

ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION BRANCH
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC REGION

SHELLFISH GROWING WATER SANITARY
SURVEY OF GALIANO, MAYNE, SATURNA,
NORTH PENDER AND SOUTH PENDER ISLANDS,
BRITISH COLUMBIA

Regional Program Report: 79-1

by

B.H. Kay
and
K.D. Ferguson

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ABSTRACT

A sanitary and bacteriological survey of the bivalve molluscan shellfish growing areas of Galiano, Mayne, North and South Pender, and Saturna islands was conducted between July 4 and August 4, 1978, by personnel of the Environmental Protection Service, Pacific Region. Additional work was conducted in Horton Bay and Village Bay during February 1979.

The bacteriological study was undertaken to evaluate shellfish growing water quality and assess the adequacy of one existing Schedule 1 shellfish closure. The sanitary survey was conducted concurrently to identify and evaluate sewage pollution sources discharging to the study area.

During the 1978 survey 803 marine samples and 25 freshwater and effluent samples were collected. A total of 122 marine stations were sampled, and of these five did not meet approved shellfish growing water standards.

Four new Schedule 1 shellfish closures are proposed.

RÉSUMÉ

Le Service de la protection de l'environnement (région du Pacifique) a effectué entre le 4 juillet et le 4 août 1978 un contrôle sanitaire et bactériologique des secteurs d'élevage de mollusques bivalves des îles Galiano, Mayne, North et South Pender et Saturna, et en février 1979 a réalisé une étude additionnelle dans les baies Horton et Village.

L'étude bactériologique visait à évaluer la qualité de l'eau d'élevage des coquillages de même que l'utilité d'une fermeture déjà en vigueur en vertu de l'Annexe I du règlement. Le contrôle sanitaire a été réalisé par la même occasion afin de déterminer et d'évaluer les sources de rejet d'eaux usées dans le secteur d'étude.

Lors du contrôle de 1978, 803 échantillons d'eau de mer et 25 échantillons d'eau douce et d'effluents ont été prélevés. Des 122 stations marines d'échantillonnage, cinq ne satisfaisaient pas aux normes approuvées pour l'eau d'élevage.

Quatre nouvelles fermetures en vertu de l'Annexe I sont recommandées.

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CONCLUSIONS

1. The waters and tidal foreshore of Montague Harbour, Galiano Island, in the vicinity of the Provincial Park are contaminated with fecal pollution to the extent that consumption of bivalve molluscan shellfish can constitute a health hazard. The major suspected pollution source was the discharge of raw sewage from boats using the provincial park facilities.
2. Localized contamination of clam beds in Retreat Cove, Galiano Island, was observed resulting from a small stream entering the cove. No pollution sources to the stream were positively identified although two homes in close proximity to the stream were considered potential sources of contamination.
3. The waters and tidal foreshore of the southern portion of Whalers Bay, Galiano Island, are subject to fecal contamination from the following sources:
 - (a) discharges from boats moored at the government dock;
 - (b) a stream draining a residential area; and
 - (c) discharges from four suspected septic tank overflow pipes.
4. The waters and tidal foreshore of Sturdies Bay, Galiano Island, are subject to fecal contamination from sewage discharged by the British Columbia Ferry terminal and the two vessels serving the island, the "Queen of Sidney" and "Queen of Tsawwassen".
5. Bennett Bay and Horton Bay on Mayne Island are subject to water quality deterioration resulting from the influence of contaminated Fraser River water reaching Mayne Island. This brackish layer of water is more likely to cause water quality degradation during freshet (late June to mid-July) although such conditions may prevail at other times of the year.
6. The waters at the head of Lyall Harbour, Saturna Island, exhibited varying degrees of fecal contamination, the source of which could not be identified.
7. The discharge of sewage from the Lyall Harbour ferry terminal did not adversely affect water quality in Boot Cove during the survey period.

8. Water quality deterioration resulting from heavy recreational boating anchorage is a potential problem in the Cabbage Island - Tumbo Island area. Boaters should be encouraged to use onshore toilet facilities.
9. The waters of Thieves Bay, North Pender Island, are subject to fecal contamination from boats moored at the marina.
10. The waters of Boat Nook, North Pender Island, were not adversely affected by the discharge of sewage from the Gulf Industries subdivision sewage treatment plant. The bacteriological quality of the effluent was good due to chlorination and did not constitute a significant bacteriological load to the receiving waters.
11. The waters and tidal foreshore of Egeria Bay, South Pender Island, are subject to fecal contamination from the following sources:
 - (a) the discharge of septic tank effluent from the Anchor Chain Holdings development,
 - (b) discharges from boats moored at the marina and Customs wharf, and
 - (c) discharges from boats anchored at the Beaumont Marine Park facility.
12. A portion of Hope Bay, North Pender Island, was contaminated with fecal pollution to the extent that consumption of bivalve molluscan shellfish can constitute a health hazard. The contamination was due, in part, to poor tidal flushing in the bay. The source(s) of contamination was not identified although septic tank seepage is suspected as the major contributor.

SCHEDULE I CLOSURES

The following Schedule I closures/amendments are recommended:

1. Area 17-7 (re-wording). The waters and tidal foreshore of Montague Harbour, Galiano Island, Area 17, lying inside a line drawn from the eastern tip of Gray Peninsula to Winstanley Point.
2. Area 17-26. The waters and tidal foreshore of Whalers Bay, Galiano Island, lying inside, that is, southeast of line drawn from Cain Point to the western shore of Galiano Island along a bearing of 265° (true).
3. Area 18-7. The waters and tidal foreshore of Thieves Bay, North Pender Island, Area 18.
4. Area 18-8. The waters and tidal foreshore lying inside, that is, north of a line drawn from the Skull Islet reef to Hay Point, South Pender Island, Area 18.
5. Area 18-9. The waters and tidal foreshore of Hope Bay, North Pender Island, lying inside, that is, south of a line drawn from the land end of the government dock to Auchterlonie Point on the opposite side.

1 INTRODUCTION

The Gulf Islands of the southern Strait of Georgia are one of the most popular recreational areas of the province and are used heavily by both tourists and residents of the local population centres on the Lower Mainland and Vancouver Island. The permanent population of these islands is also increasing, as shown in Table 1. Increased development on the islands

TABLE 1 POPULATION DATA FOR THE STUDY AREA 1966-1976

Island	1966	1971	1976	% increase 1966-1976
Galiano	344	445	525	53
Mayne	278	473	495 (680)	145
Saturna			185	
N. Pender	330	448	721 (805)	144
S. Pender			84	

Source: Land of the Trust Islands - Ministry of Municipal Affairs and Housing, April 1978.

does impose additional pressures on the marine environment, leading to heavier resource utilization and the potential for increased pollution levels.

The study described in this report is part of the continuing federal shellfish safety program and was conducted to evaluate bacteriological water quality in bivalve molluscan shellfish growing areas on five of the Gulf Islands: Galiano, Mayne, Saturna, N. Pender, and S. Pender. The study area is shown in Figure 1.

These islands were chosen for a variety of reasons. Firstly, neither a bacteriological nor sanitary survey of any of these islands had previously been undertaken; secondly, five Pollution Control Branch

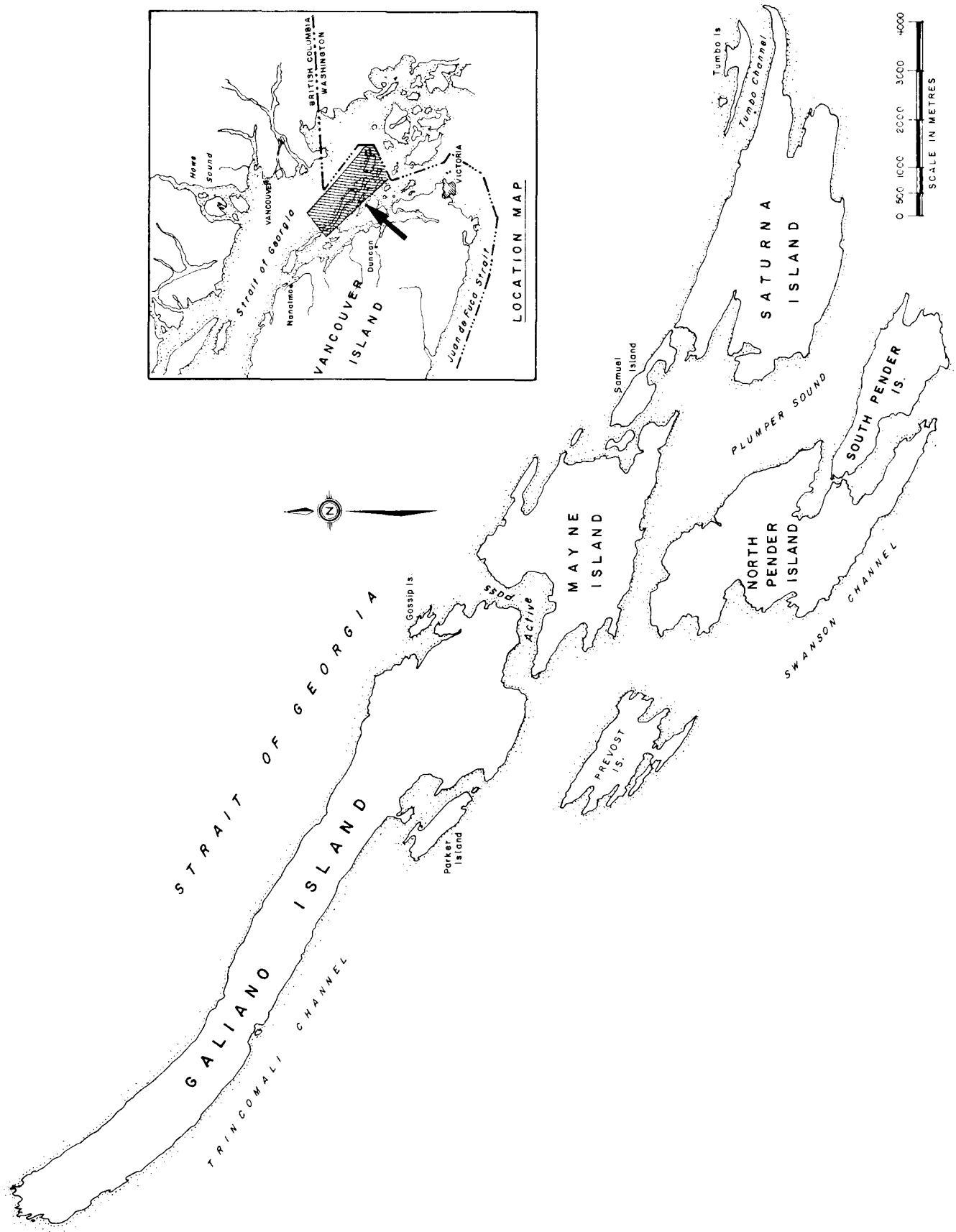


FIGURE 1 STUDY AREA

registered discharges required an evaluation to assess their impact on shellfish growing areas; and thirdly, three Lands Branch applications for commercial oyster lease purposes required reviewing.

The survey was conducted during the summer months to assess the effect of increased summer populations and boating activity on the water quality. Specifically, it was anticipated that sewage disposal facilities would be more prone to malfunction during the high usage period during the summer. Sewage contamination from pleasure boats was also considered a potential source which would be more prevalent during the summer months.

2 SAMPLE STATION LOCATIONS

Marine sample stations were located in shellfish growing areas where bacteriological contamination was anticipated due to potential pollution sources. These sources included moorage or anchorage facilities, developed areas and ferry terminals.

Freshwater and effluent samples were taken to identify specific sources of contamination and to estimate their impact on the shellfish growing waters.

Sample station locations are shown in Figures 2, 3, 4, and 5, and a detailed description of both marine and freshwater station locations is presented in Appendices I and II respectively.

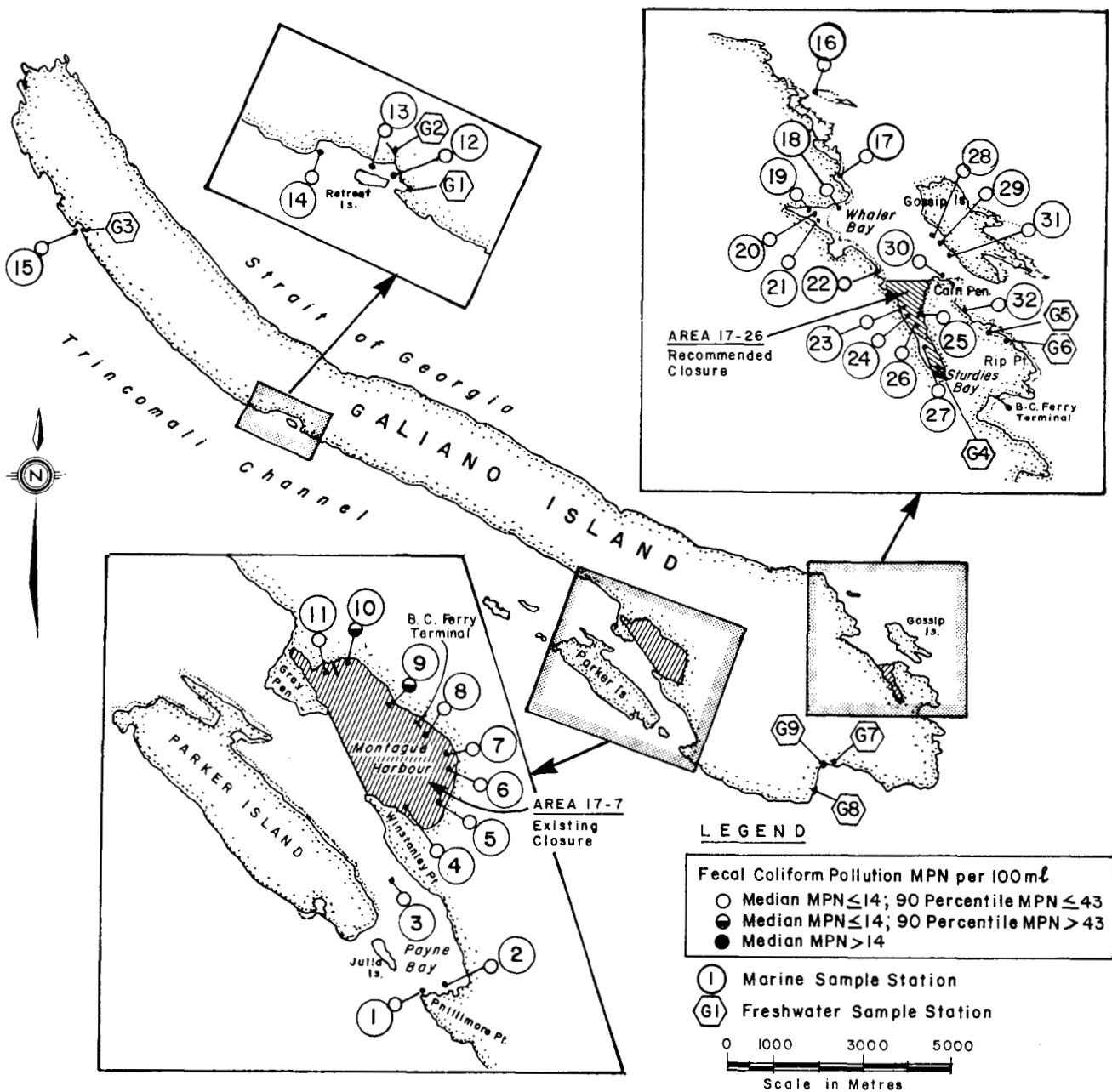


FIGURE 2 MARINE AND FRESHWATER SAMPLE STATION LOCATIONS AND RECOMMENDED SCHEDULE I CLOSURES - GALIANO ISLAND

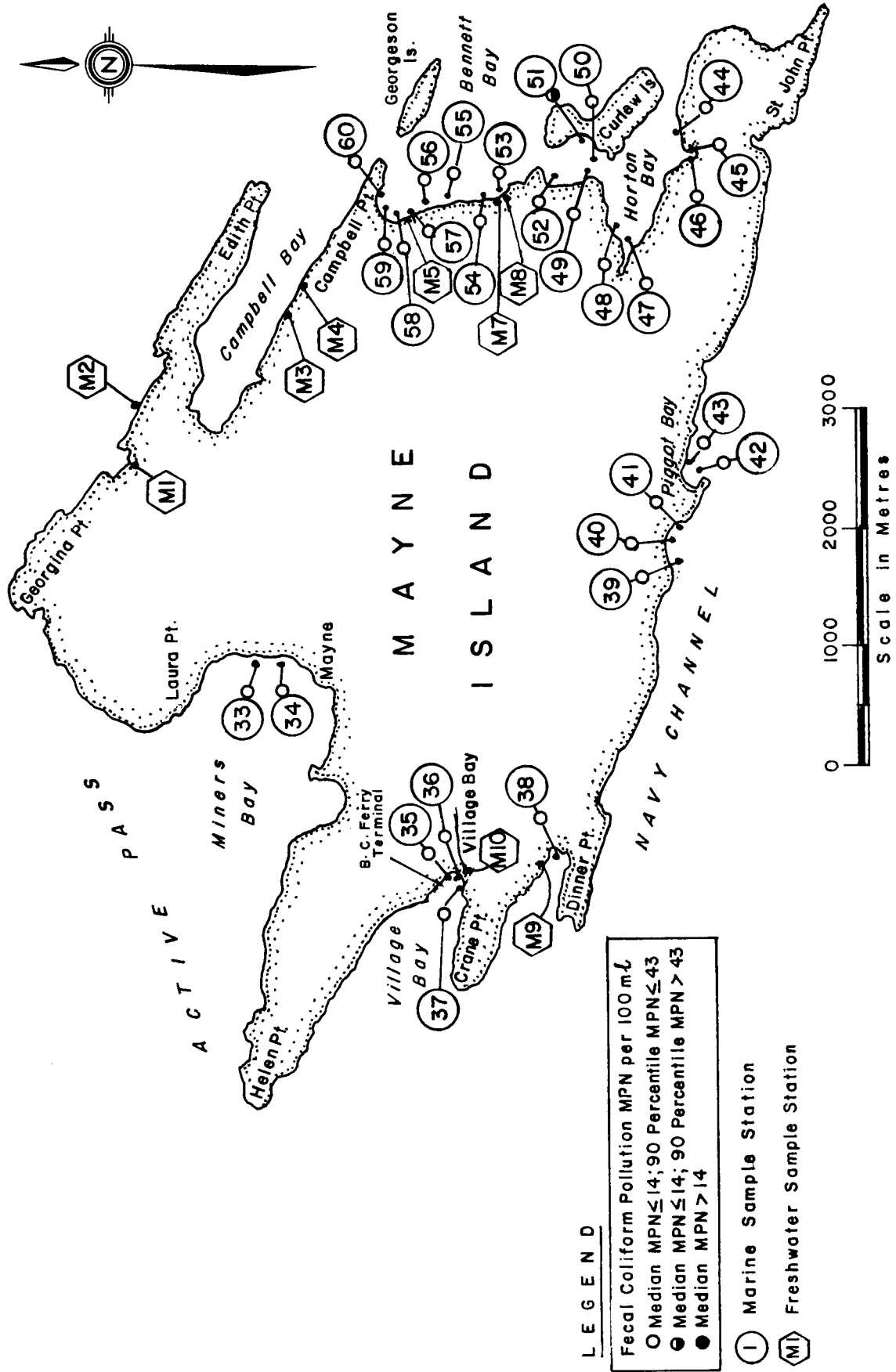


FIGURE 3 MARINE AND FRESHWATER SAMPLE STATION LOCATIONS - MAYNE ISLAND

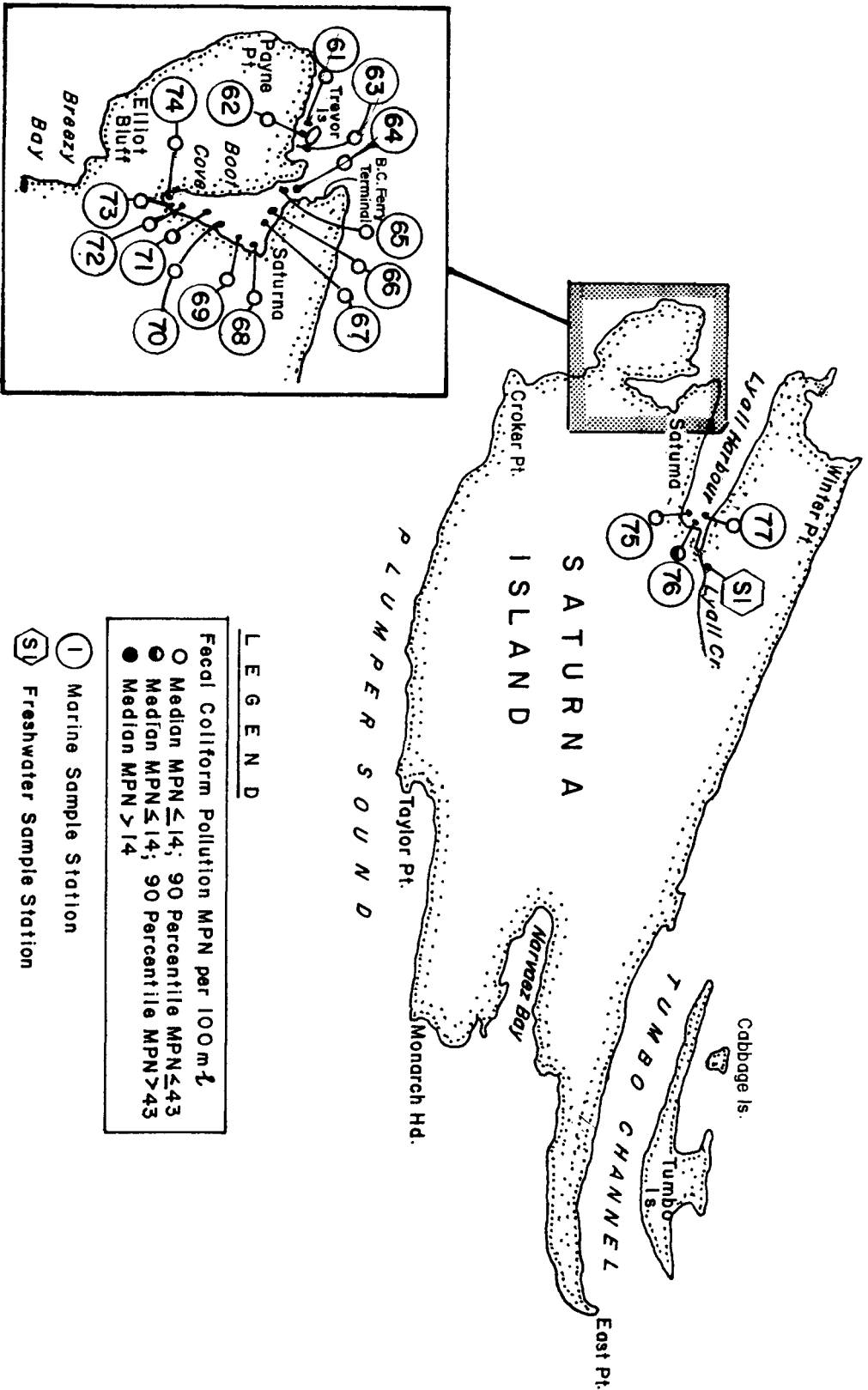


FIGURE 4 MARINE AND FRESHWATER SAMPLE STATION LOCATIONS - SATURNA ISLAND

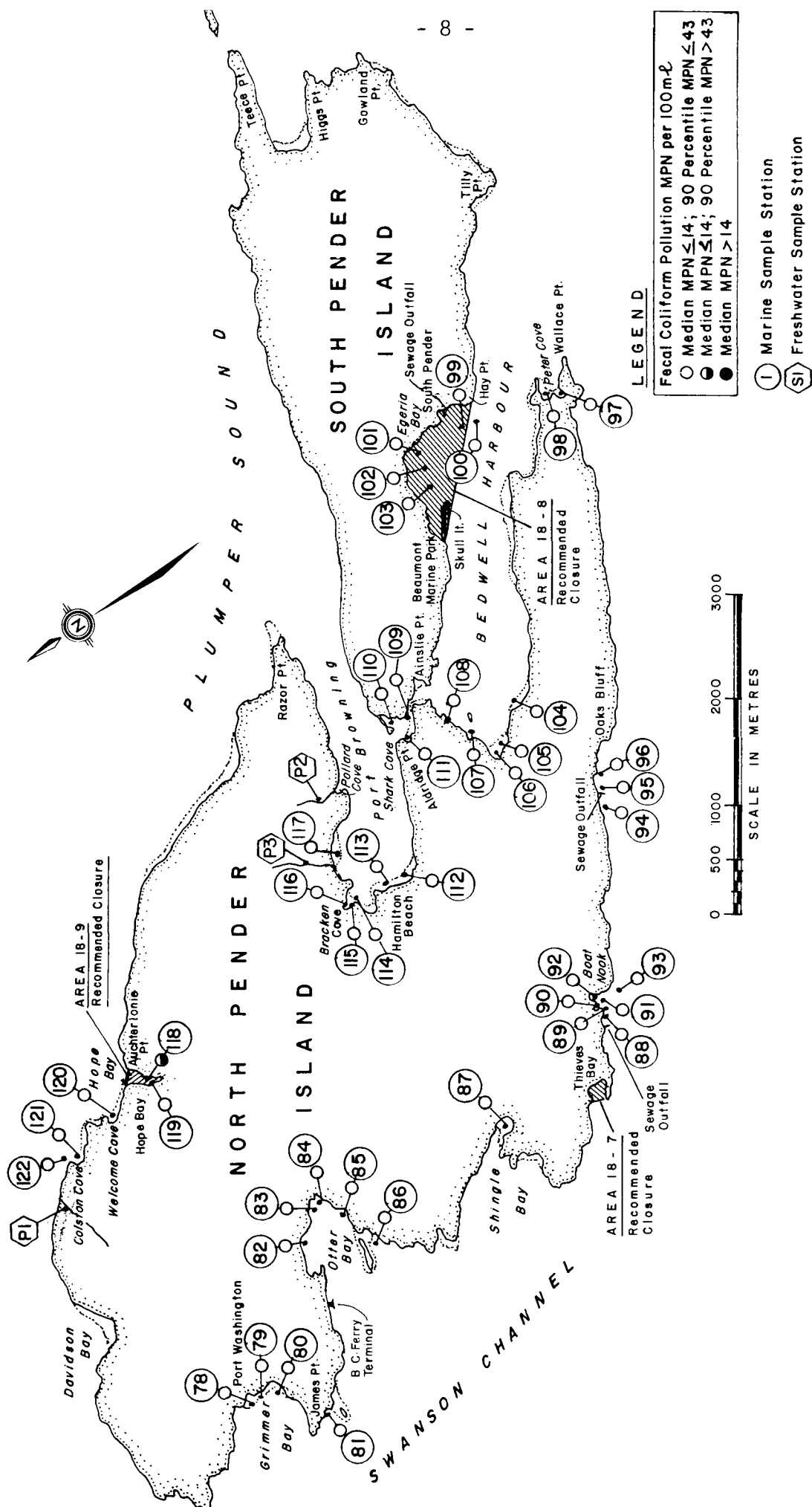


FIGURE 5 MARINE AND FRESHWATER SAMPLE STATION LOCATIONS AND RECOMMENDED SCHEDULE 1 CLOSURES - NORTH AND SOUTH PENDER ISLANDS

3 FIELD PROCEDURES AND METHODS

3.1 Bacteriological Sampling and Analyses

All marine water samples for bacteriological analyses were collected in sterile wide-mouth glass bottles, approximately 15 to 30 cm below the water surface. The water depth at collection points over shellfish beds did not exceed two meters. Samples were collected by boat or on foot. The samples were stored in coolers at temperatures not exceeding 10°C until processed. Analyses were carried out within three hours of collection in the mobile microbiology laboratory of the Environmental Protection Service, located on Mayne Island.

The fecal coliform most probable number (MPN) per 100 ml was determined using the multiple tube fermentation technique (at least three decimal dilutions of five tubes each) as described in Part 407C of the 14th edition of Standard Methods for the Examination of Water and Wastewater (1). The culture medium used was the A-1 medium, as described by Andrews and Presnell (2). This medium and the method described below were accepted by the Canadian government as the method of choice for the enumeration of fecal coliforms in shellfish growing waters in April 1977. An evaluation of the A-1 medium in the Pacific Region has been done by Kay (3) and the reader is referred to this paper for further information.

The "modified A-1" technique involves the inoculation of a series of dilutions in accordance with the multiple tube fermentation technique. Ten millilitre volumes of sample water were inoculated into five double strength tubes of A-1 medium, and 1.0 ml and 0.1 ml volumes were inoculated into five tubes each of single strength medium. The tubes were incubated at $35 \pm 0.5^{\circ}\text{C}$ in air incubators for three hours and then transferred to a water bath at $44.5 \pm 0.2^{\circ}\text{C}$ and incubated for a further 21 hours for a total of 24 ± 2 hours. All gassing tubes with growth were considered to be fecal coliform positive. The most probable number for each sample was then determined according to the manner described in Standard Methods.

All freshwater samples were collected in sterile wide-mouth glass bottles and were tested for total coliforms, fecal coliform, and

fecal streptococci, using the membrane filtration (MF) method described in Part 909 of the 14th edition of Standard Methods. Media used were m-endo LES, m-FC, and KF streptococcus agars obtained from Difco Laboratories, Detroit, Michigan, USA, for the total coliform, fecal coliform, and fecal streptococcus tests respectively. The membrane filters used were Millipore HC, obtained from Millipore Limited, Mississauga, Ontario.

3.1.1 Biochemical Identification of Bacterial Isolates. Selected gas-positive tubes from the MPN procedure were subjected to a series of biochemical tests to evaluate the selectivity of the A-1 medium for Escherichia coli. The tests included: lactose fermentation at 44.5°C, Indole production, fermentation of glucose (methyl red), production of acetyl-methyl-carbinol from glucose fermentation (Voges Proskauer), utilization of citrate as the sole carbon source, ornithine decarboxylase and motility. Methods used are described in "Identification of Enterobacteriaceae in the Clinical Laboratory" (4).

3.2 Physical and Chemical Testing Equipment and Analyses

Temperature measurements on marine and freshwater samples were made using an immersible Celcius thermometer with an accuracy of $\pm 0.5^{\circ}\text{C}$. 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. Wind speeds and direction were determined with a Telcor series 210 electronic wind speed/direction indicator, tide data used were those for Fulford Harbour (Figure 6) and rainfall data were obtained from the Climatic Data Center at Saanich (Figure 7).

All samples for chemical analysis were submitted to the Environmental Protection Service/Fisheries and Marine Service Chemistry Laboratory, Cypress Creek, West Vancouver, and analyzed according to the most recent edition of the EPS/FMS Laboratory Manual (5).

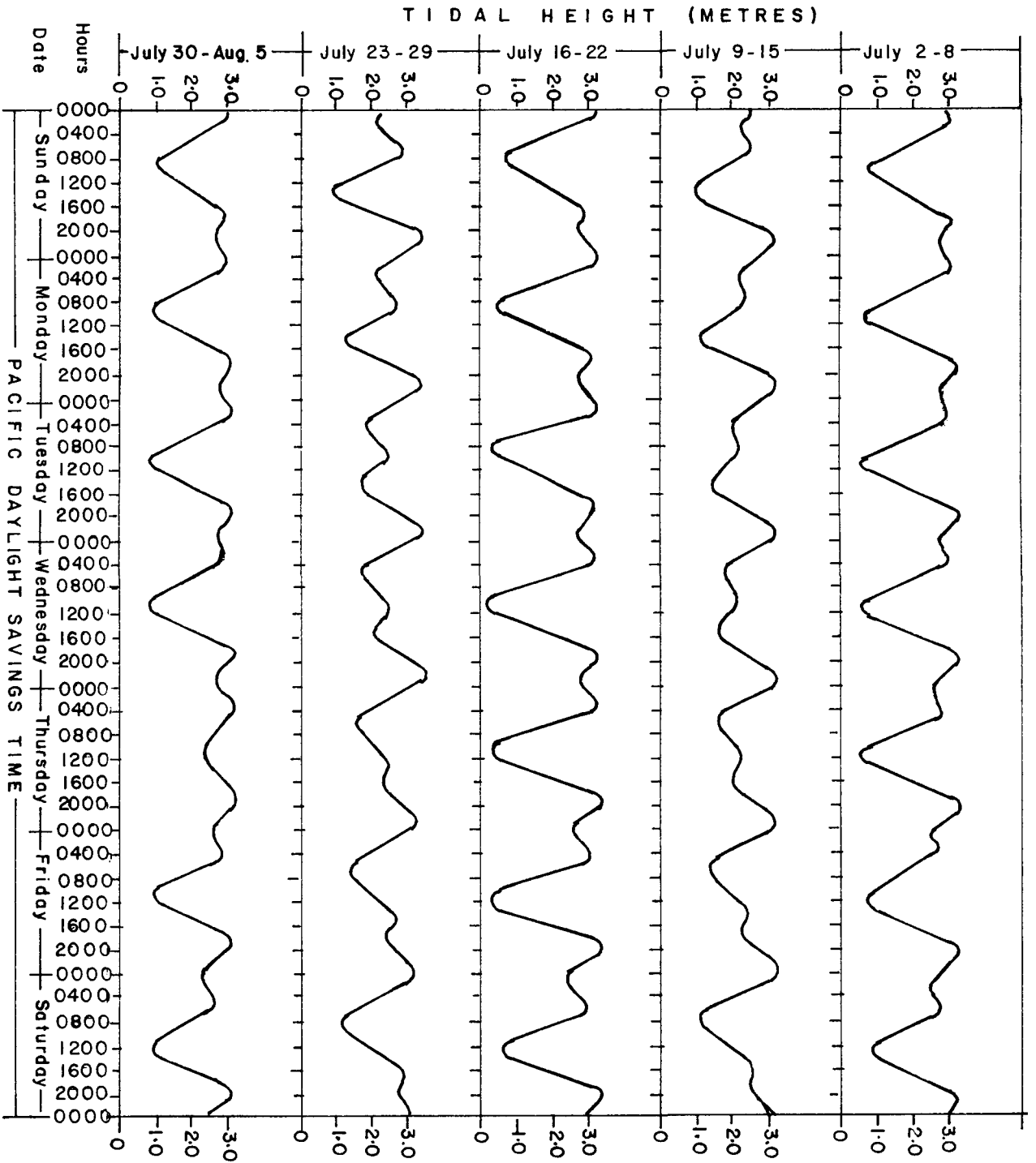


FIGURE 6

FULFORD HARBOUR, SALTSPRING ISLAND - TIDAL HEIGHT GRAPH
July 2 - August 5, 1978

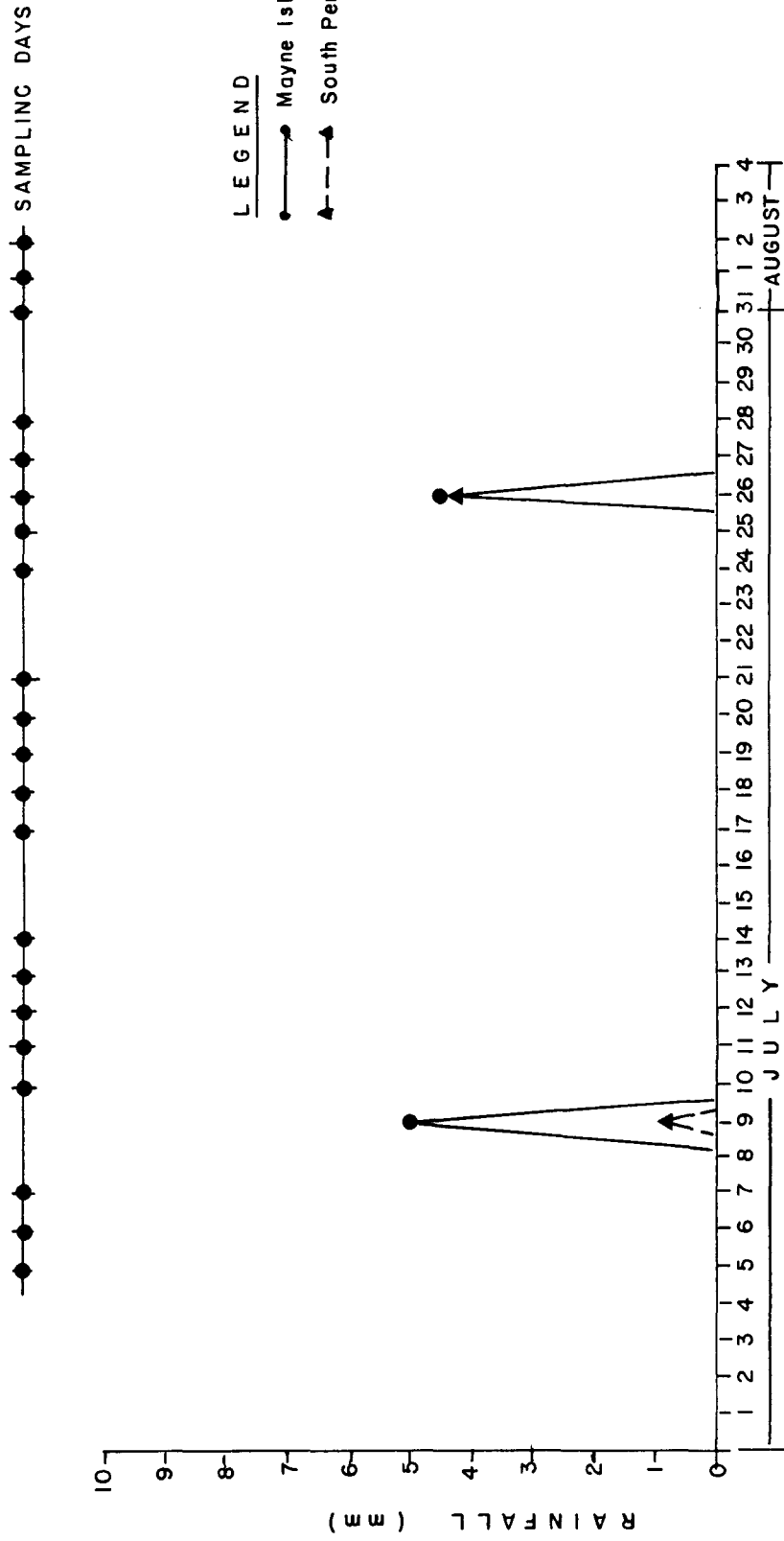


FIGURE 7 RAINFALL, July 1 - August 4, 1978 at MAYNE ISLAND AND SOUTH PENDER ISLAND

4 RESULTS AND DISCUSSION

Canadian shellfish growing waters are classified according to the following criteria:

In order that an area can be considered bacteriologically safe for the harvesting of shellfish, the fecal coliform median MPN of the water must not exceed 14 per 100 ml. Further, not more than 10 percent of the samples ordinarily exceed an MPN of 43 per 100 ml for a five tube decimal dilution test in those portions of the area most probably exposed to fecal contamination during the most unfavourable hydrographic and pollution conditions.*

Based on these criteria, only five of the 122 marine sample stations were classified as contaminated. The major causes of pollution encountered during the survey included discharges of sewage from boats, faulty septic tank disposal systems and contaminated freshwater inputs to the study areas. Five Pollution Control Branch registered sewage discharges and their respective receiving waters were also sampled.

Due to the extremely dry conditions encountered during the survey, very few streams were flowing. The total rainfall for the survey period was 10.1 mm as measured at Mayne Island, and 4.9 mm as measured at South Pender Island (Figure 7). This rainfall is approximately half that normally measured during July (6) and did not appear to result in water quality deterioration in most of the surveyed areas with the exception of Hope Bay.

Most identified pollution sources resulted in localized contamination of the receiving waters; winds and tides were not a determining factor in the extent of pollution. One notable exception was Bennett Bay which will be discussed at length in Section 4.2.6.

Membrane filtration fecal streptococci analyses were performed on all freshwater samples to determine the origin of fecal contamination observed in freshwater inputs. Geldreich and Kenner (7) have reported

*This report expresses the 10 percent limit in terms of a 90 percentile which must not exceed 43 per 100 ml.

higher fecal streptococci (FS) than fecal coliform (FC) densities 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.

Water temperature and salinity measurements taken at each marine sample station are summarized in Appendix V. Mean temperatures ranged from 12.2°C to 17.1°C and mean salinities ranged from 21.6 ppt to 29.3 ppt.

Bacteriological data for marine and freshwater stations are summarized in Tables 2 and 3 respectively. A complete location description of all stations and daily sampling results is presented in Appendices I to IV.

4.1 Galiano Island (Stations 1-32)

Thirty-two sample stations were located in selected areas around Galiano Island. There was limited or no sampling of the foreshore from Montague Harbour to Race Point, Race Point to Whalers Bay and Sturdies Bay to Georgeson Bay due to the absence of a significant shellfish resource and/or residential development.

4.1.1 Montague Harbour to Critter Bay. Montague Harbour is presently closed to shellfish harvesting under Schedule 1 closure 17-7. During the survey, sample stations 9 and 10 did not meet the approved shellfish growing water standard. There were two sources of contamination to this area which were identified. Firstly, discharges from moored boats using the Provincial Park were considered the major source of contamination. Between 10 and 40 boats were moored either at the anchor buoys or the wharf provided by the Parks Branch. There is no correlation between the number of boats and the bacteriological water quality although this is not unusual considering that discharges from boats would be intermittent and therefore not always detected. Discharges from the B.C. Ferry "Bowen Queen" was the second identified source. This vessel does not have sewage holding tanks, and although washroom doors are required to be locked prior to docking, this practice was not always followed.

No freshwater inputs to the area were evident during the sanitary survey and the remaining nine marine stations met the growing water standard.

TABLE 2 SUMMARY OF FECAL COLIFORM MPN DATA FOR MARINE STATIONS

Sample Station	Number of Samples	MPN Range	MPN/100 ml	
			Median	90 Percentile
1	6	L2 - L2	L2	L2
2	6	L2 - 2	L2	L2
3	6	L2 - L2	L2	L2
4	9	L2 - 8.3	L2	5.3
5	9	L2 - 11	L2	2.9
6	9	L2 - 7	L2	5.2
7	9	L2 - 7	4	5.2
8	9	L2 - 7	L2	2.5
9	9	L2 - G1600	L2	164.5
10	9	L2 - 350	2	50.3
11	9	L2 - 5	L2	5
12	6	L2 - 2	2	2
13	6	L2 - L2	L2	L2
14	6	L2 - 2	L2	L2
15	6	L2 - 2	L2	L2
16	6	L2 - L2	L2	L2
17	5	L2 - 7	2	6
18	5	L2 - 2	L2	L2
19	5	L2 - 2	L2	L2
20	5	L2 - 2	L2	L2
21	5	L2 - 2	L2	L2
22	5	L2 - L2	L2	L2
23	5	L2 - 17	2	10.5
24	5	L2 - 2	L2	2
25	5	L2 - 2	L2	2
26	5	L2 - 11	L2	6.5
27	5	L2 - 2	L2	L2
28	5	L2 - 13	2	7.5
29	5	L2 - L2	L2	L2
30	5	L2 - L2	L2	L2
31	4	L2 - 2	L2	L2
32	5	L2 - 7	L2	4.5
33	6	L2 - 2	L2	L2
34	6	L2 - 2	L2	2
35	6	L2 - 5	L2	3.2
36	6	L2 - 2	L2	2
37	6	L2 - 2	L2	L2
38	6	L2 - 5	L2	3.2
39	6	L2 - 2	L2	L2
40	6	L2 - 2	L2	L2
41	6	L2 - 5	L2	3.2
42	6	L2 - 8	L2	4.4
43	6	L2 - 8	L2	4.4

L - "less than"

G - "greater than"

TABLE 2 SUMMARY OF FECAL COLIFORM MPN DATA FOR MARINE STATIONS
(Continued)

Sample Station	Number of Samples	MPN Range	MPN/100 ml	
			Median	90 Percentile
44	6	L2 - 5	L2	4.4
45	8	L2 - 33	2	13
46	8	L2 - 49	3.5	28.2
47	9	L2 - 79	5	19.6
48	9	L2 - 49	5	29.2
49	9	L2 - 17	L2	8.9
50	9	L2 - 7	L2	2.5
51	9	L2 - 110	8	82.1
52	9	L2 - 22	L2	4
53	9	L2 - 17	L2	8
54	9	L2 - 33	2	6.9
55	9	L2 - 8	2	5.3
56	9	L2 - 5	L2	2.3
57	9	L2 - 49	2	9.4
58	9	L2 - 33	2	10.5
59	9	L2 - 49	L2	11.2
60	9	L2 - 17	L2	6.2
61	5	L2 - 2	L2	L2
62	5	L2 - L2	L2	L2
63	5	L2 - 5	2	3.5
64	6	L2 - 5	L2	3.2
65	6	L2 - 13	L2	6.4
66	6	L2 - 23	7.5	22.4
67	6	L2 - 8	3	6.2
68	6	L2 - 13	2	8.2
69	6	L2 - 13	2	8.2
70	6	L2 - 13	2	13
71	6	L2 - 8	L2	4.4
72	6	L2 - 17	4.5	14.6
73	6	2 - 8	3.5	8
74	6	L2 - 23	6.5	14.6
75	9	L2 - 5	L2	2.3
76	9	L2 - 130	2	51.7
77	9	L2 - 23	2	23
78	6	L2 - 8	L2	4.4
79	6	L2 - 13	2	9.4
80	9	L2 - 79	L2	37.6
81	9	L2 - 49	11	25.6
82	6	L2 - 2	L2	L2
83	6	L2 - 17	3.5	15.2
84	6	L2 - 2	L2	2
85	6	L2 - 2	2	2
86	6	L2 - 5	L2	3.2

TABLE 2 SUMMARY OF FECAL COLIFORM MPN DATA FOR MARINE STATIONS
(Continued)

Sample Station	Number of Samples	MPN Range	MPN/100 ml	
			Median	90 Percentile
87	6	L2 - 8	L2	4.4
88	6	L2 - 5	L2	3.2
89	6	L2 - L2	L2	L2
90	6	L2 - L2	L2	L2
91	6	L2 - 2	L2	L2
92	6	L2 - 2	L2	L2
93	6	L2 - L2	L2	L2
94	6	L2 - L2	L2	L2
95	6	L2 - L2	L2	L2
96	6	L2 - L2	L2	L2
97	6	L2 - 2	L2	2
98	6	L2 - 2	L2	L2
99	5	L2 - 2	L2	L2
100	5	L2 - 2	L2	L2
101	6	L2 - 14	L2	6.8
102	6	L2 - 7	L2	4
103	6	L2 - 2	L2	2
104	6	L2 - 2	L2	2
105	6	L2 - 5	2	5
106	6	L2 - 5	L2	3.2
107	6	L2 - 5	2	5
108	6	L2 - 5	L2	3.2
109	6	L2 - 5	2	3.2
110	6	L2 - 5	2	3.2
111	6	L2 - 2	L2	2
112	6	L2 - 8	L2	4.4
113	6	L2 - 11	L2	9.2
114	6	L2 - 23	8.5	17.6
115	6	L2 - 14	5	10.4
116	4	L2 - 34	8	24.8
117	6	L2 - 2	L2	2
118	9	L2 - 920	5	103.7
119	6	2 - 79	8	41.8
120	7	L2 - 2	L2	L2
121	9	L2 - 130	L2	24.7
122	9	L2 - 49	L2	8.5

TABLE 3 SUMMARY OF BACTERIOLOGICAL MEMBRANE FILTRATION DATA FOR FRESHWATER SAMPLES

Sample Station	Total Coliform/100 ml		Fecal Coliform/100 ml		Fecal Streptococci/100 ml		FC:FS Ratio
	Range	Mean	Range	Mean	Range	Mean	
G-1	L10-10	L10	L10-10	L10	L10-20	L20	-
G-2	640-2640	1330	240-2460	1085	590-820	743.3	1.46
G-3	620-870	745	L10-L10	L10	L10-20	L20	-
G-4	6800	-	7200	-	2100	-	3.43
G-5	10 000-10 400	10 200	4500-18 000	11 250	600-10 000	5350	2.1
G-6	490-9500	4995	L10-220	220	L10-20	L20	-
G-7	10 200	-	20-G500	-	570-G800	-	-
G-8	400-4200	4066	590-1900	1263	110-160	130	9.7
G-9	770-3000	1885	340-1700	1020	20-3300	1660	0.6
M-1	5400	-	70	-	40	-	1.75
M-2	1100	-	110	-	L10	-	-
M-3	18 700	-	300	-	140	-	2.1
M-4	3800	-	180	-	L10	-	-
M-5	460	-	40	-	L10	-	-
M-6	3300	-	70	-	L20	-	-
M-7	10	-	L10	-	L10	-	-
M-8	920	-	220	-	40	-	5.5
M-9	590-2200	1296.6	420-1900	1053.3	50-200	110	9.6
M-10	6200-7900	7200	1800-3200	2466.6	1160-6300	3100	0.8
M-11	3700-4100	3900	40-170	105	20-55	37.5	2.8
M-12	3000	-	1000	-	50	-	20
S-1	20-30	25	6-L10	L10	L10-30	L30	-
P-1	2900-25 000	11 166.6	160-2700	1440	2300-19 000	9400	0.15
P-2	5800	-	22	-	16 000	-	0.0001
P-3	430-4500	1900	120-400	263.3	640-55 000	18 820	0.01

number in brackets denotes number of samples
L = denotes "less than"; G = denotes "greater than"

Water quality at Retreat Cove (stations 12, 13, and 14) was acceptable although one stream entering the Cove was contaminated and may result in contamination of the clam resource in the immediate vicinity. This stream exhibited a fecal coliform count of 1085/100 ml and an FC:FS ratio of 1.46. A second stream (G1) with minimal flow entered the Cove 20 metres west of the government dock and did not exhibit significant fecal coliform levels.

A sanitary survey of the area revealed two houses in close proximity to G2 both of which were unconfirmed sources of contamination. Four upstream samples exhibited low fecal coliform levels and did not assist in locating the source of contamination.

Sample station 15, located in Critter Bay met the standard and there were no pollution sources revealed during the sanitary survey. A small stream (G3) entering the Bay had fecal coliform levels of less than 10/100 ml.

4.1.2 Whalers Bay. Seventeen sample stations were located in Whalers Bay and all met the shellfish growing water standard. Three streams were sampled during the course of the sanitary survey. G4, located in the southern end of the Bay, yielded a fecal coliform count of 7200/100 ml. This stream drains a residential area and may be contaminated by septic tank seepage although the flow at the time of sampling was very low and as a result no significant impairment of receiving water quality was noted.

Two other freshwater inputs (G5 and G6) located between Cain Point and Rip Point were also sampled. These were, in fact, seepage pools and had little impact on the receiving waters due to their low flows. G5 exhibited a mean fecal coliform count of 11 250/100 ml; G6 had a single count of 22/100 ml. The presence of fecal coliforms in G5 suggested that, even during the exceptional dry weather observed during this survey, fecal contamination was still detectable in groundwater seepage and increased precipitation during the fall and winter months may result in some water quality deterioration.

Other sources of contamination to Whalers Bay included discharges from boats moored at the government dock and discharges from four suspected septic tank overflow pipes which were noted during the sanitary survey but which were not discharging at the time.

4.1.3 Sturdies Bay. No sample stations were located in Sturdies Bay due to the absence of a significant resource. Some mussels (Mytilus edulis) were present along the southern shoreline, well removed from identified sources of contamination.

Sewage is discharged at the B.C. Ferry dock from a "package" treatment plant with an outfall located directly beneath the restrooms in approximately six metres of water. Samples taken in the vicinity of the outfall and on shore were positive for fecal coliforms, the highest MPN being 33/100 ml.

The only other identified pollution source to Sturdies Bay was the discharge of sewage from B.C. Ferry vessels while loading and unloading.

4.1.4 Georgeson Bay. The waters of Georgeson Bay are well flushed due to the tidal action in Active Pass and it is likely that any contamination entering these waters would be well dispersed. As a result no marine sampling was done in the bay.

Two streams entering Georgeson Bay were sampled. The first (G7) was a groundwater seepage pool and was not significantly contaminated. The second (G8) was a very small stream with an average flow of .0003 m³/sec. The mean fecal coliform count of 1263/100 ml indicated some septic seepage may be entering this stream although the low flow would not result in any serious water quality impairment.

4.2 Mayne Island

Marine stations 33-60 were located around Mayne Island to assess the shellfish growing water quality. With the exception of station 51, all stations met the standard.

4.2.1 Miners Bay. Miners Bay on Active Pass has a small clam resource which is utilized by visitors and residents. Two sample stations located north of the government dock did not exhibit any evidence of fecal contamination. No streams were observed entering the water in this area although a dry stream bed near station 13 passed through a grazing area for horses, and may be a source of contamination during heavy periods of rainfall. A septic tank overflow pipe was also noted however it was not discharging at the time.

The dock area is subject to fecal contamination from moored boats although there is limited dock space and anchorage available to the boating public.

The Springwater Lodge was identified as a source of fecal contamination to the immediate receiving waters. There was olfactory evidence of a faulty septic tank, and seepage was observed on the beach below the tank, which is located near the embankment. A sample of seepage taken August 4 yielded a fecal coliform MPN of greater than 1600/100 ml. Dishwater was also noted being discharged to the beach at frequent intervals.

Two septic tank overflow pipes were observed near the most westerly residence on the south shore of Miners Bay. There was no discharge from either of these pipes during the survey.

A small stream (M11) entering at the south shore of Miners Bay was not contaminated and there was no evidence of septic seepage from the homes in close proximity to the stream bed.

4.2.2 Village Bay. Village Bay is the Mayne Island terminal for the B.C. Ferry system. Three marine sample stations were located near the tidal mudflats south of the ferry terminal and all met the growing water standard.

The two major sources of contamination to the Bay were sewage discharges from the B.C. Ferries while docked at the terminal, and contaminated runoff water from the stream entering near the head of the bay (M10).

Contamination from the first source was not documented as samples were not taken while ferries were docked, although it was noted that vessel washroom doors were not normally locked at this terminal.

The second source of contamination, M10, did not impair receiving water quality although both mean fecal coliform and fecal streptococci counts were elevated (2466/100 ml and 3100/100 ml, respectively). Additional sampling of M10 and stations 35, 36 and 37 was conducted in February 1979, to assess the water quality during higher rainfall periods. The marine stations at this time were well within acceptable standards for shellfish growing waters and the fecal coliform and fecal streptococci levels in the stream were considerably lower than those obtained in July (288/100 ml and 6.5/100 ml respectively). The contamination in M10 noted during the summer sampling period was attributed primarily to animal pollution, as the stream drains a small sheep farm as well as a residential area.

4.2.3 Dinner Bay. Station 38 was located at the head of Dinner Bay and was of acceptable water quality. Only one freshwater input was noted (M9) however, the flow was insignificant. Fecal coliform levels ranged from 420/100 ml to 1900/100 ml suggesting the presence of some septic seepage although no houses were in the vicinity of the stream.

4.2.4 Conconi Reef - Piggot Bay. Stations 39-42 were of acceptable water quality and no sources of contamination to the foreshore were noted during the survey. This area is a popular recreational clam digging area although local reports indicate the resource is being rapidly depleted due to over harvesting.

4.2.5 Horton Bay. Stations 44-51 were positioned in Horton Bay to assess the growing water quality in this area. Only station 51 did not meet the standard, exceeding at the 90 percentile level (82.1/100 ml).

This bay supports both an oyster and clam resource. A foreshore lease for oyster culture is located east of the government wharf, and station 44 was placed over the lease area. No pollution

sources were evident along the foreshore and the rapid tidal action in Robson Channel would aid in the dispersal and dilution of pollutants entering the area.

The government dock is a potential source of contamination due to discharges from moored boats and fecal contamination was detected at stations 45 and 46, although both stations continued to meet the standard. The elevated fecal levels were coincident with reduced salinities indicating a significant freshwater source was responsible for the contamination. This possibility is further discussed in Section 4.2.6. Boat discharges did not appear to be a significant source of contamination partly due to the limited moorage space available.

A dry stream bed was noted at the head of the small bay by the wharf and may be a significant source of contamination during high rainfall periods. The stream drains a small farm and uplands area. Chickens have access to the stream and would probably contribute substantially to high fecal coliform levels, particularly following a storm event.

A floating home anchored nearby reportedly discharges sewage directly to the water although this would be an infrequent event as the home is not permanently occupied.

An application for a foreshore lease at the western end of Horton Bay for the purpose of oyster culture was being processed at the time of writing and an investigation of the area indicated the water was of acceptable growing water quality (stations 47 and 48). Elevated fecal coliform levels were noted on July 18, 19 and 20, particularly at station 48. The source of contamination was not confirmed although the high coliform levels occurred coincident with reduced salinities (see Section 4.2.6.)

A major drainage culvert discharges to this area of Horton Bay. The culvert receives drainage from a large uplands area although upstream investigation did not reveal any significant sources of contamination. The stream was not flowing during the summer. However, additional marine and freshwater sampling of the lease area and culvert discharge was conducted during February 1979, when the stream was flowing. During this

sampling period the culvert discharge had relatively low fecal coliform and fecal streptococci counts (52.3/100 ml and 69/100 ml respectively) and all marine stations met the shellfish growing water standard.

A potential source of contamination to this lease area is the discharge of sewage from anchored boats. The bay is a popular anchorage area for the summer boaters due to the protection afforded by Curlew Island. Up to seven boats were observed anchored in the bay during weekdays and much greater activity would be expected during the weekends.

Sample station 51, located in close proximity to the private dock on Curlew Island, was the only station classified as contaminated. Once again the elevated coliform levels occurred coincident with reduced salinities. Tidal flushing in this small bay appeared to be minimal and it was expected bacterial contamination introduced into this bay would not disperse as rapidly as in other areas of Horton Bay. There were no onshore sources of pollution identified on Curlew Island and therefore the contaminated freshwater source was considered to be the sole pollutant.

Curlew Island is a privately owned farm, and may contribute fecal contamination to Horton Bay through rain-induced runoff.

4.2.6 Bennett Bay. Water quality in Bennett Bay was acceptable during the survey although all stations (53-60) with the exception of 55 and 56 demonstrated high fecal coliform levels on July 19, 1978, and, to a lesser extent on July 20. The high counts were coincident with the reduced salinity levels previously referred to. At most stations, salinities ranged from 25-29 ppt; however on July 19 and 20 salinities ranged from 18-20 ppt. Sampling was performed just as the tide was beginning to ebb suggesting the contamination had been introduced during the flood tide and had remained in the bay during high slack.

There were no local sources of freshwater to either Bennett Bay or Horton Bay which could account for these reduced salinities. Although there is considerable groundwater seepage along the Bennett Bay foreshore, no fecal contamination was detected in any of the seepage

samples (M5-M8) suggesting the contamination was not from this source. Sewage disposal in this area is effected by septic tank systems and no malfunctions were observed during the sanitary survey. The septic tank at the Mayne Inn is reportedly emptied once each month during the peak summer season and effluent is disposed of by Gulf Island septic tank service on Saltspring Island.

The only major freshwater discharge at the time of this survey which could have exerted such an influence on the salinity levels and resulted in the increased coliform levels was the Fraser River. Local residents have reported that Fraser River water does enter Bennett Bay and Horton Bay during certain times of the year and under certain hydrographic and weather conditions. During freshet (late June to mid-July) the river flow can exceed $11\,328\text{ m}^3/\text{sec}$ and can cover a considerable area of Georgia Strait with a brackish layer varying between 1 to 10 metres deep (8). Because of the absence of interior turbulence at the Fraser estuary, this two-layered system continues into the Strait of Georgia without breaking down until it enters the turbulent, vertically homogeneous waters of the San Juan Islands (9). The influence of the river is further suggested by the reduced salinity levels recorded at the Active Pass light station independent of our survey (L. Giovando, personal communication). Salinities of 13 ppt were recorded on July 18 and 19, while levels a week previous had ranged from 24-27 ppt.

A series of aerial photographs (10) taken on June 1, 1950, indicated Fraser River water moved southward in the Strait of Georgia, reaching the northern shoreline of Mayne Island approximately five hours after the start of a large ebb. The mixture was estimated to be 1:1 freshwater to seawater. During the flood tide the plume changed its course to northeast and clearer seawater appeared to have flowed northward past Point Roberts. This situation repeated itself during a second aerial survey taken on June 10, 1950.

Further evidence of the extent of the Fraser River influence comes from photographs taken during a large flood tide in June 1948. At this time, a 1:1 freshwater-seawater mixture was seen in Bennett Bay approximately half way through the flood tide. At the time of this survey the discharge volume from the river was very high ($12\,740\text{ m}^3/\text{sec}$).

Further studies have shown that "clouds" of brackish water can break away from the main plume of the river and could conceivably reach the Bennett Bay area, particularly during freshet (L. Giovando, personal communication). The travel time from the Fraser estuary to Mayne Island would be dependent primarily on wind and may be as little as five hours or as much as five days. Once reaching Bennett Bay, the brackish water may remain for varying lengths of time; in this case the freshwater influence was noted for at least two days.

Fecal coliform levels in the Fraser River generally had a fecal coliform geometric mean of 1000/100 ml or less at the majority of estuary sampling stations during 1977 (L. Churchland, personal communication). The mean fecal coliform MPN observed at all stations in Bennett Bay and Horton Bay on July 19 was 29/100 ml; the mean salinity was 18.9 ppt. If one assumes an average salinity of 28 ppt in the surface waters of Bennett Bay and Horton Bay, the salinity values obtained on July 19 would indicate a dilution of Fraser River water in the order of 65%. Using the fecal coliform geometric mean value of 1000/100 ml, the fecal coliform levels in Bennett Bay due to dilution alone could theoretically be approximately 350/100 ml. If one assumes a further 90% reduction in fecal coliform levels resulting from bacterial die-off, it is possible to achieve levels of 35/100 ml in Bennett Bay. The travel time of this freshwater "slug" from the Fraser estuary to Mayne Island is not known, and it is therefore difficult to predict the die-off rate, since this rate is dependent upon, among other factors, the length of exposure to seawater. Carlucci and Pramer (11) have shown that E. coli survival in 75% seawater is 22.5% after 48 hours suggesting that fecal coliform levels in the order of those obtained at Bennett Bay could be observed at least 48 hours after discharge from the Fraser River.

4.2.7 Georgina Point to Campbell Point. Marine sampling was not included as part of the survey in this area due to the limited resource. There were no significant sources of contamination identified along this coastline, with almost all freshwater inputs being low flow groundwater seepage.

Two septic tank overflow pipes were noted at either end of the residential development on the southern shore of Campbell Bay although no discharges were observed.

It is conceivable that fecal contamination may occur in this area as a result of the Fraser River influence, as described in previous section.

4.3 Samuel Island

No sample stations were placed in Irish Bay due to the absence of significant sources of onshore pollution. There is limited development on the island and the only source of contamination to Irish Bay is the discharge of sewage from anchored boats.

4.4 Saturna Island (Stations 61-77)

Due to limited residential development and/or the limited shellfish resource, only Boot Cove and Lyall Harbour were sampled. All sample stations, with the exception of station 76, were of acceptable growing water quality.

4.4.1 Boot Cove - Trevor Islet. Bacteriological results for sample stations 61-74 did not reveal any significant sources of fecal pollution. The sanitary survey of the area did not identify any direct discharges to Boot Cove although three stream beds were noted which may contribute fecal pollution during high rainfall periods. One stream in the northwest corner of the cove drains part of a residential area and discharges near an oyster lease area.

Samples taken in the proposed oyster lease area at Trevor Islet did not indicate any effects from the Lyall Harbour B.C. Ferry Corporation sewage treatment plant discharge. Two samples taken of the STP effluent gave fecal coliform counts of 14 000/100 ml and 14 200/100 ml. Using theoretical dilution formulas (Rawn-Palmer) the dilution at the oyster lease site will usually bring fecal coliform levels below 14/100 ml.

4.4.2 Lyall Harbour. The only other potential pollution source to Lyall Harbour, in addition to the B.C. Ferry discharge, was Lyall Creek, and during this survey fecal coliforms levels were less than 10/100 ml on two sampling occasions. Unacceptable fecal coliform levels were detected at station 76 and elevated levels were noted at station 77. The fecal coliform MPN of 130/100 ml experienced on July 18 was coincident with a fecal coliform count

of less than 10/100 ml in Lyall Creek, suggesting the source of contamination to be located elsewhere. The bacteria counts did not appear to coincide with either tidal conditions or changing salinities.

Sediment samples taken in the dry (tidal) portions of the Lyall Creek stream bed yielded fecal coliform MPN's of 135/100 ml and 850/100 ml indicating that, at times, fecal contamination of Lyall Creek does occur and may cause water quality impairment during high rainfall periods. The high fecal coliform levels obtained at stations 76 and 77 may have been due to resuspension of contaminated sediments as a result of tidal action or turbulence.

The remainder of Saturna Island was not sampled and the sanitary survey of the area did not reveal any sources of fecal contamination.

4.5 Cabbage and Tumbo Islands

Cabbage Island is a popular recreational moorage area and has recently been purchased by the Provincial Government for development as a marine park. Clams have historically been found in abundance in this area but more recently over-exploitation has resulted in considerable depletion of the resource.

A sampling program was not instituted in this area due to time constraints, although four samples were taken on July 15 and all had fecal coliform MPN's of less than 2/100 ml. The only source of contamination to this area is the discharge of sewage from anchored boats. The area is heavily utilized for anchorage during the summer months and the potential exists for considerable bacterial contamination from boats. A pit privy facility is available for boaters on Cabbage Island.

4.6 North and South Pender Islands (Stations 78-122)

Thirty-five sample stations were positioned around the North and South Pender Island foreshore and of these, only station 118 did not meet the shellfish growing water standard.

4.6.1 Grimmer Bay (Stations 78-81). Water quality in Grimmer Bay was acceptable for shellfish harvesting although intermittent fecal contamination was noted at station 80. There were no freshwater inputs to the bay during

the survey although one dry stream bed which drained a residential area was noted. No sewage disposal problems were discovered during the sanitary survey.

4.6.2 Otter Bay (Stations 82-86). All stations in Otter Bay met the shellfish growing water standard and the sanitary survey did not reveal any sewage disposal problems or discrete discharges.

Sewage discharges may occur from moored boats at the Otter Bay Marina in Hyashi Cove although station 82, located at the small beach directly east of the marina, did not exhibit any fecal contamination.

Discharges of sewage from the Bowen Queen and the Queen of Sidney may impair water quality in the vicinity of the ferry terminal if washrooms remain open during docking. No sample stations were established in the vicinity of the terminal since the area is under a Schedule I 400 foot wharf closure.

4.6.3 Shingle Bay to Wallace Point (Stations 87-96). A single sample station established in Shingle Bay indicated that there was no fecal contamination of these marine waters. The sanitary survey did not reveal any sewage disposal problems. There was limited residential development in this bay.

Thieves Bay was not sampled since most of the bay is used as a commercial marina. Potential sewage contamination from boat discharges precludes this area from shellfish harvesting.

Boat Nook was extensively sampled to assess the effect of the Gulf Industries subdivision sewage treatment plant discharge on the foreshore areas. All stations sampled exhibited median MPN values of less than 2/100 ml and no fecal contamination was observed in any of the samples. The effluent from this treatment plant is chlorinated and samples taken on two occasions yielded fecal coliform levels of less than 10/100 ml and less than 100/100 ml. These data are comparable with effluent samples collected by the Pollution Control Branch over a period of years. The average fecal coliform MPN for 11 samples taken by the PCB was 346/100 ml, with an average flow of 23.1 m³/day (8713 Igpd) and an average chlorine residual of 0.6 mg/l. Limited receiving water sampling conducted by the PCB on two occasions did not indicate the presence of fecal contamination.

A dye study was attempted at this outfall location however due to the extremely low volume discharge combined with a high tide, no dye was observed over a period of several hours.

Current movement in Swanson Channel was observed to be fairly rapid (approximately 3 knots) which would assist in the dispersion of sewage discharged at this site.

A sewage treatment plant discharge from the Magic Lake Estates subdivision was also monitored and both the receiving waters and effluent yielded low or negative fecal coliform results. This outfall is not located in a shellfish growing area.

4.6.4 Bedwell Harbour (Stations 99-108). Sampling in Bedwell Harbour was limited to Peter Cove, Egeria Bay (Customs float) and the northwest end of the harbour.

All sample stations were well within the acceptable fecal coliform standards for shellfish harvesting and no faulty sewage disposal problems were observed at private dwellings examined during the sanitary survey.

Three major sources of sewage contamination were noted in Egeria Bay. Firstly, the discharge of septic tank effluent from the Anchor Chain Holding development may impair water quality to unacceptable levels. A single sample taken of the effluent yielded a fecal coliform count of 510 000/100 ml. Secondly, discharges from boats moored at the marina and/or vessels clearing customs may impair water quality. Thirdly, discharges from anchored boats at the Beamont Marine Park facility may also cause water quality deterioration. Since discharges from boats are intermittent, it is not surprising that fecal contamination was not observed in any of the samples taken in the marine park anchorage area. There were no samples taken in the vicinity of the customs dock or marina as this area is under a Schedule I 400 foot wharf closure. However, there is a significant potential for contamination in this area due to the considerable moorage available at the marina and the large number of boats cleared through customs. During the 1978 summer season, 8164 vessels representing 27 552 persons entered Canada at this point of entry.

4.6.5 Port Browning (Stations 109-117). Shark Cove is a popular clam harvesting area located between North and South Pender Islands. The absence of shore-based sources of sewage contamination, and the good tidal flushing in this area, were two factors contributing to the excellent water quality observed at stations 109, 110, and 111.

Sample stations at the head of Port Browning were also of acceptable water quality although there was evidence of low level fecal contamination in some of the samples, notably at station 114 in Bracken Cove. Two freshwater inputs and a marina were the only potential sources of contamination identified during the sanitary survey. When flowing, both of these streams would pass through farm areas and may be significant bacterial pollution sources following heavy rainfall.

A stream entering near station 117 (P3) was sampled on three occasions and yielded an average fecal coliform value of 263/100 ml. The average fecal streptococci levels was 18 820 indicating most of the bacterial contamination was of animal origin (FC:FS ratio = 0.01). The stream passed through a 170 acre ranch where 11 sheep and several ducks were noted. No water quality impairment was evident at station 117 although once again heavy rainfall conditions may result in significant contamination of the receiving waters in the immediate area.

Marine sample stations were not located in Pollard Cove and a stream (P2) entering the Cove yielded low fecal coliform results.

4.6.6 Hope Bay to Colston Cove (Stations 118-122). All sample stations, with the exception of 118, met the growing water standard, although stations 119, 121 and 122 all exhibited intermittent fecal contamination.

The small bay landward of Auchterlonie Point may be susceptible to contamination from two freshwater inputs which were not flowing during the survey. Tidal flushing in this bay is very poor and as a result contamination entering the bay would tend to remain there for some time. The sanitary survey did not reveal any faulty sewage disposal systems in this area.

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APPENDIX I

MARINE SAMPLE STATION LOCATIONS

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Sample Station	Latitude (North)	Longitude (West)	Description
1	48° 52.37'	123° 23.38'	Payne Bay, Galiano Island off cedar shake house with boat dock.
2	48° 52.37'	123° 23.23'	Off sand shore 78 m east of station 1.
3	47° 52.87'	123° 23.72'	Mid channel under power lines at entrance to Montague Harbour.
4	48° 53.13'	123° 23.47'	South Montague Harbour off rock outcropping
5	48° 53.17'	123° 23.35'	South Montague Harbour at anchor buoy off yellow house.
6	48° 53.25'	123° 23.28'	East Montague Harbour off private white dock.
7	48° 53.43'	123° 23.17'	East Montague Harbour off house with dock, boat house and Canadian flag.
8	48° 53.53'	123° 23.27'	East Montague Harbour off green private dock.
9	48° 53.62'	123° 23.60'	North Montague Harbour off barn-shaped house with private dock and orange buoy.
10	48° 53.88'	123° 24.00'	Northwest Montague Harbour moorage area north of Dock off "No Fire" sign. Northwest Montague Harbour south of dock off "No Camping" sign.
13	48° 56.38'	123° 30.10'	East Retreat Cove off green house with red steps.
14	48° 56.43'	123° 30.50'	Mid channel between Galiano and Retreat islands.
15	48° 59.04'	123° 34.08'	Northwest Retreat Cove off white house with union jack.
16	48° 53.97'	123° 20.10'	Critter Bay off fuschia house with white dock.
17	48° 53.83'	123° 20.18'	Midway between Lions Islets and Galiano Island.
18	48° 53.68'	123° 20.05'	Sandy Bay north of Twiss Point.
19	48° 53.55'	123° 20.15'	South of Twiss Point House with stormdrain and Canadian flag.
20	48° 53.50'	123° 20.17	North side of bay south of Twiss Point off white house with yellow trim and union jack.
21	48° 53.45'	123° 20.15	Center of bay south of Twiss point between white house and pink house. South side of Bay south of Twiss point 30.1 m off shore between pink house and floats.

APPENDIX I

MARINE SAMPLE STATION LOCATIONS (Continued)

Sample Station	Latitude (North)	Longitude (West)	Description
22	48° 53.23'	123° 19.78'	West Cains Bay off new wood house with shake roof and private dock.
23	48° 53.13'	123° 19.53'	North Cains Bay off large yellow house.
24	48° 53.12'	123° 19.58'	North Cains Bay mid channel between yellow house and white house.
25	48° 53.10'	123° 19.63'	East Cains Bay off white house with red roof and dock.
26	48° 53.00'	123° 19.45'	Cains Bay mid channel off government wharf.
27	48° 52.88'	123° 19.38'	South Cains Bay mid channel off house with green grid.
28	48° 53.43'	123° 19.40'	West Gossip Island Bay off yellow and brown house.
29	48° 53.35'	123° 19.33'	West Gossip Island off blue and white house. South of 28.
30	48° 53.25'	123° 19.37'	Cain point off new plywood frame house.
31	48° 53.30'	123° 19.20'	Gossip Island off green house with dock and Canadian flag.
32	48° 53.10'	123° 19.17'	East channel between Galiano and Gossip islands large new home on Galiano.
33	48° 51.57'	123° 17.83'	Northeast Miners Bay off brown boat house.
34	48° 51.55'	123° 17.78'	Northeast Miners Bay off brown house with white trim.
35	48° 50.60'	123° 19.28'	Northeast Village Bay off brown house with long stairs southeast of ferry terminal.
36	48° 50.57'	123° 19.30'	East Village Bay mid channel between station 35 and wood house at roadway to beach.
37	48° 50.48'	123° 19.37'	Southeast Village Bay at 150° southeast of ferry terminal in small cove.
38	48° 50.11'	123° 19.09'	East Dinner Bay off beach beside house on cliff.
39	48° 49.57'	123° 17.23'	Northeast of Conconi Reef off brown wood house with shake roof and dead arbutus tree.
40	48° 49.58'	123° 17.02'	Northeast of Conconi Reef off brown wood house with new stairway.

APPENDIX I

MARINE SAMPLE STATION LOCATIONS (Continued)

Sample Station	Latitude (North)	Longitude (West)	Description
41	48° 49.56'	123° 16.96'	Northeast of Conconi Reef off roads end by brown house.
42	48° 49.48'	123° 16.67'	South Piggot Bay at roads end.
43	48° 49.53'	123° 16.63'	North Piggot Bay.
44	48° 49.52'	123° 14.46'	East Horton Bay off wood frame shack near oyster lease.
45	48° 48.48'	123° 14.64'	Southeast Horton Bay off white house east of government wharf.
46	48° 48.45'	123° 14.63'	Southeast Horton Bay off wrecked row boat 78 m southeast of government wharf.
47	48° 49.76'	123° 15.18'	West Horton Bay off lagoon.
48	48° 49.79'	123° 15.06'	West Horton Bay off grey house.
49	48° 49.86'	123° 14.65'	Aitken Point off cable crossing.
50	48° 49.99'	123° 14.58'	Mid channel between Mayne and Curlew islands.
51	48° 49.92'	123° 14.43'	West Curlew Island north of wharf.
52	48° 50.04'	123° 14.72'	Between Padden Point and Aitken Point off house.
53	48° 50.26'	123° 14.77'	South Bennett Bay off public access to beach.
54	48° 50.34'	123° 14.78'	South Bennett Bay off white frame house with stairs to beach.
55	48° 50.48'	123° 14.74'	Bennett Bay foot of road with cement wall.
56	48° 50.61'	123° 14.83'	Bennett Bay off brown house with large windows and arbutus tree.
57	48° 50.67'	123° 14.84'	Bennett Bay off first stairway to beach southeast of Mayne Inn.
58	48° 50.76'	123° 14.99'	Bennett Bay off pilings for Mayne Inn wharf.
59	48° 50.80'	123° 14.84'	North Bennett Bay off arbutus tree and field.
60	48° 50.80'	123° 14.69'	North Bennett Bay in small rock pool.
61	48° 47.72'	123° 12.35'	Mid channel west end between Saturna and Trevor Island.
62	48° 47.71'	123° 12.25'	Mid channel east end between Saturna and Trevor Island.
63	48° 47.70'	123° 12.18'	Cove 100 m east of Trevor Island south of brown house.
64	48° 47.71'	123° 12.03'	Mid channel entrance to Boot Cove off large house on rock.
65	48° 47.66'	123° 12.04'	Northwest Boot Cove off brown house and bench.

APPENDIX I

MARINE SAMPLE STATION LOCATIONS (Continued)

Sample Station	Latitude (North)	Longitude (West)	Description
66	48° 47.65'	123° 11.91'	North Boot Cove off large "No Store" private wharf.
67	48° 47.61'	123° 11.85'	North Boot Cove off green roofed house with yellow dock.
68	48° 47.58'	123° 11.74'	Northeast corner Boot Cove off green house with red roof.
69	48° 47.55'	123° 11.80'	East Boot Cove off yellow stairway to beach.
70	48° 47.44'	123° 11.85'	East Boot Cove off large stairway to beach.
71	48° 47.40'	123° 11.92'	Mid Boot Cove between log dump and oyster float.
72	48° 47.34'	123° 11.90'	South Boot Cove off stream north of yellow house.
73	48° 47.31'	123° 11.92'	South Boot Cove off cement block fence south of yellow house.
74	48° 47.28'	123° 11.98'	Extreme south Boot Cove off white house.
75	48° 47.66'	123° 10.50'	East Lyall Harbour off white house with red roof south of dock.
76	48° 47.72'	123° 10.49'	East Lyall Harbour off roads end.
77	48° 47.80'	123° 10.48'	East Lyall Harbour off mouth of Lyall Creek.
78	48° 48.68'	123° 19.11'	East Grimmer Bay off sandy beach north of Boat Islet.
79	48° 48.60'	123° 19.11'	East Grimmer Bay off five concrete blocks on beach.
80	48° 48.52'	123° 19.18'	East Grimmer Bay off beige house with green roof and two chimneys.
81	48° 48.39'	123° 19.54'	South side of James Point off white house with green roof.
82	48° 47.97'	123° 18.36'	Otter Bay, Hyashi Cove small beach opposite marina.
83	48° 47.84'	123° 18.18'	East Otter Bay 50 m north of boat house.
84	48° 47.78'	123° 18.18'	East Otter Bay 50 m south of boat house.
85	48° 47.71'	123° 18.36'	Southeast Otter Bay off flag on cross in grass field.
86	48° 47.67'	127° 18.70'	East Ella Bay, middle of beach.
87	48° 46.75'	123° 18.55'	Head of Shingle Bay off middle of shore.
88	48° 45.98'	123° 18.27'	Sewage outfall west of Boat Nook Cove.

APPENDIX I

MARINE SAMPLE STATION LOCATIONS (Continued)

Sample Station	Latitude (North)	Longitude (West)	Description
89	48° 45.93'	123° 18.17'	Point on west side of entrance to Boat Nook Cove.
90	48° 45.98'	123° 18.21'	Northwest Boat Nook Cove off wood house on stilts.
91	48° 45.96'	123° 18.07'	Boat Nook Cove off stairway to beach with green wire fence.
92	48° 45.95'	123° 18.00'	Boat Nook Cove off red house with yellow patio railing.
93	48° 45.84'	123° 18.21'	Boat Nook Cove entrance midway between Beddis Rock and North Pender Island.
94	48° 45.33'	123° 16.89'	75 m west of Magic Lake Estates outfall.
95	48° 45.30'	123° 16.72'	Off Magic Lake Estates outfall.
96	48° 45.27'	123° 16.52'	75 m east of Magic Lake Estates outfall.
97	48° 44.27'	123° 14.05'	Southwest Peter Cove off brown house.
98	48° 44.35'	123° 13.88'	Northwest Peter Cove off brown house.
99	48° 44.77'	123° 13.81'	Bedwell Harbour entrance to marina. Two-third of way from log break water to light.
100	48° 44.83'	123° 13.70'	Bedwell Harbour entrance to marina one-third of way from log break water to light.
101	48° 45.07'	123° 13.67'	East Beaumont Marine Park off floating house.
102	48° 45.08'	123° 13.79'	East Beaumont Marine Park 25 m off cliff with "New Glasgow" written on it.
103	48° 45.09'	123° 14.00'	East Beaumont Marine Park 75 m off long brown stairway.
104	48° 45.36'	123° 15.74'	West Bedwell Harbour off house with red roof southwest of Drew Rock.
			West Bedwell Harbour off house with green "ski run" roof.
106	48° 45.64'	123° 16.03'	West Bedwell Harbour middle of beach off white house with red roof (partially hidden by trees).
107	48° 45.68'	123° 15.70'	West Bedwell Harbour north of rock "110" off long walkway.
108	48° 45.72'	123° 15.61'	West Bedwell Harbour north of rock "110" off shore south of wooden breakwater.

APPENDIX I

MARINE SAMPLE STATION LOCATIONS (Continued)

Sample Station	Latitude (North)	Longitude (West)	Description
109	48° 45.90'	123° 15.20'	Northwest side of bridge over Shark Cove.
110	48° 45.97'	123° 15.29'	East Shark Cove.
111	48° 45.97'	123° 15.54'	West Shark Cove off rock outcropping.
112	48° 46.39'	123° 16.34'	West Port Browning south Hamilton Beach off fallen logs.
113	48° 46.47'	123° 16.30'	West Port Browning Hamilton Beach off boat ramp.
114	48° 46.72'	123° 16.13'	West Port Browning mid channel at entrance to "Small Cove" northeast of Brackett Cove.
115	48° 46.75'	123° 16.20'	West Port Browning head of "Small Cove" off green boat house.
116	48° 46.77'	123° 16.19'	West Port Browning head of "Small Cove" opposite green boat house.
117	48° 46.64'	123° 15.66'	Northwest Port Browning east of government wharf off grey house.
118	48° 48.08'	123° 16.47'	Head of cove east of Hope Bay.
119	48° 48.10'	123° 16.48'	Cove east of Hope Bay off rock outcropping.
120	48° 48.37'	123° 16.59'	Hope Bay off large white house.
121	48° 48.64'	123° 16.76'	Colston Cove off large new house with stone chimney.
122	48° 48.68'	123° 16.77'	Colston Cove off white house with red roof.

APPENDIX II

FRESHWATER AND EFFLUENT SAMPLE STATION LOCATIONS

APPENDIX II

FRESHWATER AND EFFLUENT SAMPLE STATION LOCATIONS

Sample Station	Location
G1	Galiano Island; 16 meters west of government dock, Retreat Cove.
G2	Galiano Island; stream crossing southwest corner of Porlier Pass Drive entering Retreat Cove.
G3	Galiano Island; stream crossing southwest corner of Porlier Pass Drive entering Critter Bay.
G4	Galiano Island; culvert at head of Whalers Bay on Sturdies Bay Road.
G5	Galiano Island; below "Bice's" on Gulf Road.
G6	Galiano Island; below Ferguson's "Mermay" on Gulf Road.
G7	Galiano Island; below brown panelled house with dual store chimneys in Georgeson Bay.
G8	Galiano Island; head of Georgeson Bay.
G9	Galiano Island; crosses under and near the end of Active Pass Road, enters Georgeson Bay.
M1	Mayne Island; flows north below brown house on Waughs Road, enters David Cove.
M2	Mayne Island; flows northeast below Edith Point Road between green house and brown panel house, enters Campbell Bay.
M3	Mayne Island; flows northeast below Ducklows' residence on Wilkes Road, enters Campbell Bay.
M4	Mayne Island; flows northeast below red barn-shaped house southeast of Ducklows on Wilkes Road, enters Campbell Bay.
M5	Mayne Island; below Mayne Inn, Bennett Bay.
M6	Mayne Island; corner of Arbutus and Seaview, Bennett Bay.
M7	Mayne Island; below C.M. Hay's residence on Arbutus Drive, Bennett Bay.
M8	Mayne Island; below "Windshore" on Arbutus Drive, Bennett Bay.
M9	Mayne Island; flows southeast below Dinner Road, Dinner Bay.
M10	Mayne Island; flows northeast under Dalton Drive to Village Bay.
M11	Mayne Island; Miners Bay.
M12	Mayne Island; culvert below duplex bungalows in Miners Bay.
S1	Saturna Island; mouth of Lyall Creek, Lyall Harbour.
P1	North Pender Island, flows northeast under Armadale Road to Navy Channel.
P2	North Pender Island; flows south under Razor Point Road to Pollard Cove (Port Browning).

APPENDIX II

FRESHWATER AND EFFLUENT SAMPLE STATION LOCATIONS
(Continued)

Sample Station	Location
P3	North Pender Island; flows south under Razor Point Road to Port Browning.
ML	North Pender Island; Magic Lake Estates sewage treatment plant final effluent.
GI	North Pender Island; Gulf Industries sewage treatment plant final effluent.
AC	South Pender Island; Anchor Chain Holdings septic tank final effluent.

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE SAMPLE STATIONS

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
1	July 5/78	0935	L2
	6	0915	L2
	7	1400	L2
	10	1013	L2
	11	1148	L2
	12	0900	L2
		
2	July 5/78	0940	L2
	6	0920	L2
	7	1355	2
	10	1010	L2
	11	1146	L2
	12	0902	L2
		
3	July 5/78	0945	L2
	6	0925	L2
	7	1355	L2
	10	1005	L2
	11	1141	L2
	12	0905	L2
		
4	July 5/78	0955	L2
	6	0930	L2
	7	1350	L2
	10	1000	4
	11	1137	5
	12	0912	2
	31	0925	L2
	Aug 1	0856	4
	2	1035	8.3
		
5	July 5/78	1000	L2
	6	0930	L2
	7	1345	L2
	10	1000	11
	11	1134	L2
	12	0914	L2
	31	0925	L2
	Aug 1	0850	2
	2	1040	L2
		

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
6	July	5/78	
		1005	4
		6	L2
		7	L2
		10	4
		11	5
		12	L2
		31	7
	Aug	1	2
		2	L2
7	July	5/78	
		1010	L2
		6	5
		7	L2
		10	7
		11	4
		12	L2
		31	2
	Aug	1	5
		2	4
8	July	5/78	
		1015	L2
		6	L2
		7	L2
		10	7
		11	L2
		12	L2
		31	2
	Aug	1	L2
		2	L2
9	July	5/78	
		1020	2
		6	L2
		7	L2
		10	2
		11	2
		12	L2
		31	L2
	Aug	1	G1600
		2	5

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
10	July 5/78	1025	8
	6	1000	350
	7	1325	5
	10	0930	L2
	11	1114	2
	12	0936	2
	31	0945	L2
	Aug 1	0910	17
	2	1100	2
.....			
11	July 5/78	1030	L2
	6	1005	L2
	7	1320	L2
	10	0930	5
	11	1110	L2
	12	0941	2
	31	0950	5
	Aug 1	0915	4
	2	1105	4
.....			
12	July 5/78	1100	2
	6	1025	L2
	7	1300	2
	10	0900	2
	11	1050	2
	12	1002	L2
.....			
13	July 5/78	1100	L2
	6	1030	L2
	7	1300	L2
	10	0902	L2
	11	1045	L2
	12	1005	L2
.....			
14	July 5/78	1110	2
	6	1035	L2
	7	1255	L2
	10	0906	L2
	11	1042	L2
	12	1011	L2
.....			

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
15	July 5/78	1130	L2
	6	1055	L2
	7	1235	L2
	10	-	2
	11	-	L2
	12	1030	L2
		
16	July 5/78	1450	L2
	6	1300	L2
	7	1010	L2
	10	1145	L2
	11	1003	L2
	12	1244	L2
		
17	July 5/78	1500	L2
	6	1300	L2
	7	1005	2
	10	1140	7
	11	0959	5
	12	1240	2
		
18	July 5/78	1510	L2
	6	1305	L2
	10	1135	2
	11	0945	L2
	12	1235	L2
		
19	July 5/78	1515	L2
	6	1310	L2
	10	1130	2
	11	0949	L2
	12	1230	2
		
20	July 5/78	1520	L2
	6	1315	L2
	10	1130	2
	11	0946	L2
	12	1228	L2
		

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
21	July 5/78	1520	L2
	6	1320	L2
	10	1130	L2
	11	0945	2
	12	1225	L2
22	July 5/78	1635	L2
	6	1325	L2
	10	1150	L2
	11	0914	L2
	12	1154	L2
23	July 5/78	1545	2
	6	1350	L2
	10	1115	L2
	11	0928	17
	12	1210	4
24	July 5/78	1545	L2
	6	1350	L2
	10	1115	2
	11	0926	2
	12	1204	L2
25	July 5/78	1550	L2
	6	1345	L2
	10	1115	2
	11	0923	2
	12	1207	L2
26	July 5/78	1540	L2
	6	1355	L2
	10	1110	11
	11	0931	L2
	12	1212	L2

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
27	July 5/78	1535	L2
	6	1400	L2
	10	1105	2
	11	0935	L2
	12	1215	2
.....			
28	July 5/78	1635	L2
	6	1325	2
	10	1150	2
	11	0914	13
	12	1154	L2
.....			
29	July 5/78	1645	L2
	6	1330	L2
	10	1155	L2
	11	0908	L2
	12	1150	L2
.....			
30	July 5/78	1450	L2
	6	1330	L2
	10	1155	L2
	11	0905	L2
	12	1147	L2
.....			
31	July 5/78	1455	L2
	6	1335	L2
	10	1100	2
	11	0902	-
	12	1145	L2
.....			
32	July 5/78	1700	L2
	6	1415	L2
	10	1055	L2
	11	0855	L2
	12	1142	7
.....			

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
33	July 5/78	1730	L2
	6	1240	L2
	7	1115	L2
	10	1245	L2
	11	1220	L2
	12	1302	2
		
34	July 5/78	1735	2
	6	1242	L2
	7	1115	L2
	10	1248	L2
	11	1225	2
	12	1304	L2
		
35	July 5/78	1800	5
	6	1135	L2
	7	1145	L2
	10	1028	2
	11	1205	L2
	12	1115	L2
		
36	July 5/78	1805	L2
	6	1140	L2
	7	1150	2
	10	1030	2
	11	1206	L2
	12	1118	L2
		
37	July 5/78	1810	L2
	6	1140	L2
	7	1155	2
	10	1035	L2
	11	1207	L2
	12	1120	L2
		
38	July 13/78	1550	L2
	14	1150	L2
	17	1330	L2
	18	1830	5
	19	0730	2
	20	0745	2
		

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
39	July 13/78	1535	L2
	14	1141	L2
	17	1340	L2
	18	1815	2
	19	0745	L2
	20	0735	L2
		
40	July 13/78	1530	L2
	14	1138	L2
	17	1345	L2
	18	1815	L2
	19	0745	L2
	20	0730	2
		
41	July 13/78	1530	L2
	14	1135	L2
	17	1340	2
	18	1810	L2
	19	0750	L2
	20	0730	5
		
42	July 13/78	1525	L2
	14	1130	8
	17	1350	L2
	18	1810	2
	19	0755	L2
	20	0720	2
		
43	July 13/78	1520	L2
	14	1127	L2
	17	1355	L2
	18	1805	2
	19	0755	L2
	20	0720	8
		
44	July 13/78	1130	L2
	14	1002	4
	17	1500	L2
	18	1430	L2
	19	0635	2
	20	0620	5
		

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
45	July 14/78	1000	2
	17	1455	8
	18	1430	L2
	19	0630	2
	20	0615	33
	31	1015	5
	Aug 1	1005	L2
	2	0835	2
.....			
46	July 14/78	0958	5
	17	1455	L2
	18	1600	2
	19	0630	23
	20	0615	49
	31	1015	5
	Aug 1	1005	L2
	2	0830	2
.....			
47	July 13/78	1120	L2
	14	0940	13
	17	1450	5
	18	1555	5
	19	0635	79
	20	0625	11
	31	1010	L2
	Aug 1	1000	2
	2	0835	5
.....			
48	July 13/78	1110	5
	14	0936	2
	17	1445	L2
	18	1550	49
	19	0635	27
	20	0625	13
	31	1010	L2
	Aug 1	0955	7
	2	0840	2
.....			

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
49	July 13/78	1105	L2
	14	0929	2
	17	1440	2
	18	1545	2
	19	0640	17
	20	0630	8
	31	1000	L2
	Aug 1	0950	L2
	2	0845	L2
.....			
50	July 13/78	1105	L2
	14	0932	L2
	17	1445	L2
	18	1545	L2
	19	0640	7
	20	0635	2
	31	1000	L2
	Aug 1	0950	L2
	2	0845	L2
.....			
51	July 13/78	1100	L2
	14	0926	L2
	17	1440	8
	18	1540	79
	19	0645	110
	20	0635	13
	31	1000	L2
	Aug 1	0950	L2
	2	0850	14
.....			
52	July 13/78	1055	2
	14	0924	L2
	17	1435	L2
	18	1535	L2
	19	0645	22
	20	0640	2
	31	0955	L2
	Aug 1	0945	L2
	2	0850	L2
.....			

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
53	July 13/78	1045	L2
	14	0916	L2
	17	1430	L2
	18	1535	L2
	19	0650	17
	20	0640	7
	31	0950	2
	Aug 1	0935	L2
	2	0855	L2
.....			
54	July 13/78	1040	L2
	14	0914	L2
	17	1430	L2
	18	1535	L2
	19	0650	33
	20	0645	4
	31	0950	L2
	Aug 1	0930	2
	2	0900	2
.....			
55	July 13/78	1035	2
	14	0909	5
	17	1425	L2
	18	1530	2
	19	0655	8
	20	0650	5
	31	0945	L2
	Aug 1	0930	2
	2	0900	L2
.....			
56	July 13/78	1015	L2
	14	0905	2
	17	1420	L2
	18	1530	L2
	19	0700	L2
	20	0655	5
	31	0940	L2
	Aug 1	0925	L2
	2	0905	2
.....			

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
57	July 13/78	1015	L2
	14	0904	2
	17	1415	L2
	18	1525	2
	19	0700	49
	20	0700	5
	31	0935	L2
	Aug 1	0920	2
	2	0910	2
		
58	July 13/78	1010	2
	14	0900	2
	17	1410	L2
	18	1520	L2
	19	0700	33
	20	0700	8
	31	0935	5
	Aug 1	0915	L2
	2	0910	8
		
59	July 13/78	1010	L2
	14	0900	L2
	17	1410	L2
	18	1520	L2
	19	0700	49
	20	0700	7
	31	0935	L2
	Aug 1	0915	L2
	2	0910	L2
		
60	July 13/78	1005	2
	14	0957	L2
	17	1410	L2
	18	1515	L2
	19	0705	17
	20	0705	5
	31	0930	L2
	Aug 1	0915	L2
	2	0915	L2
		

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
61	July 14/78	1100	L2
	17	1550	L2
	18	1740	L2
	19	0805	L2
	20	0855	2
.....			
62	July 14/78	1058	L2
	17	1550	L2
	18	1740	L2
	19	0805	L2
	20	0855	L2
.....			
63	July 14/78	1053	L2
	17	1550	2
	18	1735	5
	19	0810	2
	20	0840	2
.....			
64	July 13/78	-	L2
	14	1146	L2
	17	1545	L2
	18	1735	L2
	19	0835	L2
	20	0850	5
.....			
65	July 13/78	1310	2
	14	1044	2
	17	1540	L2
	18	1730	L2
	19	0835	L2
	20	0845	13
.....			
66	July 13/78	1700	L2
	14	1041	L2
	17	1540	L2
	18	1730	23
	19	0830	22
	20	0845	13
.....			

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
67	July 13/78	1305	L2
	14	1038	4
	17	1335	L2
	18	1715	2
	19	0830	5
	20	0840	8
.....			
68	July 13/78	1300	2
	14	1036	L2
	17	1535	13
	18	1710	L2
	19	0830	2
	20	0840	5
.....			
69	July 13/78	1255	5
	14	1033	L2
	17	1530	2
	18	1710	L2
	19	0825	13
	20	0835	2
.....			
70	July 13/78	1250	13
	14	1030	2
	17	1530	2
	18	1705	L2
	19	0820	2
	20	0835	13
.....			
71	July 13/78	1250	L2
	14	1028	L2
	17	1525	L2
	18	1700	L2
	19	0820	L2
	20	0830	8
.....			
72	July 13/78	1245	5
	14	1026	13
	17	1525	2
	18	1705	L2
	19	0815	17
	20	0830	14
.....			

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
73	July 13/78	1245	2
	14	1024	2
	17	1520	5
	18	1700	8
	19	0815	8
	20	0825	2
.....			
74	July 13/78	1240	5
	14	1020	9
	17	1515	L2
	18	1700	2
	19	0815	23
	20	0820	8
.....			
75	July 13/78	1320	L2
	14	1107	L2
	17	1600	5
	18	1745	L2
	19	0845	L2
	20	0805	2
	31	1130	L2
	Aug 1	1050	2
	2	0940	L2
.....			
76	July 13/78	1325	L2
	14	1110	43
	17	1600	2
	18	1745	130
	19	0845	L2
	20	0810	2
	31	1130	2
	Aug 1	1055	5
	2	0945	5
.....			
77	July 13/78	1330	5
	14	1113	2
	17	1605	2
	18	1750	23
	19	0900	11
	20	0815	23
	31	1140	L2
	Aug 1	1100	2
	2	0950	L2
.....			

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
78	July 21/78	0830	L2
	24	0915	2
	25	0940	L2
	26	1400	8
	27	1225	L2
	28	1155	L2
		
79	July 21/78	0830	2
	24	0920	7
	25	0945	L2
	26	1600	2
	27	1220	2
	28	1150	13
		
80	July 21/78	0835	L2
	24	0920	33
	25	0950	L2
	26	1555	2
	27	1220	79
	28	1250	L2
	31	1010	L2
	Aug 1	0945	L2
	2	1010	L2
		
81	July 21/78	0840	8
	24	0930	49
	25	0955	8
	26	1550	L2
	27	1215	11
	28	1145	13
	31	1015	2
	Aug 1	0945	23
	2	1015	17
		
82	July 21/78	0815	L2
	24	0935	L2
	25	1005	2
	26	1340	L2
	27	1210	L2
	28	1135	L2
		

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
83	July 21/78	0815	2
	24	0940	L2
	25	1005	17
	26	1535	5
	27	1205	14
	28	1130	L2
.....			
84	July 21/78	0840	L2
	24	0945	L2
	25	1010	2
	26	1535	2
	27	1205	L2
	28	1130	L2
.....			
85	July 21/78	0840	2
	24	0950	2
	25	1015	L2
	26	1530	2
	27	1200	2
	28	1130	L2
.....			
86	July 21/78	0855	2
	24	0955	5
	25	1020	L2
	26	1325	2
	27	1155	L2
	28	1120	L2
.....			
87	July 21/78	0900	L2
	24	1005	2
	25	1025	8
	26	1520	L2
	27	1150	L2
	28	1115	L2
.....			
88	July 21/78	0910	L2
	24	1015	5
	25	1035	L2
	26	1510	L2
	27	1135	L2
	28	1105	L2
.....			

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
89	July 21/78	0915	L2
	24	1015	L2
	25	1035	L2
	26	1505	L2
	27	1130	L2
	28	1105	L2
.....			
90	July 21/78	0920	L2
	24	1020	L2
	25	1040	L2
	26	1300	L2
	27	1130	L2
	28	1100	L2
.....			
91	July 21/78	0920	L2
	24	1020	L2
	25	1045	L2
	26	1500	L2
	27	1130	L2
	28	1100	2
.....			
92	July 21/78	0920	L2
	24	1025	2
	25	1045	L2
	26	1455	L2
	27	1125	L2
	28	1100	L2
.....			
93	July 21/78	0925	L2
	24	1030	L2
	25	1050	L2
	26	1300	L2
	27	1125	L2
	28	1055	L2
.....			
94	July 21/78	0930	L2
	24	1035	L2
	25	1055	L2
	26	1445	L2
	27	1120	L2
	28	1050	L2
.....			

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
95	July 21/78	0935	L2
	24	1035	L2
	25	1055	L2
	26	1445	L2
	27	1115	L2
	28	1050	L2
.....			
96	July 21/78	0935	L2
	24	1035	L2
	25	1100	L2
	26	1445	L2
	27	1115	L2
	28	1045	L2
.....			
97	July 21/78	0945	2
	24	1055	L2
	25	1110	L2
	26	1430	2
	27	1055	L2
	28	1035	L2
.....			
98	July 21/78	1050	2
	24	1420	L2
	25	1250	L2
	26	1325	L2
	27	1015	L2
	28	0955	L2
.....			
99	July 21/78	1015	2
	24	-	-
	25	1120	L2
	26	1400	L2
	27	1100	L2
	28	1030	L2
.....			
100	July 21/78	1015	L2
	24	-	-
	25	1025	L2
	26	1400	L2
	27	1100	2
	28	1025	L2
.....			

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
101	July 21/78	1020	2
	24	1220	L2
	25	1220	L2
	26	1400	14
	27	1045	L2
	28	1020	2
.....			
102	July 21/78	1020	2
	24	1220	2
	25	1220	L2
	26	1355	L2
	27	1040	L2
	28	1020	7
.....			
103	July 21/78	1025	2
	24	1215	2
	25	1225	L2
	26	1355	L2
	27	1040	L2
	28	1020	L2
.....			
104	July 21/78	1035	2
	24	1155	L2
	25	1230	L2
	26	1345	L2
	27	1030	2
	28	1010	L2
.....			
105	July 21/78	1040	2
	24	1200	5
	25	1235	2
	26	1345	5
	27	1030	L2
	28	1005	L2
.....			
106	July 21/78	1040	2
	24	1200	L2
	25	1240	L2
	26	1340	5
	27	1025	2
	28	1005	L2
.....			

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
107	July 21/78	1045	2
	24	1205	2
	25	1245	5
	26	1335	5
	27	1020	2
	28	1000	L2
108	July 21/78	1045	2
	24	1210	2
	25	1250	L2
	26	1330	L2
	27	1020	5
	28	1000	L2
109	July 21/78	1050	5
	24	1420	L2
	25	1250	L2
	26	1325	2
	27	1015	2
	28	0955	2
110	July 21/78	1055	5
	24	1420	2
	25	1255	L2
	26	1325	L2
	27	1010	2
	28	0950	2
111	July 21/78	1055	2
	24	1425	L2
	25	1255	2
	26	1320	L2
	27	1010	L2
	28	0945	L2
112	July 21/78	1100	2
	24	1430	L2
	25	1300	L2
	26	1315	L2
	27	1005	8
	28	0940	2

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
113	July 21/78	1100	2
	24	1435	L2
	25	1305	L2
	26	1315	L2
	27	1000	11
	28	0940	8
.....			
114	July 21/78	1105	9
	24	1435	2
	25	1310	L2
	26	1310	14
	27	1000	23
	28	0935	8
.....			
115	July 21/78	1105	5
	24	1440	2
	25	1310	L2
	26	1310	14
	27	0950	5
	28	0930	8
.....			
116	July 21/78	-	-
	24	-	-
	25	1310	L2
	26	1305	11
	27	0955	34
	28	0930	5
.....			
117	July 21/78	1110	L2
	24	1445	2
	25	1315	L2
	26	1300	2
	27	0950	L2
	28	0925	2
.....			
118	July 21/78	0805	11
	24	1535	L2
	25	0930	2
	26	1355	920
	27	1355	13
	28	1055	L2
	31	1100	L2
	Aug 1	-	7
	2	0900	5
.....			

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	Collection		Fecal Coliform MPN/100 ml
	Date	Time	
119	July 21/78	0805	2
	24	1535	L2
	25	0955	2
	26	1350	79
	27	1335	5
	28	1050	17
	31	1055	11
		
120	July 21/78	0815	L2
	24	1510	L2
	25	0915	L2
	26	1420	2
	28	0910	L2
	31	1040	L2
	Aug 1	1010	L2
		
121	July 21/78	0815	2
	24	1520	L2
	25	0920	L2
	26	1415	130
	27	1235	13
	28	0900	L2
	31	1030	L2
	Aug 1	1000	2
	2	0920	L2
		
122	July 21/78	0820	2
	24	1525	L2
	25	0925	L2
	26	1415	4
	27	1225	49
	28	0905	L2
	31	1035	L2
	Aug 1	1000	L2
	2	0920	L2
		

L = denotes "less than".

G = denotes "greater than".

APPENDIX IV

DAILY BACTERIOLOGICAL RESULTS FOR
FRESHWATER AND EFFLUENT SAMPLE STATIONS

APPENDIX IV DAILY BACTERIOLOGICAL RESULTS FOR FRESHWATER
AND EFFLUENT SAMPLE STATIONS

Sample Station	Date	TC*	FC	FS
G1	July 7, 1978	10	L10	L10
	July 10, 1978	L10	10	20
G2	July 5, 1978	1 100	1 380	-
	July 6, 1978	940	260	820
	July 7, 1978	2 640	2 640	820
	July 10, 1978	640	240	590
G3	July 7, 1978	620	L10	L10
	July 10, 1978	870	L10	20
G4	July 11, 1978	6 800	7 200	2 100
G5	July 6, 1978	10 400	18 000	10 100
	July 10, 1978	10 000	4 500	600
G6	July 6, 1978	9 500	L10	L10
	July 10, 1978	490	220	10
G7	July 6, 1978	10 200	20	570
	July 10, 1978	G800	G800	G800
G8	July 6, 1978	4 200	1 900	160
	July 7, 1978	4 000	590	110
	July 10, 1978	4 200	1 300	120
G9	July 7, 1978	770	340	20
	July 10, 1978	3 000	1 700	3 300
M1	July 12, 1978	5 400	70	40
M2	July 12, 1978	1 100	110	L10
M3	July 11, 1978	18 700	300	140
M4	July 11, 1978	3 800	180	L10
M5	July 11, 1978	460	40	L10
M6	July 11, 1978	3 300	70	L20
M7	July 11, 1978	10	L10	L10
M8	July 11, 1978	920	220	40

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

Sample Station	Date	TC*	FC	FS
M9	July 13, 1978	1 100	840	80
	July 14, 1978	590	420	50
	July 17, 1978	2 200	1900	200
M10	July 13, 1978	6 200	1800	1 900
	July 14, 1978	7 500	2400	6 300
	July 17, 1978	7 900	3200	1 100
M11	July 12, 1978	3 700	170	20
	July 14, 1978	4 100	40	55
M12	July 12, 1978	8 000	1000	50
P1	July 20, 1978	25 000	1460	6 900
	July 21, 1978	2 900	160	2 300
	July 26, 1978	5 600	2700	19 000
P2	July 26, 1978	5 800	22	16 000
P3	July 20, 1978	430	270	640
	July 21, 1978	770	400	820
	July 26, 1978	4 500	120	55 000
S1	July 18, 1978	30	L10	L10
	July 19, 1978	20	6	30
ML	July 25, 1978	200	L100	L100
	July 27, 1978	L10	L10	30
GI	July 25, 1978	2 800	L100	L100
	July 27, 1978	750	L10	L10
AC	July 27, 1978	5.6x10	5.1x10	2.7x10

*TC = total coliform/100 ml
FC = fecal coliform/100 ml
L = denotes "less than"
G = denotes "greater than"

APPENDIX V

SUMMARY OF TEMPERATURE AND SALINITY
DATA FOR MARINE SAMPLE STATIONS

APPENDIX V

SUMMARY OF TEMPERATURE AND SALINITY DATA FOR MARINE
SAMPLE STATIONS

Sample Station	No. of Samples	Temperature Range (°C)	Mean Temperature (°C)	No. of Samples	Salinity Range (o/oo)	Mean Salinity
1	6	13.5 - 16.5	14.1	6	27.0 - 29.0	28.0
2	6	13.0 - 17.0	14.0	6	26.0 - 29.0	27.9
3	6	12.5 - 17.0	14.2	6	27.5 - 29.0	28.3
4	9	13.5 - 17.5	15.3	9	25.0 - 29.0	27.6
5	9	12.5 - 17.0	15.0	9	26.5 - 29.0	27.7
6	9	13.5 - 17.2	15.1	9	27.0 - 29.0	27.8
7	9	13.0 - 18.0	15.0	9	27.0 - 29.0	27.8
8	9	13.5 - 18.0	15.2	9	25.0 - 29.0	27.6
9	9	13.0 - 17.0	15.0	9	25.0 - 29.5	27.6
10	9	13.5 - 17.8	15.6	9	26.5 - 29.0	27.7
11	9	14.0 - 17.0	15.3	9	26.5 - 29.0	27.8
12	6	13.0 - 16.0	14.8	6	27.0 - 29.0	27.8
13	6	13.0 - 16.5	14.8	6	27.0 - 29.0	27.9
14	6	13.0 - 16.5	14.8	6	27.0 - 28.5	27.8
15	4	14.0 - 17.0	16.0	6	27.0 - 28.5	27.7
16	6	12.5 - 15.5	13.5	6	27.0 - 29.0	28.2
17	6	13.0 - 17.0	14.3	6	27.0 - 28.5	27.9
18	6	12.5 - 16.5	13.8	6	26.5 - 28.5	28.0
19	6	12.0 - 15.5	13.3	6	27.5 - 29.0	28.4
20	6	12.5 - 15.0	13.3	6	27.5 - 29.0	28.3
21	6	12.5 - 16.0	13.7	5	28.0 - 29.0	28.6
22	6	12.5 - 17.0	14.3	6	27.5 - 30.0	28.3
23	6	12.0 - 16.5	13.8	6	27.5 - 29.5	28.3
24	6	12.5 - 16.0	14.0	6	27.0 - 29.0	28.3
25	6	12.5 - 16.5	14.2	6	28.0 - 29.0	28.3
26	6	12.0 - 16.5	14.0	6	27.5 - 30.0	28.3
27	6	12.5 - 17.0	14.3	6	28.0 - 29.0	28.3
28	6	12.5 - 14.0	13.1	6	27.5 - 29.0	28.3
29	6	11.0 - 13.0	12.3	6	27.5 - 30.0	28.8
30	6	12.0 - 14.5	12.8	6	27.0 - 29.0	28.3
31	6	11.0 - 14.0	12.2	6	29.0 - 38.0	30.1
32	6	12.0 - 15.5	12.7	6	28.0 - 30.0	29.3
33	6	11.5 - 13.5	12.8	6	29.5 - 31.0	30.1
34	6	11.0 - 15.0	12.3	6	29.5 - 30.0	29.9
35	6	14.0 - 18.5	15.3	6	27.5 - 29.0	28.4
36	6	14.0 - 16.5	15.2	6	28.0 - 29.0	28.6
37	6	13.5 - 16.0	14.9	6	28.0 - 29.0	28.3
38	6	12.0 - 18.0	14.8	6	26.5 - 30.0	28.7
39	6	11.0 - 14.0	12.8	6	26.0 - 30.0	29.0
40	6	12.5 - 15.0	13.9	6	26.0 - 30.0	28.8
41	6	12.5 - 15.0	13.5	6	25.5 - 30.0	28.7
42	6	13.0 - 17.0	14.6	6	25.5 - 30.0	28.8

APPENDIX V

SUMMARY OF TEMPERATURE AND SALINITY DATA FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	No. of Samples	Temperature Range (°C)	Mean Temperature (°C)	No. of Samples	Salinity Range (o/oo)	Mean Salinity
43	6	13.0 - 15.5	14.0	6	25.5 - 30.0	28.5
44	6	12.5 - 17.0	14.3	6	19.0 - 30.0	25.3
45	8	14.5 - 16.5	15.3	8	20.0 - 29.0	26.6
46	8	14.0 - 16.5	14.9	8	18.5 - 29.5	25.5
47	9	13.5 - 19.0	16.1	9	20.0 - 29.0	26.4
48	9	13.5 - 17.5	15.6	9	18.0 - 29.5	25.6
49	9	13.5 - 17.0	15.3	9	18.0 - 28.5	23.8
50	9	13.5 - 17.5	14.9	9	19.0 - 38.0	26.3
51	9	13.5 - 18.0	15.5	9	20.5 - 28.5	25.2
52	9	14.0 - 17.5	15.8	9	18.0 - 29.0	24.6
53	9	12.0 - 17.0	15.1	9	18.5 - 30.0	24.9
54	9	13.5 - 18.0	15.6	9	18.0 - 29.0	24.2
55	9	14.0 - 17.0	15.5	8	18.0 - 28.5	24.4
56	9	13.0 - 17.0	15.3	9	18.5 - 29.5	24.7
57	9	14.0 - 17.0	15.7	9	18.0 - 29.5	24.8
58	9	14.5 - 18.0	15.9	9	18.0 - 38.0	25.0
59	9	14.5 - 19.0	16.1	8	18.0 - 28.0	21.6
60	9	14.0 - 17.5	15.1	9	18.0 - 28.5	23.8
61	5	13.5 - 15.0	14.2	5	23.5 - 28.5	26.7
62	5	13.0 - 15.5	14.4	5	23.5 - 28.5	26.8
63	5	13.0 - 18.5	14.7	5	24.5 - 29.0	27.4
64	6	13.5 - 16.5	14.6	6	22.5 - 30.0	27.4
65	6	13.5 - 16.5	14.8	6	23.0 - 30.0	27.7
66	6	13.5 - 17.0	15.1	6	22.5 - 30.0	27.7
67	6	15.0 - 17.0	16.0	6	22.5 - 30.0	27.7
68	6	15.0 - 18.0	17.1	6	22.5 - 30.0	27.8
69	6	14.5 - 19.5	16.4	6	22.5 - 30.0	27.8
70	6	14.0 - 18.0	15.7	6	22.0 - 30.0	27.3
71	6	13.5 - 17.0	14.8	6	22.5 - 30.0	27.6
72	6	14.0 - 17.0	15.5	6	22.0 - 30.0	27.6
73	6	14.0 - 17.5	15.8	6	22.0 - 30.0	27.5
74	6	13.5 - 20.5	16.8	6	22.0 - 30.0	27.7
75	7	13.0 - 20.5	15.8	9	23.5 - 30.0	28.3
76	7	13.0 - 20.5	15.7	9	23.0 - 30.0	28.3
77	7	14.0 - 17.5	15.4	9	24.0 - 30.0	28.3
78	6	12.5 - 15.2	14.3	6	26.5 - 29.0	27.8
79	6	13.0 - 15.5	14.5	6	26.5 - 28.0	27.6
80	8	13.5 - 16.0	14.5	9	26.5 - 28.5	27.8
81	9	12.5 - 15.5	14.3	9	26.5 - 29.0	28.0
82	6	12.5 - 15.8	14.0	6	27.5 - 28.5	28.1
83	6	12.5 - 16.5	14.3	6	27.5 - 27.5	28.1
84	6	13.5 - 15.5	14.3	6	27.0 - 28.5	27.9

APPENDIX V

SUMMARY OF TEMPERATURE AND SALINITY DATA FOR MARINE
SAMPLE STATIONS (Continued)

Sample Station	No. of Samples	Temperature Range (°C)	Mean Temperature (°C)	No. of Samples	Salinity Range (o/oo)	Mean Salinity
85	6	14.0 - 15.5	14.5	6	27.0 - 28.5	28.0
86	6	13.0 - 15.0	14.1	6	27.5 - 29.0	28.2
87	6	13.0 - 15.0	14.0	6	27.5 - 29.0	28.3
88	6	13.0 - 15.5	13.8	6	26.0 - 28.5	27.9
89	5	12.5 - 15.0	13.7	6	26.0 - 29.0	28.0
90	5	13.0 - 15.9	14.4	6	26.0 - 28.5	27.8
91	5	12.5 - 15.0	13.7	5	26.0 - 29.0	27.9
92	5	13.0 - 15.0	13.8	6	26.0 - 29.0	28.1
93	5	11.5 - 14.5	13.2	6	27.0 - 29.5	28.3
94	5	12.0 - 15.0	13.2	6	26.0 - 29.0	28.1
95	5	12.5 - 15.0	13.6	6	26.5 - 29.0	28.2
96	5	12.0 - 15.0	13.5	6	26.0 - 29.0	28.0
97	6	13.0 - 14.5	13.4	6	28.0 - 29.5	28.7
98	6	13.0 - 14.0	13.6	6	27.5 - 29.0	28.4
99	5	14.0 - 15.5	14.6	5	27.5 - 28.5	27.9
100	5	14.0 - 15.0	14.3	5	27.5 - 28.5	27.9
101	6	13.5 - 15.5	14.5	6	27.5 - 28.5	28.0
102	6	13.5 - 15.0	14.3	6	27.0 - 28.0	27.8
103	6	13.0 - 15.0	14.2	5	27.0 - 28.5	27.9
104	6	15.0 - 15.5	15.2	6	27.0 - 28.0	27.8
105	6	14.0 - 17.0	15.4	6	27.5 - 28.0	27.9
106	6	15.0 - 16.5	15.4	6	27.5 - 28.0	27.9
107	6	15.0 - 17.5	15.8	6	27.5 - 28.0	27.9
108	6	15.0 - 16.5	15.6	6	27.0 - 28.0	27.8
109	6	14.0 - 16.0	15.1	6	25.5 - 28.0	26.8
110	6	14.5 - 16.0	15.3	6	25.5 - 28.0	26.8
111	6	14.5 - 17.0	15.7	6	25.0 - 28.0	26.7
112	6	15.5 - 17.5	16.4	6	25.0 - 27.5	26.2
113	6	15.5 - 18.5	16.6	6	25.5 - 27.5	26.1
114	6	15.5 - 18.0	16.4	6	25.5 - 27.5	26.2
115	6	15.0 - 18.5	16.5	6	25.5 - 27.5	26.3
116	4	15.0 - 18.0	16.1	4	25.0 - 29.5	27.0
117	6	15.5 - 18.0	16.3	6	25.5 - 29.5	26.7
118	8	13.5 - 20.5	16.8	9	26.0 - 29.0	27.3
119	7	13.5 - 18.0	15.9	7	25.0 - 29.0	27.1
120	9	13.5 - 18.0	15.0	8	26.0 - 29.0	27.4
121	9	13.5 - 17.5	14.9	9	26.0 - 29.5	27.7
122	9	13.5 - 17.0	14.9	9	26.5 - 29.5	27.6

APPENDIX VI

A PERFORMANCE EVALUATION OF FOUR PACKAGE
SEWAGE TREATMENT PLANTS AND ONE SEPTIC
TANK LOCATED IN THE STUDY AREA

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LIST OF ABBREVIATIONS

BOD ₅	5 day biochemical oxygen demand
COD	chemical oxygen demand
DO	dissolved oxygen
EPS	Environmental Protection Service
FR	filterable residue
l	liter
LAS	anionic surfactants
MLVSS	mixed liquor volatile suspended solids
m ³ /day	cubic metres per day
ml	millilitres
mg/l	milligrams per liter
NFR	non-filterable residue
PCB	Pollution Control Branch
ppt	parts per thousand
STP	sewage treatment plant
SVI	sludge volume index
TFR	total fixed residue
TOC	total organic carbon
TPO ₄	total phosphate
TR	total residue
TRC	total residual chlorine
TVR	total volatile residue
VNFR	volatile non-filterable residue

1 INTRODUCTION

A performance evaluation was made of four package sewage treatment plants and one septic tank as part of the shellfish growing water sanitary survey of Galiano, Mayne, Saturna, North and South Pender Islands. The treatment plants included the:

- a) B.C. Ferry Corporation plant at Sturdies Bay on Galiano Island;
- b) B.C. Ferry Corporation plant at Lyall Harbour on Saturna Island;
- c) Gulf Industries Ltd. plant at Swanson Channel on North Pender Island;
- d) Magic Lake Estates Ltd. plant at Swanson Channel on North Pender Island.

The two B.C. Ferries treatment plants receive sewage from washroom facilities located at the respective ferry landings, while the latter two systems service small subdivisions.

Samples were also obtained of the final effluent from the Anchor Chain Resorts Ltd. septic tank at Egeria Bay on South Pender Island.

The characteristics of these treatment systems are summarized in Table 1.

This performance evaluation was based upon bacteriological, chemical, and toxicity analyses conducted on samples obtained from each of the treatment systems. The purpose of the study was to:

- 1) obtain bacteriological* and chemical data in support of the Galiano, Mayne, Saturna, North Pender and South Pender Islands shellfish growing water quality survey;

*The bacteriological analyses results have been previously discussed in this report.

APPENDIX VI
TABLE 1 CHARACTERISTICS OF TREATMENT SYSTEMS

Treatment System	Service Area	Type	Capacity m ³ /day	Comminution	Aeration	Clarification	Chlorination
B.C. Ferry - Sturdies Bay	intermittent - ferry terminal	extended aeration STP	maximum 10.9	yes	yes	yes	*
B.C. Ferry - Lyall Harbour	intermittent - ferry terminal	extended aeration STP	maximum 10.9	yes	yes	yes	*
Gulf Industries	continuous - subdivision	extended aeration STP	average 110	no	yes	yes	yes
Magic Lake	continuous - subdivision	extended aeration STP	average 70	no	yes	yes	yes
Anchor Chain	continuous - resort	septic tank	maximum 27.5	-	-	-	-

*Although the Pollution Control Branch permit requires chlorination, there was none at the time of this study.

- 2) obtain toxicity data as a continuation of a 1976 EPS program to obtain bioassay information for various types of sewage treatment plants in British Columbia;
- 3) obtain chemical data to assist in the interpretation of bioassay results.

2 SAMPLE PROCEDURES AND METHODS

On two different days, grab samples were obtained of the raw sewage, aeration tank, return sludge and final effluent from the Gulf Industries and Magic Lake Estates sewage treatment plants. Final effluent, aeration tank, and return sludge samples only, were collected from the two B.C. Ferry STP's because there were no accessible raw sewage sampling points. Only final effluent samples were obtained from the Anchor Chain Resorts septic tank.

In addition, 30 and 60 minute settleability tests, pH, DO, and temperature were determined in field analyses of samples obtained from each of the four sewage treatment plant's aeration tanks. Settleability, pH, and DO were determined using 1 litre Imhoff cones, J.T. Baker Universal Dual-Tint Indicator Paper, and a Hach Chemical Company colorimetric DO kit, respectively. Other samples were split and preserved as outlined in the Environment Canada Pollution Sampling Handbook (1). Samples for chemical analyses were delivered to the Department of the Environment Chemistry laboratory in West Vancouver.

Final effluent grab samples for bioassays (96 hours LC₅₀) were obtained from each of the four package sewage treatment plants. These samples were then transported in five gallon plastic jerry cans to the Environmental Protection Service Aquatic Toxicity laboratory in North Vancouver.

The 96 hour LC₅₀ is defined as the concentration of measurable lethal agent (in this case wastewater) required to kill the 50th percentile in a group of test organisms over a 96 hour period. In the test, a series of 30 1 glass vessels containing different sample dilutions with 5 to 10 rainbow trout (Salmo gairdneri) per test vessel were placed in a controlled environment room with a maintained temperature of $15.0^{\circ} \pm 1^{\circ}\text{C}$.

For this survey, a bioassay procedure was used whereby the sample was pre-aerated at 150 to 200 ml/min with air for two hours if the initial DO level was found to be below 5 mg/l; and pre-aerated for 30 minutes if the DO was greater than 5 mg/l. This procedure was followed

in order that DO would not be a factor in sample toxicity while air stripping of the wastewater's chemical constituents would be minimized. All samples had an initial DO concentration above 7.0 mg/l and were therefore pre-aerated for only 30 minutes.

3 RESULTS

The results of the chemical and toxicity analyses are shown in Tables 2 to 6, while a summary of raw sewage and final effluent sampling results are shown in Table 7 and 8.

3.1 Chemical Analyses Results

The raw sewage input to the Gulf Industries and Magic Lake Estates package sewage treatment plants may generally be described as weak. Some constituents, however, of the Magic Lake Estates raw sewage are present at concentrations typical of medium strength sewage. These constituents include FR and NH_3 . In general, the Magic Lake Estates raw sewage is stronger than that of Gulf Industries.

In terms of treatment plant performance, BOD_5 , COD, NH_3 , and TOC concentrations were reduced by the Magic Lake Estates sewage treatment plant, while the TR, TVR, NFR, NO_3 , TPO_4 , and NO_2 concentrations increased. Significant turbidity was noted in the final effluent - most probably due to the carry-over of biomass from the clarifier. Significant nitrification occurred as shown by high NO_3 and low NH_3 final effluent concentrations. Nitrification was probably responsible for the drop in pH from 7.6 in the raw sewage to 5.6 in the final effluent.

The Gulf Industries STP afforded reductions in BOD_5 , COD, NFR, and TOC, while TR, TVR, NH_3 , and TPO_4 increased. Some nitrification was noted in the final effluent.

It must be noted that final effluent BOD_5 results for the Gulf Industries and Magic Lake Estates STP's are likely in error. Samples were collected following chlorination and were not re-seeded prior to the start of the BOD_5 test. Moreover, the BOD_5/COD ratios for these treatment plants were about one-tenth those calculated for the Sturdies Bay and Lyall Harbour treatment plants (Table 9). Assuming the Gulf Industries and Magic Lakes Estates final effluent BOD_5/COD ratio should also be 0.4, then the BOD_5 for the Gulf Industries and Magic Lake Estates treatment plants should have been 45 and 55 mg/l, respectively (3).

APPENDIX VI
TABLE 2 ANCHOR CHAIN HOLDINGS SEPTIC TANK CHEMICAL ANALYSES RESULTS

Parameter	Final Effluent 27/7/78* -----mg/l-----
pH.....	7.2**
BOD ₅	157
COD.....	440
TR.....	513
TVR.....	230
NFR.....	103
NO ₂	0.0152
NO ₃	L0.010
TP0 ₄	9.70

* sampling date

** pH units

L = denotes "less than"

APPENDIX VI
TABLE 3 B.C. FERRY - STURDIES BAY STP CHEMICAL AND TOXICITY
ANALYSES RESULTS

Parameter	Sampling Date (1978)		Mean
	July 5	July 11	
-----mg/l*-----			
<u>Final Effluent</u>			
pH	7.9	7.8	7.8
BOD ₅	93	57	75
COD	170	195	182
TR	2590	2590	2590
TVR	294	288	291
NFR	41.0	22.4	32
NO ₃	0.952	1.13	1.04
NO ₂	0.313	0.298	0.306
NH ₃	65.0	65.8	65.4
TP0 ₄	7.63	7.39	7.51
TOC	32.0	20.0	26.0
LAS	0.109	0.066	0.088
LC ₅₀	39	46	43
<u>Aeration Tank</u>			
VNFR	90.3	76.2	83.2
pH	7	7	
DO	7	-	
Settleability			
30 min.	3.0	2.5	
60 min.	3.5	2.5	
Temperature	19	16	
<u>Return Sludge</u>			
VNFR	70.5	53.7	

* mg/l except: pH - pH units, LC₅₀ - %, settleability - ml/l,
temperature - °C.

APPENDIX VI

TABLE 4 B.C. FERRY - LYALL HARBOUR STP CHEMICAL AND TOXICITY ANALYSES RESULTS

Parameter	Sampling Date (1978)		Mean
	July 12	July 17	
-----mg/l*-----			
<u>Final Effluent</u>			
pH	7.6	7.7	7.6
BOD ₅	57	15	36
COD	70	100	85
TR	307	326	317
TVR	120	117	118
NFR	7.5	14	11
NO ₃	4.01	6.36	5.18
NO ₂	0.690	0.3325	0.511
NH ₃	22.0	20.4	21.2
TPO ₄	6.45	-	6.45
TOC	31.0	28.0	29.5
LAS	0.090	0.066	0.078
LC ₅₀	NT**	NT	NT
<u>Aeration Tank</u>			
VNFR	20.0	L20	
pH	7	-	
DO	9	-	
Settleability			
30 min.	0.2	0.2	
60 min.	0.2	0.2	
Temperature	16	-	
<u>Return Sludge</u>			
VNFR	31.6	L20	

* mg/l except: pH - pH units, LC₅₀ - %, settleability - ml/l, temperature - °C.

** NT- non-toxic

L - denotes "less than"

APPENDIX VI

TABLE 5 GULF INDUSTRIES STP CHEMICAL AND TOXICITY ANALYSES RESULTS

Parameter	Raw Sewage		Mean	Final Effluent		Mean Reduction
	July 25*	July 27*		July 25*	July 27*	
	-----mg/l**-----					
pH	7.1	8.1	7.6	7.6	7.6	
BOD5	60	92	76	L6	L6	G92
COD	170	190	180	115	110	38
TR	204	362	283	438	446	+56
TVR	105	133	119	174	166	+43
NFR	41	54	48	16	17	67
NO3	L0.010	0.0126	0.0113	15.4	14.5	15.0
NO2	0.430	0.0174	0.224	0.802	0.997	0.900
NH3	2.95	5.00	3.98	19.0	20.5	19.8
TP04	1.35	6.48	3.92	8.40	8.05	8.23
TOC	35.0	48.0	41.5	35.0	32.0	33.5
LAS				0.075	0.087	0.081
LC50				NT***	NT	NT

Aeration Tank

VNFR 129 102 116

pH -

DO -

Settleability

30 min. 5 4

60 min. 5 4

Temperature 16 -

Return Sludge

VNFR 108 126

* Sampling date (1978)

** mg/l except: pH - pH units, settleability - ml/l, temperature °C.

*** NT - non toxic.

L - "less than"

G - "greater than"

+ - indicates % increase of final effluent compared to raw sewage.

APPENDIX VI

TABLE 6 MAGIC LAKE ESTATES STP CHEMICAL AND TOXICITY ANALYSES RESULTS

Parameter	Raw Sewage		Mean	Final Effluent		Mean	Mean % Reduction
	July 25*	July 27*		July 25*	July 27*		
-----mg/l**-----							
pH	7.7	7.4	7.6	5.6	5.5	5.6	
BOD5	28	50	39	L6	L6	L6	G85
COD	190	185	188	140	135	138	27
TR	458	322	390	671	674	673	+73
TVR	153	157	155	294	295	294	+90
NFR	48	69	59	86	91	89	+51
NO3	0.011	L0.010	0.010	46.7	111	79	
NO2	L0.0050	L0.0050	L0.0050	0.0100	0.0113	0.0106	
NH3	44.5	42.5	43.5	4.30	3.00	3.65	92
TP04	9.75	4.48	7.12	12.8	12.4	12.6	+77
TOC	66.0	65.0	65.5	35.0	39.0	37.0	44
LAS				0.499	0.380	0.440	
LC50				85	L10	43	
Aeration Tank							
VNFR	2540	673	1606				
pH	-	-					
DO	-	-					
Settleability							
30 min.	240	240					
60 min.	240	240					
Temperature	-	16					
Return Sludge							
VNFR	2790	690					

* Sampling date (1978)

** mg/l except: pH - pH units, settleability - ml/l, temperature °C.

*** NT - non toxic.

L - "less than"

G - "greater than"

+ - indicates % increase of final effluent compared to raw sewage.

APPENDIX VI
TABLE 7 GULF INDUSTRIES AND MAGIC LAKE ESTATES RAW SEWAGE STRENGTH

Parameter	Typical Composition (2)			Gulf Industries	Magic Lake Estates
	Strong	Medium	Weak		
TR	1200	700	350	283	390
NFR	350	200	100	48	59
FR	600	350	175	235	331
TVR	600	350	175	119	155
TFR	850	500	250	164	245
BOD ₅	300	200	100	76	39
TOC	300	200	100	41.5	65.5
COD	1000	500	250	180	188
NH ₃	50	25	12	3.98	43.5
NO ₃	0	0	0	0.0113	0.010
NO ₂	0	0	0	0.224	L0.0050
TPO ₄	20	10	6	3.92	7.12

L - denotes "less than"

APPENDIX VI
TABLE 8 SUMMARY OF FINAL EFFLUENT SAMPLING RESULTS

Parameter	T R E A T M E N T F A C I L I T Y				
	Anchor Chain Septic Tank	Sturdies Bay STP	Lyal1 Harbour STP	Gulf Ind. STP	Magic Lake STP
-----mg/l*-----					
pH	7.2	7.8	7.6	7.6	5.6
BOD5	157	75	36	L6	L6
COD	440	182	85	112	138
TR	513	2590	317	442	673
TVR	230	291	118	170	294
NFR	103	32	11	16	89
NO3	L0.010	1.04	5.18	15.0	79
NO2	0.0152	0.306	0.511	0.900	0.0106
NH3		65.4	21.2	19.8	3.65
TP04	9.70	7.51	6.45	8.23	12.6
TOC		26.0	29.5	33.5	37.0
LAS		0.088	0.078	0.081	0.440
LC50		43	NT**	NT	43

* mg/l except: pH - pH units, LC50-%

** NT - non-toxic.
L - "less than"

APPENDIX VI
TABLE 9 BOD₅, COD, TOC FINAL EFFLUENT RELATIONSHIPS

Treatment System	BOD ₅	COD	TOC	BOD ₅ /TOC	BOD ₅ /COD	COD/TOC
-----mg/l-----						
Sturdies Bay	75	182	26.0	2.9	0.4	7
Lya'll Harbour	36	85	29.5	1.2	0.4	3
Gulf Industries	L6	112	33.5	0.2	0.05	3
Magic Lake	L6	138	37.0	0.2	0.04	4

L - denotes "less than"

Generally, the B.C. Ferry - Lyall Harbour STP produced the best final effluent quality. Final effluent concentrations of COD, TR, TVR, NFR, and TPO₄ were the lowest from this plant compared to the levels noted from the other three treatment systems. The B.C. Ferry - Sturdies Bay STP generally produced the poorest quality effluent - having particularly high TR and NH₃ concentrations.

Results of sampling and analysis, by the PCB, of the Gulf Industries and Magic Lake Estates final effluent generally agree with data gathered during this study (Table 10). The Magic Lake Estates final effluent NFR concentration determined by the PCB was significantly lower than that determined in this study suggesting that the problem noted here of sludge biomass carry-over from the clarifier to the final effluent is intermittent. The low BOD₅ and NFR mean concentrations determined by the PCB for the two plants indicate that they usually produce good quality effluent.

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TABLE 10 SUMMARY OF PCB MONITORING DATA FOR THE GULF INDUSTRIES AND MAGIC LAKE ESTATES STPS

Parameter	Gulf Industries		Magic Lake Estates	
	-----mg/l*-----			
Flow	40	(53)	14	(53)
pH	7.4	(8)	6.9	(10)
TR	380	(1)	758	(1)
NFR	12	(14)	36	(16)
DO	5.3	(1)	5.8	(2)
BOD5	14	(14)	27	(15)
TRC	0.63	(6)	1.3	(6)

() - number of analyses

* - mg/l except: pH - pH units, flow - m³/day.

Using the PCB flow measurements, aeration tank volumes, MLVSS concentrations, and final effluent NFR concentrations determined in this study, mean cell residence times (θ_c) may be calculated by the following equation:

$$\frac{VX}{Q_wX + (Q - Q_w) X_e}$$

where: V - is the aeration tank volume.

X - is the aeration tank MLVSS.

Q_w - is the wastage rate.

X_e - is the final effluent VSS concentration.

The recommended value of θ_c for extended aeration treatment plants is 20 to 30 days (2). The mean cell residence time for the Gulf Industries STP is 32 days whereas for the Magic Lake Estates STP it is 100 days. The Magic Lake Estates high θ_c value, which reflects the time available for establishment of a nitrifier population, explains the ability of the treatment system to achieve significant nitrification.

The performance of the four sewage treatment plants may be evaluated by comparing final effluent pollutant concentrations to the Pollution Control Branch permit requirements and literature reported performance data as shown in Table 11. Using the Pollution Control Branch permit criteria, the Gulf Industries and B.C. Ferry - Lyall Harbour treatment plants met the requirements, while the B.C. Ferry - Sturdies Bay (BOD_5) and Magic Lake Estates (NFR) did not.

The operation of package sewage treatment plants has been studied rather extensively in both Canada and the United States (4). The performance of 22 extended aeration activated sludge plants in the U.S. was evaluated by the National Sanitation Foundation. During the study, each package plant was attended by an experienced operator and the plant was operated under optimum conditions. Using these results as a best achievable performance criteria, a comprehensive study of 20 selected aeration activated sludge package plants was conducted in Ontario (4). The results of this latter study showed that over 50 percent of the

APPENDIX VI
TABLE 11 PERFORMANCE OF THE PACKAGE SEWAGE TREATMENT PLANTS

Intermittent Service			Continuous Service		
<u>Performance</u>	BOD ₅ (mg/l)	NFR (mg/l)	<u>Performance</u>	BOD ₅ (mg/l)	NFR (mg/l)
B.C. Ferry - Sturdies Bay	75	32	Gulf Industries	45*	16
B.C. Ferry - Lyall Harbour	36	11	Magic Lake	55*	89
<u>Criteria</u>			<u>Criteria</u>		
PCB permit	45	60	PCB permit	70	85
possible performance**	13	18	possible performance**	15	20
probable performance**	15	36	probable performance**	72	62

* derived BOD₅ concentrations - see text.

** findings of National Sanitation Foundation study (Ref. 4).

plants investigated did not achieve the anticipated level of performance. Reasons cited for the poor performance of some plants included process, equipment, and operator - oriented problems. These included:

- 1) Process - oriented problems
 - a) insufficient biomass in the aeration tank;
 - b) improper aeration
 - c) floating sludge
 - d) offensive odours
 - e) lack of sludge treatment facilities
- 2) Equipment - oriented problems
 - a) mechanical breakdown of comminutors
 - b) clogging of air diffusers
 - c) clogging of sludge return system
 - d) malfunction of the skimming device
 - e) icing problem
- 3) Operator - oriented problems
 - a) inadequate maintenance
 - b) insufficient operator attention
 - c) inadequacy of design

Using these literature reported criteria only, the Gulf Industries and the B.C. Ferry - Lyall Harbour final effluent NFR concentrations met the possible performance levels. The B.C. Ferry - Sturdies Bay final effluent NFR concentration and the Gulf Industries and Magic Lake Estates BOD₅ concentrations, met the probable performance criteria.

Process, equipment, and operator - oriented problems noted at each STP may be summarized as follows:

- 1) B.C. Ferry Corporation - Sturdies Bay
 - a) insufficient biomass in the aeration tank (MLVSS = 83.2 mg/l, SVI = 36).
 - b) lack of sludge treatment facilities
 - c) non-functioning sludge return system (MLVSS = 62.1 mg/l).
 - d) inadequate maintenance (sludge layer, mosquito larvae, and worms in chlorine contact tank).

- 2) B.C. Ferry Corporation - Lyall Harbour
 - a) insufficient biomass in the aeration tank
(MLVSS = less than 20 mg/l, SVI = 10).
 - b) lack of sludge treatment facilities
 - c) non-functioning sludge return systems
(MLVSS = 25 mg/l).
 - d) insufficient operator attention.
- 3) Gulf Industries
 - a) insufficient biomass in the aeration tank
(MLVSS = 116 mg/l, SVI = 43).
 - b) lack of sludge treatment facilities
 - c) non-functioning sludge return system
(MLVSS = 126 mg/l).
- 4) Magic Lake Estates
 - a) lack of sludge treatment facilities
 - b) carry-over of biomass from clarifier
possibly due to bulking sludge or
hydraulic over-loading.

3.2 Bioassay Results

A study of municipal wastewater toxicity of eight sewage treatment plants was conducted by personnel of the Environmental Protection Service during 1976 and the results appear in EPS published reports by T.W. Higgs (5). In that study three chemical parameters were regularly noted to be responsible for acute toxicity to the test fish. These were anionic surfactants, un-ionized NH_3 , and TRC. Critical concentrations of these parameters reported in the literature are shown in Table 12. A detailed discussion of this subject is beyond the scope of this report and the reader is referred to the appropriate references listed.

Generally, the toxicity results obtained from samples collected from each of the four package sewage treatment plants correlated well with the chemical results (Table 13). Samples collected from the final effluent of the B.C. Ferry - Lyall Harbour and Gulf Industries treatment

APPENDIX VI

TABLE 12 CRITICAL CONCENTRATIONS OF ANIONIC SURFACTANTS, UN-IONIZED NH₃, AND TRC REPORTED TO BE TOXIC TO FISH

Parameter	Concentration (mg/l)	Significance	Reference
Un-ionized NH ₃	0.006	desirable upper limit	(6)
	0.025	maximum tolerated	(7)
	0.44	100% mortality after 96 hours	(8)
Anionic surfactants	3.3-6.4	96 hour LC ₅₀	(9)
	5.9	96 hour LC ₅₀	(10)
TRC	0.02	likely toxic	(11)

APPENDIX VI
TABLE 13 SUMMARY OF 96 HOUR LC₅₀ BIOASSAY RESULTS AND SELECTED CHEMICAL ANALYSES RESULTS

Sample Location	Type of Sample	96 hour LC ₅₀	Un-ionized NH ₃ * (mg/l)	Anionic Surfactants (mg/l)	Average TRC (mg/l)
B.C. Ferry - Sturdies Bay	grab	43%	1.6	0.088	-
B.C. Ferry - Lyall Harbour	grab	NT	0.29	0.078	-
Gulf Industries	grab	NT	0.27	0.081	**
Magic Lakes Estates	grab	43%	0.0004	0.440	**

* Un-ionized NH₃ concentrations were calculated using NH₃ concentration, pH, temperature data, and tables prepared by Emerson, et al (13).

** Chlorination is practised at these treatment plants, but, the TRC concentration is unknown.
NT - non-toxic.

plants were non-toxic which is compatible with low un-ionized NH_3 and anionic surfactants concentrations. The B.C. Ferry - Sturdies Bay final effluent samples exhibited a mean LC_{50} of 43%, probably reflecting a high un-ionized NH_3 concentration. The Magic Lakes Estates final effluent samples produced a mean LC_{50} of 48%. This result did not correlate with any chemical results, although the known use of chlorine as a disinfectant was a possible contributing factor.

The synergistic and/or antagonistic effects of many compounds may reduce or increase toxic responses relative to predictions derived from chemical analyses results. Modifying conditions for bioassays include the effects of temperature, water hardness, alkalinity, pH, dissolved oxygen, among others (12).

Also, chemical constituents in addition to those determined in this study may have been responsible, at least in part, for the toxicity noted.

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