ENVIRONMENTAL PROTECTION BRANCH
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC REGION

SHELLFISH GROWING WATER SANITARY SURVEY OF THE NANAIMO HARBOUR AREA, FROM PAGE LAGOON TO DODD NARROWS, BRITISH COLUMBIA, 1978

78-17

Regional Program Report: 78-17

by

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ABSTRACT

A bacteriological survey of the molluscan shellfish-growing waters of Nanaimo Harbour from Dodd Narrows to Page Lagoon was conducted from March 13 to April 7, 1978, by personnel of the Environmental Protection Service, Pacific Region.

A sanitary survey was conducted concurrently with the bacteriological survey to identify and evaluate sources of fecal pollution to the study area. Chemical, acute toxicity, and bacteriological analyses were performed on various treatment stages at the Greater Nanaimo Water Pollution Control Centre to evaluate the operation of the plant.

During the study, 74 marine stations, 27 freshwater stations, and 3 effluent stations were established, representing 601, 104, and 11 samples, respectively. Seven marine stations did not meet the approved shellfish-growing water standard.

Modification of the present Schedule 1 closure of Nanaimo Harbour is described.

RÉSUMÉ

Entre le 13 mars et le 7 avril 1978, le Service de la protection de l'environnement a effectué, dans le port de Nanaimo, une étude bactériologique des eaux à mollusques situées entre le passage Dodd et la lagune Page.

Parallèlement à cette étude, une analyse de la salubrité visait, por sa part, à déterminer et évaluer les sources de pollution fecale dans cet habitat. Au Greater Nanaimo Water Pollution Control Centre, les experts ont procéde à des analyses chimiques et bactériologiques, de même qu'à la détermination de la toxicité aigue d'échantillons préléves à différents stades de l'épuration. Le but de ces recherches était de déterminer l'efficacité de l'usine d'épuration.

Dans cette optique, on a choisi 74 stations de prélèvement d'eau marine, 27 d'eau douce et trois d'effluents, dans lesquelles on a respectivement recueilli 601, 104 et 11 échantillons. Les eaux de sept stations marines n'étaient pas conformes aux critères établis pour la qualité des zones maricoles.

Nous donnons ici les modifications apportées au secteur interdit du port de Nanaimo, que décrit l'annexe 1 du règlement.

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CONCLUSIONS

1. The waters and tidal foreshore of Northumberland Channel were of acceptable bacteriological quality for the purpose of shellfish harvesting. Domestic sewage discharges from the Harmac pulp mill and Hooker Chemical plant were considered insignificant sources of fecal pollution.
2. The waters of Nanaimo Harbour were of acceptable bacteriological quality for the purpose of shellfish harvesting. None of the freshwater inputs to the harbour area were considered to be major contributors of fecal pollution, although three storm drains yielded fecal coliform counts which would result in localized receiving water degradation. The source(s) of contamination to these storm drains was not ascertained. Although water quality in Nanaimo Harbour was acceptable, the heavy use of the waters for industrial and shipping purposes, and the uncontrolled discharges of human sewage from seagoing vessels are incompatible activities with shellfish growth and harvesting.
3. The water quality of the intertidal area surrounding Newcastle and Protection islands was acceptable for shellfish harvesting during the survey period. Intermittent contamination observed at some sample stations was associated with freshwater influences from the harbour area. Additional contamination may result on both islands due to increased recreational activity during the summer. Of specific concern are sewage discharges from pleasure boats moored at the Newcastle Island Park marina, and possible discharges from faulty sewage disposal systems on Protection Island, the majority of which are used only during the summer months. A brief sanitary survey conducted in July by EPS in cooperation with the Central Vancouver Island Health Unit did not reveal any land-based pollution problems with the exception of the Lee Shore Marina. Marine sampling at this time indicated little or no fecal contamination entering the foreshore waters.
4. The waters and tidal foreshore of Departure Bay are of acceptable water quality for shellfish harvesting, with the exception of the intertidal area at the head of the bay. Storm drainage comprised of urban and

agricultural runoff caused contamination of the receiving waters in this area. Departure Creek was primarily responsible for the unacceptable water quality noted at marine sample stations. Animal fecal matter in runoff is suspected as the principal source of this contamination. Other areas of Departure Bay, although meeting the growing water standards, remain prohibited to shellfish harvesting due to their proximity to the B.C. Ferry Terminal and the Biological Station dock. Such areas must remain under closure in the absence of regulations preventing sewage discharge from vessels.

5. Unacceptable fecal contamination was observed at Stephenson Point. The contamination was believed to be from septic tank seepage originating from houses located close to the foreshore in an area characterized by a thin soil layer covering the bedrock.
6. Low theoretical wet well retention times coupled with the absence of warning systems for pump malfunctions or power disruptions indicates that contamination of the foreshore by sewage overflows from the City of Nanaimo sewage pump stations at the Madill's, William's and Fagin's residences is possible.
7. The discharge of sewage from the Greater Nanaimo Water Pollution Control Centre (GNWPCC) through the Five Finger Islands submarine diffuser did not impair the bacteriological quality of the surrounding intertidal waters.
8. The waters of Page Lagoon are of acceptable water quality for shellfish harvesting. However, the presence of a sewage overflow pipe into the lagoon from a City of Nanaimo pump station poses a serious threat to the shellfish consumer in the event that an overflow of raw sewage occurs.
9. Chemical analyses of samples collected at the GNWPCC indicates that under normal operating conditions, the treatment plant produces an effluent of typical quality for this type of system. Bioassay results showed that the sewage effluent after sedimentation and the final chlorinated effluent were acutely toxic to the test fish. The final effluent was found to be the most toxic due primarily to residual chlorine and un-ionized ammonia concentrations.

SCHEDULE 1 CLOSURES

1. The Schedule 1 17-4 closure should be revoked and replaced with the following closures:

   (a) "Area 17-4A. The waters and tidal foreshores of Departure Bay and Nanaimo Harbour from Horswell Bluff to Jack Point."

   (b) "Area 17-4B. The waters and tidal foreshore of Newcastle Island."

   (c) "Area 17-4C. The waters and tidal foreshore of Protection Island lying within a 300 metre radius of the Lee Shore marina docks."

   (d) "Area 17-4D. The waters and tidal foreshore of Pirate's Beach, Protection Island, lying inside, that is easterly of a line drawn from Goose Point southeast to Gallows Point."

These proposed closure changes are illustrated in Figure 1.

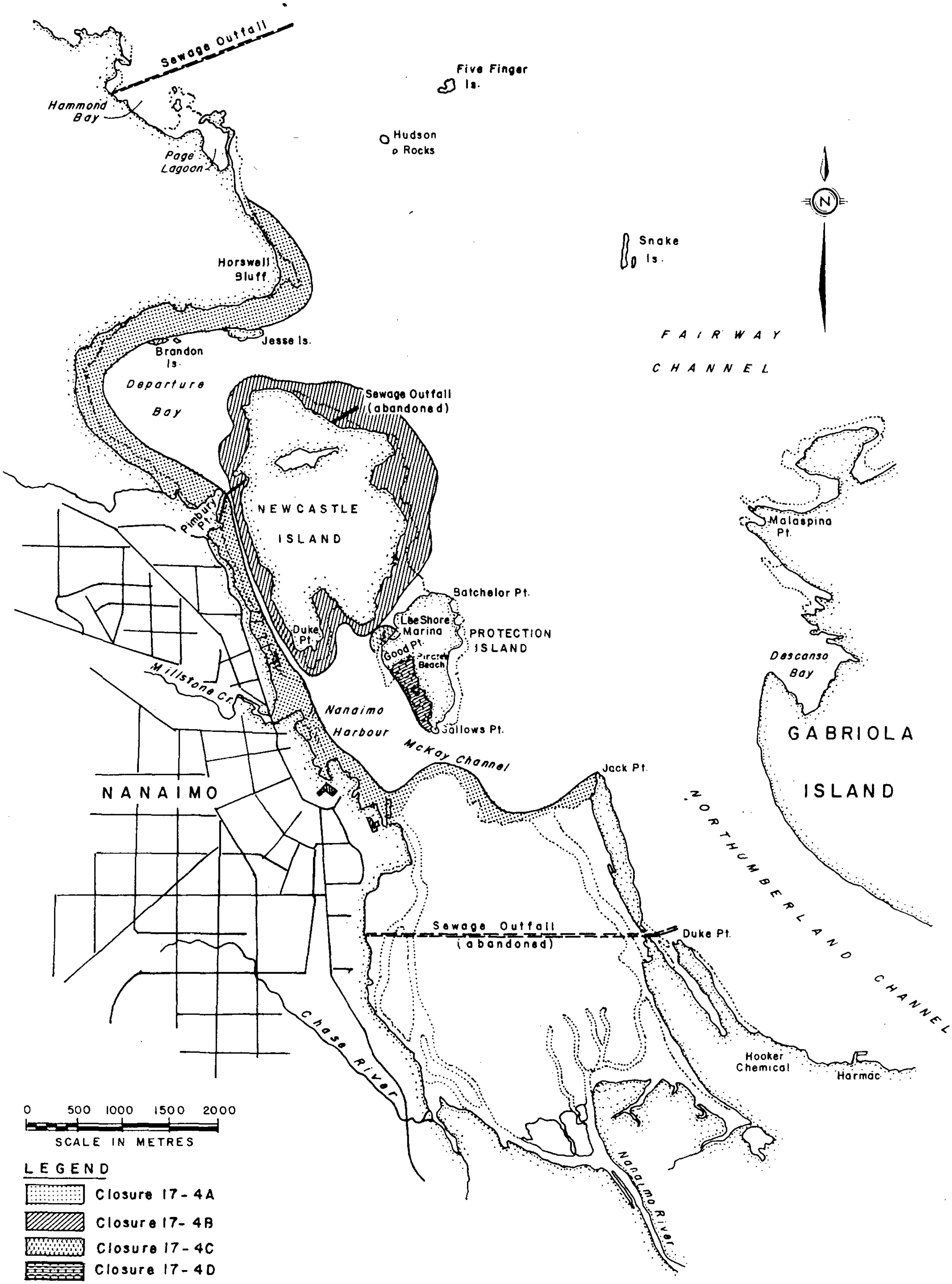

FIGURE I PROPOSED SCHEDULE I CLOSURES

1 INTRODUCTION

The City of Nanaimo is the second largest city on Vancouver Island and has traditionally been the transportation hub for the Island, with ferry service for passengers and freight provided for many years by the Canadian Pacific Railway and more recently by the British Columbia Ferry Corporation. The area presently supports a population of 40 336 (1976 census, Statistics Canada).

Nanaimo has had a comparatively long history of industrial development, with coal mining being a major activity since the mid 1800's. As coal mining was phased out due to depletion of the resource, forestry, including logging and sawmilling became a major economic base for the community. The forest products industry is supported mainly by the MacMillan Bloedel Limited kraft pulp mill at Harmac, two chemical industries and several sawmills and lumber companies. Because of the available harbour facilities and the connecting railway and highway lines to nearby logging areas on Vancouver Island, Nanaimo has become a major port for lumber export. Additional bulk loading and industrial facilities are planned at Duke Point and land clearing is proceeding under the direction of the British Columbia Development Corporation.

Commercial and recreational fishing has always been conducted out of Nanaimo. At the present time there is only one commercial herring roe processor and one small custom canning establishment in operation.

No commercial molluscan shellfishery exists in the Nanaimo Harbour/Departure Bay area due to the current Schedule 1 "contaminated area" closure. A shellfish closure was first imposed on Nanaimo Harbour in November 1949 by the Federal Minister of Fisheries and included the areas of "Nanaimo Harbour, Exit Channel, and adjacent waters lying inside, or southerly of, a straight line drawn from Pimbery Point, through Newcastle and Protection islands to Jack Point" (1). At the time this closure was imposed, the City of Nanaimo was discharging raw sewage directly into Nanaimo Harbour from the outfalls located (i) at Assembly Wharf (ii) behind the Malaspina Hotel and (iii) at the southern end of Newcastle Island Passage (2). By 1958, two new outfalls were built, one near Duke Point and the other on the northeast shore of Newcastle Island. Comminuted raw sewage was discharged at both these locations however these changes in sewage disposal were not considered adequate to protect the shellfish resource and the closure remained in effect.

In 1972, the shellfish closure was amended for inclusion in Schedule J (now Schedule 1) of the British Columbia Fishery Regulations and the area of closure was extended to include Departure Bay. The present Schedule 1 closure now reads: "Area 17-4. The waters and tidal foreshore of Nanaimo Harbour lying inside a line drawn from Horswell Bluff to Malaspina Point and thence to Duke Point."

In October of 1974, the City of Nanaimo began discharging raw sewage through a deep sea outfall located at Five Finger Island and by July 1975, the sewage was receiving primary treatment with chlorination at the new Greater Nanaimo Water Pollution Control Centre (GNWPCC). At the same time the sewage treatment plant was being constructed, a diffuser was installed on the Five Finger outfall. The completion of the sewage treatment plant and diffuser outfall resulted in the cessation of sewage discharges at the Duke Point and Newcastle Island outfalls.

Water quality and biological monitoring (3, 4) of the waters adjacent to the Five Fingers outfall prior to and following discharges indicated that the sewage discharged from the outfall has not had an observable detrimental effect on the surrounding intertidal area. Significant improvements in water and oyster tissue coliform levels were observed in the vicinity of the Newcastle Island outfall following the cessation of the discharge at this point.

As a result of this improved method of sewage treatment and disposal and the reported improvements in bacteriological water quality in the vicinity of the old Newcastle Island outfall, the Environmental Protection Service undertook a shellfish water quality survey of Nanaimo Harbour and Departure Bay from Dodd Narrows to Page Lagoon including Newcastle and Protection Island in March and early April 1978.

The purpose of the survey was threefold:

1. To investigate the validity of the present Schedule 1 contaminated area closure of Nanaimo Harbour, which had not previously been surveyed.

2. To determine the effects of the Five Finger Island sewage discharge on the surrounding intertidal areas with respect to their suitability for shellfish harvesting.
3. To identify and evaluate other sources of pollution to the study area.

Additional sanitary investigative work was conducted in July 1978, to assess the impact of summer residences and boat moorage on selected intertidal areas of Protection and Newcastle Islands.

2 SAMPLE STATION LOCATIONS

Marine sample stations were located in the intertidal and subtidal areas to assess the degree of fecal pollution resulting from known or suspected sources of contamination. Potential sources of fecal contamination which determined the positioning of the samples stations included: (i) Harmac Pulp Mill, (ii) Hooker Chemicals, (iii) Nanaimo River, (iv) Millstone River, (v) Five Fingers Island sewage outfall, and (vi) numerous storm drains discharging to Departure Bay. Sample stations were also positioned in areas known to have a molluscan shellfish resource, the most noteworthy being the passage between Newcastle and Protection islands and the Page Lagoon area.

Both depth and surface samples were taken at selected sample stations in Nanaimo Harbour to assess the degree of fecal contamination in the water column.

Freshwater and effluent sample stations were established on all major inputs to the study area to determine the significance of their bacterial contributions to the receiving environment. The freshwater sampling program was done concurrently with the marine sampling.

Sample station locations are shown in Figures 2 and 3.

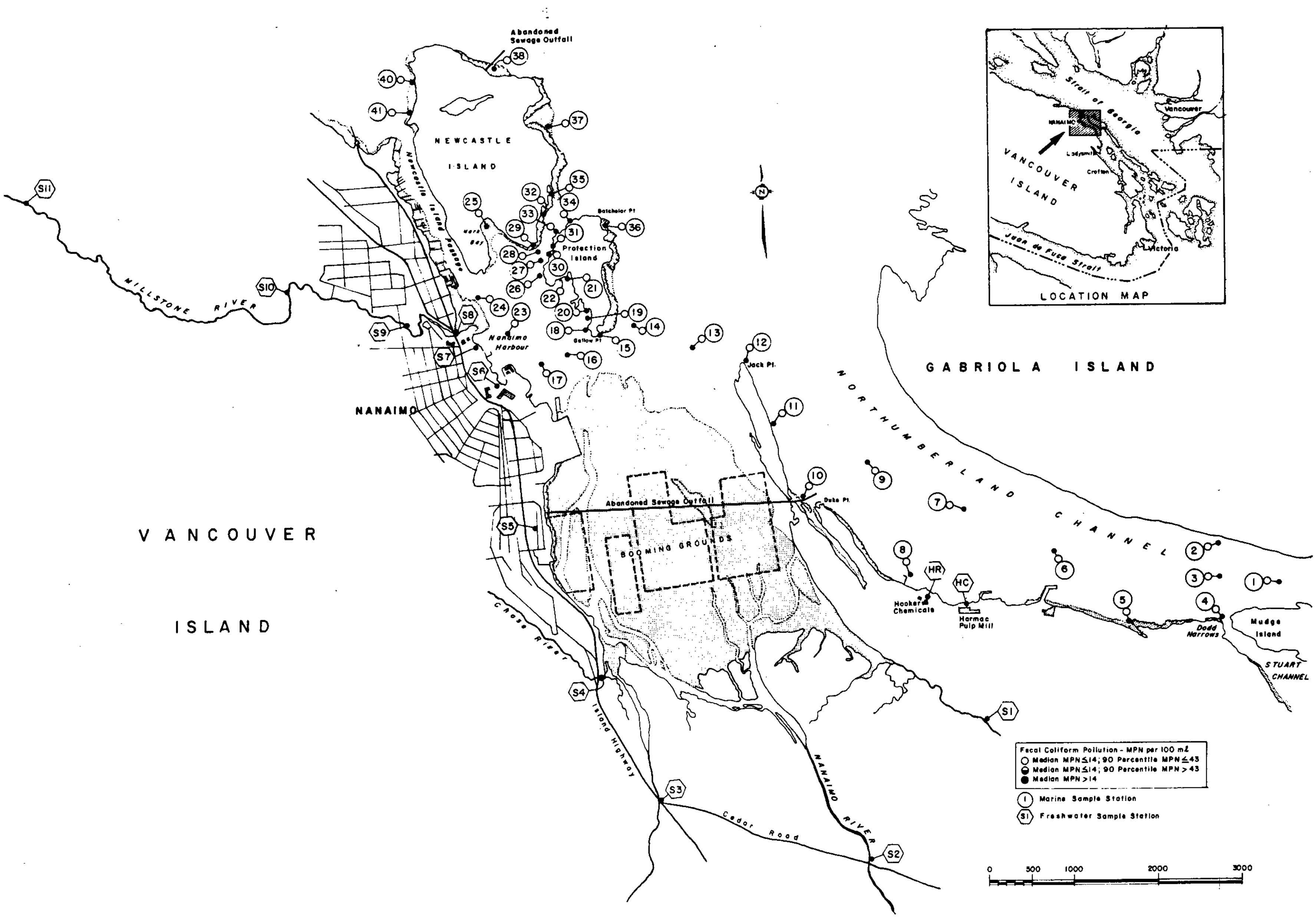

FIGURE 2 SOUTH SECTOR MARINE AND FRESHWATER SAMPLE STATION LOCATIONS

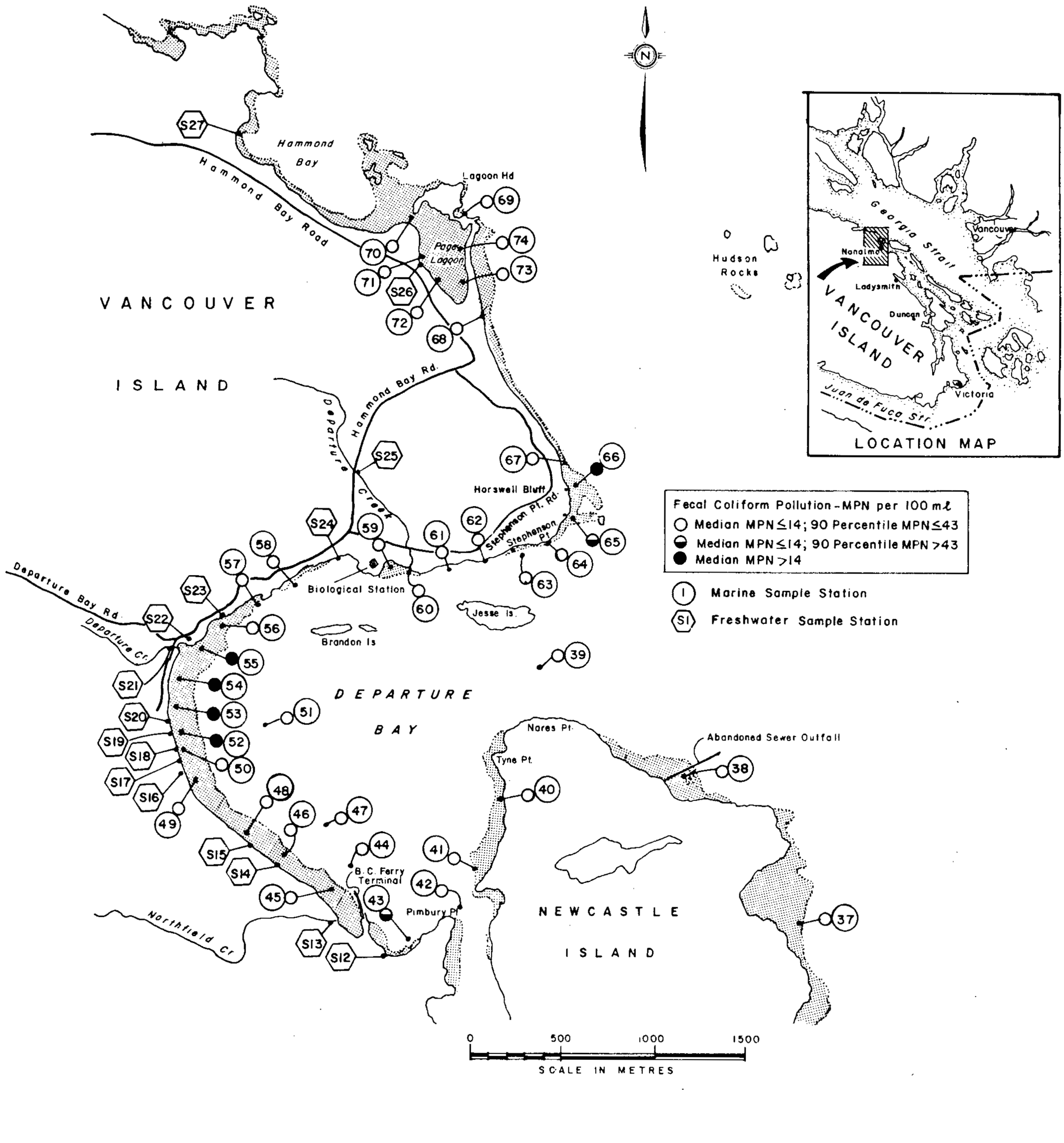

FIGURE 3 NORTH SECTOR MARINE AND FRESHWATER SAMPLE STATION LOCATIONS

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 in Nanaimo.

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 (5). The culture medium used was the A-1 medium, as described by Andrews and Presnell (6). 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 (7) 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 milliliter 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°C in air incubators for three hours and then transferred to a water bath at 44.5 $\pm$ 0.2°C and incubated for a further 21 hours for a total of 24 $\pm$ 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 coliform, 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, Missisauga, Ontario.

3.1.1 Biochemical Identification of Bacterial Isolates. Bacterial isolates from MPN gas-positive tubes 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" (8).

3.2 Physical and Chemical Testing Equipment and Analyses

Temperature measurements of marine and freshwater samples were taken with an immersible Celsius thermometer with an accuracy of ±0.5°C. The salinity of all marine samples was determined using an American Optical refractometer (Catalogue No. 10413) which has a resolution to the nearest 0.5 part per thousand. Wind speeds and direction were determined with a Telcor series 210 electronic wind speed/direction indicator.

Rainfall data were obtained from the Nanaimo Airport at Cassidy (Figure 4) and tide data used was that for Point Atkinson (Figure 5).

All samples for chemical analysis were submitted to the Environmental Protection Service/Fisheries and Marine Service Chemistry Laboratory, Cypress Creek, West Vancouver. Physical and chemical testing procedures and methods employed in the sampling of the GNWPCC are discussed in Appendix VII.

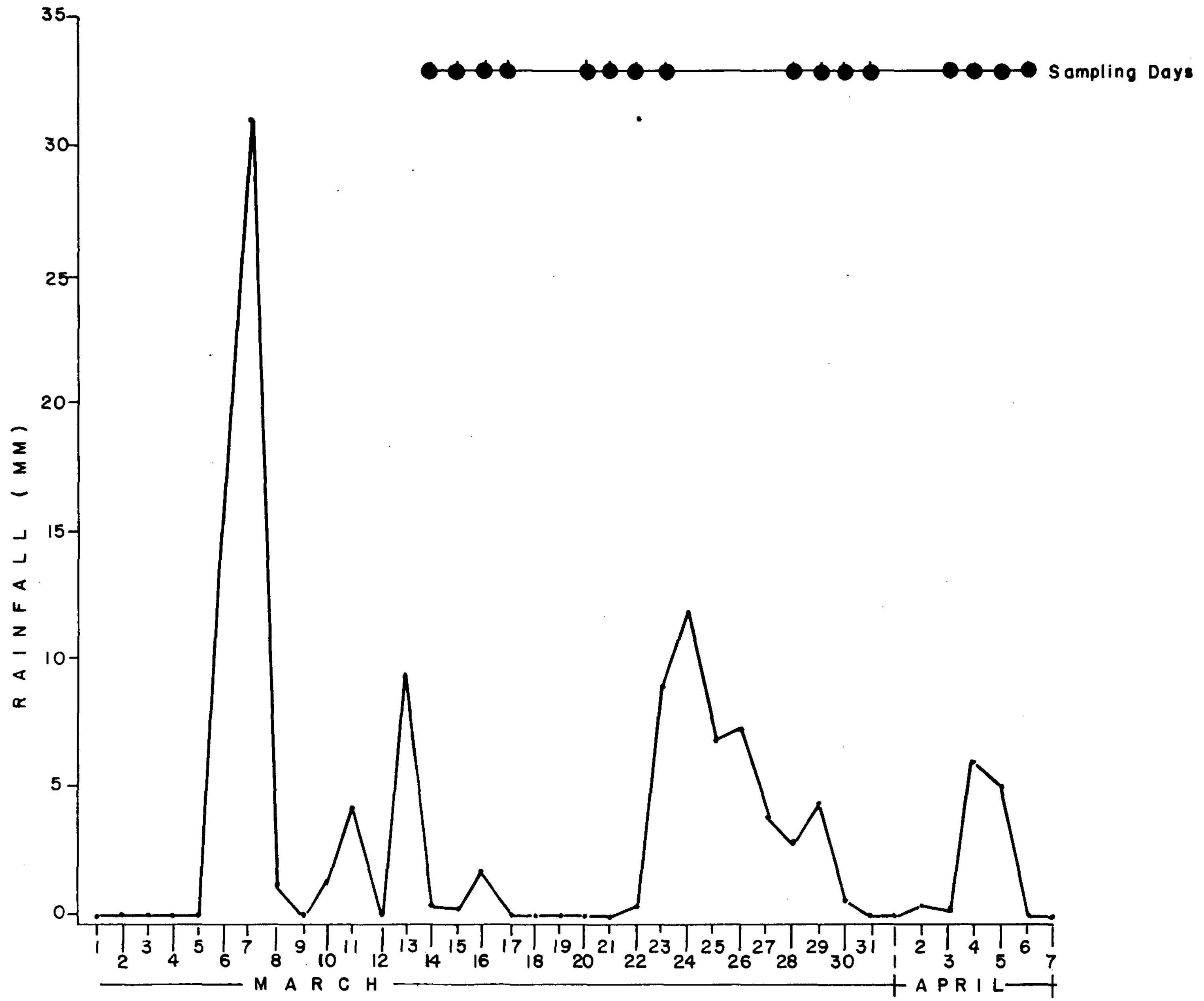

FIGURE 4 RAINFALL - MARCH 1- APRIL 7, 1978 - CASSIDY AIRPORT

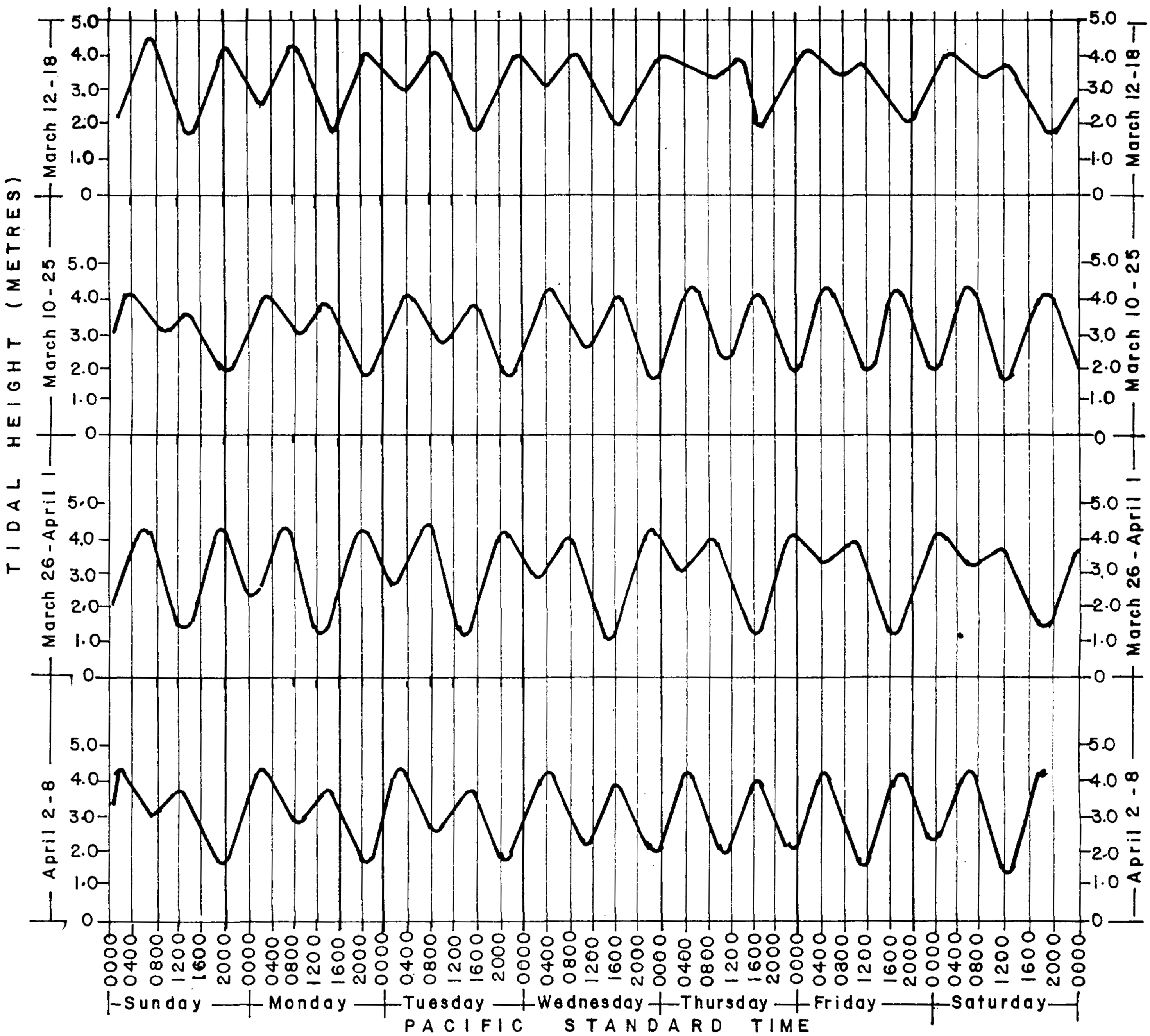

FIGURE 5 TIDAL HEIGHT GRAPH - POINT ATKINSON, March 12 - April 8, 1976

4 RESULTS

The bacteriological results for marine and freshwater sample stations are summarized in Tables 1 and 2, while daily bacteriological results are presented in Appendices III and IV, respectively. Descriptions of marine and freshwater sample stations are listed in Appendices I and II, and salinity and temperature data from marine sample stations are summarized in Appendix V.

The fecal coliform results obtained from the marine stations are used in classifying the shellfish growing waters according to the following criteria:

In order that an area be considered bacteriologically safe for the harvesting of bivalve molluscan shellfish, the fecal coliform median MPN of the water must not exceed 14/100 ml. In addition, not more than 10% of the samples may exceed an MPN of 43/100 ml for a 5-tube decimal dilution test, in those portions of the area most probably exposed to fecal contamination during the most unfavourable hydrographic and pollution conditions. (This report expresses the 10% limit in terms of a 90 percentile which cannot exceed 43/100 ml.)

The approved growing water standard was met at all stations, with the exception of stations 43, 52, 53, 54, 55, 65 and 66, located in the Departure Bay - Stephenson Point area.

Membrane filtration fecal streptococci analyses were performed on all freshwater sample in an attempt to determine the origin of fecal contamination in the major freshwater inputs. Geldreich and Kenner (9) have reported higher fecal streptococci 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. FC:FS ratios were calculated for all freshwater inputs sampled and a summary of these results is presented in Table 2.

In addition to FC:FS ratio calculations, population equivalents were also calculated for all freshwater inputs. The concept of "population equivalents", which takes into account both the fecal coliform concentration and the flow of contaminated water, is useful in comparing

TABLE 1 SUMMARY OF FECAL COLIFORM MPN RESULTS FOR MARINE STATIONS

Sample Station	No. of Samples	MPN Range	Fecal MPN/100 ml Median	Fecal MPN/100 ml 90th Percentile
1	6	< 2	< 2	< 2
2	6	< 2	< 2	< 2
3	6	< 2 - 2	< 2	< 2
4	6	< 2 - 2	< 2	< 2
5	6	< 2 - 11	2	6.8
6	6	< 2 - 5	< 2	3.2
7	6	< 2 - 8	< 2	4.4
8	6	< 2 - 2	< 2	< 2
9	6	< 2 - 2	< 2	< 2
10	6	< 2 - 2	< 2	< 2
11	6	< 2	< 2	< 2
12	6	< 2 - 2	< 2	< 2
13	6	< 2 - 2	< 2	2
14	6	< 2 - 2	< 2	2
15	6	< 2 - 5	< 2	3.2
16	6	< 2 - 8	3.5	8
17	10	< 2 - 33	6	23
18	6	< 2 - 8	< 2	5.6
19	6	< 2 - 23	4.5	17
20	6	< 2 - 8	2	5.6
21	6	< 2 - 11	3.5	9.2
22	6	< 2 - 11	3.5	7.4
23	9	< 2 - 23	< 2	14.0
24	13	< 2 - 130	5	40.9
25	12	< 2 - 46	3	33
26	11	< 2 - 33	2	22.4
27	9	< 2 - 13	2	11.2
28	12	< 2 - 79	2	40.2
29	12	< 2 - 130	2	7.4
30	12	< 2 - 46	2	21.0
31	11	< 2 - 23	< 2	8.0
32	9	< 2 - 13	< 2	7.6
33	9	< 2 - 13	< 2	5.8
34	9	< 2 - 2	< 2	2.0
35	9	< 2 - 17	2	6.2
36	5	2 - 5.6	2	3.8
37	6	< 2	< 2	< 2.0
38	6	< 2 - 2	< 2	< 2.0
39	6	< 2 - 5	< 2	3.2
40	8	< 2 - . 33	< 2	8.2
41	6	< 2 - 5	< 2	3.2
42	10	< 2 - 23	< 2	13.0
43	6	< 2 - 79	2	61
44	6	< 2 - 2	< 2	2
45	6	< 2 - 17	2	14.6
46	6	< 2 - 8	< 2	4.4
47	6	< 2 - 7	< 2	4
48	6	< 2 - 11	3.5	7.4
49	6	2 - 49	5	33.4
50	6	< 2 - 79	4.5	40
51	6	< 2 - 7	3	5.8
52	8	< 2 - 170	32	66.8
53	8	< 2 - 280	23	106.4
54	8	< 2 - 350	39.5	133.2
55	8	< 2 - 540	25	171.2
56	6	< 2 - 17	3.5	11.6
57	6	< 2 - 17	5	13.4
58	6	< 2 - 33	3.5	16.2
59	6	< 2 - 13	< 2	10
60	6	< 2 - 9	< 2	8.5
61	6	< 2 - 8	3.5	7.4
62	6	< 2 - 11	3.5	8.6
63	6	< 2 - 9	4	7.8
64	6	2 - 17	3	14.6
65	6	2 - 240	8	106.2
66	6	< 2 - 49	15.5	39.4
67	6	< 2 - 8	< 2	7.4
68	6	< 2 - 17	< 2	11.6
69	6	< 2 - 2	2	< 2
70	6	< 2 - 11	3.5	8
71	6	< 2 - 79	2	36.4
72	6	< 2 - 17	5	13.4
73	6	< 2	< 2	< 2
74	6	< 2 - 11	< 2	5.6

TABLE 2 SUMMARY OF BACTERIOLOGICAL RESULTS FOR FRESHWATER STATIONS

Sample Station	No. of Samples	Fecal Coliform MF Counts/100 ml Range	Fecal Coliform MF Counts/100 ml Mean	Fecal Streptococci MF Counts/100 ml Mean	FC/FS Ratio
S1	3	< 10 - 50	23	< 10	-
S2	5	< 10 - 20	12	< 10	-
S3	3	< 10 - 10	10	25	0.33
S4	5	< 10 - 120	42	42	1.0
S5	5	700 - 9300	3290	2675	1.23
S6	3	930 - 2600	1497	380	3.94
S7	3	40 - 740	280	190	1.47
S8	2	20 - 90	55	< 10	5.5
S9	5	30 - 90	62	75	0.83
S10	2	60 - 130	95	60	1.58
S11	2	50 - 70	60	90	0.67
S12	2	10 - 20	15	50	0.30
S13	5	< 10 - 68	29	80	0.36
S14	5	< 10 - 330	74	9	8.2
S15	4	< 10 - 164	27	27	1.0
S16	1	-	< 10	10	-
S17	4	< 10 - <10	< 10	< 10	-
S18	6	< 10 - 2200	388	104	3.73
S19	6	< 2 - <10	8	9	0.89
S20	5	< 10 - 58	22	34	0.65
S21	6	< 10 - 270	108	170	0.64
S22	3	< 10 - <10	10	97	0.10
S23	4	< 10 - <10	10	< 10	-
S24	4	< 10 - 110	38	38	1.0
S25	3	8 - <10	9	7	1.3
S26	4	< 10 - 100	33	127	0.26
S27	5	2 - <10	7	25	0.28
STP	6	< 10 - 120	34	642	0.053
HC	3	20 - 60	43	77	0.55
HR	3	< 10 - 440	170	290	0.59

theoretical relative impacts of freshwater inputs. The population equivalent of a source of fecal organisms may be calculated using an average value for the fecal coliform contribution per capita to a sewage system. An average person discharges 1.6×10^{11} total coliforms/day. The fecal coliform concentration in domestic sewage has been estimated at 20% of the total concentration (10). This yields a value of 3.2×10^{10} fecal coliforms/person/day. The equation for population equivalent becomes:

$$\text{Population Equivalents} = \frac{\text{Fecal Coliform Discharged per day}}{\text{Fecal Coliforms/Person/day}}$$

$$= \frac{\text{Flow x Fecal Coliform Counts}}{3.2 \times 10^{10}}$$

The population equivalents for all freshwater and effluent stations are presented in Table 3.

Biochemical analysis of fecal coliform isolates obtained from the marine sampling conducted on three days was performed to evaluate the selectivity of the A-1 medium for *E. coli*. Of the 244 isolates examined, 234 (95.9%) were identified as *E. coli*, indicating the coliform results obtained were reflecting pollution levels due to fecal contamination and not interference from ubiquitous coliform organisms.

The average March rainfall for the last 23 years is 101.3 mm, as measured at Cassidy airport (11). In March 1978, the total rainfall measured 110.3 mm while 69.3 mm was recorded during the survey period (March 13 to April 7). Thus, the March rainfall was typical for that normally experienced for this time of year although much of the month's rainfall preceded the start of the survey. It is probable therefore, that other factors being equal, bacteriological results for marine and freshwater samples were typical of those normally expected for that time of year. Higher bacteriological levels would be anticipated during the higher rainfall months of October to February, as most of the contamination observed during this survey resulted from stormwater discharges, which are significantly affected by rainfall events. Although it is difficult to correlate high fecal coliform levels at marine stations with specific rainfall events, there is a strong

TABLE 3 MEAN POPULATION EQUIVALENTS FOR FRESHWATER STATIONS

Sample Station	No. of Samples	Mean Fecal Coliforms (MF Counts/100 ml)	Average Flow (m^3/sec)	Mean Population Equivalent	Percent Of Sector Total
South Sector					
S1	3	23	0.36	0.224	1.27
S2	5	12	36.51	11.83	67.13
S3	3	10	0.41	0.11	0.62
S4	5	42	0.97	1.11	6.30
S5	5	3290	0.008	0.712	4.04
S6	3	1497	0.010	0.405	2.30
S7	3	280	0.004	0.03	0.17
S8	1	55	2.22	3.2	18.16
S9	5	62	2.22	3.72	-
S10	2	95	2.22	5.69	-
S11	2	60	2.22	3.6	-
North Sector					
S12	2	15	0.006	0.002	0.34
S13	5	29	0.11	0.086	14.7
S14	5	74	0.003	0.006	1.0
S15	4	27	0.008	0.001	0.17
S16	1	< 10	0.003	0.0008	0.047
S17	4	< 10	0.009	0.0024	0.41
S18	6	388	0.015	0.158	26.9
S19	6	8	0.005	0.001	0.17
S20	5	22	0.0005	0.0003	0.051
S21	6	108	0.10	0.292	50.0
S22	3	10	0.0009	0.0002	0.34
S23	4	10	0.009	0.002	0.34
S24	4	38	0.002	0.002	0.34
S25	3	9	0.08	0.02	3.4
S26	4	33	0.003	0.003	0.51
S27	5	7	0.05	0.009	1.5
STP	5	34	0.198	0.18	-
HC	3	43	2.60	4.56	-
HR	3	170	0.14	0.64	-
P1	1	< 10	0.0003	0.00008	-
P2	1	< 10	0.0003	0.00008	-
P3	1	< 10	0.0003	0.00008	-

correlation between high fecal coliform counts and reduced salinities. These reduced salinity values are attributable to higher rainfall and associated increased flow from freshwater inputs, which in turn causes the bacteriological quality of the receiving water to deteriorate as a result of urban landwash effects.

Winds during the survey period were predominantly from the northwest and southeast, and did not appear to significantly influence water quality through the movement of contaminated surface water (Table 4).

4.1 South Sector - Dodd Narrows to Newcastle Island

Marine stations 1-38 were selected to assess shellfish growing water quality in the south sector. All marine stations met the approved shellfish growing water standard, although two areas of significant resource potential, Duke Point lagoon and Nanaimo River estuary were not sampled for reasons discussed later.

Freshwater sample stations S1-S11, and effluent sample stations HC (Harmac) and HR (Hooker Chemicals) were sampled concurrently with the marine sampling.

4.1.1 MacMillan Bloedel Harmac Division (HC).

The MacMillan Bloedel Harmac pulp mill, located on the west shore of Northumberland Channel, began operation in 1950, and originally produced 318 metric tons of full bleach kraft pulp per day. The mill now averages 940 metric tons per day and remains the largest full bleach kraft pulp producer in B.C. today.

Mill effluent is discharged through a submarine diffuser into Northumberland Channel at the rate of 2.8 m^3/sec (44 500 US gal/min). Domestic sewage from the mill receives secondary treatment on site, and is subsequently discharged with the total combined mill wastes. Prior to 1976, sewage from the mill was discharged via the alkaline sewer system with the exception of sewage from the laboratory buildings and main office, which have separate outfalls. The No. 3 woodroom discharged via a septic tank outfall. Bacteriological sampling of Northumberland Channel conducted in 1975 (12) by the Environmental Protection Service

TABLE 4 SUMMARY OF WIND DATA

Date	Average Direction in Each Quadrant			
	0°-90°	91°-180°	181°-270°	271°-360°
March 14	4.8%	-	23.8%	71.4%
15	17.6%	73.5%	5.8%	2.9%
16	5 %	80 %	2.5%	-
17	23.1%	61.5%	15.4%	-
20	74.3%	2.6%	-	23.1%
21	2.5%	2.5%	7.5%	87.5%
22	31.4%	39.0%	4.9%	21.9%
23	24.0%	68.0%	8 %	-
28	33.3%	60 %	2.2%	4.4%
29	74.2%	9.7%	-	16.1%
30	2.9%	14.7%	11.8%	70.6%
31	14.3%	2.9%	5.7%	77.1%
April 3	39.3%	50 %	-	10.7%
4	64.3%	14.3%	14.3%	7.1%
5	35.7%	42.9%	14.3%	7.1%
6	-	-	38.5%	61.5%
Cumulative Average	29.96%	37.25%	11.9%	35.49%
	N - E	E - S	S - W	W - N

did not detect any significant fecal levels, although at the time of sampling, the mill was shut down by a labor dispute with a consequent 90% reduction in domestic sewage discharge.

Sample stations 1 to 12 located in Northumberland Channel did not exhibit unacceptably high fecal coliform levels. Mill effluent (HC) samples taken on three occasions yielded a mean fecal coliform count of 65/100 ml with a corresponding population equivalent of 4.56. Relative to other inputs, the Harmac pulp mill effluent was therefore not considered a major source of bacterial contamination during the survey period.

4.1.2 Hooker Chemicals. Hooker Chemical Co. is situated on Northumberland Channel next to the Harmac Plant, and produces chlorine and caustic soda for use in the pulping process. The plant has been operating since 1962, and currently discharges up to 9191 m^3/day of wastewater which consists of 92% seawater, 7% condensate and 1% septic tank effluent through a submerged outfall with a 10.4 m diffuser.

Domestic sewage generated in the plant receives treatment via a septic tank and is discharged with the process effluent. During the study period, the mean fecal coliform count for this effluent was 170/100 ml which corresponds to a population equivalent of 0.64. Thus, effluent from this plant was not considered a significant source of fecal coliforms as indicated by the acceptable marine water quality.

4.1.3 Duke Point. Sample stations 10 to 12 were located along the foreshore between Duke Point and Jack Point to measure the effect of the Harmac and Hooker effluents. As previously mentioned, these stations met the approved growing water quality standards.

Sample station 10 was located at the old sewage outfall at Duke Point to determine whether any unintentional discharges of sewage were occurring at this point. The discharge of sewage from this outfall was stopped in 1974 concurrent with the Five Finger Island outfall becoming operational and no sewage was detected at station 10.

SCUBA dive examinations of the Duke Point sewage outfall conducted by EPS in 1975 (13) revealed a high concentration of organic material located directly in front of the outfall pipe, with a scattered array of non-biodegradable debris decreasing to background levels within 40 m of the outfall.

Duke Point lagoon, located just inside Duke Point, is a tidal lagoon, approximately 1.1 km long and 0.1 km wide. The lagoon supports a considerable oyster and clam resource, however, the water quality was not investigated due to the proposed filling of the lagoon as part of the Duke Point Industrial Park development. The oyster resource is presently being depleted through the issuance of commercial oyster harvesting permits.

4.1.4 Nanaimo Harbour. Marine sample stations 13 to 17, 23 and 24 were positioned in Nanaimo Harbour to detect contamination from the major onshore potential pollution sources. All stations met the shellfish growing water standard, although station 24 was marginally contaminated, having a 90 percentile fecal coliform MPN of 40.9/100 ml.

The molluscan shellfish resource is limited in the Harbour area, although oysters are plentiful on the central gravel bar of the Nanaimo River estuary. Butter clams, horse clams, littleneck and soft-shelled clams are also found in this area. Oysters from the estuary have been used to stock provincial oyster reserves, however, no commercial harvesting takes place in this harbour area due to its relatively heavy utilization as a log booming ground.

The major freshwater inputs to the harbour area are the Nanaimo River (S2), the Chase River (S4) and the Millstone River (S8-S11). In addition to these rivers, five other freshwater inputs were sampled (S1, S3, S5 to S7) and a description of the sampling locations can be found in Appendix II.

The mean population equivalent data (Table 3) show that the Nanaimo River and the Millstone River accounted for 67.1% and 18.2% respectively, of the total measured fecal coliform load in the south sector. The high P.E. value for the Nanaimo River was due to the large discharge (36.5 m^3/sec) rather than high fecal coliform counts (mean count of 12/100 ml). The FC:FS ratio for this source could not be determined due to the non-detectable levels of fecal streptococci (<10/100 ml). The fecal coliform levels detected in the river were not considered significant and most probably result from landwash effects.

The Millstone River (S9) exhibited a mean fecal coliform count of 62/100 ml and a FC:FS ratio of 0.83. Stations S10 and S11, located upstream from station S9 yielded similar ratios indicating the source of contamination to be either human, animal or both. The river drains both urban areas and farmland, with most of the farms in the Nanaimo area being concentrated in the valley of the Millstone River (East Wellington and Northfield districts). Although few animals appeared to have direct access to the river, runoff from pastureland would no doubt reach it. A duck pond in the Lions Animal Park (Bowen Park) discharges directly to the Millstone River. The impact of this discharge would appear to be negligible as upstream and downstream sampling did not indicate any change in water quality.

The influence of these two rivers manifested itself in reduced salinities at marine stations 16, 17, 23 and 24. Higher fecal coliform levels in the seawater corresponded to reduced salinities. Depth samples taken at stations 16, 23 and 24 all exhibited lower fecal coliform counts and higher salinities than the surface water samples indicating the contamination observed was confined to the surface waters of the harbour and was associated with freshwater inputs. Oceanographic observations of the study area demonstrate the harbour is vertically stratified in salinity and density (2) and freshwater entering the system tends to remain on the surface.

Additional bacteriological sampling data obtained by the Central Vancouver Island Health Unit during the Summer of 1978 indicated the Millstone River fecal coliform levels were slightly higher than those observed during our survey. The fecal coliform MPN ranged from 9/100 ml - 1100/100 ml, with a median of 75/100 ml over 13 samples. This data is consistent with ours, although higher levels were occasionally obtained during the summer sampling.

With the exception of stations S5, S6 and S7, the fecal coliform counts at all other freshwater sample points were low. These three sample points were storm sewer outfalls and exhibited mean fecal coliform counts of 3290/100 ml, 1497/100 ml and 280/100 ml, respectively. The source/sources of contamination to these storm drains was not ascertained and the FC:FS ratios were inconclusive. It is possible that cross connections between sanitary and storm sewers exist; however, this is not indicated, as fecal coliform levels increased with higher rainfall, suggesting urban landwash to be the major contributor. Groundwater contamination resulting from a broken sanitary line may also have contributed to the cause of these high fecal coliform counts.

Other possible sources of fecal pollution to the harbour which were not monitored include discharges from pleasure craft, freighters, ferries and other seagoing vessels.

4.1.4.1 Nanaimo sewage collection system. The entire Nanaimo Harbour area is sewered, and during this survey, nine sewage pump stations (H-O and RDG) were investigated. Pump station characteristics and locations are given in Appendix VI.

Pump stations G, H, L, M and N in the City of Nanaimo do not discharge overflow sewage directly to the marine environment, but in virtually all cases, overflows could eventually reach the marine environment. No data are available to calculate minimum overflow times, but with the exception of Station N, wet well retention capacities are reported to be sufficient to prevent sewage overflows should a pump failure occur provided that emergency measures are taken within a reasonable length of time. In the case of the Park Avenue pump station (N) the minimum overflow time is only three minutes. There is a standby auxiliary power generator at the station as well as a telemetry system hook-up. No problems have been reported with this sytem.

All pump stations are checked twice every working day for proper operation. Only one overflow has been reported in the last 1.5 years. Pump station K at the Indian Reserve overflowed because of a clogged pump impellor in early 1978.

4.1.5 Newcastle and Protection Islands. Nanaimo Harbour is protected from the open Strait of Georgia by both Newcastle and Protection islands. Newcastle Island has been designated a provincial park, providing camping facilities, swimming, picnicking and boat moorage. Access to the Island is by ferry or private boat, and no cars are permitted.

There are no permanent residences, and sewage disposal facilities provided for the public consist of pit privies located a considerable distance from the foreshore and flush toilets. The toilets discharge to a holding tank and this effluent is subsequently pumped to a tile field located well away from the foreshore. No sewage disposal problems were observed during the survey, and all marine stations met the shellfish growing water standard. High coliform levels experienced at sample stations 25 to 30 on March 28 were coincident with a period of heavy rainfall as demonstrated by the reduced salinities at all stations. Generally, the degree of contamination attributable to the freshwater influence lessened as one proceeded northward through the channel separating Protection and Newcastle islands. This area has a considerable clam and oyster resource which is presently unusable because the entire harbour area is under Schedule 1 closure. In addition, the Newcastle Island Park is designated as a Class A Provincial Park and consequently all shellfish harvesting from the island foreshore is prohibited (regardless of water quality).

The major freshwater influences on this area are the Millstone and Nanaimo rivers. Based on the bacteriological data obtained during this survey, and bacteriological data obtained by the Health Unit (Section 4.1.4), intermittent contamination of these areas may occur when high fecal coliform levels discharged by the rivers (particularly the Millstone) receive minimal dilution in the seawater and reach the islands. Although some die-off of bacteria will occur prior to the brackish water reaching the islands, the approved growing water standard may still be exceeded during these specific cases.

A potential pollution source exists at the park marina and Mark Bay, due to raw sewage discharges from moored and anchored boats. In 1976, Parks Branch officials counted 3054 pleasure craft moored at these facilities from June 1 to September 30.

Sample station 38 was located off the old Newcastle Island sewage outfall to monitor possible discharges from this source. The outfall has reportedly been disconnected, and during the survey period, no evidence of fecal contamination was detected in the vicinity. The results are consistent with those obtained by Packman (12) in a survey conducted by EPS in 1975.

Protection Island, unlike Newcastle Island, has 40 permanent residents and numerous summer homes. The island, which is considered part of the City of Nanaimo, has been subdivided into 344 parcels, the majority of which are summer residences. However, since the inclusion of the island in the Nanaimo City limits, many of the homes are being converted to permanent residences.

The majority of marine sample stations were established on the west side of the island, where the oyster and clam resources were most abundant. As a result, a sanitary inspection was not conducted on the east side of the island. Sample stations 18 to 22, 26, 30, 31, 33 and 34 all met the shellfish growing water standard.

A sanitary survey of the island was conducted on March 28, 1978, with the assistance of Mr. D. Murray of the Central Vancouver Island Health Unit. The inspection concentrated on the northwest shore of the island where the largest oyster bed is located. The majority of the homes utilize septic tanks with some having pit privies. As most are summer residences, they were not occupied at the time of the inspection and the absence of visible sewage disposal problems does not necessarily imply properly operating disposal systems. Three homes of particular concern were located on the channel separating Newcastle and Protection islands (Lots 4, 5 and 6). These summer residences were stilt structures built below the high tide line, and each had sink drains discharging directly to the foreshore. Although the possibility of sewage discharge from these homes is remote (all have pit privies) sink discharges containing organic material, soap, etc. may cause localized environmental degradation, or at the very least an aesthetically displeasing situation.

Lee Shore Marina, located at the southern entrance to the channel, can accommodate 52 boats (under 20 feet) at its moorage facility. The marina does not permit live-aboards, and boaters using the facility on a casual basis generally rent cabins at the adjoining resort. Washroom facilities are not provided for "day" boaters, although facilities are provided at the Newcastle Island Provincial Park. A septic tank and drainage field service the office building, while pit privies are in use for the cabin facilities.

Freshwater samples were collected from three streams discharging to the oyster beds and the fecal coliform results were very low, all streams having counts of 10/100 ml or less.

Time restraints did not permit an inspection of the foreshore residences located south of Lee Shore Resorts on the west side of the island at this time. All marine stations were well within the growing water standard and it was expected that any water quality impairment would occur during the summer months, when sewage disposal problems would become more evident due to increased usage of homes. Log booming activity in this area is a potential pollution source, as a sewage discharges from tug boats may cause localized problems.

Additional sampling and sanitary survey work was conducted by EPS in this area on July 4 and 5, 1978, in cooperation with the Central Vancouver Island Health Unit. Marine stations 25 to 31, 33 and 34 were sampled and all had fecal coliform MPN levels of 2/100 ml or less. Additional samples taken off the floats at Newcastle Island were also of acceptable water quality.

Approximately 30 dwellings were examined of which half utilized septic tanks and the remainder used pit privies. The inspection was carried out along the western shoreline of Protection Island and revealed two potential problems. Firstly, the septic tank servicing Lee Shore Marina was completely exposed and leaking from one corner. Further, in view of the tank's close proximity to the foreshore, it appears that the tile field extends to the beach and could be partially flooded at high tide. Secondly, the northeastern section of Pirates Beach (lots 242 and

243) was very marshy and was not suitable for either septic tank or privy facilities. No other potential sewage disposal problems were observed during this inspection.

Sample stations were not placed in Newcastle Island Passage, which separates Newcastle Island from Nanaimo. This passage provides sheltered waters and as a result several marinas have located here. Oil tank farms are also present with facilities for unloading petroleum products from small coastal tankers and barges. Sample stations 24 and 42 were located at the southern and northern entrances to the Passage, respectively, to monitor any contamination which may have been contributed by the marina facilities. Both stations were of acceptable water quality although station 24 had a 90 percentile MPN of 40.9/100 ml. However, this intermittent contamination was attributed to the Millstone River and not to sources in Newcastle Island Passage.

4.2 North Sector - Departure Bay to Page's Lagoon

Marine stations 39 to 74 were selected for the north sector and their locations are shown in Figure 3. Sample stations 43, 52 to 55 in Departure Bay, and stations 65 and 66 at Stephenson Point did not meet the approved shellfish growing water standards.

Freshwater sample stations S12 to S27 and effluent sample station STP were located on major inputs and sampled concurrently with the marine sampling.

4.2.1 Departure Bay.

Marine sample stations 40 to 62 were positioned in Departure Bay to assess the impact of numerous storm drains and creeks on the receiving environment (S12-S25).

The shellfish resource in Departure Bay consists of oysters (*C. gigas*), native littleneck clams (*P. staminea*), manilla clams (*V. japonica*) butterclams (*S. giganteus*) and cockles (*C. nuttali*). Much of the resource is concentrated along the northern foreshore towards Stephenson Point, with cockles being the predominant species at the head of the Bay. A relatively large oyster bed has also been reported near the British Columbia Ferry Terminal (14).

Marine sample stations 43, 52, 53, 54 and 55 all exhibited unacceptable fecal coliform levels for the purposes of shellfish harvesting.

Sample station 43 was located off the Ocean Construction Supplies Ltd.-Ready-Mix plant, in close proximity to the B.C. Ferry Terminal. This station experienced intermittent contamination, with three possible pollution sources being identified in the immediate vicinity: (i) discharges from B.C. Ferries, (ii) high fecal counts contributed by Northfield Creek, and (iii) discharges from other vessels associated with the nearby Esso oil tank farm. The first source will be discussed in detail in Section 4.2.1.3. Northfield Creek experienced the highest fecal counts concurrent with the high counts in station 43 on March 28 and 29. The high bacterial levels followed a period of heavy rainfall and on one day were coincident with a low salinity value (11.5^{o}/oo) implicating Northfield Creek as the source. It should be noted however, that the fecal coliform levels in the creek were not inordinately high (mean MF of 29/100 ml), and contaminated urban landwash is probably the source of bacteria to the stream.

Imperial Oil coastal tankers unload petroleum products once a week at the Departure Bay tank farm and no sewage discharges are permitted. As a result of in-house regulations, sewage on all Imperial Oil coastal tankers is reportedly treated on board prior to discharge, and no discharge occurs while the vessels are docked (Captain J. Waters, personal communication).

The Ocean Construction Supplies Ltd.-Ready-Mix plant is not a source of bacterial contamination. Domestic sewage from this facility is collected and treated by the Nanaimo Regional District System.

The head of Departure Bay is a popular recreational area, with park and swimming facilities. Marine sample stations 52 to 55 were adversely influenced by the numerous storm drain discharges to the intertidal area and specifically Departure Bay Creek (S21). Generally, the mean salinity values obtained at these sample stations were somewhat lower than those obtained from the surrounding waters, indicating the freshwater influence (Appendix V).

Although mean fecal coliform concentrations in the freshwater sources were low, each discharge had a localized effect on the receiving water. None of the discharges had a significant effect on the water quality of the entire Bay, although Departure Creek (S21) was responsible for the largest volume of freshwater entering the Bay. The population equivalents of the three most significant creeks, S21, S18 and S13, were 0.292, 0.158, and 0.086 illustrating their relatively localized effects.

There were no obvious sources of pollution to Departure Bay Creek (S21), and the contamination was assumed to originate from animal fecal matter in runoff. The highest fecal coliform concentrations for S21 were noted for samples collected on March 28 and April 5, when 2.6 mm and 5.0 mm, respectively of rain fell, further indicating the contaminated runoff is the principle source of the bacteria.

Samples taken by the Central Vancouver Island Health Unit during summer 1978 at two stations in Departure Bay, indicate that water quality is variable, although both stations would exceed the approved growing water standard. The sample stations approximate EPS stations 53 and 54 and are consistent with the results presented herein.

4.2.1.1 Nanaimo sewage collection system. The Nanaimo sewage collection system is also a potential contributor of bacterial contamination to Departure Bay. Virtually all of the old City of Nanaimo is serviced by a sewage collection system and within the North sector study area, only the Stephenson Point region is unsewered.

Sewage is collected within the city and is pumped by 15 small pump stations or flows by gravity to the Nanaimo Regional District's Departure Bay pump station located at the intersection of Departure Bay and Hammond Bay roads. From this station, sewage flows via the Regional District's trunk lines to the Greater Nanaimo Water Pollution Control Centre where it is treated and discharged to the Strait of Georgia near Five Finger Islands.

The characteristics and locations of the City of Nanaimo's sewage pump stations are shown in Appendix VI.

Average daily flows were calculated for selected pump stations by multiplying the approximate number of homes on the system by 1.4

m^3/day (300 IGPD) of sewage/capita by 2.5 persons per home. Wet well sewage retention times were then calculated using the wet well dimensions and daily flows. Actual retention times could be lower than those calculated because of groundwater infiltration, stormwater inflow, and daily variations in sewage flows.

Pump stations C, D, E, F, M and O service up to three residences each. No warning system is provided in the event of pump malfunction or power disruptions at any of these stations, and stations C, D and E can discharge overflow sewage directly to Departure Bay. Under average flow conditions, the theoretical maximum wet well retention time is 2.4 hours for stations D and E and 1.6 hours for station C. Only one pump station overflow, as noted previously, has been recorded by the City since the installation of these systems, and foreshore sample stations 56-62 all met the approved shellfish growing water standards during this survey.

4.2.1.2 Fisheries and Marine Service Nanaimo Biological Research Station sewage systems. Sewage collected within the Nanaimo Biological Station is treated by the Greater Nanaimo Water Pollution Control Centre and has been since 1975.

Many vessels visit or are assigned to the biological station and some have sewage holding tanks. Pump facilities are available at the Biological Station dock. Previously, sewage was aerated for three to four days, discharged to a wet well in the basement of the Taylor Building, and pumped to the Regional District's trunk sewer. Strong odors were produced in the Taylor Building when the sewage was transferred from the dock facilities. As a result, the pump-out facilities are no longer used. Reportedly, vessels with holding tanks now discharge the sewage outside of embayed areas (15).

A relatively large creek (S25) enters Departure Bay just northeast of the Biological Station at marine station 59; however, no water quality deterioration was noted during the sampling period and fecal coliform levels in the creek were low.

4.2.1.3 B.C. Ferries' sewage disposal. Departure Bay to Horseshoe Bay is a major B.C. ferry route. Up to 24 trips are usually made between the two terminals each day in the summer, and more during peak periods.

With the exception of the Queen of Surrey and Queen of Tsawwassen, all ferries operating on this route are equipped with sewage holding tanks and discharges occur in the Strait of Georgia away from the terminals. Sewage collected onboard the Queen of Tsawwassen and Surrey is discharged directly to the Strait. On normal trips, the washroom doors of these two vessels are locked when the two ferries approach the terminals and are re-opened when the vessels leave the bays.

During this survey (0845 March 29) soapy water was observed to be discharged from the Queen of Tsawwassen and a water sample obtained approximately 15 meters from the ferry exhibited a 350 fecal coliform count/100 ml. B.C. Ferry Corporation officials (16) reported that the ferry was not in normal use at that time. Crew were working on the vessel and had access to washroom facilities on board.

Due to buoyancy problems, some ferries must be lengthened in order to accommodate holding tanks. Apparently, this would be necessary for both the Queen of Tsawwassen and Surrey, but cannot be done because of the structural characteristics of the two vessels.

4.2.2 Stephenson Point. Marine sample stations 63 to 67 were established to monitor the water quality at Stephenson Point. Station 65 experienced intermittent contamination and station 66 experienced continuous contamination during the sampling period. The contamination at these stations did not appear to be due to freshwater inputs as none of consequence were noted, nor did salinity measurements for these two stations indicate same. The area is not sewered, and the contamination was most probably the result of septic seepage.

During the sanitary survey of Stephenson Point, groundwater seepage between the overburden and underlying bedrock was noted. This seepage did not appear to be of a septic nature. However, given the close proximity of houses to the beach, and the apparently thin soil layer, the potential for contamination of the foreshore by septic tank seepage exists.

Two plastic pipes from a residence appear to discharge sink wastes to the foreshore near stations 65 and 66. It would be doubtful that this discharge was solely responsible for the high fecal coliform levels in the receiving waters.

Marine samples collected by GNWPCC staff near EPS station 63 indicated that water quality in this area met shellfish growing standards. Samples collected from July 1977 to July 1978, at their Stephenson Point Road station had a median fecal coliform MPN of <2/100 ml and a 90 percentile level of 33.1/100 ml.

4.2.3 Page Lagoon. Sample stations 69 to 74 were established to assess the shellfish growing water quality in Page Lagoon. This lagoon is a popular recreational shellfish area for oysters, clams and mussels and is well utilized by residents and visitors alike.

All sample stations met the approved growing water standard, however a sewage pump station in the vicinity poses a threat to water quality. About 47 homes in the Page Lagoon area are serviced by this pump station (B) located at the intersection of Place Drive and Lagoon Road. This station has been recently upgraded and two new submersible pumps installed. A dye test of the overflow pipe from the pump station revealed that sewage could be discharged about 25 meters from shore into Page Lagoon. This would occur if a pump failure or extended power disruption allowed the sewage to fill the 16.0 m^3 pump station wet well, back-up in the sewer line, fill a 0.4 m^3 manhole, and flow via a 15 cm diameter cast iron overflow pipe into the lagoon. Under average flow conditions this would occur in about 6.2 hours if the wet well was virtually empty when the pump failure occurred, and in about 3.8 hours if the pumps where about to be started by the level control system.

The City of Nanaimo plans to connect the Piper's Lagoon pump station to a telemetry system. A warning signal of pump failure or power disruption at the station will be sent to the Nanaimo Water District Office during normal working days, and to a 24-hour manned fire hall at all other times. Depending upon the problem, mobile generators or pumps would then be used to maintain sewage flow from the pump station to the Nanaimo Regional Districts trunk line.

A storm drain (S26) also discharges to Page Lagoon, although during the study period no significant levels of contamination were observed.

Water samples taken by GNWPCC staff at the entrance to Page Lagoon exhibited a median fecal coliform MPN of less than 2/100 ml and a 90 percentile level of 90/100 ml. This data is based on 22 samplings between July 1977 and July 1978, and would indicate intermittent contamination at this station. These results are not consistent with our data although the GNWPCC data is skewed high by two samplings in November 1977 (both 91/100 ml). Differences in precipitation, sampling and analytical techniques and/or possible overflows from the pump station may account for the discrepancy.

4.2.4 Five Finger Islands Sewage Outfall. Sewage generated by the City of Nanaimo is treated by the Greater Nanaimo Water Pollution Control Centre and is discharged to the Strait of Georgia near Five Finger Islands through a submarine diffuser. During the survey, an operational evaluation of the treatment plant was performed and the results are presented in Appendix VII.

Sewage discharged through the Five Finger outfall did not cause bacteriological degradation of the foreshore water quality during the study. This is consistent with numerous other reports on the subject (3, 4, 12) and indicates the discharge is having virtually no effect on the foreshore environment.

Sample stations 67 and 68, located between Stephenson Point and Lagoon Head were both of acceptable water quality.

The mean fecal coliform concentration of the treatment plant's final effluent was 34/100 ml. The outfall has been designed for an initial dilution of 100:1 and a 1000:1 dilution is predicted prior to the time of effluent posses Gabriola Island. As such, the design initial dilution is sufficient to reduce the final effluent to non-detectable fecal coliform levels.

These data support the contetion that contamination observed at stations 65 and 66 arose from local sources.

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APPENDIX I

MARINE SAMPLE STATION LOCATIONS AND DESCRIPTIONS

APPENDIX I MARINE SAMPLE STATION LOCATIONS AND DESCRIPTIONS

Sample Station	Latitude (North)	Longitude (West)	Description
1	49°08.40	123°48.42	Midway under power line
2	08.66	49.00	Site 23 and 24 off Gabriola booms
3	08.43	49.00	Midway to Dodds Narrows from Gabriola Island
4	08.17	48.99	Dodd Narrows
5	08.16	49.90	Telephone cable, old pilings
6	08.65	50.60	Mid-channel off end of Harmac loading dock
7	08.97	51.46	Mid-channel from Harmac
8	08.55	52.05	Conveyor Dock
9	09.30	52.38	Mid-channel from pipeline sign
10	09.10	53.05	Pipeline outfall by red-roof house on left
11	09.60	53.32	Clearing midpoint to Jack Point
12	10.02	53.52	Jack Point
13	10.15	64.10	1/3 way across fish boundary at Jack Point
14	10.28	54.60	2/3 way across fish boundary in line with Gabriola tip
15	10.24	54.99	Stone house (east side of Protection Island)
16	10.14	55.25	1/3 way from lighthouse to Nanaimo docks between buoy and tower
17	10.07	55.58	2/3 way from lighthouse to Nanaimo docks between green light and tower
18	10.28	55.06	Dirt mound at pink house past lighthouse
19	10.35	55.05	Pink house and green house (Protection Island)

Sample Station	Latitude (North)	Longitude (West)	Description
20	49°10.41	123°55.08	Dark red house with green fence
21	10.64	55.23	Pink and grey house with fence
22	10.63	55.31	Red house ("Private" sign)
23	10.30	55.82	Midway between P.11 and Protection Light, Newcastle Beacon, and dock marker
24	10.54	56.18	Marker P.11 (Green) midway between Protection Light and harbour
25	11.02	56.01	Head of Mark Bay (Newcastle Island)
26	10.65	55.48	Lee Shore off white fence
27	10.78	55.39	First Green shack on stilts (south end of Protection Island)
28	10.83	55.49	Mid-channel
29	10.87	55.53	Bath-house (Newcastle Island)
30	10.58	55.37	White & yellow house (Protection Island)
31	10.88	55.38	Blue house (Protection Island)
32	11.01	55.43	Shelters on Newcastle Island opposite marker on Protection Island
33	10.99	55.35	Marker south of Protection Island
34	11.01	55.17	Blue & white A-frame (Protection Island)
35	11.18	55.35	Green bridge (Newcastle Island)
36	10.98	54.80	Bay on NE side of Protection Island, off brown house with yellow railing
37	11.60	55.32	Tip of shelf off Angle Point (Protection Island)
38	12.01	55.80	Old outfall (Newcastle Island pipeline)
39	12.32	56.48	Mid-channel between Newcastle fishing boundary and beacon
40	11.95	56.67	Long beach with old maple on hill, west Newcastle Island

Sample Station	Latitude (North)	Longitude (West)	Description
41	49°11.74	123°56.75	Long beach on west Newcastle Island, in line with red buoy
42	11.13	56.82	5 mph sign (Newcastle Island)
43	11.54	57.05	Old ferry terminal at Ocean Cement plant (Departure Bay)
44	11.75	57.32	Newcastle Rock and end of ferry terminal in line with Station 40
45	11.65	57.37	Spanish-style red roof house off ferry terminal
46	11.75	57.60	Dark brown house NW of Station 45
47	11.87	57.45	Between end of ferry terminal and antenna on rock hill, off rock outcropping (Departure Bay)
48	11.84	57.76	Rock outcropping offshore (Departure Bay)
49	12.00	58.00	Offshore of large rock (Departure Bay)
50	12.09	58.05	Near rail and cement boat launch
51	12.16	57.70	Off large road-drain, in line with Terminal and antenna
52	12.12	58.07	Directly off large road-drain
53	12.22	58.10	Yellow beach-house
54	12.29	58.09	Departure Bay store
55	12.38	58.00	Left of unmarked breakwater
56	12.44	57.90	Right of breakwater off white house
57	12.52	57.74	Brown house with green roof
58	12.58	57.55	Off cement-piled dock (Biological Station)
59	12.62	57.14	River mouth beside Biological Station
60	12.60	57.04	Small cement hut
61	12.62	56.87	Off-shore of old wooden float
62	12.63	56.71	Near lowering ramp
63	12.66	56.55	Off fishing boundary

Sample Station	Latitude (North)	Longitude (West)	Description
64	49°12.71	123°56.44	Flat-roofed house with stone chimney, in line with Newcastle Fishing Boundary (Stephenson Point)
65	12.78	56.35	Stone outdoor fireplace in line with boundary (Stephenson Point)
66	12.87	56.34	Left of public access at Stephenson Point
67	12.92	56.36	Red-roofed grey house
68	13.35	56.72	White & green house
69	13.64	56.83	Rock outcropping
70	13.65	57.02	Close to Station 59 of Nanoose Survey, 1977, mouth of Piper's Lagoon
71	13.59	56.95	Close to Station 60 of Nanoose Survey, 1977, mid Piper's Lagoon
72	13.55	56.90	Close to Station 61 of Nanoose Survey, 1977, head of Piper's Lagoon
73	13.43	56.84	Close to Station 62 of Nanoose Survey, 1977, head of Piper's Lagoon
74	13.52	56.84	Close to Station 63 of Nanoose Survey, 1977, mid Piper's Lagoon

APPENDIX II

FRESHWATER SAMPLE STATION LOCATIONS AND DESCRIPTIONS

APPENDIX II FRESHWATER SAMPLE STATION LOCATIONS AND DESCRIPTIONS

Sample Station	Description
S1	Stream on McMillan Road at Nanaimo City boundary
S2	Nanaimo River at Cedar Road bridge
S3	Stream at Cedar Road and Trans-Canada Highway intersection
S4	Chase River at Trans-Canada Highway
S5	Manhole at Robins and Eaton Streeets
S6	Storm drain at Front and Cameron Streets
S7	Storm drain at Comox and Front Streets
S8	Millstone River at Terminal Avenue
S9	Millstone River in Bowen Park near Wall Street
S10	Millstone River at Bowen Road Bridge
S11	Millstone River at Durnin Road Bridge
S12	Manhole on Beach Drive near Brechin Road
S13	Northfield Creek at mouth
S14	Culvert at 160 Cilair Drive
S15	Catchbasin at 157 Cilair Drive
S16	Culvert opposite 2565 Battersea Road
S17	Culvert opposite 2585 Battersea Road
S18	Stream at Battersea and Balmoral Roads
S19	Stream at east end of Randall Road
S20	Cement pipe at sea wall at Loat Street
S21	Departure Creek at mouth
S22	Stream at 2947 Hammond Bay Road
S23	Stream 2973 Hammond Bay Road
S24	Culvert at 3144 Hammond Bay Road
S25	Cottle Creek at Hammond Bay Road
S26	Culvert at Place Drive and Lagoon Road

Sample Station	Description
S27	Morningside Creek at Morningside Drive
HR	Hooker Chemical process effluent stream monitoring station
HC	McMillan Bloedel (Harmac) process effluent stream monitoring station
STP	Greater Nanaimo Water Pollution Control Centre final effluent at flow measurement flume
P1	Stream on Protection Island at Lot 10
P2	Stream on Protection Island on Lot 14
P3	Stream on Protection Island at Lot 20

APPENDIX III

DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

APPENDIX III DAILY BACTERIOLOGICAL RESULTS FOR MARINE STATIONS

Sample Station	Collection Date	Collection Time	Fecal Coliform MPN/100 ml	Sample Station	Collection Date	Collection Time	Fecal Coliform MPN/100 ml
1	14/3	0950	< 2	2	14/3	1005	< 2
	15	0945	< 2		15	1005	< 2
	16	1150	< 2		16	1140	< 2
	20	0920	< 2		20	0920	< 2
	21	0905	< 2		21	0900	< 2
	22	1145	< 2		22	1140	< 2
3	14/3	1000	2	4	14/3	1010	< 2
	15	0955	< 2		15	1005	2
	16	1145	< 2		16	1147	< 2
	20	0925	< 2		20	0925	< 2
	21	0912	< 2		21	0915	< 2
	22	1140	< 2		22	1140	< 2
5	14/3	1015	11	6	14/3	1020	< 2
	15	1009	2		15	1012	5
	16	1140	4		16	1130	< 2
	20	0930	< 2		20	0935	< 2
	21	0920	< 2		21	0920	< 2
	22	1135	2		22	1130	< 2
7	14/3	1030	< 2	8	14/3	1035	< 2
	15	1015	< 2		15	1020	2
	16	1125	8		16	1118	< 2
	20	0940	< 2		20	0940	< 2
	21	0930	< 2		21	0935	< 2
	22	1125	< 2		22	1130	< 2
9	14/3	1040	< 2	10	14/3	1045	< 2
	15	1025	< 2		15	1030	< 2
	16	1114	< 2		16	1111	< 2
	20	0945	< 2		20	0945	< 2
	21	0940	< 2		21	0945	2
	22	1123	2		22	1120	< 2
11	14/3	1056	< 2	12	14/3	1055	< 2
	15	1035	< 2		15	1040	< 2
	16	1105	< 2		16	1205	< 2
	20	0950	< 2		20	0955	< 2
	21	0950	< 2		21	0955	2
	22	1118	< 2		22	1115	< 2

Sample Station	Collection Date	Collection Time	Fecal Coliform MPN/100 ml	Sample Station	Collection Date	Collection Time	Fecal Coliform MPN/100 ml
13	14/3	1100	2	14	14/3	1105	< 2
	15	1043	< 2		15	1045	< 2
	16	1058	2		16	1050	2
	20	0955	< 2		20	1000	2
	21	1000	< 2		21	1004	< 2
	22	1110	< 2		22	1105	2
15	15/3	1240	< 2	16	14/3	1112	8
	16	1055	< 2		15	1050	< 2
	20	1000	2		16	1030	8
	21	1005	< 2		20	1105	< 2
	22	1105	5		21	1010	< 2
	28	0755	2		22	1045	5
17	14/3	1115	9	18	14/3	1120	2
	15	1055	2		15	1100	< 2
	16	1035	23		16	1025	8
	20	1125	< 2		20	1125	< 2
	21	1010	5		21	1125	< 2
	22	1040	5		22	1005	4
	28	0805	17				
	29	0815	33				
	30	0940	2				
	31	0920	7				
19	14/3	1125	7	20	14/3	1125	< 2
	15	1110	< 2		15	1110	4
	16	1020	13		16	1012	2
	20	1125	< 2		20	1130	< 2
	21	1125	< 2		21	1125	2
	22	0955	23		22	0955	8
21	14/3	1140	5	22	14/3	1145	2
	15	1115	2		15	1118	5
	16	0907	11		16	1005	11
	20	1135	< 2		20	1135	< 2
	21	1130	< 2		21	1130	< 2
	22	0950	8		22	0948	5

Sample Station	Collection Date	Collection Time	Fecal Coliform MPN/100 ml	Sample Station	Collection Date	Collection Time	Fecal Coliform MPN/100 ml
23	16/3	1036	< 2	24	16/3	0950	< 2
	20	1005	< 2		20	1035	8
	21	1030	13		21	1110	< 2
	22	1006	7		22	1028	49
	28	0807	23		28	0810	130
	4/4	1445	2		29	0805	22
	5	1425	< 2		30	0945	5
	6	1430	< 2		31	0905	< 2
					3/4	0915	< 2
					4	1440	4
					5	1430	5
					6	1430	< 2
25	15/3	1150	7	26	15/3	1125	2
	16	0940	33		16	0955	23
	20	1145	< 2		20	1140	< 2
	21	1140	< 2		21	1135	< 2
	22	0940	4		22	0945	2
	28	0818	46		28	0815	33
	29	0820	33		30	0935	2
	30	0930	< 2		31	0850	17
	31	0850	2		4/4	1500	5
	4/4	1450	8		5	1410	2
	5	1420	2		6	1420	< 2
	6	1425	< 2				
27	15/3	1200	< 2	28	15/3	1205	< 2
	16	0930	2		16	0935	< 2
	20	1150	< 2		20	1150	2
	21	1145	< 2		21	1140	< 2
	22	0930	8		22	0930	46
	28	0825	13		28	0820	79
	4/4	1505	11		29	0825	17
	5	1410	< 2		30	0920	< 2
	6	1415	< 2		31	0845	2
					4/4	1505	5
					5	1410	< 2
					6	1415	< 2

Sample Station	Collection Date	Collection Time	Fecal Coliform MPN/100 ml	Sample Station	Collection Date	Collection Time	Fecal Coliform MPN/100 ml
29	15/3	1207	2	30	15/3	1212	< 2
	16	0936	5		16	0929	13
	20	1150	< 2		20	1155	< 2
	21	1145	< 2		21	1150	< 2
	22	0933	8		22	0925	< 2
	28	0820	130		28	0825	46
	30	0920	< 2		30	0915	11
	31	0845	< 2		31	0840	23
	3/4	0910	5		3/4	0910	2
	4	1505	< 2		4	1510	5
	5	1410	< 2		5	1405	2
	6	1415	< 2		6	1410	< 2
31	15/3	1215	< 2	32	15/3	1225	< 2
	16	0925	8		16	0920	5
	20	1155	< 2		20	1200	< 2
	21	1150	< 2		21	1155	< 2
	22	0920	5		22	0920	7
	28	0830	23		28	0830	13
	30	0910	< 2				
	31	0840	4				
	4/4	1510	8				
	5	1405	< 2				
	6	1410	< 2				
33	15/3	1220	< 2	34	15/3	1230	< 2
	16	0918	2		16	0915	< 2
	20	1200	< 2		20	1205	< 2
	21	1153	< 2		21	1155	< 2
	22	0920	< 2		22	0915	2
	28	0830	13		28	0835	2
35	16/3	0912	< 2	36	30/3	0900	2
	20	1200	2		31	0830	5.6
	21	1156	< 2		3/4	0900	< 2
	22	0915	5		4	1530	2
	28	0838	17		5	1345	< 2
	4/4	1520	< 2				
	5	1355	5				
	6	1400	2				

Sample Station	Collection Date	Collection Time	Fecal Coliform MPN/100 ml	Sample Station	Collection Date	Collection Time	Fecal Coliform MPN/100 ml
37	15/3	1255	< 2	38	15/3	1307	< 2
	16	0902	< 2		16	0855	< 2
	20	1210	< 2		20	1215	< 2
	21	1200	< 2		21	1240	< 2
	22	0910	< 2		22	0903	2
	28	0840	< 2		28	0845	< 2
39	23/3	1115	2	40	15/3	1316	< 2
	28	0850	5		16	0845	< 2
	29	1015	< 2		20	1215	< 2
	30	1145	< 2		21	1245	< 2
	31	1035	< 2		22	0900	2
	3/4	1100	< 2		28	1015	33
					30	1005	< 2
					31	0925	< 2
41	15/3	1320	< 2	42	15/3	1325	< 2
	16	0840	< 2		16	0835	< 2
	20	1220	< 2		20	1225	< 2
	22	0855	< 2		21	1250	< 2
	28	1015	2		22	0855	< 2
	4/4	1550	5		23	0845	23
					28	1010	13
					29	0840	13
					30	1003	< 2
					31	0920	< 2
43	23/3	0845	2	44	23/3	0850	< 2
	28	1020	79		28	1025	2
	29	0845	49		29	0850	< 2
	30	1010	< 2		30	1017	2
	31	0930	2		31	0930	< 2
	3/4	0935	< 2		3/4	0940	2
45	23/3	0855	< 2	46	23/3	0905	< 2
	28	1020	< 2		28	1025	< 2
	29	0850	13		29	0855	2
	30	1015	17		30	1020	< 2
	31	0930	< 2		31	0935	< 2
	3/4	0935	2		3/4	0940	8

Sample Station	Collection Date	Collection Time	Fecal Coliform MPN/100 ml	Sample Station	Collection Date	Collection Time	Fecal Coliform MPN/100 ml
47	23/3	0920	7	48	23/3	0915	11
	28	1030	2		28	1035	< 2
	29	0900	< 2		29	0900	5
	30	1025	< 2		30	1030	2
	31	0935	< 2		31	0940	2
	3/4	0945	2		3/4	0945	5
49	23/3	0930	23	50	23/3	0935	14
	28	1035	5		28	1020	5
	29	0905	5		29	0910	4
	30	1030	2		30	1035	2
	31	0940	2		31	0945	< 2
	3/4	0950	49		3/4	0955	79
51	23/3	0945	4	52	23/3	0940	13
	28	1045	5		28	1040	33
	29	0915	7		29	0910	31
	30	1040	< 2		30	1035	2
	31	0950	< 2		31	0945	< 2
	3/4	1000	2		3/4	0950	41
					4	1105	170
					5	1035	33
53	23/3	0948	8	54	23/3	0953	26
	28	1045	63		28	1050	46
	29	0920	23		29	0920	79
	30	1045	< 2		30	1050	23
	31	0950	< 2		31	0955	< 2
	3/4	1000	280		3/4	1000	79
	4	1110	33		4	1105	33
	5	1045	23		5	1050	350
55	23/3	0956	7	56	23/3	1004	5
	28	1050	33		28	1055	8
	29	0918	17		29	0930	17
	30	1050	< 2		30	1055	2
	31	1000	< 2		31	1000	< 2
	3/4	1005	33		3/4	1010	2
	4	1110	79				
	5	1055	540				

Sample Station	Collection		Fecal Coliform	Sample Station	Collection		Fecal Coliform
	Date	Time	MPN/100 ml		Date	Time	MPN/100 ml
57	23/3	1012	11	58	23/3	1015	5
	28	1100	5		28	1100	33
	29	0930	17		29	0935	5
	30	1055	< 2		30	1100	2
	31	1005	< 2		31	1010	< 2
	3/4	1015	5		3/5	1015	< 2
59	23/3	1020	8	60	23/3	1022	8
	28	1100	13		28	1105	9
	29	0935	< 2		29	0935	< 2
	30	1105	< 2		30	1105	< 2
	31	1010	< 2		31	1015	< 2
	3/4	1020	< 2		3/4	1020	< 2
61	23/3	1030	5	62	23/3	1032	7
	28	1110	7		28	1110	11
	29	0945	8		29	0945	5
	30	1110	< 2		30	1110	< 2
	31	1015	2		31	1015	< 2
	3/4	1025	< 2		3/4	1025	< 2
63	23/3	1038	4	64	29/3	1100	17
	28	1115	9		30	1225	2
	29	0950	7		31	1125	4
	30	1115	4		3/5	1200	2
	31	1020	2		4	1020	13
	3/4	1030	< 2		5	0900	2
65	29/3	1105	8	66	29/3	1110	8
	30	1230	2		30	1235	33
	31	1130	17		31	1140	< 2
	3/4	1210	240		3/4	1215	2
	4	1030	2		4	1030	23
	5	0905	8		5	0910	49
67	23/3	1055	7	68	23/3	1100	< 2
	28	1120	2		28	1120	< 2
	29	1000	2		29	1003	8
	30	1125	< 2		30	1130	< 2
	31	1030	< 2		31	1030	< 2
	3/4	1040	8		3/4	1045	17

Sample Station	Collection Date	Collection Time	Fecal Coliform MPN/100 ml	Sample Station	Collection Date	Collection Time	Fecal Coliform MPN/100 ml
69	23/3	1105	< 2	70	29/3	1102	2
	28	1125	< 2		30	-	5
	29	1005	2		31	-	6
	30	1135	< 2		3/4	1130	< 2
	31	1035	< 2		4	1615	2
	3/4	1045	< 2		5	1545	11
71	29/3	1100	2	72	29/3	1035	11
	30	-	8		30	-	8
	31	-	< 2		31	-	2
	3/4	1130	2		3/4	1130	17
	4	1615	79		4	1615	< 2
	5	1550	2		5	1555	< 2
73	29/3	1040	< 2	74	29/3	1045	11
	30	-	< 2		30	-	2
	31	-	< 2		31	-	< 2
	3/4	1130	< 2		3/4	1130	< 2
	4	1615	< 2		4	1615	< 2
	5	1600	< 2		5	1605	< 2
16M	20/3	1115	< 2(6.7m)	16D	20/3	1115	< 2(13.4m)
	21	1220	2(6.1m)		21	1220	5(12.2m)
	22	1100	< 2(6.1m)		22	1100	< 2(12.2m)
23M	20/3	1005	< 2(6.1m)	23D	20/3	1005	< 2(12.2m)
	21	1035	5(6.1m)		21	1035	5(12.2m)
	22	1010	4(6.1m)		22	1010	< 2(12.2m)
24M	20/3	1015	< 2(3m)	24D	20/3	1015	2(6.1m)
	21	1115	< 2(3m)		21	1115	< 2(6.1m)
	22	1030	5(3m)		22	1030	2(6.1m)
Ferry Wash: Queen of Tsawwassen	29/3	0850	350	Seepage Station 65	5/4		< 2

APPENDIX IV

DAILY BACTERIOLOGICAL RESULTS AND SAMPLING CONDITIONS FOR FRESHWATER STATIONS

APPENDIX IV DAILY BACTERIOLOGICAL RESULTS AND SAMPLING CONDITIONS FOR FRESHWATER STATIONS

Station	Sample Date	Sample Time	(MF Counts/100 ml) Coliform Total	Coliform Fecal	Fecal Streptococci	Estimated Flow (m^3/sec)	Population Equivalent	FC:FS	Daily Precip. (mm)
S1	15/3	0920	270	<10	<10	0.32	0.087	-	0.2
	16	0940	210	<10	<10	0.31	0.084	-	1.8
	17	0945	830	50	10	0.46	0.62	-	-
S2	15/3	0920	30	<10	<10	36.51	9.9	-	0.2
	16	0950	10	<10	<10	36.51	9.9	-	1.8
	17	1000	120	<10	<10	36.51	9.9	-	-
	4/4	845		20	<10	36.51	19.9	-	6.0
	5	0915		10	<10	36.51	9.9	-	5.0
S3	15/3	0950	530	<10	<10	0.44	0.12	-	0.2
	16	0955	110	10	30	0.44	0.12	0.33	1.8
	17	1005	550	<10	<10	0.37	0.10	-	-
S4	15/3	1550	140	<10	<10	0.97	0.26	-	0.2
	16	1105	70	<10	60	0.97	0.26	-	1.8
	17	1010	140	<10	<10	0.97	0.26	-	-
	4/4	900		120	<10	0.97	3.2	-	6.0
	5	925		60	220	0.97	1.6	0.27	5.0
S5	15/3	1000	5200	9300	2500	0.02	5.0	3.7	0.2
	16	1115	6000	700	600	0.006	0.11	1.2	1.8
	17	1015	7300	2900	3800	0.009	0.71	0.76	-
	20	1020	600	700	3800	0.003	0.057	0.18	-
	23	935	7900	2850		0.003	0.23	-	8.8
S6	15/3	1530	2900	930	340	0.009	0.23	2.7	0.2
	16	1500	3400	960	420	0.007	0.18	2.3	1.8
	23	1055	3000	2600		0.014	0.98		8.8

Station	Sample Date	Sample Time	(MF Counts/100 ml) Coliform Total	Coliform Fecal	Fecal Streptococci	Estimated Flow (m^3/sec)	Population Equivalent	FC:FS	Daily Precip. (mm)
S7	15/3	1540	7600	40	240	0.003	0.0033	0.17	0.2
	16	1520	3400	60	140	0.003	0.0049	0.43	1.8
	23	1120	>1000	740		0.005	0.10		8.8
S8	16/3	1540		90	10	2.22	5.4	9.0	1.8
	4/4			20	< 10	2.22	1.2		6.0
S9	15/3	1500	50	40	10	2.22	2.4	4.0	0.2
	16	1130	220	80	< 10	2.22	4.8		1.8
	17	1040	500	90	10	2.22	5.4	9.0	-
	5/4	0940		70	130	2.22	4.2	0.54	5.0
	6	0800		30		2.22	1.8		-
S10	5/4	0950		130	60	2.22	7.8	2.2	5.0
	6	0810		60		2.22	3.6		-
S11	5/4	1005		50	90	2.22	3.0	0.56	5.0
	6	0815		70		2.22	4.2		-
S12	29/3	1230	260	20	40	0.006	0.0032	0.50	4.4
	31	1125	1730	10	60	0.006	0.0016	0.17	-
S13	20/3	1055	160	< 10	10	0.13	0.035		-
	21	1145	250	< 10	10	0.13	0.035		-
	22	1005	380	20	< 10	0.13	0.070		0.3
	28	1030	1190	68	330	0.08	0.15	0.21	2.6
	29	1215	140	38	42	0.08	0.082	0.90	4.4

Station	Sample Date	Sample Time	(MF Counts/100 ml) Coliform Total	Coliform Fecal	Fecal Streptococci	Estimated Flow (m^3/sec)	Population Equivalent	FC:FS	Daily Precip. (mm)
S14	20/3	1100	250	10	< 10	0.003	0.00081		-
	21	1150	720	<10	10	0.003	0.00081		-
	22	1030	60	<10	< 10	0.003	0.00081		0.3
	29	1235	490	10	2	0.006	0.0016	5.0	4.4
	3/4	0835		330	10	0.002	0.018	33	0.2
S15	20/3	1110	220	10	< 10	0.003	0.00081		-
	29	1245	1800	164	56	0.014	0.062	2.9	4.4
	31	1135	3000	<10	< 10	0.014	0.0038		-
	3/4	0840		<10	30	0.002	0.00054		0.2
S16	3/4	0850		<10	10	0.003	0.00081	-	0.2
S17	20/3	1125	180	<10	< 10	0.009	0.0024	-	-
	22	1040	320	<10	< 10	0.009	0.0024	-	0.3
	30	1155	< 10	<10	< 10	0.009	0.0024	-	0.6
	3/4	0855		<10	< 10	0.008	0.0022	-	0.2
S18	20/3	1130	2200	20	30	0.01	0.0054	0.67	-
	21	1205	5200	10	30	0.01	0.0027	0.33	-
	22	1040	2500	<10	20	0.01	0.0027	-	0.3
	28	1040	4300	2200	430	0.013	0.78	5.1	2.6
	30	1200	70	80	< 10	0.013	0.028	-	0.6
	6/4	0835		<10	-	0.03	0.0081	-	-
S19	20/3	1135	< 10	<10	< 10	0.004	0.0011		-
	21	1205	50	4	2	0.004	0.00043	2.0	-
	22	1045	16	< 2	< 2	0.004	0.00022		0.3
	30	1200	< 10	<10	20	0.007	0.0019		0.6
	3/4	0900		<10	10	0.004	0.0011		0.2
	6	0840		<10		0.004	0.0011		-

Station	Sample Date	Sample Time	Coliform Total (MF Counts/100 ml)	Coliform Fecal (MF Counts/100 ml)	Fecal Streptococci (MF Counts/100 ml)	Estimated Flow (m^3/sec)	Population Equivalent	FC:FS	Daily Precip. (mm)
S20	20/3	1140	< 10	< 10	< 10	0.0006	0.00016		-
	21	1210	28	58	130	0.0006	0.00094	0.45	-
	30	1200	10	< 10	< 10	0.0006	0.00016		0.6
	31	1140	780	< 10	< 10	0.0006	0.00016		-
	3/4	0900		< 10	< 10	0.0003	0.00008		0.2
S21	20/3	1145	270	50	10	0.06	0.081	5.0	-
	22	1050	70	120	20	0.06	0.20	6.0	0.3
	28	1045	1050	270	650	0.10	0.73	0.42	2.6
	30	1205	870	< 10	50	0.09	0.024		0.6
	5/4	1025		160	120	0.10	0.43	1.3	5.0
	6	0845		40		0.19	0.20		-
S22	20/3	1150	10	< 10	10	0.0006	0.00016		-
	30	1210	< 10	< 10	< 10	0.0012	0.00032		0.6
	3/4	0910		< 10	270	0.001	0.00027		0.2
S23	21/3	0905	110	< 10	< 10	0.009	0.0024		-
	22	1055	26	< 10	< 10	0.009	0.0024		0.3
	30	1215	< 10	< 10	< 10	0.009	0.0024		0.6
	3/4	0915		< 10	< 10	0.007	0.0019		0.2
S24	21/3	0920	140	< 10	70	0.002	0.00054		-
	22	1100	134	12	50	0.002	0.00065	0.24	0.3
	30	1220	30	110	< 10	0.002	0.0060		0.6
	3/4	0910		< 10	20	0.002	0.00054		0.2
S25	21/3	0935	70	< 10	< 10	0.08	0.022		-
	22	1105	< 10	8	2	0.08	0.017	4.0	0.3
	30	1410	< 10	< 10	< 10	0.08	0.022		0.6

<table>
<tr><th rowspan="3">Station</th><th colspan="2">Sample</th><th colspan="3">(MF Counts/100 ml)</th><th rowspan="3">Estimated Flow (m3/sec)</th><th rowspan="3">Population Equivalent</th><th rowspan="3">FC:FS</th><th rowspan="3">Daily Precip. (mm)</th></tr>
<tr><th rowspan="2">Date</th><th rowspan="2">Time</th><th colspan="2">Coliform</th><th rowspan="2">Fecal Streptococci</th></tr>
<tr><th>Total</th><th>Fecal</th></tr>
<tr><td>S26</td><td>28/3</td><td>1050</td><td>1700</td><td>100</td><td>360</td><td>0.003</td><td>0.0081</td><td>0.28</td><td>2.6</td></tr>
<tr><td></td><td>30</td><td>1420</td><td>< 10</td><td>< 10</td><td>< 10</td><td>0.003</td><td>0.00081</td><td></td><td>0.6</td></tr>
<tr><td></td><td>31</td><td>0845</td><td>390</td><td>< 10</td><td>< 10</td><td>0.003</td><td>0.00081</td><td></td><td>-</td></tr>
<tr><td></td><td>6/4</td><td>0900</td><td></td><td>< 10</td><td></td><td>0.0009</td><td>0.00024</td><td></td><td>-</td></tr>
<tr><td>S27</td><td>21/3</td><td>1020</td><td>20</td><td>< 10</td><td>50</td><td>0.06</td><td>0.016</td><td></td><td>-</td></tr>
<tr><td></td><td>22</td><td>1110</td><td>182</td><td>2</td><td>2</td><td>0.06</td><td>0.0032</td><td>1.0</td><td>0.3</td></tr>
<tr><td></td><td>28</td><td>1055</td><td>470</td><td>3</td><td>52</td><td>0.04</td><td>0.0032</td><td>0.57</td><td>2.6</td></tr>
<tr><td></td><td>30</td><td>1425</td><td>60</td><td>< 10</td><td>< 10</td><td>0.04</td><td>0.011</td><td></td><td>0.6</td></tr>
<tr><td></td><td>5/4</td><td>1035</td><td></td><td>< 10</td><td>< 10</td><td>0.05</td><td>0.013</td><td></td><td>5.0</td></tr>
<tr><td>STP</td><td>21/3</td><td>1045</td><td>210</td><td>< 10</td><td>10</td><td>0.19</td><td>0.051</td><td></td><td>-</td></tr>
<tr><td></td><td>22</td><td>1120</td><td>TNTC</td><td>10</td><td>TNTC</td><td>0.18</td><td>0.049</td><td></td><td>0.3</td></tr>
<tr><td></td><td>28</td><td>1105</td><td>7100</td><td>20</td><td>< 10</td><td>0.22</td><td>0.12</td><td></td><td>2.6</td></tr>
<tr><td></td><td>30</td><td>1500</td><td>1340</td><td>120</td><td>2500</td><td>0.20</td><td>0.65</td><td>0.048</td><td>0.6</td></tr>
<tr><td></td><td>31</td><td>0910</td><td>1900</td><td>< 10</td><td>50</td><td>0.20</td><td>0.54</td><td></td><td>-</td></tr>
<tr><td>HC</td><td>15/3</td><td>0905</td><td>6300</td><td>50</td><td>130</td><td>2.6</td><td>3.5</td><td>0.38</td><td>0.2</td></tr>
<tr><td></td><td>16</td><td></td><td></td><td>20</td><td>10</td><td>2.6</td><td>1.5</td><td>2.0</td><td>1.8</td></tr>
<tr><td></td><td>17</td><td></td><td>230</td><td>60</td><td>90</td><td>2.6</td><td>4.2</td><td>0.67</td><td>-</td></tr>
<tr><td>HR</td><td>15/3</td><td>0925</td><td>< 10</td><td>< 10</td><td>< 10</td><td>0.14</td><td>0.038</td><td></td><td>0.2</td></tr>
<tr><td></td><td>16</td><td></td><td>370</td><td>60</td><td>50</td><td>0.14</td><td>0.23</td><td>1.2</td><td>1.8</td></tr>
<tr><td></td><td>17</td><td></td><td>550</td><td>440</td><td>810</td><td>0.14</td><td>1.7</td><td>5.4</td><td>-</td></tr>
</table>

APPENDIX V

SUMMARY OF TEMPERATURE AND SALINITY DATA FOR MARINE STATIONS

APPENDIX V SUMMARY OF TEMPERATURE AND SALINITY DATA FROM MARINE STATIONS

Sample Station	Number of Samples	Temperature Range (°C)	Mean Temperature (°C)	Number of Samples	Salinity Range (°/oo)	Mean Salinity
1	2	9.0 - 10.0	9.5	7	28.0 - 29.0	28.1
2	2	8.0 - 10.0	9.0	7	27.5 - 29.0	28.2
3	3	9.0 - 10.0	9.7	7	27.5 - 29.0	28.2
4	2	8.5 - 10.0	9.3	7	27.5 - 30.0	28.8
5	2	9.5 - 10.0	9.8	7	25.5 - 28.0	27.5
6	2	9.0 - 10.0	9.5	7	27.0 - 28.5	27.6
7	2	9.0 - 10.0	9.5	7	27.5 - 28.5	27.8
8	2	9.0 - 10.0	9.5	7	26.5 - 28.5	27.5
9	2	9.0 - 10.0	9.5	7.	27.0 - 28.5	27.9
10	2	9.0 - 10.0	9.5	7	26.5 - 29.0	27.6
11	2	9.0 - 10.0	9.5	7	27.0 - 28.5	27.9
12	2	9.0 - 10.0	9.5	7	23.5 - 28.5	26.6
13	2	9.0 - 10.0	9.5	7	14.0 - 28.5	23.4
14	2	9.0 - 10.0	9.5	7	21.0 - 29.0	27.7
15	2	7.5 - 9.0	8.3	7	21.0 - 28.0	24.2
16	2	8.5 - 10.0	9.3	7	22.0 - 26.0	24.2
Mid.	-	-	-	3	27.0 - 28.0	27.7
Bot.	-	-	-	3	28.0 - 30.0	28.7
17	6	7.5 - 10.0	7.0	11	20.0 - 28.0	25.3
18	1	8.0	8.0	7	24.0 - 27.5	26.0
19	1	8.0	8.0	7	23.5 - 27.0	25.4
20	1	8.0	8.0	7	20.0 - 27.0	24.1
21	1	8.0	8.0	7	15.5 - 28.0	23.6
22	1	8.0	8.0	7	15.5 - 27.5	24.0
23	3	8.0 - 8.5	8.2	8	22.0 - 28.0	26.2
Mid.	-	-	-	3	27.5 - 28.0	27.8
Bot.	-	-	-	3	28.5 - 29.0	28.8
24	7	8.0 - 8.5	8.1	12	14 - 29.5	24.4
Mid.	-	-	-	3	28.0	28.0
Bot.	-	-	-	3	28.0	28.0
25	6	7.0 - 8.5	7.9	13	6.0 - 30.0	21.7
26	5	7.5 - 9.0	8.0	12	11.0 - 29.5	24.5
27	3	7.5 - 9.0	8.0	10	11.0 - 28.0	24.1
28	6	7.0 - 8.5	7.9	13	10.5 - 28.0	25.4
29	6	7.0 - 9.0	8.0	13	10.0 - 29.5	24.4
30	6	7.0 - 9.0	7.8	13	13.0 - 27.5	22.9
31	5	7.5 - 8.5	7.8	12	13.0 - 29.0	24.8
32	3	7.0 - 8.0	7.5	10	22.0 - 28.0	25.1
33	2	8.0	8.0	10	15.0 - 29.5	24.8
34	3	8.0 - 8.5	8.2	10	23.5 - 29.0	27.1
35	3	7.5 - 8.5	7.8	9	22.0 - 29.5	26.7
36	4	7.0 - 8.0	8.3	5	27.0 - 29.0	27.9

Sample Station	Number of Samples	Temperature Range (°C)	Mean Temperature (°C)	Number of Samples	Salinity Range (°/oo)	Mean Salinity
37	2	8.0	8.0	7	27.0 - 29.0	28.2
38	2	8.0 - 8.5	8.3	7	25.0 - 29.0	27.7
39	6	8.0 - 9.0	8.4	6	27.0 - 28.0	27.8
40	4	8.0	8.0	9	22.0 - 29.0	26.6
41	3	8.0	8.0	8	25.5 - 28.5	27.4
42	6	8.0 - 9.5	8.3	11	22.0 - 28.0	24.9
43	6	8.0 - 9.0	8.3	6	11.5 - 28.0	25.2
44	6	7.5 - 9.0	8.6	6	28.0 - 29.5	28.3
45	6	8.0 - 9.0	8.8	6	23.5 - 28.5	27.3
46	6	8.0 - 9.0	8.6	6	23.0 - 28.5	27.3
47	6	8.0 - 9.0	8.4	6	23.5 - 28.0	26.3
48	6	8.0 - 9.0	8.3	6	27.5 - 29.0	27.4
49	6	8.0 - 9.0	8.2	6	24.5 - 29.0	26.4
50	6	8.0 - 9.0	8.3	6	24.5 - 28.0	26.3
51	6	8.0 - 9.0	8.2	6	22.0 - 29.0	26.0
52	6	8.0 - 9.0	8.3	8	22.0 - 28.0	25.5
53	6	8.0 - 9.0	8.6	8	20.0 - 28.0	24.7
54	6	8.0 - 9.0	8.6	8	11.0 - 29.0	23.6
55	6	8.0 - 9.0	8.3	8	16.0 - 28.0	24.9
56	6	8.0 - 9.0	8.8	6	22.0 - 29.0	25.1
57	6	8.0 - 9.0	8.6	6	17.5 - 28.0	25.0
58	6	8.0 - 9.5	8.9	6	16.0 - 29.0	23.8
59	6	8.0 - 9.5	8.6	6	18.0 - 28.0	23.3
60	6	8.0 - 9.5	8.6	6	22.0 - 28.0	26.1
61	6	8.5 - 9.5	8.8	6	23.5 - 28.5	26.2
62	6	8.0 - 9.5	8.8	6	23.5 - 28.0	26.3
63	6	8.0 - 9.5	8.8	6	22.0 - 28.5	26.3
64	-	-	-	6	25.5 - 28.5	27.3
65	-	-	-	6	27.5 - 29.0	28.2
66	-	-	-	6	27.5 - 29.5	28.3
67	5	8.0	8.0	6	28.0 - 29.0	28.3
68	6	7.5 - 9.0	8.6	6	28.0 - 29.0	28.3
69	6	8.0 - 9.0	8.6	6	28.0 - 29.5	28.6
70	3	9.0	9.0	6	28.0 - 29.5	29.0
71	3	9.0	9.0	6	27.5 - 30.0	29.2
72	3	9.0	9.0	6	28.0 - 29.5	28.8
73	3	9.0 - 9.3	9.1	6	29.0 - 30.0	29.3
74	3	9.0 - 9.5	9.2	6	28.0 - 29.5	28.8

APPENDIX VI

CITY OF NANAIMO SEWAGE PUMP STATIONS

a) Characteristics
b) Locations

APPENDIX VI CITY OF NANAIMO SEWAGE PUMP STATION

a) Characteristics

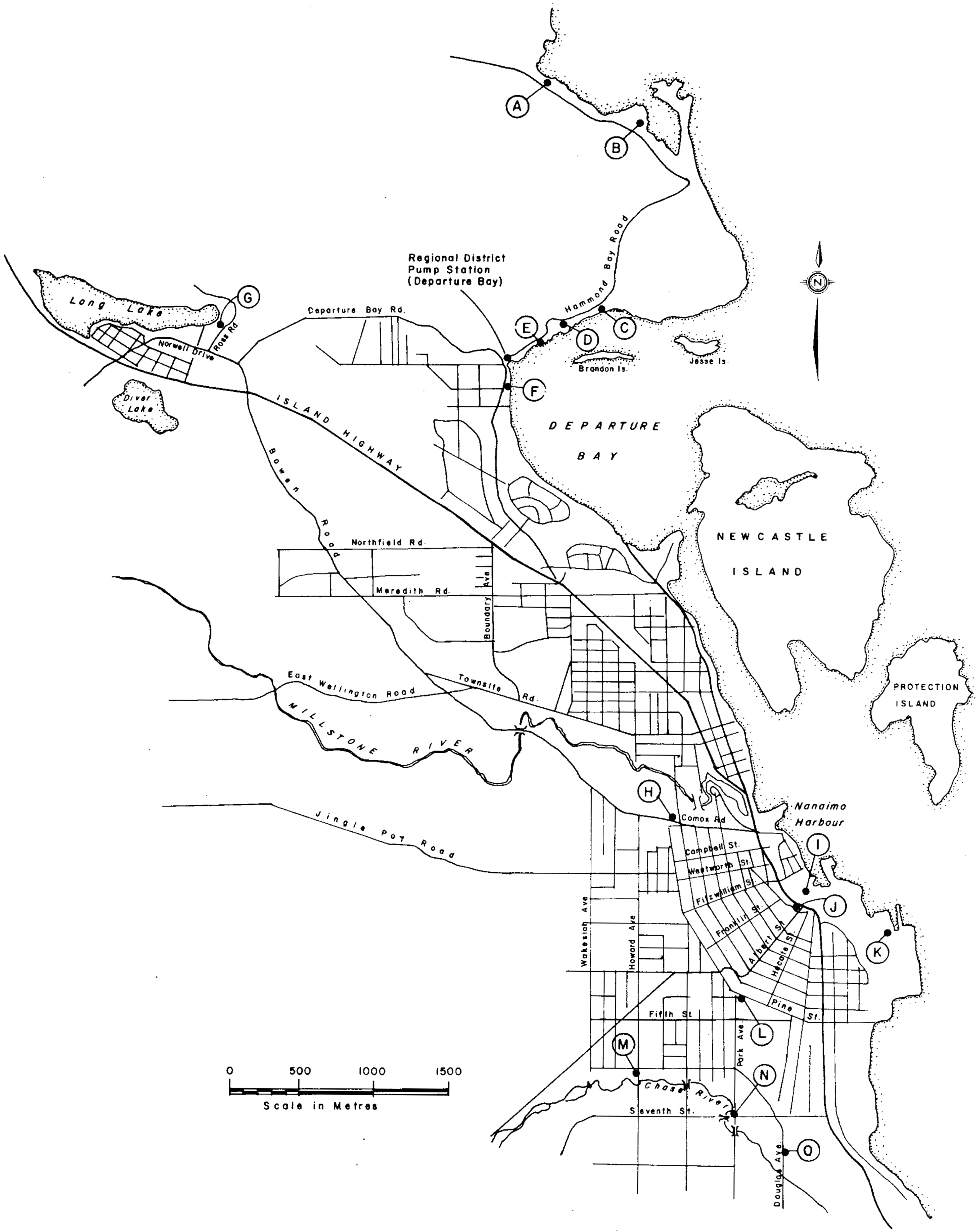
		Pumps						Overflow				
				Power/pump		Flow						
									wet well	overflow time (hrs)		
No.	Name and Location	No.	Operation	kw	HP	m3/day	IGPD*	Location	volume (m^3)	max.	min.	warning system
A	Piper Crescent	2	alternate	3.7	5	11.0	2400	Hammond Bay	23.0	50.0	-	none
B	Piper's Lagoon, 3672 Place Dr.	2	alternate	22.0	30	64.0	14100	Piper's Lagoon	16.4	6.2	3.8	telemetry system
C	Madills, 3092 Hammond Bay Rd.	1	-	2.2	3	6.8	1500	Departure Bay	0.46	1.6	-	none
D	Williams, Hammond Bay Rd.	1	-	2.2	3	2.7	600	Departure Bay	0.27	2.4		none
E	Faggins, Hammond Bay Rd.	1	-	2.2	3	2.7	600	Departure Bay	0.27	2.4		none
F	Datt, Departure Bay Rd.	1	-	2.2	3	1.4	300	Storm drain to Departure Bay	0.27	4.6	-	none
G	Long Lake, Ross Road	2	alternate	4.5	6			Long Lake				warning buzzer
H	Nanaimo Curling Rink	1	-	2.2	3			Millstone River				none

(continued)

* assuming 300 IGPD/residence

No.	Name and Location	Pumps: No.	Operation	Power/pump: kw	Power/pump: HP	Flow: m3/day	Flow: IGPD*	Overflow: Location	wet well volume (m^3)	overflow time (hrs): max.	overflow time (hrs): min.	warning system
I	Gordon Street	1	-	3.7	5			Nanaimo Harbour				none
J	Queens Hotel	1	-	3.7	5			Storm drain (to Nanaimo Harbour)				none
K	Indian Reserve	1	-	4.5	6			Nanaimo Harbour				none
L	Pine Street	2	alternate	11.0	15			Storm ditch				tele-metering system
M	Howard Avenue	1	-	2.2	3			Chase River				none
N	Park Avenue	2	alternate	22.0	30	12700	450000	Chase River		0.05		standby generator + tele-metering system
O	Douglas Road	1	-	2.2	3	9.1	2000	top manhole				none
RDG	Regional District Pump Station at Departure Ck.	4		260.0	350							standby generator + tele-metering system

* assuming 300 IGPD/residence



(b) LOCATION OF CITY OF NANAIMO SEWAGE PUMP STATIONS

APPENDIX VII

AN OPERATIONAL REPORT OF THE GREATER NANAIMO WATER POLLUTION CONTROL CENTRE

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LIST OF ABBREVIATIONS

BOD	5-day biochemical oxygen demand
CFM	cubic feet per minute
COD	chemical oxygen demand
DO	dissolved oxygen
EPS	Environmental Protection Service
FR	filterable residue
GNWPCC	Greater Nanaimo Water Pollution Control Centre
kg	kilograms
l	litres
m^3/day	cubic metres per day
mm	millimetres
MIGPD	million imperial gallons per day
ml	millilitres
MGD	million gallons per day
mg/l	milligrams per litre
NFR	non-filterable residue
ppm	parts per million
surfactants	anionic surfactants
TFR	total fixed residue
TOC	total organic carbon
TPO_4	total phosphate
TR	total residue
TRC	total residual chlorine
TVR	total volatile residue
WC	water content
WPCC	Water Pollution Control Centre

1 INTRODUCTION

Untreated domestic and industrial wastewaters collected in the City of Nanaimo have been discharged to Nanaimo Harbour since the turn of the century (1). The discharge of raw sewage was discontinued in 1975 with the completion of the Nanaimo Interceptor, Departure Bay Pumping Station, Greater Nanaimo Water Pollution Control Centre, and the Five Fingers Island Outfall. Sewage is now collected, treated, and discharged to Georgia Strait.

The Greater Nanaimo Water Pollution Control Centre (GNWPCC) is a primary type sewage treatment plant utilizing screening, barminuting, aerated grit removal, sedimentation, and chlorine disinfection of the liquid effluent (Figure A). Sludge from the sedimentation tanks is treated in two serial anaerobic digestors and dried on sludge beds. Supernatant from the digestors is returned to the treatment plant influent. Selected design characteristics of the GNWPCC are shown in Table A.

A performance evaluation of the treatment system was conducted by personnel from the Environmental Protection Service from March 21 to 29, 1978. The purpose of this study was:

1) to obtain bacteriological and chemical analysis data in support of the Nanaimo shellfish growing water quality survey;
2) to obtain toxicity data as a continuation of a 1976 EPS program to obtain bioassay data for various types of sewage treatment plants in British Columbia;
3) to obtain chemical data to assist in the interpretation of bioassay results.

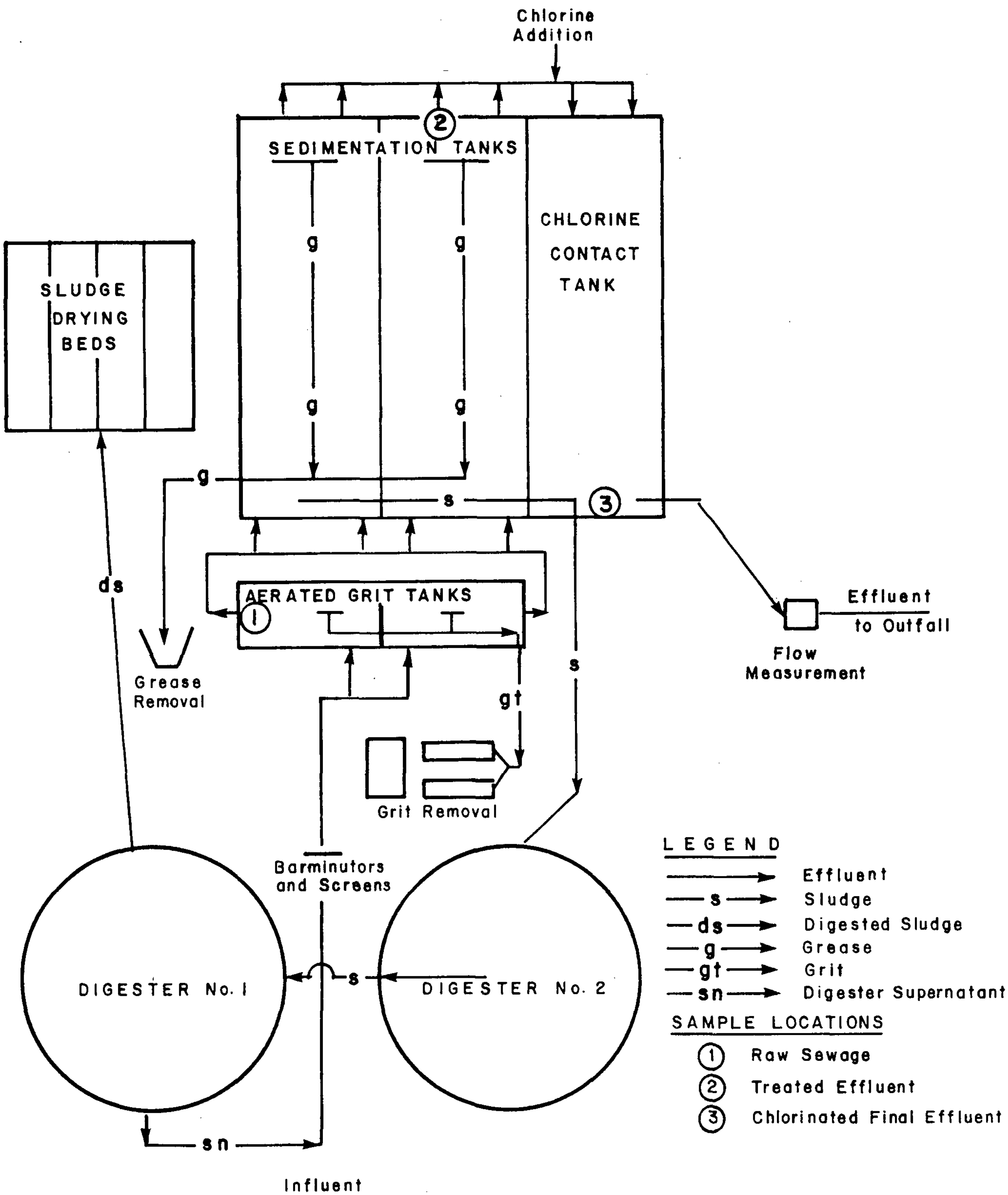

FIGURE A. GREATER NANAIMO WATER POLLUTION CONTROL CENTRE - FLOW DIAGRAM AND SAMPLE POINT LOCATIONS

TABLE A SELECTED DESIGN DATA FOR THE GREATER NANAIMO WATER POLLUTION CONTROL CENTRE(2)

Present Population	32 000
Average Flow (m^3/day)	27 300 (6 MIGPD)
Peak Flow (m^3/day)	79 500 (17.5 MIGPD)
Suspended Solids Loading (kg/day)	4 090 (9000 lb/day)
BOD Loading (kg/day)	3 680 (8100 lb/day)
No. of Barminutors	1

Aerated Grit Tanks

Number	2
Detention Time @ Avg. Flow (min)	21
Air Supply (m^3/min)	2.8 to 20 (100 to 700 CFM)

Sedimentation Tanks

Number	2
Detention Time @ Avg. Flow (hrs)	2.12
Overflow Rate (m^3/m^2/day) @ Avg. Flow	32.5 (665 gal/ft^2/day)
Maximum Capacity (m^3/day) @ Avg. Flow	39 800 (8.75 MGD)

Chlorine Contact Tank

Detention Time @ Avg. Flow (hrs)	1.06
Average Chlorine Doseage (ppm)	10
Chlorine Consumption Avg. Flow (kg/day)	270 (600 lb/day)

Digesters

Number	2
Volume (m^3)	1900 (68 000 ft^3)
Volume of Solids, 98% WC @ Avg. Flow (m^3/day)	66 (14 600 gal/day)

Plant Effluent

Suspended Solids @ Avg. Flow (kg/day)	1760 (3880 lb/day)
BOD @ Avg. Flow (kg/day)	2210 (4860 lb/day)

2 SAMPLE PROCEDURES AND METHODS

Commencing 0800 March 21 and continuing until 0800 March 22, 1.5 litre samples of the treated effluent after the sedimentation process, and final chlorinated effluent (Figure A) were collected every 15 minutes using a submersible pump and an Eagle signal timer; concurrently, approximate 250 ml samples of the raw sewage were taken every 2.5 minutes using a Markland Model 2101-Spec. Duckbill sampler. Samples were combined and mixed in plastic-lined, 45-gallon drums at each sampling location.

Grab samples of the raw sewage, treated effluent, and chlorinated effluent were obtained using a bucket on a rope at 0800 March 22.

Twenty-four hour composite sample of the raw sewage and treated effluent were obtained from 0800 March 28 to 0800 March 29, and a grab sample of the chlorinated effuent was obtained at 0800 March 29 using the methods described above.

Samples were split and preserved as outlined in the Environment Canada Pollution Sampling Handbook (3). Samples for chemical analyses were delivered to the Department of Fisheries and Environment, Chemistry Laboratory in West Vancouver within 4 hours of sampling.

Samples from each location were transferred in three 5-gallon capacity plastic jerry cans for bioassay determination (96 hour LC_{50}) to the Environmental Protection Service, Aquatic Toxicity Laboratory in North Vancouver within 4 hours of sampling.

The 96 hour LC_{50} 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-litre, 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 $15.0°\pm1°C$.

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 dissolved oxygen level was found to be below 5 ppm, and pre-aerated for 30 minutes if the DO was greater than 5 ppm. 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 ppm and were therefore pre-aerated for only 30 minutes.

Samples of the chlorinated final effluent were obtained hourly from 0800 to 1500 on March 22. Upon collection, samples were immediately analysed for total residual chlorine (TRC) using a Fisher and Porter Company Amperometric Titrator Model 17T1010. The procedure used is a back titration method which involves the neutralization of an oxidizing agent (free iodine) with a reducing agent (phenylarsine oxide solution) of known strength in the presence of potassium iodide. Total residual chlorine as determined by this method yields the concentration of compounds in the wastewater containing active chlorine which include monochloramines, dichloramines, and hypochlorous acid.

3 RESULTS

3.1 Chemical Analyses Results

Composite and grab samples were obtained of the raw sewage influent, effluent after the sedimentation process, and final chlorinated effluent and the results of chemical analyses performed on these samples are shown in Tables B and C.

On March 21 and 22, operational difficulties were experienced with the GNWPCC's anaerobic digesters. An excessively thick layer of scum had formed on the upper layers of the digester and supernatant was drawn from a lower level than usual. Supernatant was discharged to the influent line above the raw sewage sampling point used during this survey. The effects of the unusual quality supernatant discharged on March 21 and 22 can readily be seen in the raw sewage chemical analyses results. The TR, FR, and TFR concentrations for samples collected on those days were approximately quadruple those noted for raw sewage samples collected on March 28 - 29. BOD_5, TOC, COD, TVR, and NH_3 concentrations were also slightly lower during the latter sampling, although this was due in part to precipitation and associated infiltration/inflow (Figure B) during this period.

According to the results of the March 28 - 29 sampling, the GNWPCC raw sewage would generally be classified as weak (normal dry weather sewage would be somewhat stronger).

The Pollution Control Branch permit for the GNWPCC requires that the final effluent NFR and BOD be an average of 122 and 130 mg/l, respectively. Results of this study indicate that the final effluent meets these criteria.

Metcalf and Eddy (7) report that efficiently designed and operated primary sedimentation tanks should remove from 50 to 65% NFR and from 25 to 40% BOD_5. According to our test results, the GNWPCC affected an average 52% reduction in NFR and a 32% reduction in BOD_5.

Table D summarizes the results of tests performed by the treatment plant operators. Generally these BOD and NFR removal efficiencies were slightly higher than those measured during this study, although this may

TABLE B RAW SEWAGE STRENGTH

Parameter (mg/l)	Typical Raw Sewage (6)			Raw Sewage Chemical Analyses Results		
	Strong	Medium	Weak	March 21-22	22	28-29
TR	1200	700	350	1090	1260	457
NFR	350	200	100	95	150	115
FR	600	350	175	995	1110	342
TVR	600	350	175	203	198	183
TFR	850	500	250	887	1062	274
BOD_5	300	200	100	210	176	143
TOC	300	200	100	95	85	78
COD	1000	500	250	299	310	277
Organic N	35	15	8	38.2	34.3	-
NH_3	50	25	12	19.5	19.9	18.0
NO_3	0	0	0	0.010	0.012	0.0010
NO_2	0	0	0	0.0065	0.0055	0.0050
TPO_4	20	10	6	5.50	5.40	-

TABLE C CHEMICAL ANALYSES RESULTS

Parameter	Raw Sewage			Effluent After Sedimentation			Final Chlorinated Effluent		
	March			March			March		
	21-22	22	28-29	21-22	22	28-29	21-22	22	28-29
	mg/l								
pH (pH units)	7.2	7.1	7.3	7.2	7.1	7.3	7.4	7.0	7.2
TR	1090	1260	457	1130	1050	416	1080	1170	424
NFR	95	150	115	61	74	59	65	51	55
FR	995	1110	342	1069	976	357	1015	1119	369
TVR	203	198	183	139	134	134	149	146	147
TFR	887	1062	274	991	916	282	931	1024	277
BOD_5	210	176	143	230	123	112	125	117	116
TOC	95	85	78	84	75	62	81	78	66
COD	299	310	277	264	259	227	264	305	287
Organic N	38.2	34.3	-	38.2	30.0	-	39.8	34.3	-
NH_3	19.5	19.9	18.0	23.1	22.2	19.6	24.6	24.5	19.5
NO_3	0.010	0.012	0.0010	0.010	0.010	0.0010	0.015	0.010	0.001
NO_2	0.0065	0.0055	0.0050	0.0115	0.0080	0.0084	0.0318	0.0185	0.009
TPO_4	5.50	5.40		6.00	6.00		6.00	6.25	
Surfactants	1.90	1.35	2.23	1.96	1.98	2.39	1.98	2.66	3.15

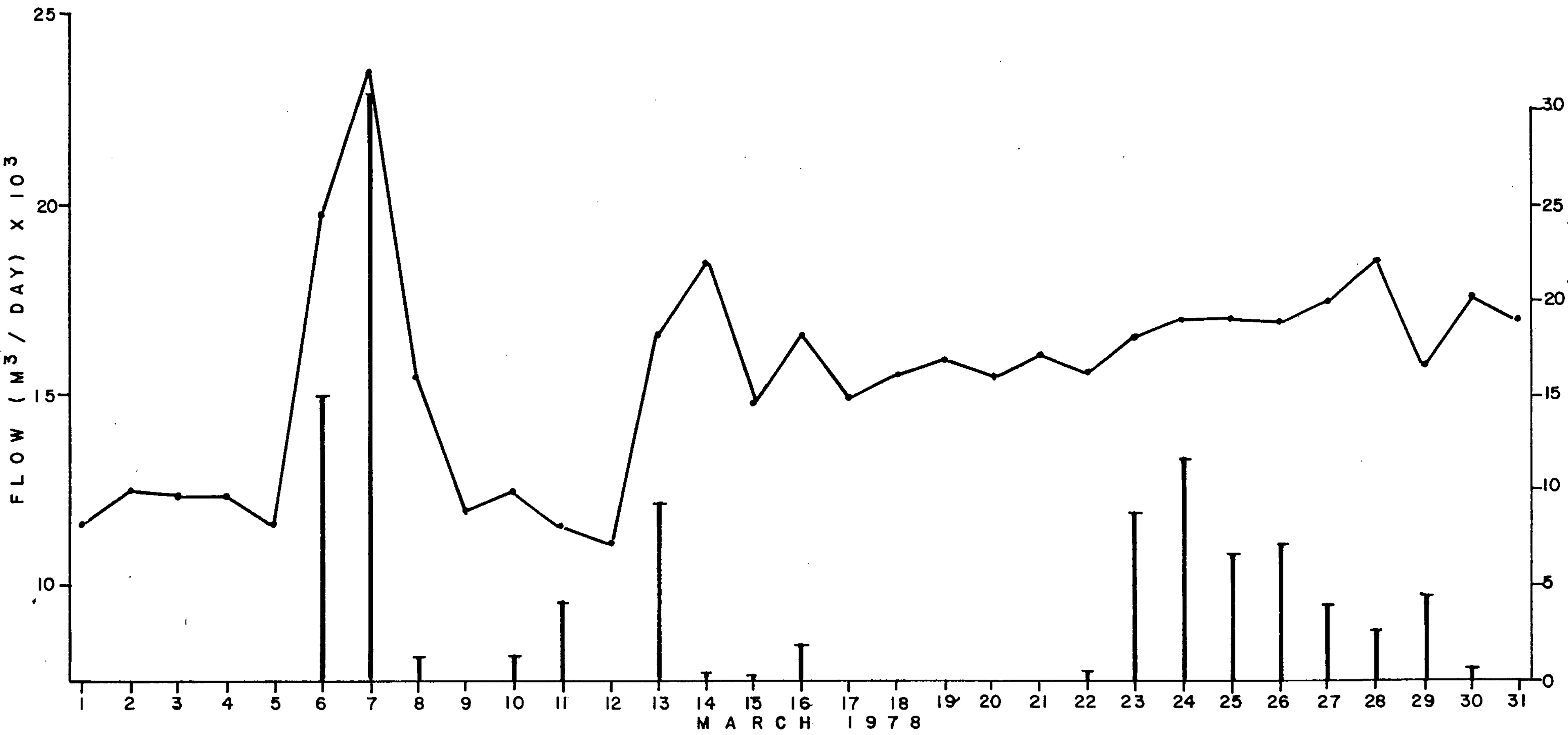

FIGURE B. FLOW THROUGH THE GREATER NANAIMO WATER POLLUTION CONTROL CENTRE AND DAILY PRECIPITATION

TABLE D GREATER NANAIMO WATER POLLUTION CONTROL CENTRE ANNUAL SUMMARY OF PLANT OPERATION

Date		Average Daily Flow	Influent				Effluent						Chlorine		
		m /day	pH	DO mg/l	NFR mg/l	BOD_5 mg/l	pH	DO mg/l	NFR mg/l	NFR (%)	BOD_5 mg/l	BOD_5 (%)	kg used /day	(lbs)	TRC mg/l
1975	October	18 200	7.0	1.4	155	325	7.4	6.0	60	(61)	100	(40)	45	(100)	0.16
	November	19 300	6.6	5.5	241	135	6.65	8.9	43	(82)	49	(64)	60	(133)	0.08
	December	-	6.9	5.4	268	250	7.1	9.3	62	(69)	78	(53)	54	(120)	0.14
1976	January	17 900	6.8	4.3	183	139	7.0	6.8	67	(62)	59	(57)	44	(96)	0.16
	February	18 000	7.0	4.3	240	193	7.0	6.4	89	(56)	30	(54)	48	(105)	0.10
	March	16 100	7.0	4.4	338	107	7.5	6.4	70	(73)	43	(64)	47	(104)	0.4
	April	16 600	-	-	-	-	-	-	-	-	-	-	-	-	-
	May	15 600	-	-	-	-	-	-	-	-	-	-	-	-	-
	June	12 000	6.9	1.4	210	190	7.1	2.6	65	(61)	80	(45)	26	(57)	0.5
	July	11 500	6.7	1.5	290	310	6.6	3.8	100	(62)	100	(42)	71	(156)	0.2
	August	12 900	6.8	1.2	509	370	6.8	3.7	94	(60)	90	(35)	106	(234)	0.2
	September	18 400	6.8	0.3	1156	450	6.8	2.5	142	(60)	135	(38)	128	(283)	0.4
	October	14 200	6.8	0.9	420	355	6.8	3.5	107	(67)	135	(36)	121	(267)	0.5
	November	15 600	7.2	1.2	380	195	7.0	3.6	53	(65)	50	(40)	121	(266)	0.4
	December	16 800	7.0	2.2	215	217	6.7	5.0	50	(76)	98	(54)	139	(306)	0.2
1977	January	16 100	7.1	2.6	273	120	6.7	6.1	76	(68)	59	(54)	105	(231)	0.2
	February	16 100	7.0	2.6	215	128	6.8	5.6	90	(56)	38	(58)	102	(225)	Trace
	March	16 700	7.0	4.2	167	129	6.7	6.2	60	(73)	59	(54)	99	(219)	0.3
	April	11 800	6.8	1.4	288	250	6.8	3.6	42	(85)	159	(36)	86	(190)	0.3
	May	11 400	7.0	0.5	245	350	7.0	2.2	63	(74)	226	(35)	106	(233)	0.0
	June	11 400	7.0	0.3	315	259	7.0	2.2	74	(76)	168	(35)	133	(292)	0.0
	July	13 200	7.0	0.0	196	222	7.0	2.8	55	(70)	80	(64)	132	(290)	0.3
	August	13 500	7.0	0.2	331	268	7.0	1.9	73	(75)	125	(53)	128	(283)	Trace
	September	13 400	6.9	0.8	239	226	6.9	1.9	66	(72)	103	(55)	147	(323)	0.2
	October	13 700	6.9	0.8	297	258	6.9	2.0	68	(77)	124	(45)	124	(275)	0.2
	November	20 000	7.0	2.6	160	192	7.0	4.3	52	(68)	100	(47)	129	(285)	Trace
	December	17 800	6.9	4.5	183	230	6.9	6.6	68	(62)	87	(55)	139	(307)	Trace

have been due to differences in sampling and analytical methods (GNWPCC staff use flow-proportional, composite samples).

Results of the 8-hour final effluent TRC survey are shown in Figure C. The Pollution Control Branch permit for this treatment system requires that the operator maintain a chlorine residual between 0.1 and 1.0 mg/l. TRC concentrations for samples collected at 0830 and 0930 were slightly above the maximum permitted level - 1.08 and 1.05mg/l, respectively. The operator reduced the chlorine feed rate at about 1230. At design average flows, the chlorine contact tank detention time is 1.06 hrs (Table A). Since the flows encountered on March 22 were about half of the design flow, the chlorine contact tank detention time was about 2 hrs. The effect of the reduction in chlorine feed rate then can be seen in the results of the TRC analysis of the sample collected at 1530 (0.36 mg/l). Since chlorine addition is flow-proportionally controlled, the adjusted chlorine feed rate should be suitable for all flow rates (assuming constant chlorine demand of the wastewater).

3.2 Bioassay Results

Bioassays were performed on composite and grab samples of the raw sewage effluent after sedimentation, and final chlorinated effluent and the results are shown in Table E.

Also shown in Table E are selected chemical analyses 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 are discussed in EPS published reports by T.W. Higgs (9). In this study, three primary chemical parameters were implicated as contributing to the acutely toxic responses exhibited by 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 F. A detailed discussion of the subject is beyond the scope of this report and the reader is referred to the appropriate references listed.

Total residual chlorine concentrations of the final effluent were measured immediately after sample collection at the treatment plant, upon

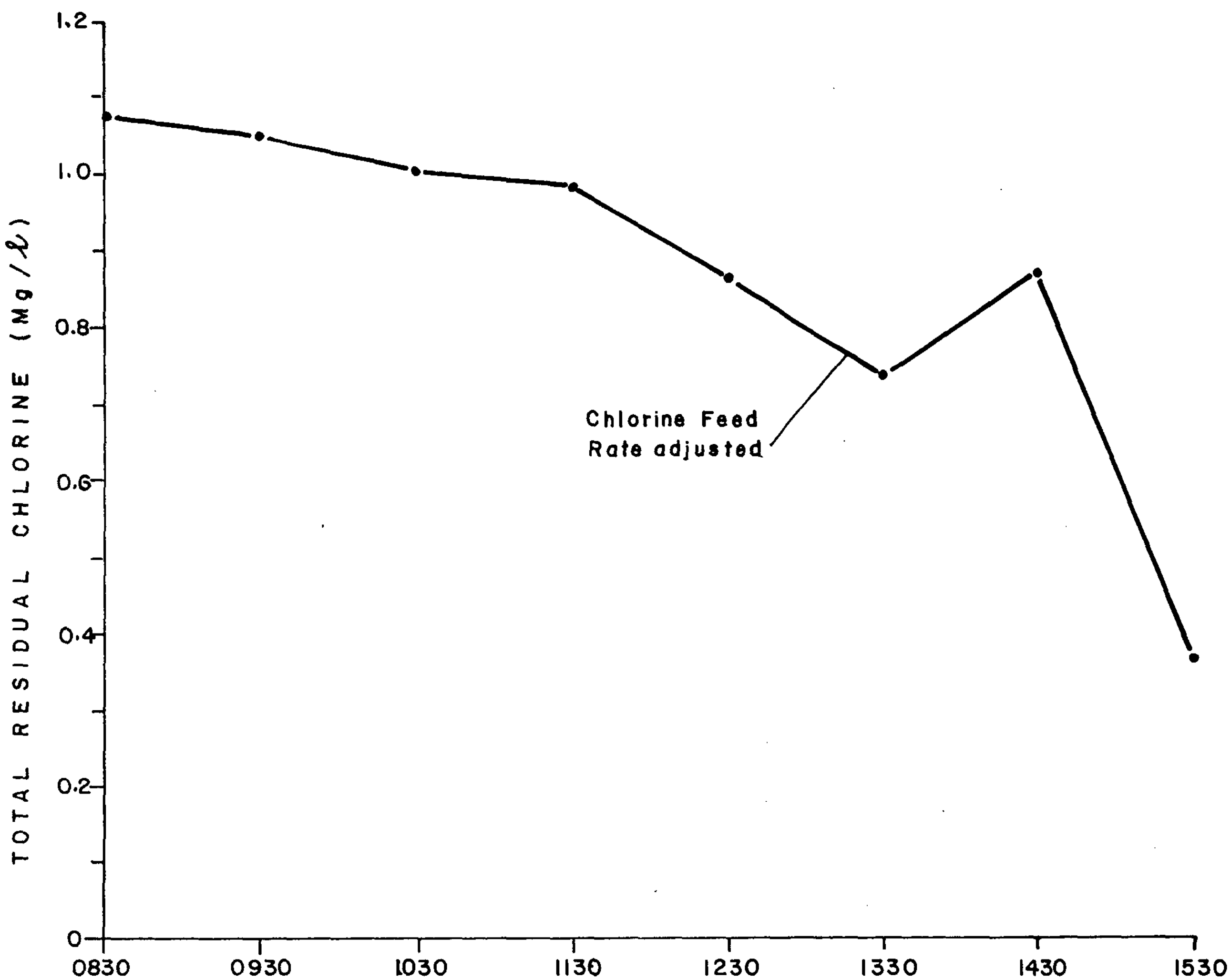

FIGURE C TOTAL RESIDUAL CHLORINE ANALYSES RESULTS be due to differences in sampling and analytical methods (GNWPCC staff use flow-proportional, composite samples).

Results of the 8-hour final effluent TRC survey are shown in Figure A3. The Pollution Control Branch permit for this treatment system requires that the operator maintain a chlorine residual between 0.1 and 1.0 mg/l. TRC concentrations for samples collected at 0830 and 0930 were slightly above the maximum permitted level - 1.08 and 1.05mg/l, respectively. The operator reduced the chlorine feed rate at about 1230. At design average flows, the chlorine contact tank detention time is 0106 hrs (Table A1). Since the flows encountered on March 22 were about half of the design flow, the chlorine contact tank detention time was about 2 hrs. The effect of the reduction in chlorine feed rate then can be seen in the results of the TRC analysis of the sample collected at 1530 (0.36 mg/l). Since chlorine addition is flow-proportionally controlled, the adjusted chlorine feed rate should be suitable for all flow rates (assuming constant chlorine demand of the wastewater).

3,2 <u>Bioassay Results</u>

Bioassays were performed on composite and grab samples of the raw sewage effluent after sedimentation, and final chlorinated effluent and the results are shown in Table A5.

Also shown in Table A5 are selected chemical analyses 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 are discussed in EPS published reports by T.W. Higgs (9). In this 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 A6. A detailed discussion of the subject is beyond the scope of this report and the reader is referred to the appropriate references listed.

Total residual chlorine concentrations of the final effluent were measured immediately after sample collection at the treatment plant, upon

TABLE E 96 HOUR LC_{50} BIOASSAY RESULTS AND SELECTED CHEMICAL ANALYSES RESULTS

Sample	Date	Type of Sample	96 hour LC_{50} (%)	Un-ionized NH_3** (mg/l)	Anionic Surfactants (mg/l)	Average TRC (mg/l)		
						WPCC	Lab	Start Test
Raw Sewage	March 21-22	24-hr Composite	70	0.099	1.90			
Treated*	March 21-22	24-hr Composite	61	0.11	1.96			
Final Effluent	March 21-22	24-hr Composite	45	0.18	1.98	0.002	0.002	ND
Raw Sewage	March 22	Grab	55	0.078	1.35			
Treated	March 22	Grab	49	0.087	1.98			
Final Effluent	March 22	Grab	39	0.067	2.66	0.54	0.54	0.21
Raw Sewage	March 28-29	24-hr Composite	49	0.11	2.23			
Treated	March 28-29	24-hr Composite	44	0.12	2.39			
Final Effluent	March 29	Grab	55	0.099	3.15	ND	ND	ND

* Effluent after sedimentation process.

** Un-ionized NH_3 concentrations calculated using NH_3 concentration, pH, sample temperature, and tables published by Emerson et al (10).

ND Non-detectable.

TABLE F CRITICAL CONCENTRATIONS OF ANIONIC SURFACTANTS, UN-IONIZED NH_3, AND TRC REPORTED TO BE TOXIC TO FISH

Parameter	Concentration (mg/l)	Significance	Reference
Un-ionized NH_3	0.006	desirable upper limit	(11)
	0.025	maximum tolerated	(12)
	0.44	100% mortality after 96 hours	(13)
Anionic surfactants	3.3-6.4	96-hr LC_{50}	(14)
	5.9	96-hr LC_{50}	(15)
TRC	0.2	likely toxic	(16)

arrival at the Aquatic Toxicity Laboratory, and at the start of the 96-hr LC_{50} test. The March 22 grab sample exhibited a much higher TRC concentration (0.54 mg/l) than the 24-hour composite (0.002 mg/l). This was attributed mainly to the increased storage time of the aliquots which allowed further chlorine reaction and dissipation.

Unfortunately, due to a heavy work load in the laboratory, the samples were stored about 24 hrs at 4°C before the 96-hr LC_{50} test was begun. The sample TRC concentrations were re-analyzed at that time and the composite sample's TRC was found to be non-detectable while the grab sample's was 0.21 mg/l.

In an attempt to obtain more information on toxicity due to chlorine, a grab sample of the final effluent was obtained at 0800 on March 29. However, the chlorine gas cylinder at the treatment plant "ran dry" during the preceeding night and, therefore, there was no chlorine in the final effluent at the time of sampling. The 96-hr LC_{50} test was begun immediately upon sample arrival at the laboratory.

The bioassay results correlate well with the chemical analyses results. The final effluent sample was the most toxic (45% LC_{50}) of the March 21-22 composite set, probably due to the highest un-ionized NH_3 concentration of the set. The final effluent sample was also the most toxic of the March 22 grab set, probably due primarily to the high TRC concentration and partially to the un-ionized NH_3 concentration.

The March 29 grab sample was the least toxic of the final effluent samples while the March 22 grab sample was the most toxic - both observations correlate well with the chemical results. With the exception of the March 28-29 sample set, the raw sewage sample was the least toxic, followed by the treated effluent sample, and the final effluent was the most toxic. The March 28-29 samples were not comparable since the raw sewage and treated effluent samples were composites while the final effluent was a grab sample.

All anionic surfactant concentrations were below reported LC_{50} levels.

Other factors, beyond those reported here, are known to influence toxicity. Synergistic and antagonistic effects by various chemical agents may be important in these analyses. Moreover, since in this study time constraints necessitated that only limited sampling for bioassays could be conducted, the results and evaluation must be viewed as an indication only of the actual wastewater toxicity. Chemical agents other than those measured in this study would undoubtedly also contribute to the wastewater toxicity.

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