	High Slack	9	28.0
			83/02/14	1350	Flood	2	25.0
			83/02/16	1150	Ebb	8	27.0
			83/02/21	1255	Ebb	<2	26.0
			83/02/23	1120	High Slack	7	22.5
LH054	48 59.38	123 45.24	83/02/08	1400	Ebb	2	28.0
			83/02/10	1145	High Slack	<2	27.0
			83/02/11	1200	High Slack	14	28.0
			83/02/14	1355	Flood	2	23.5
			83/02/16	1150	Ebb	<2	28.0
			83/02/21	1250	Ebb	<2	25.5
			83/02/23	1120	High Slack	14	21.0

APPENDIX I

TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH055	49 01.07	123 46.46	83/02/08	1410	Ebb	<2	27.0
			83/02/10	1225	High Slack	11	27.0
			83/02/14	1405	Flood	2	23.5
			83/02/16	1200	Ebb	<2	26.5
			83/02/21	1215	Ebb	2	27.0
			83/02/23	1130	High Slack	23	23.0
			83/03/21	1335	Ebb	<2	27.5
			83/03/22	1635	Ebb	<2	26.0
			83/03/23	1625	Ebb	<2	27.0
			83/03/24	1400	Ebb	<2	27.5
LH056	49 01.11	123 47.10	83/02/08	1415	Ebb	8	28.0
			83/02/10	1230	High Slack	2	26.0
			83/02/14	1405	Flood	17	23.0
			83/02/16	1200	Ebb	<2	24.0
			83/02/21	1220	Ebb	<2	25.5
			83/02/23	1135	High Slack	46	17.5
			83/03/21	1340	Ebb	<2	26.5
			83/03/22	1640	Ebb	<2	26.0
			83/03/23	1630	Ebb	<2	26.5
			83/03/24	1400	Ebb	<2	25.5
LH057	49 01.24	123 47.18	83/02/08	1420	Ebb	<2	24.5
			83/02/10	1230	High Slack	2	25.0
			83/02/14	1410	Flood	33	27.0
			83/02/16	1205	Ebb	8	23.5
			83/02/21	1225	Ebb	5	22.0
			83/02/23	1140	High Slack	17	16.5
			83/03/21	1345	Ebb	<2	26.5
			83/03/22	1640	Ebb	2	25.5
			83/03/23	1630	Ebb	2	26.5
			83/03/24	1405	Ebb	<2	27.0
LH058	49 01.36	123 47.22	83/02/08	1425	Ebb	<2	22.0
			83/02/10	1235	High Slack	22	26.0
			83/02/14	1410	Flood	70	20.0
			83/02/16	1210	Ebb	33	17.5
			83/02/21	1225	Ebb	<2	25.0
			83/02/23	1140	High Slack	46	8.0
			83/03/21	1345	Ebb	5	23.5
			83/03/22	1645	Ebb	<2	25.0
			83/03/23	1635	Ebb	<2	26.0
			83/03/24	1405	Ebb	<2	27.5
LH059	49 01.40	123 47.16	83/02/08	1430	Ebb	<2	24.0
			83/02/10	1235	High Slack	23	26.5
			83/02/14	1415	Flood	8	18.0
			83/02/16	1210	Ebb	11	21.0

APPENDIX I
TABLE 1 : Daily Data Record for Marine Sample Stations
(Area LH)

Station	Latitude	Longitude	Date	Time	Tide	Fec.Colif.	Salinity
LH059	continued...		83/02/21	1230	Ebb	<2	22.0
			83/02/23	1145	High Slack	23	11.5
			83/03/21	1350	Ebb	23	25.5
			83/03/22	1645	Ebb	5	26.0
			83/03/23	1640	Ebb	2	26.0
			83/03/24	1410	Ebb	<2	28.0
LH060	49 02.35	123 45.03	83/02/08	1445	Ebb	<2	23.5
			83/02/10	1250	High Slack	<2	28.0
			83/02/14	1430	Flood	<2	27.5
			83/02/16	1245	High Slack	14	28.0
			83/02/21	1200	Ebb	<2	26.5
			83/02/23	1305	Ebb	2	26.5
LH061	49 02.41	123 45.14	83/02/08	1440	Ebb	<2	23.5
			83/02/10	1250	High Slack	<2	26.0
			83/02/14	1430	Flood	<2	23.5
			83/02/16	1245	High Slack	2	28.0
			83/02/21	1200	Ebb	<2	24.5
			83/02/23	1305	Ebb	27	19.0
LH062	48 59.00	123 47.25	83/02/11	1140	High Slack	>1600	28.0
			83/02/14	1120	Ebb	9	19.0
			83/02/21	1110	Ebb	79	20.0
			83/02/22	1630	Ebb	13	17.5
			83/02/23	1055	High Slack	17	24.0
			83/03/21	1250	Ebb	>1600	27.0
			83/03/22	0940	High Slack	350	26.0
			83/03/24	0920	High Slack	13	26.0
			83/03/24	1450	Ebb	2	26.5

APPENDIX II

SUMMARY OF FECAL COLIFORM DATA
FOR MARINE SAMPLE STATIONS

APPENDIX II SUMMARY OF FECAL COLIFORM MPN DATA FOR MARINE SAMPLE STATIONS

SAMPLE	FEBRUARY/MARCH 1983				JUNE/JULY 1983				OCTOBER 1983/MARCH 1984				ALL DATA - 1983 and 1984			
		MPN/100 mL				MPN/100 mL				MPN/100 mL				MPN/100 mL		
STATION	No. of Samples	Range	Median	90 PCT	No. of Samples	Range	Median	90 PCT	No. of Samples	Range	Median	90 PCT	No. of Samples	Range	Median	90 PCT
1	6	2-79	41	79	-	-	-	-	-	-	-	-	6	2-79	41	79
2	6	2-> 1600	104.5	808	-	-	-	-	-	-	-	-	6	2-> 1600	104.5	808
3	6	< 2 - 920	79.5	446	-	-	-	-	-	-	-	-	6	< 2-920	79.5	446
4	6	5-> 1600	28	687	-	-	-	-	-	-	-	-	6	5-> 1600	28	687
5	6	5-350	39.5	242	-	-	-	-	-	-	-	-	6	5-350	39.5	242
6	10	< 2-920	13	49	8	2-130	13	52	7	< 3-43	7	43	25	< 2-920	13	46
6 (Depth)	-	-	-	-	-	-	-	-	3	< 3-< 3	-	-	3	< 3-< 3	-	-
7	10	< 2-49	10.5	33	-	-	-	-	-	-	-	-	10	< 2-49	10.5	33
8	10	< 2-130	14	79	-	-	-	-	-	-	-	-	10	< 2-130	14	79
9	13	< 2-49	8	44	8	2-33	5	25	7	< 3-9	4	9	28	< 2-49	5.5	33
9 (Depth)	-	-	-	-	-	-	-	-	7	< 3-7	< 3	7	7	< 3-7	< 3	7
10	11	< 2-70	11	31	8	< 2-33	8	17	7	< 3-240	11	88	26	< 2-240	8.5	33
11	11	< 2-79	17	76	8	< 2-140	12.5	84	7	4-1100	23	360	26	< 2-1100	17	79
12	11	< 2-33	22	32	-	-	-	-	-	-	-	-	11	< 2-33	22	32
13	14	< 2-33	2	29	8	< 2-33	2	11	7	< 3-14	4	11	29	< 2-33	2	23
13 (Depth)	-	-	-	-	-	-	-	-	7	< 3-4	< 3	4	7	< 3-4	< 3	4
14	12	< 2-110	23	77	-	-	-	-	-	-	-	-	12	< 2-110	23	77
15	11	2-110	23	93	-	-	-	-	-	-	-	-	11	2-110	23	93
16	11	< 2-49	8	45	-	-	-	-	-	-	-	-	11	< 2-49	8	45
17	11	< 2-110	2	32	8	< 2-13	2	11	7	< 3-23	4	23	26	< 2-110	4	23
18	11	< 2-79	7	45	-	-	-	-	-	-	-	-	11	< 2-79	7	45
19	14	< 2-33	3	23	-	-	-	-	-	-	-	-	14	< 2-33	3	23
20	11	2-49	21	47	-	-	-	-	-	-	-	-	11	< 2-49	21	47
21	11	2-79	23	70	-	-	-	-	-	-	-	-	11	2-79	23	70
22	14	< 2-33	2.5	21	8	< 2-13	5	13	7	< 3-43	9	19	29	< 2-43	2	18

Continued...

APPENDIX II SUMMARY OF FECAL COLIFORM MPN DATA FOR MARINE SAMPLE STATIONS (Continued)

SAMPLE STATION	FEBRUARY/MARCH 1983				JUNE/JULY 1983				OCTOBER 1983/MARCH 1984				ALL DATA - 1983 and 1984			
	No. of Samples	MPN/100 mL			No. of Samples	MPN/100 mL			No. of Samples	MPN/100 mL			No. of Samples	MPN/100 mL		
		Range	Median	90 PCT		Range	Median	90 PCT		Range	Median	90 PCT		Range	Median	90 PCT
22 (Depth)	-	-	-	-	-	-	-	-	3	< 3-< 3	-	-	3	< 3-< 3	-	-
23	11	< 2-49	5	32	-	-	-	-	-	-	-	-	11	< 2-49	5	32
24	11	< 2-49	8	33	-	-	-	-	-	-	-	-	11	< 2-49	8	33
25	14	< 2-110	5	56	-	-	-	-	-	-	-	-	14	< 2-110	5	56
26	14	< 2-49	6	27	7	< 2-17	2	17	7	< 3-21	4	13	28	< 2-49	4.5	18
27	13	< 2-46	2	21	7	< 2-23	2	10	7	< 3-23	4	17	27	< 2-46	4	22
28	11	< 2-70	11	23	-	-	-	-	-	-	-	-	11	< 2-70	11	23
29	10	< 2-110	9.5	49	-	-	-	-	6	< 3-43	12	31	16	< 2-110	10	47
30	10	< 2-17	2	14	-	-	-	-	-	-	-	-	10	< 2-17	2	14
31	11	< 2-33	< 2	13	-	-	-	-	-	-	-	-	11	< 2-33	< 2	13
32	11	< 2-27	2	25	-	-	-	-	7	< 3-9	4	6	18	< 2-27	2	14
33	11	< 2-13	2	8	-	-	-	-	-	-	-	-	11	< 2-13	2	8
34	11	< 2-23	2	21	-	-	-	-	7	< 3-23	9	17	18	< 2-23	< 2	16
35	11	< 2-79	< 2	4	-	-	-	-	-	-	-	-	11	< 2-79	< 2	4
36	11	< 2-49	< 2	10	-	-	-	-	-	-	-	-	11	< 2-49	< 2	10
37	12	< 2-22	< 2	4	-	-	-	-	-	-	-	-	12	< 2-22	< 2	4
38	15	< 2-49	2	12	-	-	-	-	7	< 3-93	4	58	22	< 2-93	4	38
39	12	< 2-49	4.5	15	-	-	-	-	-	-	-	-	12	< 2-49	4.5	15
40	15	< 2-31	2	17	-	-	-	-	-	-	-	-	15	< 2-31	2	17
41	14	< 2-33	5	18	-	-	-	-	-	-	-	-	14	< 2-33	5	18
42	14	< 2-33	< 2	21	-	-	-	-	-	-	-	-	14	< 2-33	< 2	21
43	14	< 2-79	< 2	16	-	-	-	-	-	-	-	-	14	< 2-79	< 2	16
44	14	< 2-49	< 2	15	10	23-240	64	240	-	-	-	-	24	< 2-240	6.5	188
45	14	< 2-79	< 2	27	10	5-130	41	94	-	-	-	-	24	< 2-130	8	79

Continued...

APPENDIX II SUMMARY OF FECAL COLIFORM MPN DATA FOR MARINE SAMPLE STATIONS (Continued)

SAMPLE STATION	FEBRUARY/MARCH 1983				JUNE/JULY 1983				OCTOBER 1983/MARCH 1984				ALL DATA - 1983 and 1984			
	No. of Samples	MPN/100 mL Range	MPN/100 mL Median	MPN/100 mL 90 PCT	No. of Samples	MPN/100 mL Range	MPN/100 mL Median	MPN/100 mL 90 PCT	No. of Samples	MPN/100 mL Range	MPN/100 mL Median	MPN/100 mL 90 PCT	No. of Samples	MPN/100 mL Range	MPN/100 mL Median	MPN/100 mL 90 PCT
46	11	< 2-17	2	11	-	-	-	-	-	-	-	-	11	< 2-17	2	11
47	11	< 2-26	< 2	8	-	-	-	-	-	-	-	-	11	< 2-26	< 2	8
48	11	< 2-13	< 2	2	-	-	-	-	-	-	-	-	11	< 2-13	< 2	2
49	15	< 2-22	< 2	8	-	-	-	-	-	-	-	-	15	< 2-22	< 2	8
50	7	< 2-33	2	26	-	-	-	-	-	-	-	-	7	< 2-33	2	26
51	7	< 2-22	14	19	-	-	-	-	-	-	-	-	7	< 2-22	14	19
52	7	< 2-49	11	29	-	-	-	-	-	-	-	-	7	< 2-49	11	29
53	7	< 2-9	2	8	-	-	-	-	-	-	-	-	7	< 2-9	2	8
54	7	< 2-14	2	14	-	-	-	-	-	-	-	-	7	< 2-14	2	14
55	10	< 2-23	< 2	11	-	-	-	-	-	-	-	-	10	< 2-23	< 2	11
56	10	< 2-46	< 2	17	-	-	-	-	-	-	-	-	10	< 2-46	< 2	17
57	10	< 2-33	2	17	-	-	-	-	-	-	-	-	10	< 2-33	2	17
58	10	< 2-70	2.5	46	-	-	-	-	-	-	-	-	10	< 2-70	2.5	46
59	10	< 2-23	6.5	23	-	-	-	-	-	-	-	-	10	< 2-23	6.5	23
60	6	< 2-14	< 2	7	-	-	-	-	-	-	-	-	6	< 2-14	< 2	7
61	6	< 2-27	< 2	12	-	-	-	-	-	-	-	-	6	< 2-27	< 2	12
62	9	2-> 1600	17	> 1600	-	-	-	-	-	-	-	-	9	2-> 1600	17	> 1600

APPENDIX III

FRESHWATER SAMPLE STATION LOCATIONS

APPENDIX III LADYSMITH HARBOUR FRESHWATER SAMPLE STATION DESCRIPTIONS

STATION NUMBER	DESCRIPTION
S1	Holland Creek at Trans-Canada Highway
S2	Storm Culvert at government dock north of STP.
S3	Storm Culvert at old Pilings south government wharf
S4	Storm Culvert north of S3
S5	Rocky Creek at Trans-Canada Highway
S6	Bush Creek at Trans-Canada Highway
S7	Small Creek south of Takala Road at Trans-Canada Highway
S8	Walker Creek at road to Chemainus Reserve
S9	Culvert 30 m east of S8
S10	Culvert east of Schon Mill entrance
S11	Thomas (Kuuista) Creek at the road to Chemainus Reserve
S12	Unnamed creek entering head of Burleith Arm
S13	Creek on Chemainus Road halfway between S12 and S14
S14	Chemainus water supply creek at the mouth
S15	Chemainus water supply creek below pump house
S16	Storm ditch on road to Coffin Point
S17	Storm ditch at K-Camp boat ramp
S18	Creek west of house no. 12832
S19	Runoff north of white house with brown/black roof
S20	Runoff west of new house next to no. 4205
S21	Storm drain on highway just north of Davis Lagoon
S22	West bank ditch - Davis Lagoon at bridge
S23	Stream - west side Davis Lagoon
S24	Stocking Creek at head Davis Lagoon
S25	East bank ditch - Davis Lagoon at bridge
S26	Culvert below Seaview Motel
S27	Drain pipe south-east of S26 off brown house white trim
S28	Ditch east of school, south Oyster School Road
S29	Ditch on west side Bazan Road near beach
S30	Ditch on east side Bazan Road near beach
S31	Ditch at the east end - south side Gardner Road
S32	Ditch at Gardner Road and south Oyster School Road
S33	Ditch at 3636 Seaview Crescent
S34	Ditch at Sturat Road and Shannon Drive
S35	Small creek south-east of bush on Trans-Canada Highway
S36	Small creek south-east of S.7 at Chemianus Reserver
S37	S11 at Cedar Highway
S38	S8 at Trans-Canada Highway
S28a	Corner of south Oyster School Road and Gardner - east S32

APPENDIX IV

DAILY BACTERIOLOGICAL MF DATA FOR FRESHWATER AND EFFLUENT SAMPLE STATIONS

APPENDIX IV DAILY BACTERIOLOGICAL MF DATA FOR FRESHWATER AND EFFLUENT SAMPLE STATIONS

SAMPLE STATION	COLLECTION DATE 1983	COUNT/100 mL			SAMPLE STATION	COLLECTION DATE 1983	COUNT/100 mL		
		F.C.	F.S.	FC:FS			F.C.	F.S.	FC:FS
S1	Feb. 9	< 10			S6	Feb. 9	50		
	10	30				10	< 10		
	11	30				11	20		
	14	3				14	4		
	Mar. 21	< 10	< 10			Oct. 24	33*		
	22	< 10	< 10			25	1600*		
	Oct. 24	79*				26	240*		
	25	920*							
	26	130*			S7	Feb. 9	< 10		
						10	< 10		
S2	Feb. 9	10				11	220		
	10	10				14	0		
	11	30							
					S8	Feb. 9	260		
S3	Feb. 9	90				10	120		
	10	60				11	3200	680	
	11	200				14	60		
	14	90				16	40	< 10	
						Mar. 21	40	10	
S4	Feb. 9	330				22	40	< 10	
	10	80				23	30		
	11	130				Oct. 24	5*		
	14	40				25	< 2*		
						26	< 2*		
S5	Feb. 9	40							
	10	10			S9	Feb. 9	< 10		
	11	50				10	< 10		
	14	6				11	240		
	Oct. 24	540*				14	1		
	25	170*				16	< 10	< 10	
	26	> 2400*				Oct. 24	2*		
						25	< 2*		
						26	< 2*		

*MPN determination

Continued...

APPENDIX IV DAILY BACTERIOLOGICAL MF DATA FOR FRESHWATER AND EFFLUENT SAMPLE STATIONS (Continued)

SAMPLE STATION	COLLECTION DATE 1983	COUNT/100 mL			SAMPLE STATION	COLLECTION DATE 1983	COUNT/100 mL		
		F.C.	F.S.	FC:FS			F.C.	F.S.	FC:FS
S10	Feb. 9	90			S12 upstream	Feb. 15	< 10		
	10	< 10							
	11	190			S13	Feb. 9	10		
	14	10				10	< 10		
	16	20	< 10			11	80		
S10 upstream	Feb. 15	50			S14	Feb. 9	40		
						10	40		
S11	Feb. 9	700				11	60		
	10	130				14	35		
	11	240							
	14	90			S15	Feb. 9	90		
	16	1500	250	6		10	10		
	Mar. 21	140	10	14		11	60		
	22	760	20	38					
	23	220	20	11	S16	Feb. 9	130		
	Jun. 5	7300	50	146		10	< 10		
	7	2300	160	14.4		11	190		
	Mar. 20/84	3500*				16	40		
	21/84	330*							
	22/84	1700*			S17	Feb. 9	110		
	23/84	170*				10	< 10		
						11	170		
S12	Feb. 9	650							
	10	160			S18	Feb. 9	10		
	11	1440				10	50		
	14	10				11	180		
	16	280	17000			14	40		
	21	< 10	10			16	20		
	22	10	10						
	23	< 10	10						

*MPN determination

Continued...

APPENDIX IV DAILY BACTERIOLOGICAL MF DATA FOR FRESHWATER AND EFFLUENT SAMPLE STATIONS (Continued)

SAMPLE STATION	COLLECTION DATE 1983	COUNT/100 mL		
		F.C.	F.S.	FC:FS
S19	Feb. 9	40		
	10	< 10		
	11	40		
	16	40		
S20	Feb. 9	10		
	10	< 10		
	11	120		
S21	Feb. 10	20		
	11	140		
	14	110		
S22	Feb. 10	< 10		
	11	1200		
	14	< 10		
S23	Feb. 10	< 10		
	11	110		
	14	< 10		
S24	Feb. 10	< 10		
	11	30		
	14	3		
	Mar. 21	< 10	< 10	
	22	< 10	< 10	
	Jun. 7	30	< 10	
S25	Feb. 10	10		
	11	290		
	14	40		

SAMPLE STATION	COLLECTION DATE 1983	COUNT/100 mL		
		F.C.	F.S.	FC:FS
S26	Feb. 10	330		
	11	1080	780	1.4
	14	2800	700	4
	16	800	90	8.8
	22	3900	10	
	Mar. 21	10	< 10	
	22	3300	1500	2.2
	23	200	20	
	Jun. 5	0	30	
S27	Feb. 2	< 10		
S28	Feb. 10	10		
	11	90		
	14	700		
S28A	14	2800	700	4
	Mar. 21	840	< 10	
S29	Feb. 10	40		
	11	50		
	14	0		
S30	Feb. 10	100		
	11	120	350	0.3
	14	8	40	
S31	Feb. 10	120		
	11	140	260	0.5
	14		90	

Continued...

APPENDIX IV DAILY BACTERIOLOGICAL MF DATA FOR FRESHWATER AND EFFLUENT SAMPLE STATIONS (Continued)

SAMPLE STATION	COLLECTION DATE 1983	COUNT/100 mL			SAMPLE STATION	COLLECTION DATE 1983	COUNT/100 mL		
		F.C.	F.S.	FC:FS			F.C.	F.S.	FC:FS
S32	Feb. 10	610			S38	Mar. 21	< 10	< 10	
	11	490	150	3.3		22	< 10	< 10	
	14	700	< 10			23	20	< 10	
S33	Feb. 10	240			Ladysmith STP	Feb. 8	1.2×10^{6}		
	11	1300	160	8.1	- Influent	10	8.0×10^{5}		
	14	150	30			11	2.0×10^{6}		
	16	7300				14	8.1×10^{5}		
	22	70	40						
					Ladysmith STP	Feb. 8	< 10		
S34	Feb. 10	10			- Final Effluent	10	< 10		
	11	50				11	< 10		
	14	3				14	< 10		
	16	330							
					Ladysmith STP	Feb. 10	1.6×10^{6}		
S35	Feb. 14	10			- Bypass	11	2.2×10^{6}	5×10^{4}	44
	15	10				22	1.1×10^{5}		11.3
	16	180				Mar. 23	1.8×10^{6}	1.6×10^{5}	
S36	Feb. 14	10			YP-1	Feb. 16	< 10		
	15	< 10				17	< 10		
	16	120				22	30		
S37	Mar. 21	20	< 10		Sludge	Feb. 22	2.6×10^{5}		
	22	30	< 10						
	23	20	< 10						

APPENDIX V

SUMMARY OF BACTERIOLOGICAL RESULTS FOR FRESHWATER AND EFFLUENT SAMPLE STATIONS

APPENDIX V SUMMARY OF BACTERIOLOGICAL RESULTS FOR FRESHWATER AND EFFLUENT SAMPLE STATIONS

SAMPLE STATION	FECAL COLIFORM/100 mL			FECAL STREPTOCOCCI/100 mL		
	No. of Samples	Range	Mean	No. of Samples	Range	Mean
S1	9	3 - 920*	136	2	< 10 - < 10	< 10
S2	3	10 - 30	17			
S3	4	60 - 200	110			
S4	4	40 - 330	145			
S5	7	6 - > 2400*	459			
S6	7	4 - 1600*	280			
S7	4	0 - 220	60			
S8	11	< 2 - 3200*	345	4	< 10 - 680	178
S9	8	1 - 240*	34	1	< 10	-
S10	5	< 10 - 190	64	1	< 10	-
S10-upstream	1	50	-			
S11	14	90 - 7300*	1360	6	10 - 250	85
S12	8	< 10 - 1440	321	4	10 - 17000[1]	4258[1]
S12-upstream	1	< 10	-			
S13	3	< 10 - 80	33			
S14	4	35 - 60	44			
S15	3	10 - 90	53			
S16	4	< 10 - 190	93			
S17	3	< 10 - 170	97			
S18	5	10 - 180	60			
S19	4	< 10 - 40	25			
S20	3	< 10 - 120	47			
S21	3	20 - 140	90			
S22	3	< 10 - 1200	407			
S23	3	< 10 - 110	43			
S24	6	3 - 30	16			
S25	3	10 - 290	113			
S26	9	0 - 3900	1380	8	< 10 - 1500	393
S27	1	< 10	-			
S28	3	10 - 700	267			
S28A	2	840 - 2800	1820	2	< 10 - 700	355

*includes data obtained by MF and MPN methods

[1]single high value of 17,000/100 mL may not be reliable

Continued...

APPENDIX V SUMMARY OF BACTERIOLOGICAL RESULTS FOR FRESHWATER AND EFFLUENT SAMPLE STATIONS (Continued)

SAMPLE STATION	FECAL COLIFORM/100 mL			FECAL STREPTOCOCCI/100 mL		
	No. of Samples	Range	Mean	No. of Samples	Range	Mean
S29	3	0 - 50	30			
S30	3	8 - 120	76	2	40 - 350	195
S31	2	120 - 140	130	2	90 - 260	175
S32	3	490 - 700	600	2	< 10 - 150	80
S33	5	70 - 7300	1812	3	30 - 160	77
S34	4	3 - 330	98			
S35	3	< 10 - 180	67			
S36	3	< 10 - 120	47			
S37	3	20 - 30	23	3	< 10 - < 10	< 10
S38	3	< 10 - 20	< 10	3	< 10 - < 10	< 10
Ladysmith Sewage Treatment Plant						
Influent	4	8.0×10^5-2.0×10^6	1.2×10^6			
Effluent	4	< 10 - < 10	< 10			
Bypass	4	1.1×10^5-2.2×10^6	1.4×10^6	2	5.4×10^4-1.6×10^5	1.1×10^5
Sludge	1	2.6×10^5				

APPENDIX VI

DYE TRACER STUDY OF THOMAS CREEK

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CONCLUSIONS

1. The topography of Ladysmith Harbour contributes to contamination of the eastern shore because a majority of the headwaters on an ebb tide flow out of the head of the harbour through a natural channel paralleling the eastern shore. Lateral dispersion was more evident past Wedge Point; however, dye visibly hung on the east side extending towards Page Point.

2. Station one on the borderline of the open area shows dilution predictions which will not meet shellfish growing water standards.

3. Station two within the inner harbour open area shows dilution prediction which will meet acceptable growing water standards.

4. Station three within the outer closed area shows dilution predictions which will meet acceptable growing water standards.

1.0 INTRODUCTION

In addition to the primary roles of assessing the bacteriological quality of the waters in shellfish growing areas and identifying the sources of pollution to these areas there is an additional aim of understanding how these pollutants are dispersed so that the area upon which they will have an impact can be identified. The concepts of dispersion, dilution and time of travel are the fundamental components in the science of hydrography and are used extensively for the purposes of pollution tracing.

In the case of Ladysmith Harbour, the eastern shoreline of the Inner harbour area exceeded the 90 percentile growing water standard in all cases. Thomas Creek at the head of the harbour, was a major contributor of fecal coliforms and was suspected of being a source of pollution to the eastern shores of the inner harbour.

On July 13, 1983 a tracer dye was released at the head of Ladysmith Harbour to study the movement of these waters during the latter stages of an ebb tide through to the intital stages of a flood tide.

2.0 FIELD INSTRUMENTS AND PROCEDURE

The tracer dye used in this study was Rhodamine WT 20%. A Turner Designs Model 10-005 fluorometer with a flow through cuvette and little Giant submersible pump were used for in situ measurement.

Two liters of Rhodamine WT fluorescent dye were released in a line at the head of the harbour (Figure 1). The boat was anchored at Stations 1 and 2 and water continuously pumped through the fluorometer as the patch of dye moved past. Samples were drawn from the first meter of water for fluorometric analysis.

A longitudinal traverse was made between Stations 3 and 4. Starting at Station 3, water was continuously pumped through the fluorometer as the boat moved to Station 4.

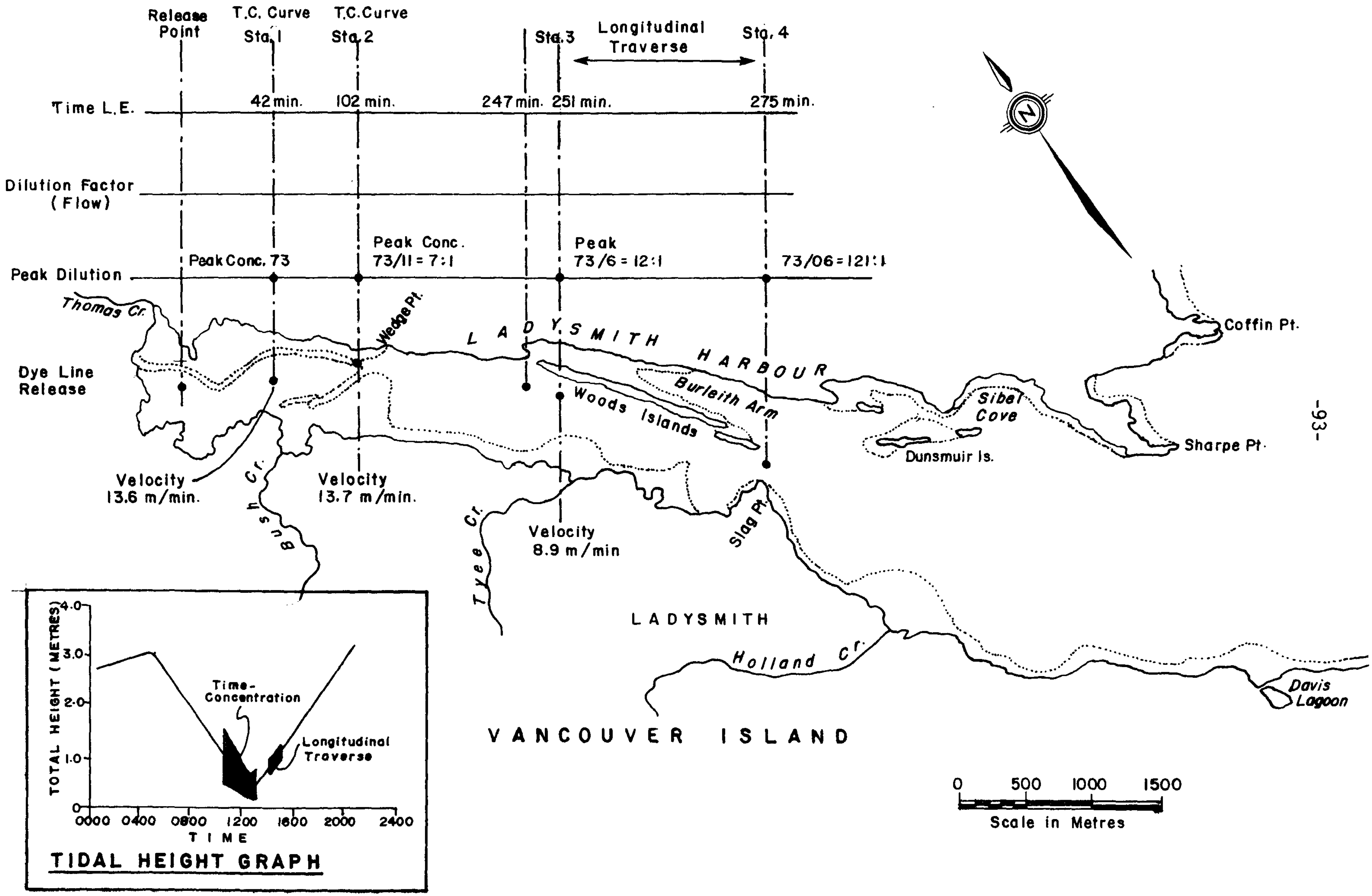

FIGURE I INSTANTANEOUS DYE RELEASE - LADYSMITH HARBOUR, July 13, 1983

3.0 DISCUSSION OF RESULTS

3.1 Dilution and Dispersion

Rhodamine WT in large bodies of water is visible at concentrations as low as 10 ug/l. From the release point, dye appeared to disperse over the waters, but as the tide started to ebb the bulk of the dye moved in a line down the North East channel of the harbour (Figure 2). However, it must be noted that initially lateral dispersion caused some of the dye to move over the center sub-tidal area at the head. Also, as the dye was carried to deeper and slower moving waters, both vertical and lateral dispersion spread the patch causing dye mass recovery to decrease from station to station.

Instantaneous line releases of dye in open bodies of water such as this harbour are valuable in determining longitudinal spread of a pollution slug. However, they are less than ideal for determining dilution due to lateral and vertical dispersion caused by of the action of tidal currents and mixing.

The flow and relative dilution between stations is calculated by plotting a time and concentration curve. The area under the curve should be equal for each station if velocities do not fluctuate significantly and there is uniform vertical mixing. However, as shown in Figure 3, the decreasing area between the two curves indicates an obvious dye loss due to vertical and lateral dispersion. It can also be seen that the time spread of the curves differ with distance and with time, indicating longitudinal dispersion of the slug. Based on the TC curve, 50% of the dye had passed Station 1 45 minutes after release and Station 2 110 minutes after release.

Figure 1 presents a temporal display of the movement of dye from the release point at 10:15 a.m. The shortest time of travel between release point and first detection for Stations 1 and 2 was 34 and 82 minutes respectively. As the patch began to disperse longitudinally the

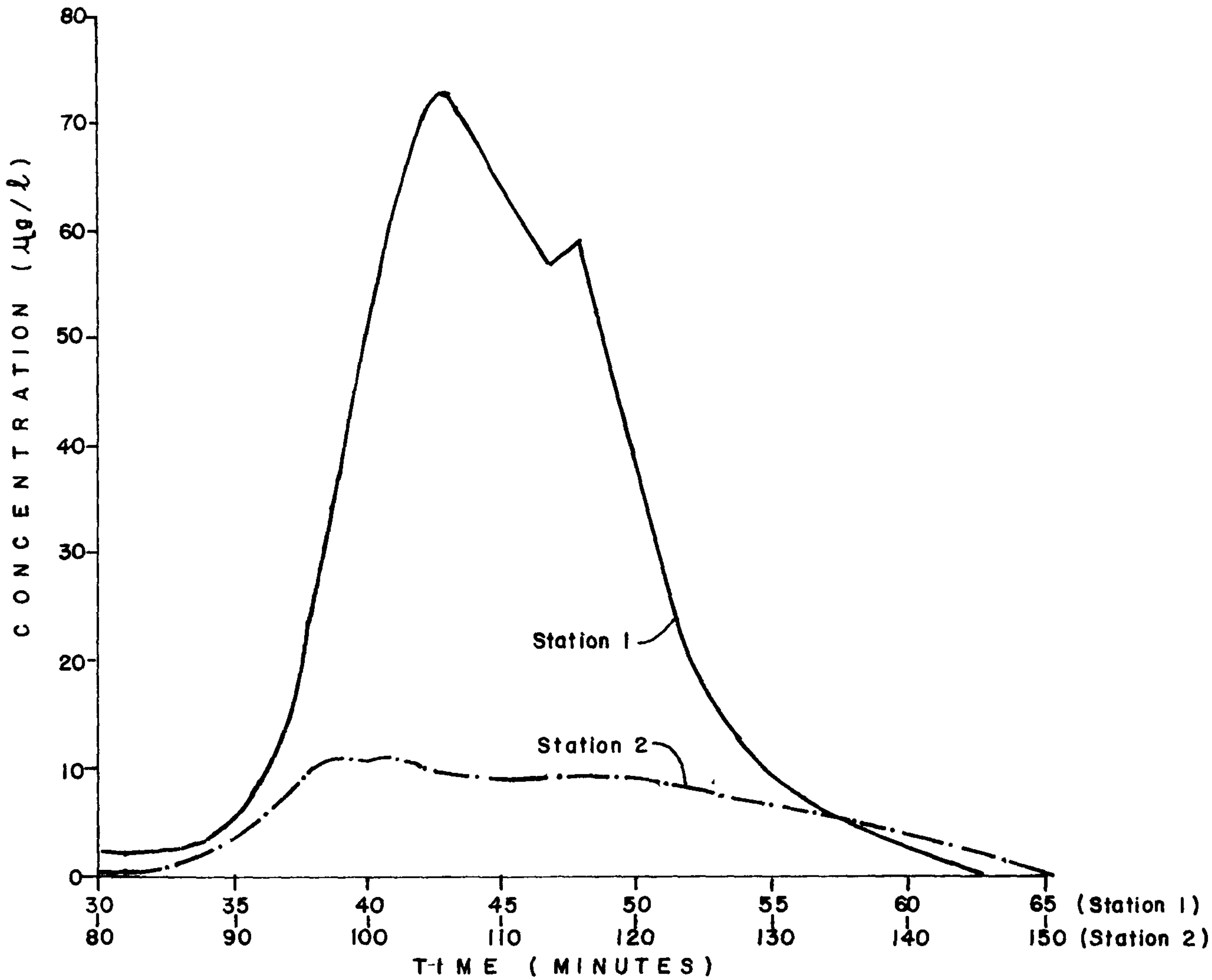

FIGURE 3 TIME AND CONCENTRATION CURVES FOR STATIONS 1 AND 2

difference in time between stations for first and last trace of dye was 23 minutes for Station 1 and 70 minutes for Station 2.

Peak concentrations for Stations 1, 2, and 5 were 73, 11, and 6 ug/l.

The original concentration of dye at the release point was calculated to be in the range of 1000 ug/l, roughly equivalent to some of the higher concentrations of fecal coliforms found in those areas. The following table presents dilution values between stations.

STATIONS	1	2	3
Release point	13.7	91	167
1		6.6	12
2			1.8

Figure 4 shows the dilution, time of travel, and predicted coliform/100 ml of contaminated waters moving down the harbour on an ebb tide. The predicted values do not include other sources of contaminaiton along the east shores.

Predicted values at Station 1 show the present closure line to be contaminated. However, predicted values at Station 2 through to Station 3 meet shellfish growing water criteria.

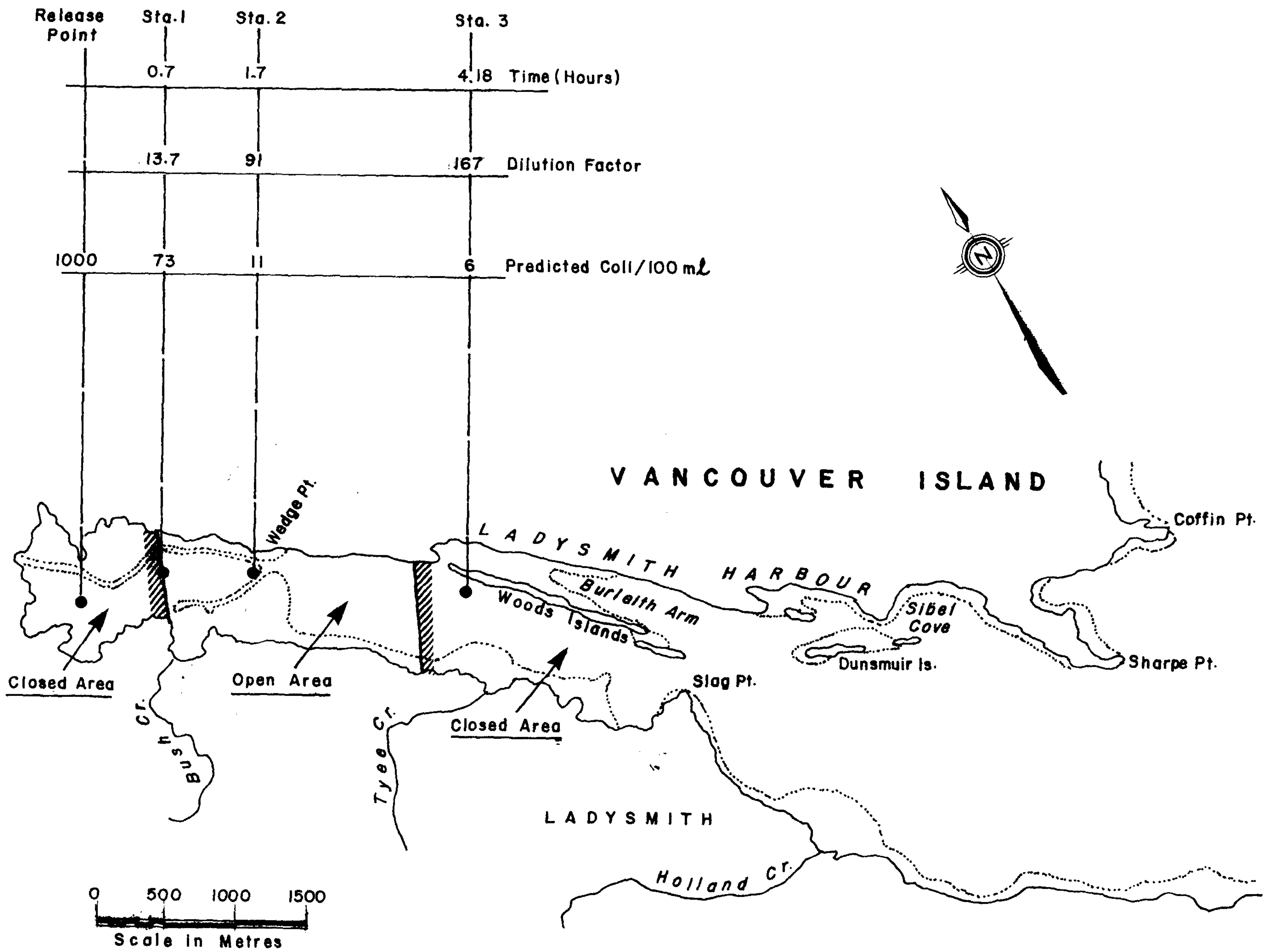

FIGURE 4 PREDICTED DILUTION AND COLIFORM VALUES - LADYSMITH HARBOUR

APPENDIX VII

OPERATIONAL ASSESSMENT OF THE LADYSMITH SEWAGE TREATMENT PLANT

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CONCLUSIONS

1. The treatment capacity of the Ladysmith plant is based on U.S. gallons. The metering device used to monitor and regulate flows through the plant measures in imperial gallons. Therefore, at peak flows the discrepancy between the two units of measurement causes the treatment system to be overloaded by 20%.

2. As would be expected for this this treatment process, the stabilized sludge has a higher concentration of most metals. Mercury levels are particularly high when compared to those levels allowed under the Federal Ocean Dumping Control Regulations for sediment disposed in marine waters.

1.0 INTRODUCTION

Twenty-four hour composite sampling of the Ladysmith sewage treatment plant was undertaken concurrent with the shellfish growing water quality study of Ladysmith Harbour during February and March 1983.

Influent and effluent samples were collected at one hour intervals for 24 hours over a three day period February 8, 9 and 11. Each composite sample was analysed for nutrients, residues, BOD, and metals. Preservation was according to the Environment Canada Pollution Sampling Handbook. Daily samples for bacteriology were taken from the raw, final, and plant bypass and analysed on site.

During March 1983, total residual chlorine and total sulphite tests were done on the final effluent. Bacteriological analyses were done on samples of the plant bypass as well as sludge drawn from the digester.

2.0 DISCUSSION

2.1 Plant Description

The Ladysmith STP serves a population of 4558 residents (Statistics Canada 1981 Census). Although the plant ideally is intended for sanitary wastes only, flows to the plant will increase significantly during periods of wet weather. This is due to the infiltration of storm and ground water to many of the older sanitary sewer mains. Figure 1 illustrates the impact of infiltration during the month of February and compares the daily rainfall as recorded at the Cassidy Airport (Atmospheric Environment Service) with the total daily flows to the Ladysmith STP (Daily plant records).

Designed treatment capacity is 2726 m^3/d. (These values are based on Igpd and are discussed later in the text.) However, for optimum treatment of the plant influent, flow to the headworks is held to 2500 m^3/d by a flow control baffle ahead of the comminutor. Figure 2 is a schematic

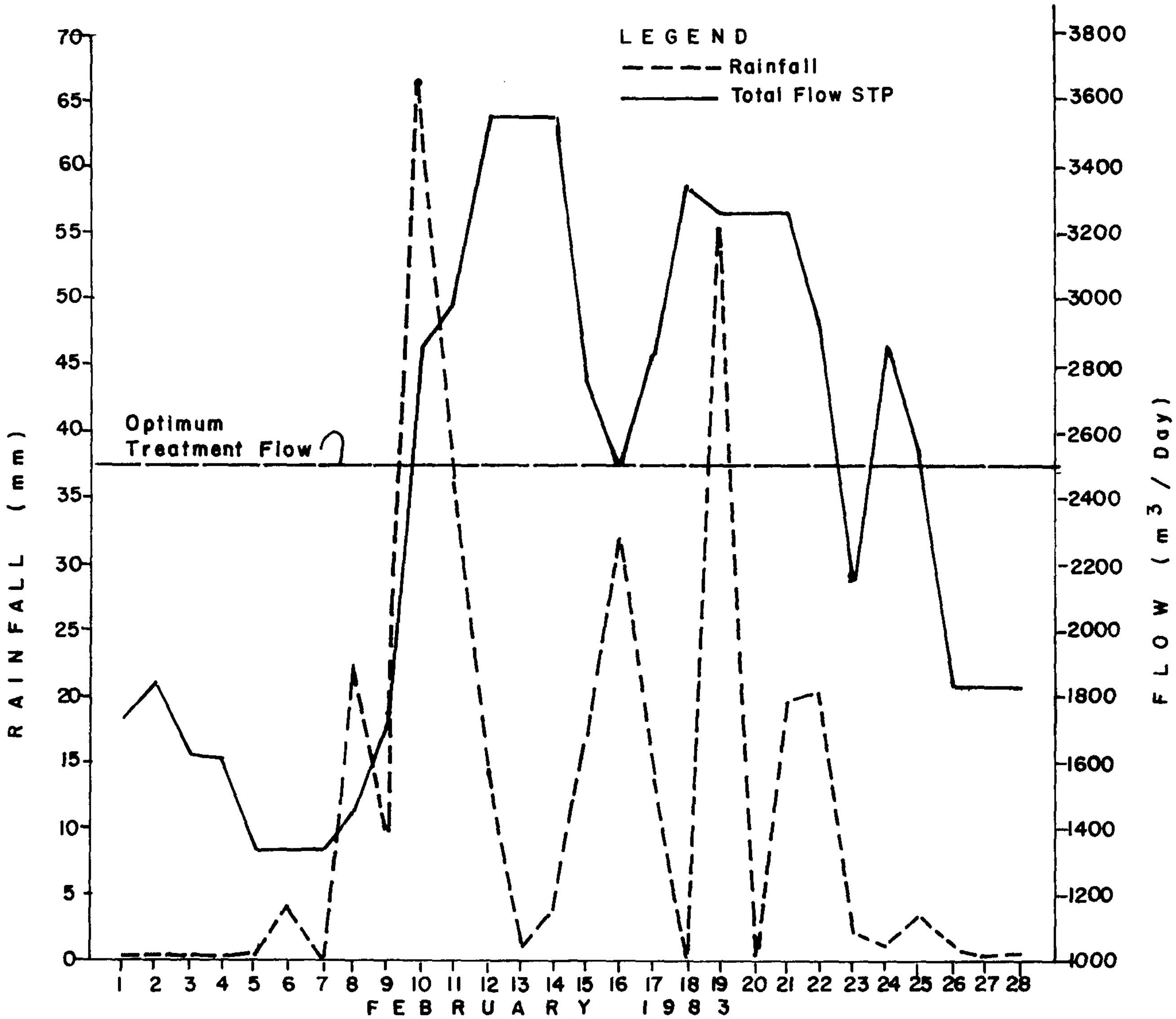

FIGURE I LADYSMITH STP FLOW VERSUS RAINFALL - CASSIDY AIRPORT

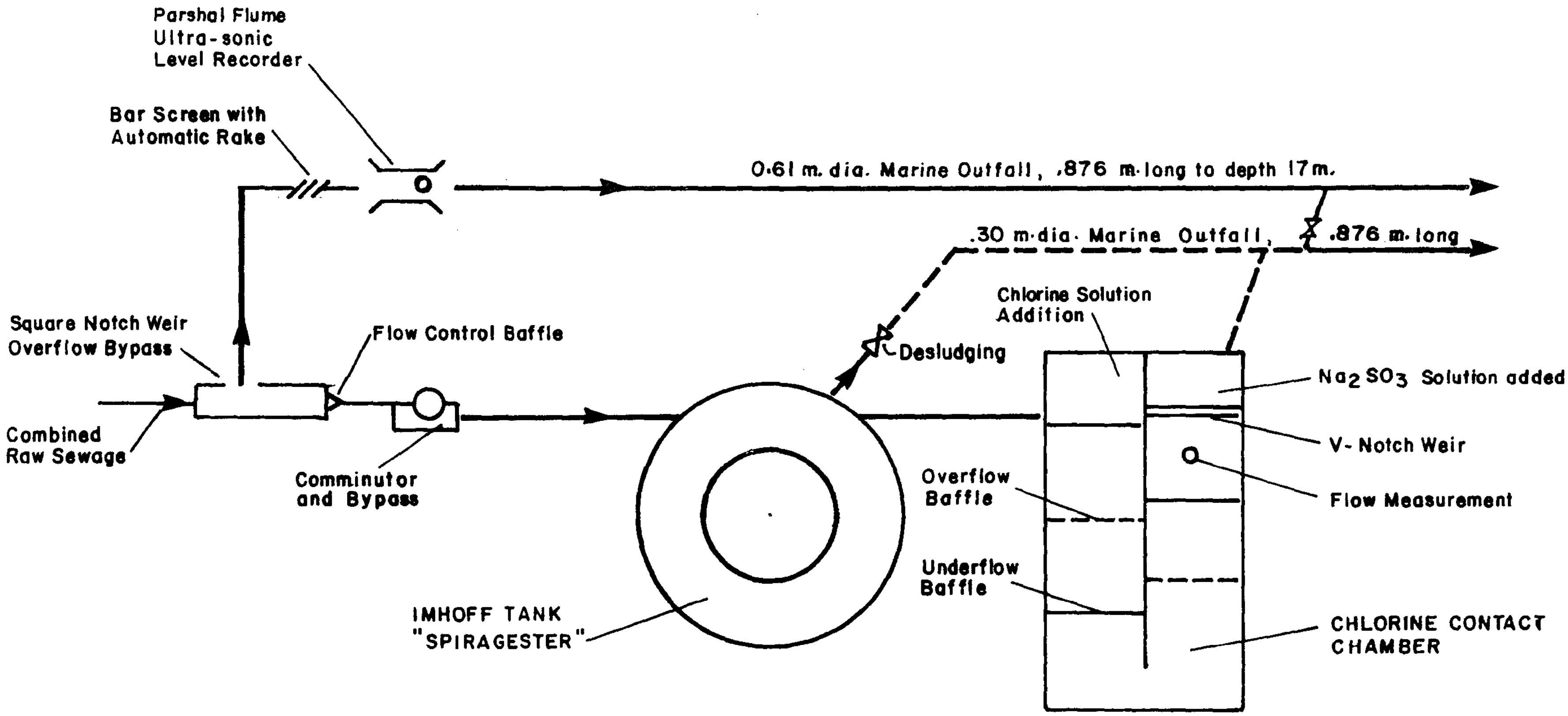

FIGURE 2 LADYSMITH SEWAGE TREATMENT PLANT LAYOUT

of the Ladysmith STP. Combined raw sewage enters a flow channel where flows in excess of 2500 m^3/d overflow a square notch weir. Bypassed sewage flows through a self cleaning bar rake to a parshall flume with an ultrasonic flow measuring device. Liquid level in the flume is measured, translated to flow, and recorded on a circular 7 day recording chart. Combined bypass effluent is then discharged through an outfall 0.66 m in diameter and 876 m in length that parallels the original 0.33 m diameter outfall. (Point of discharge is Lat. 48-59-00, Long. 123-47-45).

Raw sewage flowing to the plant is first comminuted then coarse-screened. Flows that are too large for the comminutor are by-passed directly to the Spiragester (Figure 3). Basically an Imhoff type tank, the Spiragester performs two functions in the treatment of raw sewage. The upper portion of the tank acts as a settling chamber where incoming sewage flows around an outer race and at the same time passes down under a skirt. As the flow reaches the skirt bottom it slows down, giving solids a chance to drop to the digester tank below. The clarified liquid then rises to the top of the inner portion of the chamber where it passes over weirs on its way to the chlorine contact chamber. Floating solids carried into the race are trapped, skimmed to the scum box and recirculated to the stack of the digester.

Sludge that is deposited in the digestion tank is also recirculated by the same scum pump to the stack of the cone. This serves a dual purpose in seeding the upper portion of the digestion chamber and circulating sludge through the chamber. Periodically sludge is wasted through the sludge drawoff which is connected to the marine outfall. The present practice of sludge disposal to Ladysmith Harbour is subject to the approval of the Regional Manager of the Ministry of the Environment, Waste Management Branch and a notification procedure directed to local oyster growers. Additionally, sludge drawdowns must be done on an ebb tide.

Once the clarified effluent has left the spiragester and enters the chlorine contact chamber it is flow proportionally dosed with chlorine gas. The contact chamber is a series of overflow/underflow baffles

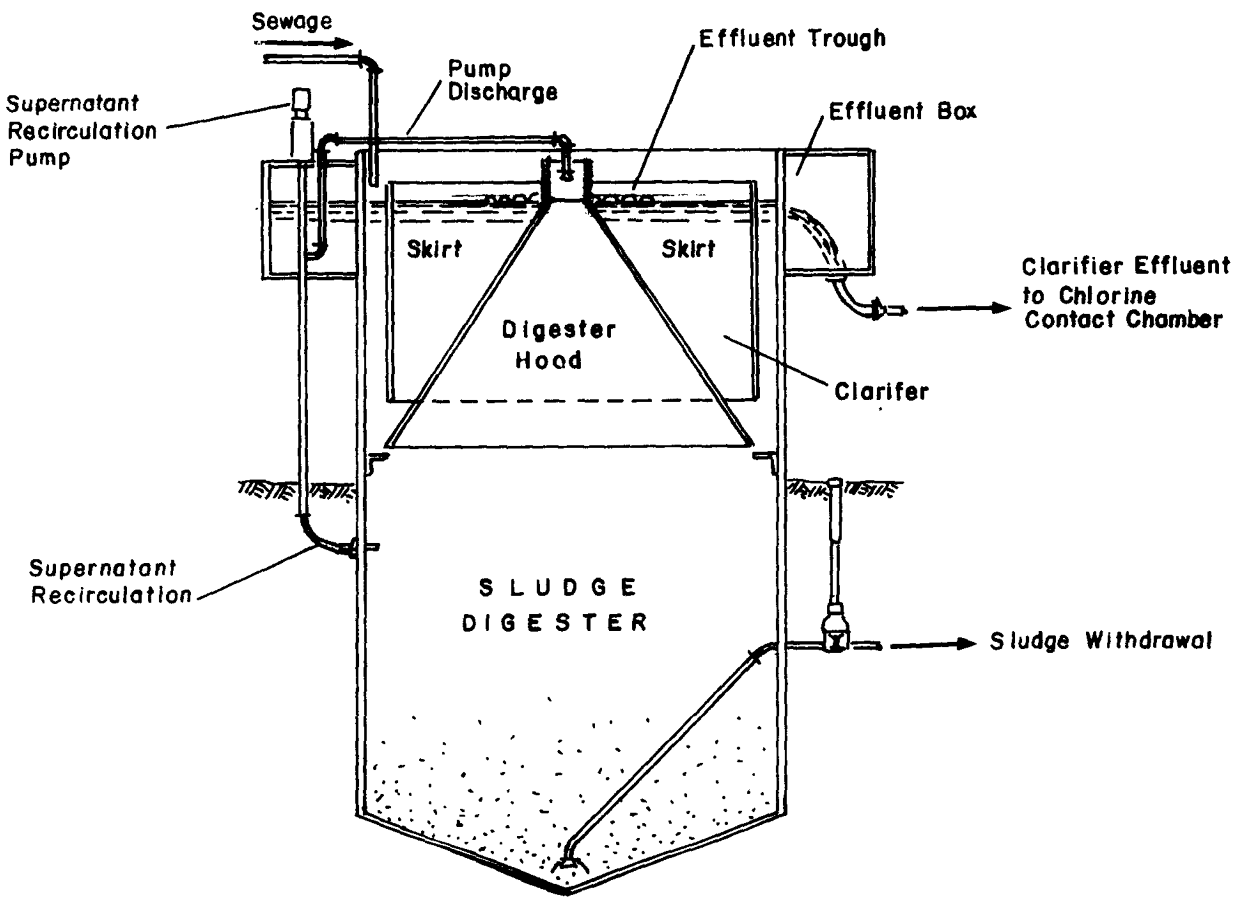

FIGURE 3 CIRCULAR SPIRAGESTER

designed to create a plug flow of effluent so that the optimum contact time will be realized. For further information on the performance of the chamber the reader is referred to a dye tracer study of the chlorine contact chamber done during a previous EPS survey (B. Shepherd April, 1982 Internal EPS Report). The chlorinated effluent exits the chamber through a v-notched weir at which point the effluent is flow proportionally de-chlorinated with sodium sulphite. Plant flows are measured just ahead of the de-chlorination system.

2.2 Wastewater Characteristics

Generally, the overall concentration of sewage can be classified as being strong, medium, or weak. Tables 1 and 2 present the analytical results for the three days of composite sampling at the Ladysmith STP. None of the parameters tested for were particularly high. According to the data, Ladysmith sewage contains a relatively small proportion of sewage matter to water and so would be considered weak. This is likely due to the high dilution it receives as a result of infiltration and the absence of industrial input to the system.

A treatment plant of this design can be expected to remove, on the average, 30% SS and 50% BOD. February 8 showed a 53% removal of SS and 48% removal of BOD when flows were 1442 m^3/d (317,384 Ipgd). As flows increased with the increase in rainfall, the ability of the plant to treat the incoming sewage declined. On February 11, when flows were 2998 m^3/d (659,860 Igpd) the amount of SS and BOD in the plant effluent increased from that in the influent by 67% and 56% respectively. During this study, mean percentage removal of all constituents with the exception of ammonia and a few of the metals showed a net increase or no change in concentration between the final effluent as compared to the raw influent. For example, suspended solids increased by 11%, BOD increased by 25%, and total phosphorus increased by 22%. This would seem to indicate that within the

TABLE 1 RESULTS OF 24 HOUR COMPOSITE SAMPLES - LADYSMITH STP[1]

PARAMETER	FEBRUARY 8			FEBRUARY 9			FEBRUARY 11			MEAN
	RAW	FINAL	% REMOVAL	RAW	FINAL	% REMOVAL	RAW	FINAL	% REMOVAL	% REMOVAL
pH	6.9	7.0	-	7.0	7.1	-	6.9	6.9	-	-
BOD	25	13	48	12	20	[2]-67	9	14	-56	-25
NFR	72	34	53	58	58	90	42	70	-67	-11
NFVR	60	30	50	26	16	38	< 5	26	-420	-110
TPO_4	3.15	3.63	-15	2.53	2.45	3	0.776	1.19	-53	-22
NITRITE (NO_2)	0.006	0.294	-4800	0.006	0.041	-583	0.101	0.033	67	-1772
NITRATE (NO_3)	< 0.01	0.41	-4000	< 0.01	1.13	-11200	1.11	2.29	-106	-5102
AMMONIA	13.9	9.05	37	7.84	6.59	15.94	2.23	2.8	-25.5	9.14
MERCURY	0.0007	0.0007	-	0.0004	0.0004	-	< 0.0002	0.0004	> 100	
PLANT FLOW (m^3/day)	1442			1710			2998			
BYPASS (m^3/day)	143.6			761			9480			

[1]All values in mg/L except pH
[2]Negative - Values indicate a percent increase

TABLE 2 TOTAL METALS - LADYSMITH S.T.P. FEBRUARY 8-11 24 HOUR COMPOSITE [ug/mL]
(Negative values indicate increase in constituent)

ELEMENT	FEBRUARY 8			FEBRUARY 9			FEBRUARY 11			MEAN
	RAW	FINAL	% REMOVAL	RAW	FINAL	% REMOVAL	RAW	FINAL	% REMOVAL	
As	< .05	< .05	-	< .05	< .05	-	< .05	< .05	-	-
B	.192	.229	-19.	.13	.192	-47.7	.057	.108	-89.5	-52.1
Ba	.031	.032	-3.	.04	.031	22.5	.02	.03	-66.7	-7.5
Be	< .001	< .001	-	< .001	< .001	-	< .001	< .001	-	-
Cd	.006	.007	-17.	.003	.005	-66.7	.006	.005	16.7	-5.6
Co	< .005	< .005	-	< .005	< .005	-	< .005	< .005	-	-
Cr	< .005	.024	-38.	< .005	.036	-620	< .005	.021	>-320	-326
Cu	.107	.087	18.7	.075	.076	-1.3	.029	.045	-55.	-12.5
Mn	.029	.028	3.	.03	.033	-10.	.017	.029	-70.5	-26
Mo	< .005	< .005	-	< .005	< .005	-	< .005	< .005	-	-
Ni	< .02	< .02	-	< .02	< .02	-	< .02	< .02	-	-
P	< .01	4.49	-12.	3.15	3.35	-6.3	1.01	1.79	77	-31.8
Pb	.05	.04	20.	< .02	.04	-100	.02	.04	100	-60.
Sb	< .05	< .05	-	< .05	< .05	-	< .05	< .05	-	-
Se	< .05	< .05	-	< .05	< .05	-	< .05	< .05	-	-
Sn	< .01	< .01	-	< .01	< .01	-	< .01	< .01	-	-
Sr	.072	.067	7.	.072	.066	8.	.078	.089	-14	.33
Ti	.029	.021	27.6	.052	.04	23.	.054	.055	-2	16.2
V	< .01	< .01	-	< .01	< .01	-	< .01	< .01	-	-
Zn	.137	.183	-33.6	.144	.155	-7.6	.108	.122	-13	-18.07
Al	.44	.35	20.5	.82	.71	13.4	.45	.95	-111	-25.7
Fe	.417	.395	5.5	.757	.759	.2	.353	.891	-152	-48.8
Si	5.0	5.2	-4.	4.8	4.9	-2.	3.6	4.8	-33.	-13.
Ca	13.3	12.9	3.	12.4	12.1	2.5	11.9	14.2	-19.	-4.5
Mg	2.9	3.0	-3.5	3.2	2.9	9.4	1.8	2.4	-33.	-9.0
Na	23.5	29.9	-27.	24.5	23.6	3.7	9.1	12.6	-38.5	-14.0

treatment system a re-suspension of solids from the digestion chamber is causing the increase in the final effluent constituents.

The Spiragester at Ladysmith was selected for a design population of 5000. To achieve the 30% SS and 50% BOD reduction, the size of the settling chamber is designed for 2 hours retention based on a 24 hour average flow. (The Lakeside Spiragester) The following table presents the settling times of the plant during the sampling period.

TABLE 3 PLANT SETTLING TIMES AND OVERFLOW RATES

DATE	FLOW (m^3/d)	SETTLING TIME (hours)	OVERFLOW RATE ($m^3/m^2 \cdot d$)
February 8	1710	2.2	25.3
February 9	2860	1.3	42.3
February 11	3554	1.06	52.6

As previously mentioned, the present treatment capacity is held to 2500 m^3/d based on Igpd measurement, however, the maximum flow this plant was designed to treat while still maintaining a two hour settling time is 1890 m^3/d based on USgpd plant design. On both February 9 and 11 this value was exceeded. Detention time was consequently decreased, thereby lowering the efficiency of the settling process.

The efficiency of the settling basin is a function of the settling velocity. Commonly known as the overflow rate, it is represented by the following equation.

$$V_s = Q/A$$

where V_s = overflow velocity ($m^3/m^2 \cdot d$)

Q = flow rate (m^3/d)

A = surface area (m^2)

In the case of the Ladysmith plant, the theoretical overflow rate is calculated to be 28 $m^3/m^2 \cdot d$ based on the plant design treatment volume.

The recommended rate to obtain a 50%-60% removal of SS should be between 25-30 $m^3/m^2 \cdot d$. The overflow rate on February 11 was 52.6 $m^3/m^2 \cdot d$, considerably higher than the recommended rate. Peak overflow rate for the same day based on a recorded peak flow of 3785 m^3/d, was 58 $m^3/m^2 \cdot d$.

In addition, it is speculated that as a result of the increase in flow, higher velocities through the plant re-suspended sludge from the digestion chamber occur causing a net increase in constituents in the final effluent. On February 11, 1662 m^3 of excess wastewater was put through the treatment process, 88% more than the plant's treatment ability.

2.3 Sludge Characteristics

On February 21, two samples of sludge were drawn from the digestion chamber of the treatment plant. Sample station 1 was taken from the upper region of the sludge layer and station 2 was taken from a lower depth in the sludge layer. Analytical results are presented in Table 4.

TABLE 4 SLUDGE COMPOSITION LADYSMITH STP - FEBRUARY 21, 1983

CONSTITUENTS	SAMPLE NO. 1	SAMPLE NO. 2
SVR (mg/kg)	753,000	393,000
TOTAL PCB (mg/kg)	< 0.05 (wet wt.)	< 0.05 (wet wt.)
PENTACHLOROPHENOL		
Wet Weight	0.004	0.01
Dry Weight	.075	0.034
TETRACHLOROPHENOL		
Wet Weight	0.004	0.003
Dry Weight	0.070	0.011

CONTINUED...

TABLE 4 SLUDGE COMPOSITION LADYSMITH STP - FEBRUARY 21, 1983 (Continued)

CONSTITUENTS	SAMPLE NO. 1	SAMPLE NO. 2
Hg (mg/kg)	4.62	7.14
As (ug/g)	< 7	< 9
Ba	123	182
Be	< 1	< 2
Cd	2.2	17.6
Co	< 7	8.5
Cr	29	75.4
Cu	321	778
Mn	75.8	230
Mo	3.4	35.7
Ni	15	67
P	2910	3800
Pb	95	384
Sn	39	82
Sr	29.7	42.6
Ti	184	653
V	16	49
Zn	1660	756
Al	6690	12700
Fe	5680	20000
Si	3410	5010
Ca	5370	10300
Mg	1440	3240
Na	610	790

TABLE 5 FECAL COLIFORM/100 mL - LADYSMITH STP

DATE (1983)	INFLUENT	EFFLUENT	BYPASS	SLUDGE
February 8	1.2×10^6	< 10	-	-
February 10	8.0×10^5	< 10	1.6×10^6	-
February 11	2.0×10^6	< 10	2.2×10^6	-
February 14	2.8×10^5	< 10	-	-
February 22	-	-	1.1×10^5	2.6×10^5
March 23	-	-	1.8×10^6	

Ladysmith STP uses a single stage, low rate, anaerobic digestion process to reduce (stabilize) raw sludge to a less offensive form. Putrescible matter is reduced to liquid, dissolved solids and gaseous by-products.

In the upper zone of the digestion chamber acid forming organisms convert complex organic compounds in the solid portion of the feed to volatile organic acids. Further breakdown of these acids yields final by-products of methane and carbon dioxide gas. The reactions occur simultaneously and depend on a number of factors, including pH and temperature for process efficiency. Stabilized sludge accumulates on the bottom of the tank. It is generally lower in the organic fraction, but more concentrated in other constituents that will not decompose or that solubilize at much slower rates (MOP No. 11).

Typically, this process will reduce volatile residues within the range of 40 to 60%. Volatile solids reduction (SVR) for Ladysmith was 47.8%. This represents the reduction between sludge that is newly deposited (Sample No. 1) and sludge that has been anaerobically digested (Sample No. 2).

Metal concentrations as presented in Table 4 shows higher levels in digested sludge than newly deposited sludge. Increases occurred in all metals tested for except zinc, which decreased. Noticeably, the concentration of mercury in the stabilized layer of sludge is 7.14 mg/kg. Although there are no regulations concerning maximum concentrations of allowable metals in sludge discharged to marine waters, present Federal Ocean Dumping Control Regulations, by comparison require that sediment and other materials disposed of at sea must contain less than 0.75 mg/kg of mercury in the solid phase.

2.4 Bacteriological

Table 5 presents a summary of results for the plant bacteriology, and Table 6 presents data for residual chlorine and residual Na_2SO_3.

TABLE 6 RESIDUAL CHLORINE AND RESIDUAL Na_2SO_3 - LADYSMITH STP

DATE	TIME	Na_2SO_3	Cl pre Na_2SO_3	Cl post Na_2SO_3
March 22	1020	1.0	0.95	0.0
March 23	1315	2.0	0.20	0.0

2.5 Sewage Lift Stations

There are four pump stations lifting sewage to the treatment plant. (Personal communication J. Vreeling, Superintendant of Works, Ladysmith.) Two are located inland at Cloak Road and Russel Road and two are on the foreshore of Ladysmith Harbour at Sandy Beach and Gil Road. The following table presents a summary of the features of each pump station.

TABLE 7 SEWAGE LIFT STATIONS - LADYSMITH

STATION	ALARM	OVERFLOW	STANDBY POWER
Cloak Road	Horn 12-Volt	Overflow to ground Retention time not known	Gasoline powered
Russel Road	None	Overflow to ground Retention time not known	No standby power
Sandy Beach	None	To Foreshore Retention time not known	No standby power
Gil Road	None	To Foreshore 16 hour observed retention time	Level activated gasoline powered backup pumps

*The town of Ladysmith is presently considering a telemetry alarm system for the lift stations at Sandy Beach and Gil Road.

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APPENDIX VIII

DYE TRACER STUDIES OF
THE LADYSMITH SEWAGE TREATMENT OUTFALL PLUME

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1.0 INTRODUCTION

During July 1983, and March 1984, personnel of the Environmental Protection Service conducted dye, bacteriological, and drogue tracer studies to assess the movement of bypassed unchlorinated sewage in Ladysmith Harbour.

2.0 METHODS AND MATERIALS

2.1 July 1983

Continuous and slug addition methods were used to inject tracer dye to the final effluent. On July 12 Rhodamine dye was continuously fed to the effluent stream as it overflowed the wier at the exit of the chlorine contact chamber. Continuous additions of dye were flow proportional and extended for 1.5 hours. Dye concentration at both the plant and in the harbour was monitored with a Turner Designs model 10-005 fluorometer. Harbour sampling was accomplished with a submersible pump connected to a continuous flow through cuvette. Sightings were done using a sextant. Profiling for temperature and conductivity was accomplished with the use of a Hydro-lab Model 4041 insitu water quality monitor.

2.2 March 1984

Methods for dye release and tracking were identical to those used during July 1983. In addition to the dye tracing, bacteriological tracing and drogue tracking were also used in following the movement of the effluent.

3.0 RESULTS AND DISCUSSION

3.1 July 1983

Neither the continuous release of dye nor the slug releases of dye surfaced in the harbour during this study. Profiling of the outfall on

July 13 and subsequent use of this information in a dilution prediction model predicted that the effluent was being trapped at the 7 m depth. During one pass with the sampling pump at a depth of 6.5 m, the fluorometer registered a reading of between 20 and 30 ppb of dye. The position of this slug of dye was estimated to be approximately 350 to 500 m west and north of the point of discharge. Tides were flooding at the time of this dye injection.

3.2 March 1984

As a result of the July 1983 dye study and more specifically, the difficulties experienced in tracing an effluent that did not surface, study personnel decided to employ bacteriological tracing and drogue tracking to supplement the tracer dye techniques.

On March 20, both dye tracing and bacteriological sampling were used in an attempt to trace the movement of effluent from the treatment plant. Overflow conditions at the plant were created by decreasing flow to the plant thereby forcing sewage to bypass. Sample stations are shown on Figure 1 and results are presented in Table 1.

Sample stations 1 through 6 were positioned within 50 m of the outfall terminus marker. Sample stations 8 through 14 were intended to follow the same pattern at 100 m off the marker; however, due to difficulties in positioning and holding the boat because of rough seas the resulting station positions are as shown in Figure 1.

Dye was not found in the first six stations around the outfall but fecal coliform samples were taken at various depths. Dye was first detected at station 20-7 over the outfall approximately two hours after the beginning of dye addition. The greatest concentration of dye and bacteria appeared to be between the 3 m and 5 m depth for stations 7 to 14. A profile of temperature and conductivity over the outfall showed temperature to rise from 8.0°C on the bottom to 8.7°C on the surface, whereas conductivity rose steadily from the bottom to about 5 m depth and then began to drop from there to the surface. It appears that neither a thermocline nor a

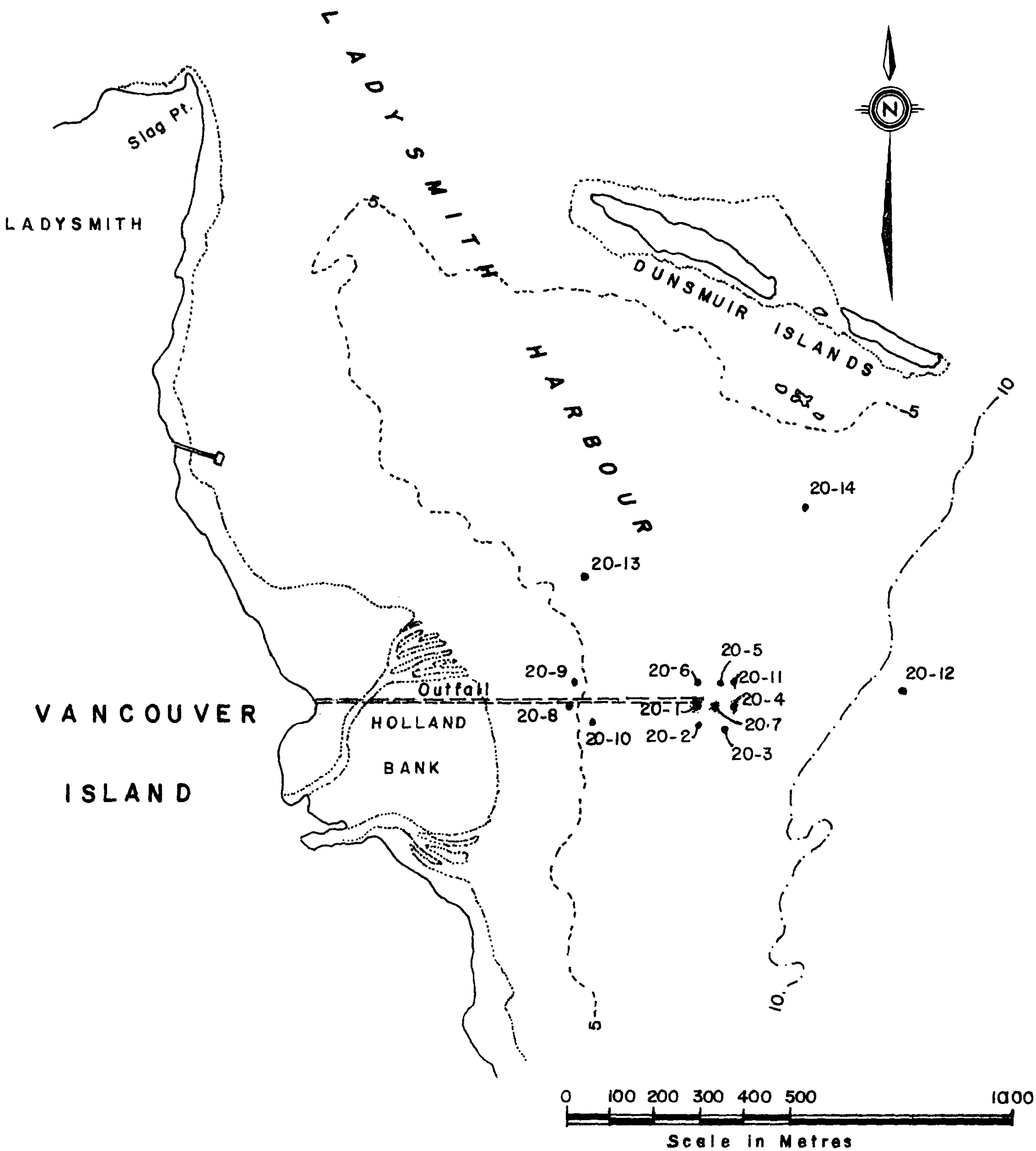

FIGURE 1 LADYSMITH DYE TRACKING - March 20, 1984

TABLE 1 LADYSMITH HARBOUR DYE RDGS AND BACTERIOLOGICAL RESULTS - MARCH 20, 1984

STATION	FC/100 mL at DEPTH - FLUORMETER RDG (ppb)													
	0 m	PPB	2 m	PPB	3 m	PPB	4 m	PPB	5 m	PPB	10 m	PPB	15 m	PPB
20-1	< 3								< 3		< 3		< 3	
20-2	< 3								> 2400		< 3		< 3	
20-3	< 3								1100		< 3		9	
20-4	93								7		< 3		5	
20-5	9								> 2400		< 3		< 3	
20-6	43								> 2400		7		4	
20-7	930	100												
20-8	150	1.9												
20-9	23	0.9												
20-10	23	0.2	93	1.0	2400	68	4600	55						
20-11		0.6	4	0.8	230	20			< 3	0.7				
20-12	< 3			4.5		4.0								
20-13					930	50	9	0.65						
20-14					4	6.2								

picnocline existed so that the effluent was not trapped prior to reaching the surface. Also, there was an obvious boil with associated solids. However, the data reveal that the greatest concentration of dye and bacteria was between the 3 m and 5 m depth.

Sampling and dye tracing during this addition were done on a flood tide and the results of this study suggest that the effluent is being carried in the direction of Slag Point and could possible affect the Transfer Beach foreshore. However, the data are not conclusive and further sampling was not possible at that time because of the lateness of the hour.

On March 23, 1984 drogue tracking and dye tracing were used to following the movement of effluent in Ladysmith Harbour. Surface and depths drogues were released over the outfall coordinates at 11:45 h. Tracking is shown in Figure 2. On the ebb tide, drogues at the surface and at the 5 m depth moved south east out of the harbour. The average velocity for the surface drogue was 14.5 cm/s and for the depth drogues 8.7 cm/s.

The addition of dye was done in the same fashion as previous days for one hour beginning at 0945. The dye was not found at any station nor at any depth in the area of the outfall. The reason for this was discovered later when the plant flow charts were inspected. The overflow that was created to simulate bypass conditions followed the flow regime of normal diurnal plant inflow. As morning peak flows to the plant decreased, flow through the bypass dropped off completely. Under these conditions dye would have a much longer residence time in the outfall.

Bacteriological sampling of the harbour on March 23 in the area of the outfall is depicted in Figure 3 and results are presented in Table 2. On this occasion the sampling pattern was again concentric to the outfall but at distances of 100 m and 200 m off the outfall terminus, and, except for station 1, all stations were sampled at the 4 m depth.

Fecal coliform values are lower in concentration than those samples from the previous day. This may be attributable to the decrease in volume over time of sewage bypassed resulting in a greater amount of

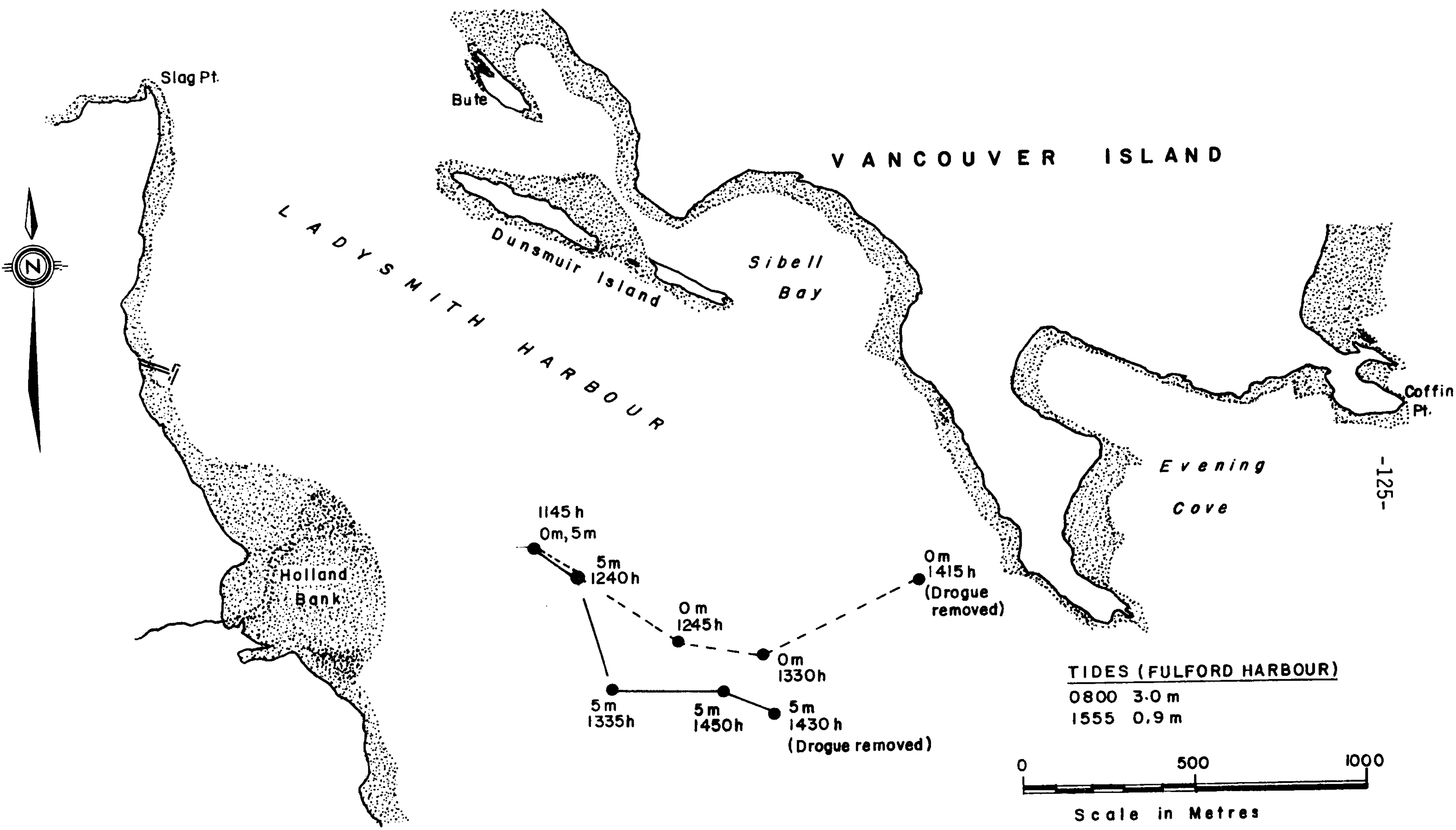

FIGURE 2 DROGUE TRACKING - March 23, 1984

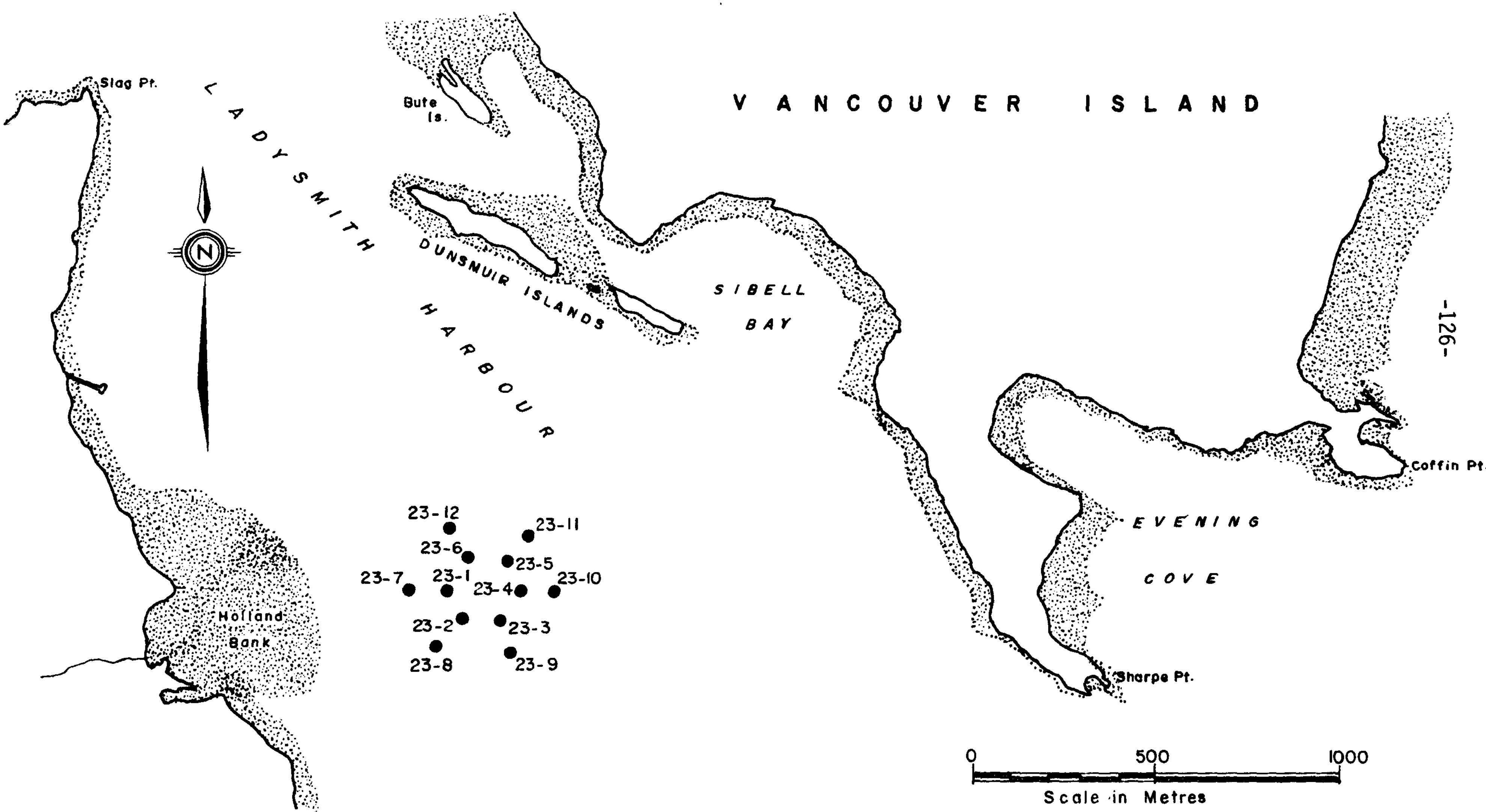

FIGURE 3 LADYSMITH BACTERIOLOGICAL TRACING - March 23, 1984

dilution available. Although there are not enough data to establish the direction of travel of the effluent, the data continues to indicate that sewage bacteria is most concentrated between the 2 m and the 5 m depth.

TABLE 2 BACTERIOLOGICAL TRACING LADYSMITH, MARCH 23, 1984

STATION	DEPTH (m)	FC/100 ml
23-1	0	7
23-1	2	75
23-1	5	43
23-1	10	< 3
23-1	15	< 3
23-1	4	43
23-2	4	15
23-3	4	9
23-4	4	43
23-5	4	75
23-6	4	460
23-7	4	< 3
23-8	4	23
23-9	4	93
23-10	4	150
23-11	4	< 3
23-12	4	7

APPENDIX IX

TRACE METAL RESULTS
(*C. gigas*) TISSUE SAMPLES

APPENDIX IX

TABLE 1 TRACE METAL TISSUE RESULTS - May 17, 1983

	SAMPLE STATION							
	1		2		3		4	
	Wet Wt.*	Dry Wt.*	Wet Wt.*	Dry Wt.*	Wet Wt.*	Dry Wt.*	Wet Wt.*	Dry Wt.*
As	1.4	8.0	1.8	9.0	1.6	8.0	1.7	11.0
Ba	0.341	1.86	0.72	3.52	0.18	0.88	0.288	1.81
Be	< 0.009	< 0.05	< 0.01	< 0.05	< 0.01	< 0.05	< 0.008	< 0.05
Cd	1.37	7.5	1.52	7.4	1.55	7.5	1.28	8.1
Co	0.19	1.0	0.14	0.7	0.12	0.6	0.29	1.8
Cr	0.09	0.5	0.12	0.6	0.08	0.4	0.13	0.8
Mn	2.76	15.1	3.33	16.3	4.31	20.7	3.97	24.9
Mo	< 0.04	< 0.2	< 0.05	< 0.2	< 0.05	< 0.3	< 0.04	< 0.2
Ni	< 0.2	< 1.0	< 0.2	< 1.0	< 0.2	< 1.0	< 0.2	< 1.0
Pb	< 0.2	< 1.0	< 0.2	< 1.0	< 0.2	< 1.0	< 0.2	< 1.0
Sb	< 0.4	< 2.0	< 0.5	< 2.0	< 0.5	< 3.0	< 0.4	< 2.0
Sn	0.6	3.3	< 0.1	< 0.5	< 0.1	< 0.5	1.44	9.1
Sr	5.6	30.6	1.51	7.37	2.76	13.3	5.02	31.5
Ti	0.3	1.7	0.23	1.1	0.15	0.7	0.35	2.2
V	< 0.09	< 0.5	< 0.1	< 0.5	< 0.1	< 0.5	< 0.08	< 0.5
Al	7.6	42.0	5.3	26.0	4.3	21.0	8.5	53.0
Si	14.2	78.0	10.0	49.0	9.0	45.0	13.2	83.0
Cu	20.4	112.0	11.5	56.2	17.0	81.7	44.4	279.0
Zn	210	1150	146	716	201	963	338	2130
Fe	39.2	214	29	142	23.3	112	59.4	373
P	1500	8180	1450	7100	1360	6520	1560	9830
Ca	1940	10600	197	964	535	2570	1560	9800
Mg	273	1490	276	1350	400	1920	374	2350
Na	1270	6950	1230	6000	2340	11200	2240	14100

*$ug.g^{-1}$

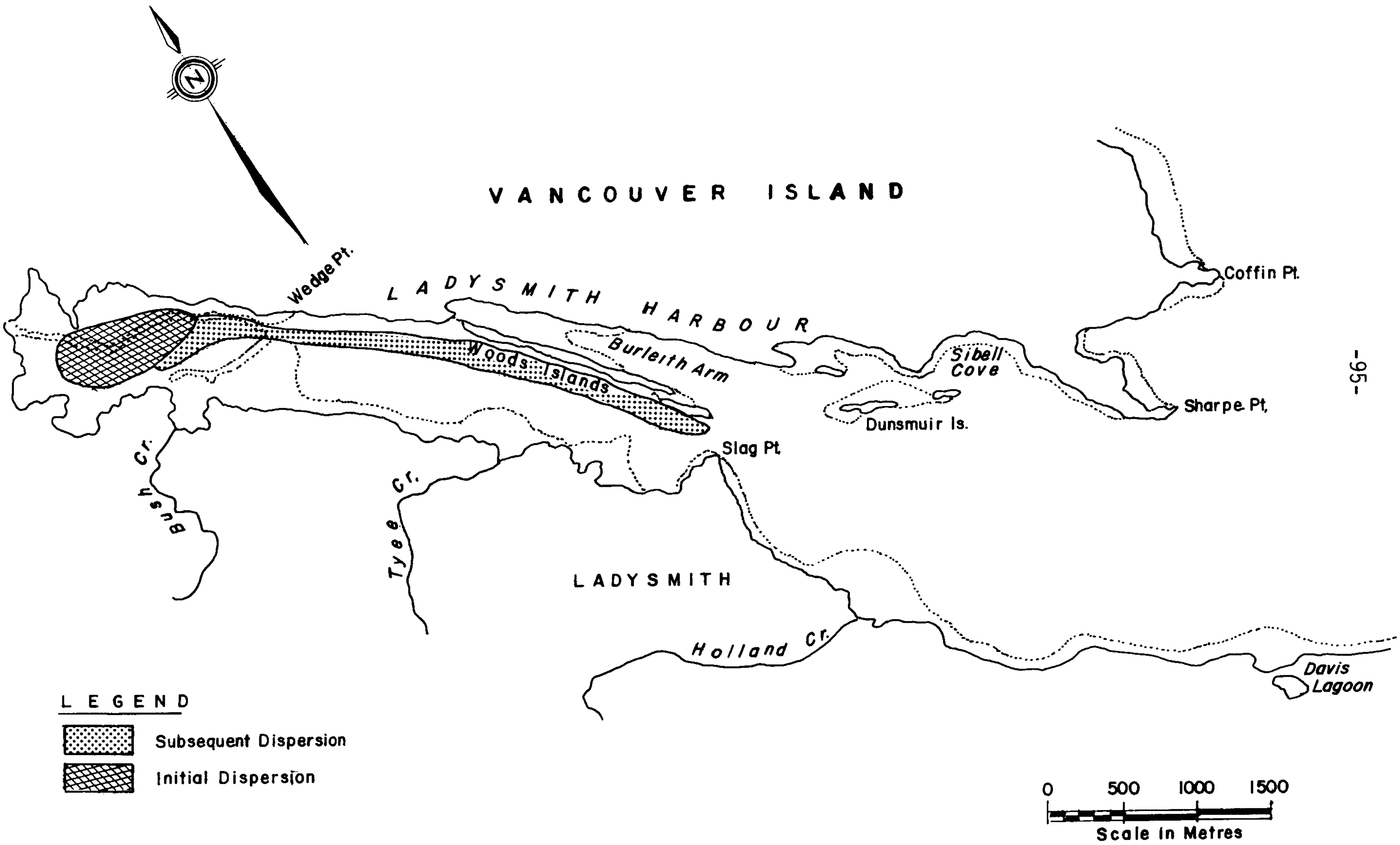

FIGURE 2 LADYSMITH HARBOUR - DYE DISPERSION, July 13, 1983

APPENDIX IX

TABLE 2 TRACE METAL TISSUE RESULTS - July 11, 1983

	SAMPLE STATION							
	1		2		3		4	
	Wet Wt.*	Dry Wt.*	Wet Wt.*	Dry Wt.*	Wet Wt.*	Dry Wt.*	Wet Wt.*	Dry Wt.*
As	1.5	9.0	2.0	10.0	2.1	11.0	1.0	9.0
	1.6	9.0	1.8	9.0	2.0	10.0	0.5	0.5
Ba	0.089	0.55	0.17	0.81	0.09	0.46	0.05	0.45
	0.083	0.46	0.14	0.66	0.09	0.44	0.041	0.38
Be	< 0.008	< 0.05	< 0.01	< 0.05	< 0.01	< 0.05	< 0.006	< 0.05
	< 0.009	< 0.05	< 0.01	< 0.05	< 0.01	< 0.05	< 0.005	< 0.05
Cd	0.8	4.9	1.0	4.7	0.85	4.3	0.46	4.2
	0.76	4.2	0.98	4.7	0.87	4.5	0.7	6.4
Co	0.1	0.6	0.1	0.5	0.07	0.4	0.11	1.0
	0.11	0.6	0.06	0.3	0.07	0.3	0.07	0.7
Cr	0.13	0.8	0.14	0.7	0.13	0.7	0.11	0.9
	0.24	1.3	0.13	0.6	0.12	0.6	0.18	1.7
Hg	0.03	0.18	0.03	0.16	0.03	0.18	0.04	0.37
	0.03	0.16	0.03	0.12	0.03	0.16	0.04	0.32
Mn	7.47	46.1	7.35	34.6	8.64	43.3	4.5	40.5
	7.19	39.8	6.25	30.0	8.65	44.7	2.76	25.3
Mo	0.03	0.2	0.05	0.2	< 0.05	< 0.3	< 0.3	< 0.2
	< 0.04	< 0.2	< 0.05	< 0.2	< 0.05	< 0.2	< 0.3	< 0.2
Ni	< 0.2	< 1.0	< 0.2	< 1.0	< 0.2	< 1.0	< 0.1	< 1.0
	< 0.2	< 1.0	< 0.2	< 1.0	< 0.2	< 1.0	< 0.1	< 1.0
Pb	< 0.2	< 1.0	0.2	1.0	< 0.2	< 1.0	< 0.1	< 1.0
	0.2	1.0	< 0.2	< 1.0	< 0.2	< 1.0	0.1	1.0
Sb	< 0.4	< 2.0	< 0.5	< 2.0	< 0.5	< 3.0	< 0.3	< 2.0
	< 0.4	< 2.0	< 0.5	< 2.0	< 0.5	< 2.0	< 0.3	< 2.0
Sn	< 0.08	< 0.5	< 0.1	< 0.5	< 0.1	< 0.5	< 0.06	< 0.5
	< 0.09	< 0.5	< 0.1	< 0.5	< 0.1	< 0.5	< 0.05	< 0.5
Sr	6.34	39.1	3.27	15.4	2.65	13.3	4.64	41.8
	6.18	34.2	2.92	14.0	2.68	13.9	5.19	47.5
Ti	0.24	1.5	0.55	2.6	0.19	0.9	0.31	2.7
	0.24	1.3	0.22	1.1	0.18	1.0	0.18	1.6

CONTINUED...

APPENDIX IX

TABLE 2 TRACE METAL TISSUE RESULTS - July 11, 1983
(Continued)

	SAMPLE STATION							
	1		2		3		4	
	Wet Wt.*	Dry Wt.*	Wet Wt.*	Dry Wt.*	Wet Wt.*	Dry Wt.*	Wet Wt.*	Dry Wt.*
V	< 0.08	< 0.5	< 0.1	< 0.5	< 0.1	< 0.5	< 0.06	< 0.5
	< 0.09	< 0.5	< 0.1	< 0.5	< 0.1	< 0.5	< 0.05	< 0.5
Al	5.2	32.0	8.8	41.0	3.4	17.0	6.6	60.0
	5.6	31.0	4.2	20.0	3.6	18.0	4.1	38.0
Si	16.1	99.0	42.0	196.0	15.0	75.0	12.7	114.0
	15.2	84.0	15.0	74.0	14.0	75.0	10.7	98.0
Cu	15.3	94.2	9.42	44.3	15.2	76.2	18.7	168.0
	13.6	75.3	8.31	39.9	13.6	69.9	7.57	69.3
Zn	189	1170	147	689	217	1090	266	2400
	160	885	149	715	200	1030	112	1020
Fe	28.1	174	29.7	139	20.2	102	29.4	265
	29.0	160	24.2	116	20.1	103	23.8	218
P	1880	11600	1890	8900	1790	9000	859	7730
	2240	12400	2100	10100	1670	8580	750	6860
Ca	1380	8520	528	2490	215	1080	537	4830
	1570	8680	390	1880	260	1360	519	4740
Mg	593	3660	483	2270	600	3010	679	6110
	592	3280	497	2390	578	2980	784	7170
Na	3620	22300	2480	11600	3040	15300	4780	43000
	3420	18900	2630	12600	2900	15000	6210	56800

*ug.g^{-1}

APPENDIX X

BIOCHEMICAL CONFIRMATION RESULTS

1 INTRODUCTION

The accuracy of the MPN test procedure in recovering fecal coliforms (specifically *Escherichia coli*) from the marine environment is routinely tested as part of the microbiology laboratory quality control procedure.

During shellfish surveys, a minimum of 10% of all positive (growth + gas) A-1 media tubes are subjected to biochemical identification to confirm the presence of *E. coli* in the sample. Positive tubes generally are picked randomly unless anomolous results are observed at individual sample stations.

2 MATERIALS AND METHODS

Inocula from positive A-1 tubes are streaked on Levine's EMB agar to obtain isolated colonies. After 24 hours incubation on Levine's EMB, typical coliform colonies are picked for further biochemical identification. If no typical coliform colonies are present, atypical colonies are selected for biochemical screening.

All isolates are subjected to biochemical screening using the API20E system (Analytab Products, New York).

3 RESULTS AND DISCUSSION

The percentage of recovery of *E. coli* was 95.4% (106/111) for the February 1983 survey.

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