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NORTH VANCOUVER, B.C.

MARINE MONITORING OF NORTHUMBERLAND CHANNEL NEAR HARMAC PULPMILL, HARMAC, B.C. 1986, 1989

EP REGIONAL DATA REPORT: DR 92-04

By

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REVIEW NOTICE

Data reports are prepared to make preliminary data available without full analysis or interpretation. This report has been reviewed by the Environmental Effects Branch, Environmental Protection and approved for limited distribution. For further information, please contact:

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ABSTRACT

Environmental Protection has monitored marine waters around coastal pulpmills since 1976. Northumberland Channel has been part of this annual routine marine monitoring programme. Water quality records were kept of temperature, salinity, dissolved oxygen and colour relative to water depth. Marine sediment was collected for trace metals, volatile residue and particle size analysis. Trawls of fish and crustaceans were collected, identified and analyzed for trace metals.

This data report summarizes the sampling done near Harmac pulpmill in Northumberland Channel by Environmental Protection in April 1986 and 1989. Methods used for collection and analysis are described and results are presented without analysis or interpretation. The sole intent of this report is to provide historical data for Harmac pulpmill.

RESUME

La Protection de l'Environnement a échantillonné les eaux marines réceptrices aux environs des usines de pâte côtières depuis 1976. Northumberland Channel a fait partie d'un programme d'échantillonnage marin de routine annuel. Les données de qualité de l'eau sont concentrées sur la température, salinité, oxygène dissous, et couleur en relation à la profondeur d'eau. Des échantillons instantanés de sédiment furent recueillis pour des analyses de métal à l'état de trace, de résidu volatil, et grosseur de particules. Des poissons et crustacés attrapés au chalut furent recueillis, identifiés et analysés pour métaux à l'état de trace.

Ce rapport de donnée résume l'échantillonnage fait dans le Northumberland Channel par la Protection de l'Environnement en Avril 1986 et Avril 1989 près de Nanaimo, C.-B. Les rapports de données résument les méthodes utilisées pour l'échantillonnage et l'analyse. Les résultats sont présentés en tables ou graphiques sans analyse ni interprétation. La seule intention de ces rapports est de fournir des données historiques.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

Harmac pulpmill is located 6.0 km southeast of the Nanaimo, B.C. on Vancouver Island (Figure 1). MacMillan Bloedel has operated the mill since 1950. The mill has undergone several expansions and presently has an average pulp production of 1,188 metric tonnes per day. In 1993, total suspended solids (TSS) averaged 8,054 kg/day and biochemical oxygen demand (BOD) averaged 23,954 kg/day. Appendix I summarizes the effluent discharge volumes.

Mill effluent discharges into Northumberland Channel and, since 1976, has been released via a submarine outfall and diffuser. This alleviated the problem of effluent in surface waters and the associated effects on the nearby intertidal zone (Young, 1986). Discharge at this location, however, produced another problem by creating a white filamentous mat on the surrounding seabed. This has been studied by University of Victoria and found to be composed primarily of the sulfur bacteria, *Beggiatoa* sp. (Ellis and Ostrovsky, 1984). Anoxic, highly reduced sediments occur below the mats and cause significant changes in benthic productivity (Pearson and Rosenberg, 1978).

Effluent dispersion in Northumberland Channel was studied in detail by Seaconsult in 1990 (Hodgins and Webb, 1991). A dye study traced Harmac effluent dilution both in distance and time. It was found that effluent does not enter the Nanaimo River estuary, but does pass through Dodd Narrows. Effluent trapping was observed at depths of 30 to 40 m and principal seabed contact in Northumberland Channel occurred at depths less than 90 m.

1.1 Oceanography

Northumberland Channel is a 6.5-kilometre passage separating the east coast of Vancouver Island from Gabriola Island (Figure 2). Waldichuk (1965) described Northumberland Channel as a partially-mixed tidal system having relatively rapid replacement of its waters. In the vicinity of the Harmac diffuser, Waldichuk described the development of a three-layer flow pattern during flood tides with surface and bottom waters flowing southeast towards Dodd Narrows (between Mudge Island and Vancouver Island) and a middle layer between 5 and 10 m flowing northwest toward Fairway Channel. During ebb tides, water retreats through Dodd Narrows resulting in mixing over the sill.

Seaconsult (Hodgins and Webb, 1991) carried out detailed oceanographic surveys to more clearly define seasonal flow patterns. The differences in winter and summer stratification of the water column are graphically presented in their report.

1.2 Fisheries

The area around Harmac pulpmill is heavily used by the logging industry. Besides the mill, there is extensive use of the nearshore as a booming ground. Associated with this are large numbers of Stellar sea lions as well as some California sea lions. Recent information from Department of Fisheries and Oceans describe this area as a major ling cod fishery and herring staging area. Close to a thousand eagles and large numbers of diving birds frequent Northumberland Channel (Hillaby, pers. comm., 1992).

There is a minor groundfish and shrimp trawling fishery in the vicinity of Harmac. Major commercial clamming and oyster leases are located south of Dodd Narrows. Throughout the area there is recreational and native clamming (Harbo, DFO, pers.comm.).

In November 1989, a national dioxin study by Environment Canada and Fisheries and Oceans Canada demonstrated the presence of dioxins and furans in harvested fish and shellfish in the vicinity of several pulpmills. Harmac was on this list and closures resulted for the commercial crab fisheries (Figure 2). Recreational and native harvesting of clam, crab and oysters remained open; however, some crab hepatopancreas consumption guidelines were instituted. MacMillan Bloedel carried out a comprehensive baseline organochlorine survey of mill effluent, receiving water, sediments and biota (Dwernychuk, 1990).

2.0 MATERIALS AND METHODS

Sampling in Northumberland Channel was done from the C.S.S. *Vector* on April 9-10, 1986 and April 26, 1989 at stations shown in Figure 3. Stations were located using ship's LORAN-C and radar. Station positions are recorded in Appendix II. Tables 1 and2 summarize water quality, sediment and tissue parameters sampled for each year and techniques are summarized in Table 3. Lab analyses were done at the EP/DFO West Vancouver laboratory.

2.1 Water Samples

In 1986, water quality was sampled at the outfall (NC-5) and a reference site (NC-9). Colour samples were also collected as markers of mill effluent. In 1989, water sampling was restricted to the outfall area (NC-5) and at the boundaries of the sampling area (northwest at NC-9 and southeast at NC-20)

Water samples were collected at discrete depths with polypropylene N.I.O. (National Institute of Oceanography) water bottles using standard oceanographic techniques at stations depicted in Figure 3. Conductivity, temperature and depth (CTD) profiles were taken using a Guildline 8770 CTD/DO sensor.

2.1.1 Analytical Procedures - Water. Oxygen concentrations were determined in the ship's lab using the azide modification of the Winkler method. The equations of Gameson and Robertson (1955) were used in the calculation of percent dissolved oxygen saturation:

$$C=\frac{475-(2.65xS)}{33.5+T}$$

$$\%Saturation=\frac{A}{C}x100$$

where: C = saturation of oxygen in the sample water

S = salinity of the sample water

T = corrected temperature of the sample water

A = observed dissolved oxygen concentration in the sample

Tri-stimulus colour values of previously frozen samples were determined spectrophotometrically in the lab.

2.2 Sediment Samples

To more clearly define the boundaries of the organic deposits at Harmac, and to reconfirm 1983 findings, a series of 22 benthic stations were sampled on April 9-10, 1986. This extensive sampling was repeated on April 26, 1989.

Sediment grabs were taken at the stations depicted in Figure 3 using a stainless steel 0.1 m^2 Smith-MacIntyre grab. The surficial (2 cm) sediment layer was collected using a plastic scoop, avoiding the sediment near the sides of the grab. Samples for trace metal, volatile residue, and particle size analysis were placed in paper sediment bags inside plastic bags and immediately frozen. Sediments collected for PCB and resin acid analysis were collected using a heat-treated metal spoon and stored frozen in heat-treated glass jars.

2.2.1 Analytical Procedures - Sediment. Sediment samples were analyzed by the EP/DFO West Vancouver Laboratory for trace metals, volatile residue and particle size according to the procedures described by Swingle and Davidson (1979) with some modification by the lab (Millward and Kluckner, 1989). Trace metal samples were dried at 60°C and passed through a nylon sieve (0.15 mm mesh) then digested in a 4:1 nitric:hydrochloric acid solution diluted slightly with 1 ml of distilled water. Samples were digested in a microwave oven for 15 minutes at 720 joules/sec (watts). Trace metals were determined using a Perkin-Elmer Inductively Coupled Argon Plasma (ICAP) Optical Emission Spectrophotometer. A Jarrel Ash 850 Atomic Absorption Spectrophotometer (AAS) with an FLA 100 graphite tube furnace was used to detect low-level cadmium. Electron capture gas liquid chromatography was used for PCB and resin acid determination.

2.3 Biota Samples

On April 26, 1989, two trawls were taken in Northumberland Channel. Fish and invertebrates were collected for trace metal analysis from Harmac Trawl Stations NC-9 (reference area) and NC-15 (outfall). Samples were placed in plastic bags and frozen prior to analysis. The following species were used for analysis:

Dover sole	*Microstomus pacificus*
Rex sole	*Glyptocephalus zachirus*
English sole	*Parophrys vetulus*
Hake	*Merluccius productus*
Ratfish	*Hydrolagus colliei*
Rockfish	*Sebastes elongatus*
Prawn	*Pandalus platyceros*
Sidestripe shrimp	*Pandalopsis dispar*
Smooth shrimp	*Pandalus jordani*
Pink shrimp	*Pandalus borealis*
Dungeness crab	*Cancer magister*

2.3.1 Analytical Procedures - Biota. At the EP/DFO West Vancouver Lab samples were thawed, blended, freeze-dried and oxidized in a low temperature asher. The ash (metallic salts) was dissolved in warm concentrated nitric acid, then analyzed on the ICAP Spectrophotometer. Low-level cadmium was analyzed using a Jarrel Ash 850 Atomic Absorption Spectrophotometer (AAS) with an FLA 100 graphite tube furnace.

TABLE 1: WATER, SEDIMENT AND BIOTA SAMPLING STATIONS, NORTHUMBERLAND CHANNEL SAMPLING SUMMARY, APRIL 10, 1986

STATION	WATER			SEDIMENT				
	CTD	DO	COLOUR	PS	SVR	PCBs	RA	TM
1				X	X	X	X	X
2				X	X	X	X	X
3				X	X	X	X	X
4				X	X	X	X	X
5	X	X	X	X	X	X	X	X
6				X	X	X	X	X
7				X	X	X	X	X
8				X	X	X	X	X
9				X	X	X	X	X
10	X	X	X	X	X	X	X	X
11				X	X	X	X	X
12				X	X	X	X	X
13				X	X	X	X	X
14				X	X	X	X	X
15				X	X	X	X	X
16				X	X	X	X	X
17				X	X	X	X	X
18				X	X	X	X	X
19				X	X	X	X	X
20				X	X	X	X	X
21				X	X	X	X	X
22				X	X	X	X	X

CTD Conductivity (Salinity), Temperature, Depth
DO Dissolved Oxygen
PS Particle Size
SVR Sediment Volatile Residue
PCBs Polychlorinated Biphenyls
RA Resin Acids
TM Trace Metals

TABLE 2: WATER, SEDIMENT AND BIOTA SAMPLING STATIONS, NORTHUMBERLAND CHANNEL SAMPLING SUMMARY, APRIL 26, 1989

STATION	WATER		SEDIMENT					BIOTA
	CTD	DO	PS	SVR	PCBs	RA	TM	TM
1			X	X	X	X	X	
2			X	X	X	X	X	
3			X	X	X	X	X	
4			X	X	X	X	X	
5	X	X	X	X	X	X	X	
6			X	X	X	X	X	
7			X	X	X	X	X	
8			X	X	X	X	X	
9	X	X	X	X	X	X	X	
10			X	X	X	X	X	
11			X	X	X	X	X	
12			X	X	X	X	X	
13			X	X	X	X	X	
14			X	X	X	X	X	
15			X	X	X	X	X	
16			X	X	X	X	X	
17			X	X	X	X	X	
18			X	X	X	X	X	
19			X	X	X	X	X	
20	X	X	X	X	X	X	X	
21			X	X	X	X	X	
22			X	X	X	X	X	
TRAWL NC-9								X
TRAWL NC-15								X

CTD Conductivity, Temperature, Depth
DO Dissolved Oxygen
PS Particle Size
SVR Sediment Volatile Residue
PCBs Polychlorinated Biphenyls
RA Resin Acids
TM Trace Metals

TABLE 3: SUMMARY OF ENVIRONMENTAL PROTECTION METHODS FOR WATER, SEDIMENT AND TISSUE ANALYSES

SAMPLE TYPE	METHODS	REFERENCE
WATER		
Salinity, temperature, depth	CTD	Goyette & MacLeod, 1984
Dissolved Oxygen	Azide Modification of Winkler	Swingle & Davidson, 1979 Gameson & Robertson, 1955
Colour	Spectrophotometer	Swingle & Davidson, 1979
SEDIMENT		
Particle Size	Freeze drying, Screening	Swingle & Davidson, 1979 Griffiths, 1967
Trace Metals	ICAP Optical Emission Spectrophotometer	Swingle & Davidson, 1979 Millward & Kluckner, 1989
Volatile Residue	Wt. loss on ignition 550°C for 1 hr.	Swingle & Davidson, 1979
TISSUE		
Trace Metals	ICAP Optical Emission Spectrophotometer	Swingle & Davidson, 1979

3.0 RESULTS

3.1 Water Quality

Salinity, temperature, dissolved oxygen (DO), % oxygen saturation and colour data from Harmac water quality stations are summarized in Tables 4 to 8. Water quality profiles from Northumberland Channel did not suggest any appreciable impact from the pulpmill effluent. Dissolved oxygen values during both surveys were from 5.2 to 10.7 mg/L in the top 50 m. Colour was detected near the outfall but values were low. In 1986, no dissolved oxygen depression was apparent: minimum 6.8 mg/L near bottom at both the outfall and reference site.

TABLE 4: WATER QUALITY, HARMAC STATION NC-5, OUTFALL, APRIL 10, 1986

DEPTH (m)	TEMPERATURE (°C)	SALINITY (ppt)	DISSOLVED OXYGEN (mg/L)	% OXYGEN SATURATION	COLOUR
0	9.2	26.8	11.7	123.67	6
2	9.1	26.9	11.8	124.51	7
5	9.1	27.2	11.8	124.76	7
10	9.0	27.4	11.5	121.46	5
15	8.9	27.8	11.1	117.27	6
20	8.9	29.9	11.2	119.99	7
50	7.7	29.9	7.8	81.20	<5
100	7.8	30.4	6.9	72.25	5

TABLE 5: **WATER QUALITY, HARMAC STATION NC-9, REFERENCE, APRIL 10, 1986**

DEPTH (m)	TEMPERATURE (°C)	SALINITY (ppt)	DISSOLVED OXYGEN (mg/L)	% OXYGEN SATURATION	COLOUR
0	9.2	27.3	12.0	127.25	7
2	9.1	27.3	11.9	125.90	7
5	9.1	27.3	11.9	125.90	8
10	9.1	27.3	11.7	123.78	8
15	9.0	27.4	11.6	122.52	7
20	8.7	28.3	10.5	110.77	7
50	7.7	29.8	8.0	83.23	<5
100	7.8	30.4	6.9	72.25	5
120	7.8	30.6	6.8	71.30	5

TABLE 6: **WATER QUALITY, HARMAC STATION NC-5, OUTFALL, APRIL 26, 1989**

DEPTH (m)	TEMPERATURE (°C)	SALINITY (ppt)	DISSOLVED OXYGEN (mg/L)	% OXYGEN SATURATION
0	10.05	29.17	8.6	94.17
2	9.98	29.18	7.8	85.28
5	9.43	29.50	7.3	78.97
10	8.93	29.91	5.6	60.04
20	8.40	30.32	5.4	57.33
50	8.08	30.65	4.6	48.57
100	7.92	30.95	4.5	47.43

TABLE 7: WATER QUALITY, HARMAC STATION NC-9, REFERENCE, APRIL 26, 1989

DEPTH (m)	TEMPERATURE (°C)	SALINITY (ppt)	DISSOLVED OXYGEN (mg/L)	% OXYGEN SATURATION
0	10.30	28.30	8.5	93.07
2	7.50	28.58	8.0	82.15
5	7.49	29.37	7.4	76.37
10	7.54	29.66	7.2	74.54
20	7.47	30.34	5.4	56.07
50	7.50	30.64	4.9	51.02
100	7.54	30.91	4.8	50.11
120	7.79	31.04	4.9	51.51

TABLE 8: WATER QUALITY, HARMAC STATION NC-20, REFERENCE, APRIL 26, 1989

DEPTH (m)	TEMPERATURE (°C)	SALINITY (ppt)	DISSOLVED OXYGEN (mg/L)	% OXYGEN SATURATION
0	10.02	29.16	8.2	89.73
2	9.80	29.16	7.8	84.92
5	9.44	29.30	7.5	81.05
10	8.53	30.22	5.9	62.79
20	8.29	30.41	5.1	54.04
45	8.10	30.65	5.0	52.82

3.2 Sediment Quality

Results of sediment sampling in Northumberland Channel are summarized in Tables 9 and 10. Median particle size and trace metal analysis are recorded for the 22 stations sampled on April 10, 1986 and April 27, 1989 around the Harmac mill. Most stations contained fine sediments ranging from very fine sand to silt and clay.

In 1986, no sediment samples had detectable levels of PCB and resin acids. All PCB levels were <0.02 μg/g and resin acids were <0.05 μg/g. Trace metal analysis indicated elevated levels of copper and zinc localized in the vicinity of the outfall; mercury levels in 1986 were high.

3.3 Biota Quality

Tables 9 and 10 list the results of trace metal analyses on several different species of marine fish and invertebrates collected in Northumberland Channel trawls at Harmac Trawl Stations NC-9 and NC-15.

TABLE 9: SEDIMENT QUALITY, HARMAC, NORTHUMBERLAND CHANNEL, APRIL 10, 1986

HARMAC STATION NUMBER	DEPTH (m)	MEDIAN PARTICLE SIZE	SVR (%)	Al (%)	Hg (µg/g)	Cd (µg/g)	Cr (µg/g)	Cu (µg/g)	Fe (%)	Ni (µg/g)	Pb (µg/g)	Zn (µg/g)
1	100	v. fine sand	18.6	2.4	0.298	ND	90.2	57.8	2.59	29	27	131
2	100	v. fine sand	21.2	2.1	0.224	0.8	72.0	48.2	2.35	24	22	105
3	112	v. fine sand	18.3	2.4	0.352	0.6	57.2	41.5	2.71	24	30	97
4	126	v. fine sand	17.8	2.4	0.305	ND	65.8	47.2	2.61	26	28	109
5	112	v. fine sand	20.1	2.2	0.257	ND	87.7	58.6	2.67	29	32	127
6	113	v. fine sand	11.3	1.9	0.172	ND	54.0	39.7	2.26	21	15	85
7	103	v. fine sand	16.9	2.5	0.228	0.5	79.7	55.2	2.70	27	27	124
8	128	v. fine sand	15.2	2.1	0.251	ND	72.1	59.5	2.48	25	14	118
9	130	coarse sand	6.5	1.8	0.199	ND	62.5	35.0	2.36	32	19	88
10	115	v. fine sand	14.9	2.3	0.207	ND	70.7	51.8	2.53	25	20	117
11	76	fine sand	6.71	1.5	0.161	ND	62.3	28.6	2.16	17	17	78

TABLE 9: SEDIMENT QUALITY, HARMAC, NORTHUMBERLAND CHANNEL, APRIL 10, 1986

HARMAC STATION NUMBER	DEPTH (m)	MEDIAN PARTICLE SIZE	SVR (%)	Al (%)	Hg (μg/g)	Cd (μg/g)	Cr (μg/g)	Cu (μg/g)	Fe (%)	Ni (μg/g)	Pb (μg/g)	Zn (μg/g)
12	111	v. fine sand	19.4	2.3	0.427	ND	81.4	58.4	2.58	28	22	129
13	140	v. fine sand	15.1	2.2	0.267	0.5	56.7	43.4	2.67	24	25	94
14	126	v. fine sand	13.2	2.3	0.223	0.3	54.7	42.9	2.79	24	24	94
15	110	fine sand	19.3	2.5	0.265	ND	81.5	54.6	2.67	27	30	119
16	64	v. fine sand	11.1	1.6	0.136	0.4	55.9	28.8	1.97	19	18	86
17	88	silt & clay	15.8	2.3	0.219	ND	70.7	46.3	2.42	24	27	111
18	68	v. fine sand	13.7	1.8	0.149	ND	61.5	33.0	2.04	21	24	97
19	82	fine sand	6.0	1.4	0.102	0.3	54.1	26.0	1.93	17	13	76
20	66	fine sand	3.4	1.1	0.064	0.3	38.1	15.7	1.57	13	10	67
21	130	v. fine sand	16.4	2.3	0.323	ND	73.8	54.9	2.59	28	25	121
22	120	v. fine sand	15.4	2.4	0.226	0.7	66.3	49.2	2.83	25	24	108

TABLE 10: SEDIMENT QUALITY, HARMAC, NORTHUMBERLAND CHANNEL, APRIL 26, 1989

STATION NUMBER	DEPTH (m)	MEDIAN PARTICLE SIZE	SVR (%)	Al (%)	Cd (μg/g)	Cr (μg/g)	Cu (μg/g)	Fe (%)	Ni (μg/g)	Pb (μg/g)	Zn (μg/g)
1	127	v.fine sand	16.8	2.14	0.84	56.7	62.7	2.90	32	12.8	115
2	111	v.fine sand	18.1	2.12	0.64	57.8	67.4	2.84	33	14.8	113
3	117	N.D.	15.5	2.28	0.66	54.2	64.5	2.91	33	13.8	133
4	124	silt & clay	17.7	2.27	0.53	54.7	63.5	2.90	34	14.5	129
5	109	v.fine sand	19.2	2.21	0.68	60.4	68.1	2.86	34	15.4	122
6	97	silt & clay	15.5	1.69	0.19	30.7	64.0	2.25	22	5.4	83.4
7	110	silt & clay	17.2	2.20	0.62	54.2	59.9	2.83	32	14.8	116
8	126	silt & clay	15.1	2.21	0.23	49.6	45.5	2.95	33	13.8	113
9	130	fine sand	10.8	1.85	0.09	48.2	58.8	2.76	27	11.6	89.7
10	112	silt & clay	15.5	2.09	0.42	48.4	58.8	2.81	32	13.5	104
11	75	fine sand	65.1	1.34	0.25	40.4	27.6	2.22	19	6.6	59.3

TABLE 10: SEDIMENT QUALITY, HARMAC, NORTHUMBERLAND CHANNEL, APRIL 26, 1989

STATION NUMBER	DEPTH (m)	MEDIAN PARTICLE SIZE	SVR (%)	Al (%)	Cd (µg/g)	Cr (µg/g)	Cu (µg/g)	Fe (%)	Ni (µg/g)	Pb (µg/g)	Zn (µg/g)
12	116	silt & clay	15.4	2.24	0.56	55.9	67.5	2.93	32	15.2	118
13	125	ND	71.7	2.09	0.34	44.6	58.8	2.85	30	11.7	97.9
14	109	silt & clay	13.0	2.09	0.34	44.0	52.4	2.64	30	11.8	96
15	116	silt & clay	18.8	2.36	0.67	64.1	67.1	3.04	35	15.3	117
16	73	fine sand	71.6	1.20	0.27	35.4	25.8	1.90	17	7.2	53.6
17	86	silt & clay	98.9	1.65	0.48	37.3	37.9	2.09	22	8.9	73.8
18	58	fine sand	73.9	1.24	0.24	34.5	25.9	1.81	17	0.2	55.2
19	72	fine sand	63.6	1.14	0.20	35.9	25.0	2.14	17	5.5	53.9
20	54	fine sand	42.6	0.95	0.19	29.3	18.5	1.76	10	4.1	47.4
21	119	silt & clay	19.5	2.32	0.55	53.2	61.7	3.00	31	13.0	109
22	122	silt & clay	14.0	2.03	0.23	46.4	58.3	2.97	30	12.9	113

TABLE 11: TRACE METALS IN BIOTA, HARMAC, TRAWL NC-9, REFERENCE AREA, APRIL 26, 1989

	ROCK FISH	ROCK FISH	ROCK FISH	ROCK FISH	DOVER SOLE	HAKE	HAKE	HAKE	RAT FISH	RAT FISH	RAT FISH	RAT FISH
	28.8 cm 365 g	30.5 cm 441 g	28.5 cm 324 g	25.5 cm 329 g	33 cm 309 g	58 cm 1087 g	30.8 cm 170.4 g	42.8 cm 405 g	59 cm 1239 g	59 cm 1018 g	47 cm 490 g	50 cm 515 g
Cd	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Pb	0.37	0.27	0.20	0.31	0.28	0.17	0.16	0.23	0.27	0.21	0.17	0.16
Hg	2.040	2.680	1.870	1.340	0.260	0.812	0.140	0.380	1.800	2.690	0.601	1.380
Al	7	<4	<4	<4	4	6	5	<4	<4	<4	29	5
As	12	29	8	17	263	<4	<4	<4	77	19	50	29
Ba	0.20	<0.08	<0.08	<0.08	0.10	<0.08	0.20	0.20	<0.08	0.09	0.10	<0.08
Be	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Co	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Cr	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Cu	1.2	<.4	0.7	0.6	0.5	1.1	2.8	1.7	0.9	0.9	0.9	0.9
Fe	19.5	9.1	11.7	6.5	10.5	15.1	23.7	17.5	7.8	14.3	42.4	17.2
Mg	1350	1380	1360	1390	1240	1410	1580	1510	1120	1050	1090	1070
Mn	1.9	0.7	0.9	0.7	1.9	1.6	2.4	3.3	1	0.9	2.8	1.3
Ni	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sb	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Sn	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Sr	16.2	1.9	3.9	6.3	2.9	4.5	11.0	9.1	0.9	1.4	1.8	1.4
Ti	0.5	0.6	0.8	0.4	0.7	0.8	0.6	0.7	0.6	0.6	2.2	0.7
V	<0.8	<0.8	<0.8	<0.8	2.0	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8
Zn	28.3	14.4	15.1	15.3	18.8	21.9	24.0	18.8	15.0	16.4	20.5	14.4
% mois.	79.4	77.7	78.8	79.6	78.7	83.4	81.4	78.8	71.5	58.7	81.8	76.7

TABLE 12: TRACE METALS IN BIOTA, HARMAC, TRAWL NC-15, OUTFALL, APRIL 26, 1989

	HAKE	HAKE	HAKE	HAKE	HAKE	HAKE	CRAB	CRAB	ENG SOLE	ENG SOLE	ENG SOLE	PRAWN TAIL
	52 cm 887 g	50 cm 784 g	45 cm 493 g	28 cm 153 g	30 cm 164 g	25 cm 113 g	154 cm 434 g	145 cm 346 g	32 cm 260 g	29 cm 175 g	30 cm 220 g	composite (2)
Cd	0.020	<0.008	0.010	<0.008	<0.008	<0.008	0.050	0.030	<0.008	<0.008	<0.008	0.050
Pb	0.14	0.06	0.25	0.08	<0.04	0.08	0.30	0.46	0.06	0.20	<0.04	0.20
Hg	0.696	0.917	0.590	0.068	0.040	0.060	0.620	0.550	0.380	0.140	0.220	0.075
Al	4	<4	<4	9	5	<4	25	43	<4	<4	5	6
As	<4	<4	<4	8	<4	<4	36	36	35	32	107	17
Ba	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	1.20	0.95	<0.08	<0.08	<0.08	0.30
Be	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Co	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	0.5	0.5	<0.4	<0.4	<0.4	<0.4
Cr	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Cu	1.5	1.2	1.2	1.2	0.8	0.9	52.2	37.5	0.9	0.5	0.6	24.2
Fe	14.8	14.6	13.1	14.1	17.5	11.6	80.5	86.0	11.6	12.9	10.9	16.0
Mg	1290	1250	1390	1500	1540	1500	1740	1710	1500	1120	1210	1610
Mn	1.5	0.5	0.9	0.9	1.0	0.6	3.3	3.2	0.6	0.2	0.2	1.5
Ni	<2	<2	<2	<2	<2	<2	2	12	<2	<2	<2	<2
Sb	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Sn	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Sr	5.2	1.3	2.8	2.2	2.2	0.6	175	106	0.6	1.5	1.4	57.9
Ti	0.6	0.6	0.5	1.0	0.6	0.5	0.5	2.4	0.5	0.5	0.6	0.3
V	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8
Zn	4.2	12.4	12.4	13.8	11.8	11.1	240	216	11.1	13.3	12.9	50.8
% mois.	78.4	81.1	79.3	77.7	81.0	78.2	67.6	79.9	78.2	78.6	74.6	65.9

TABLE 12: TRACE METALS IN BIOTA, HARMAC, TRAWL NC-15, OUTFALL, APRIL 26, 1989

	DOVER SOLE	DOVER SOLE	DOVER SOLE	REX SOLE	REX SOLE	REX SOLE	PINK SHRIMP	PINK SHRIMP	PINK SHRIMP	SMOOTH SHRIMP	SIDEST. SHRIMP	SIDEST. SHRIMP
	36 cm 378 g	35 cm 330 g	32 cm 274 g	31 cm 231 g	36 cm 262 g	composite (5)	composite (10)	composite (10)	composite (10)	composite (10)	composite (10)	composite (10)
Cd	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	0.040	0.050	0.040	0.030	0.020	0.009
Pb	0.12	0.04	<0.04	0.66	<0.04	0.07	0.13	0.14	0.10	<0.04	0.19	0.17
Hg	0.12	0.22	0.53	0.13	0.10	0.11	0.26	0.31	0.26	0.20	0.19	0.22
Al	<4	13	<4	<4	10	4	144	86	50	60	30	13
As	48	101	21	21	31	32	24	30	20	22	25	23
Ba	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	0.60	0.50	0.30	0.50	0.20	<0.08
Be	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Co	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	0.9	<0.4	<0.4	<0.4	<0.4	<0.4
Cr	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Cu	0.6	1.1	<.4	<0.4	0.9	0.5	19.7	19.1	22.3	24.0	16.0	23.6
Fe	0.2	21	8.2	8.2	12.4	9.4	208	108	73.4	72.5	36.8	22.5
Mg	1080	1140	1160	1090	1220	1110	1470	1530	1500	1640	1420	1310
Mn	0.6	0.9	0.4	0.5	0.7	0.8	2.8	2.3	1.8	2.1	1.4	1.0
Ni	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Sb	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Sn	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Sr	2.4	4.7	1.3	1.1	1.2	7.1	13.6	22.8	25.4	42.3	13.4	14.1
Ti	0.4	1.1	0.6	0.6	1.0	0.5	9.0	5.6	3.2	3.7	1.0	0.5
V	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8
Zn	13.3	14.3	12.0	9.2	16.4	10.9	43.7	47.4	46.1	48.0	43.3	42.8
% mois.	67.2	80.7	78.4	76.3	79.9	72.7	75.7	77.1	76.9	76.6	64.4	71.2

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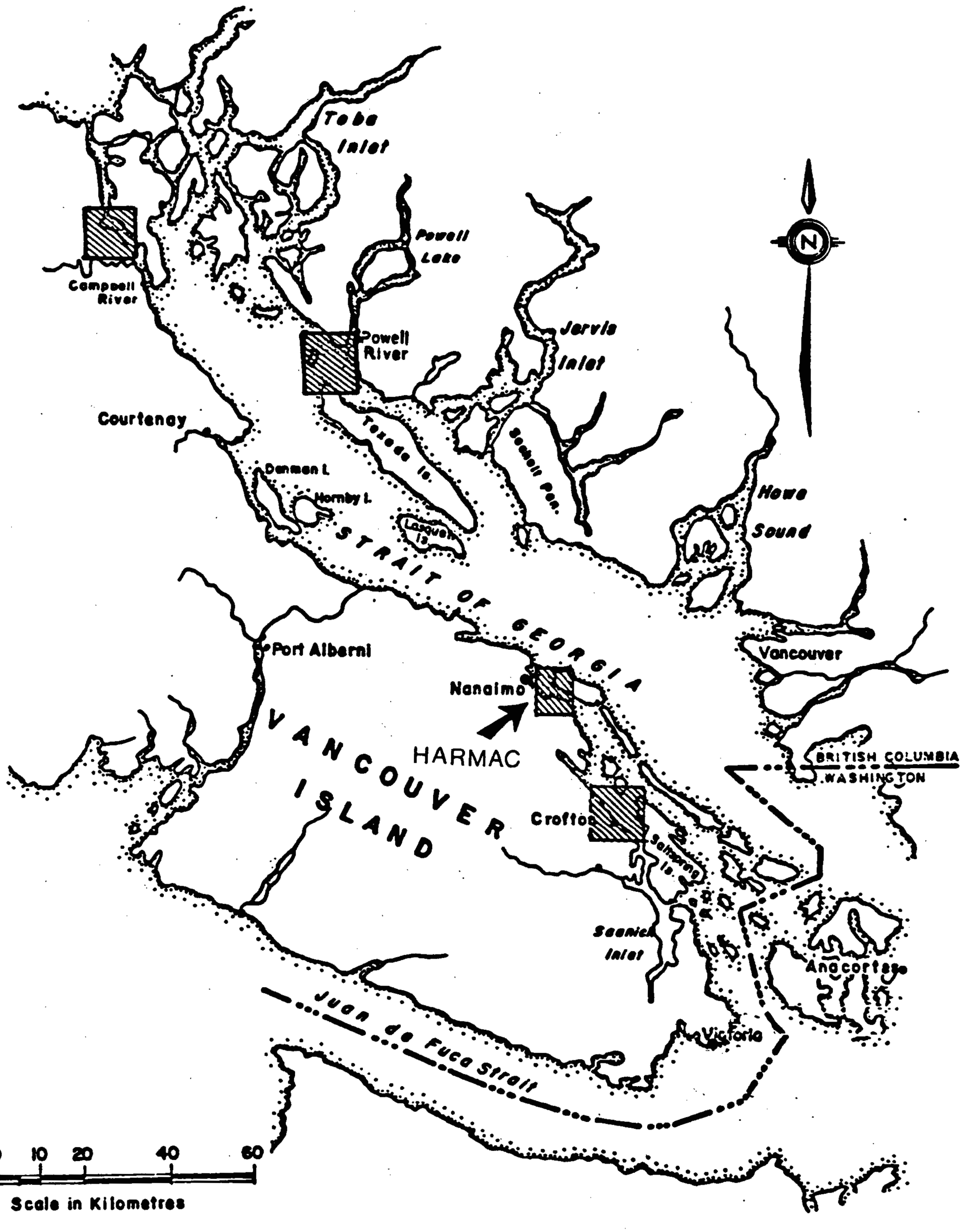

FIGURE 1: LOCATION MAP - HARMAC

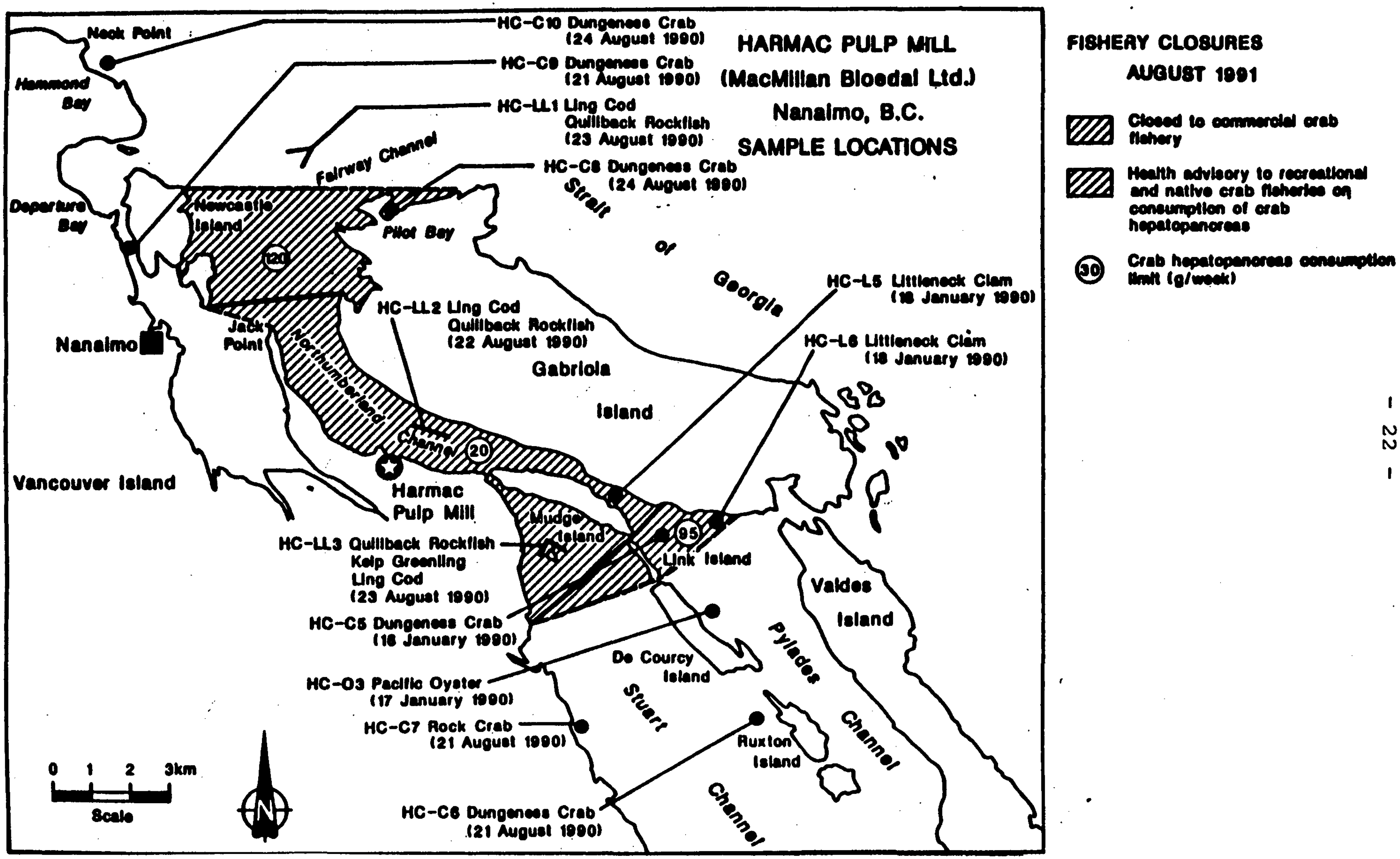

FIGURE 2: HARMAC FISHERIES CLOSURES, 1991

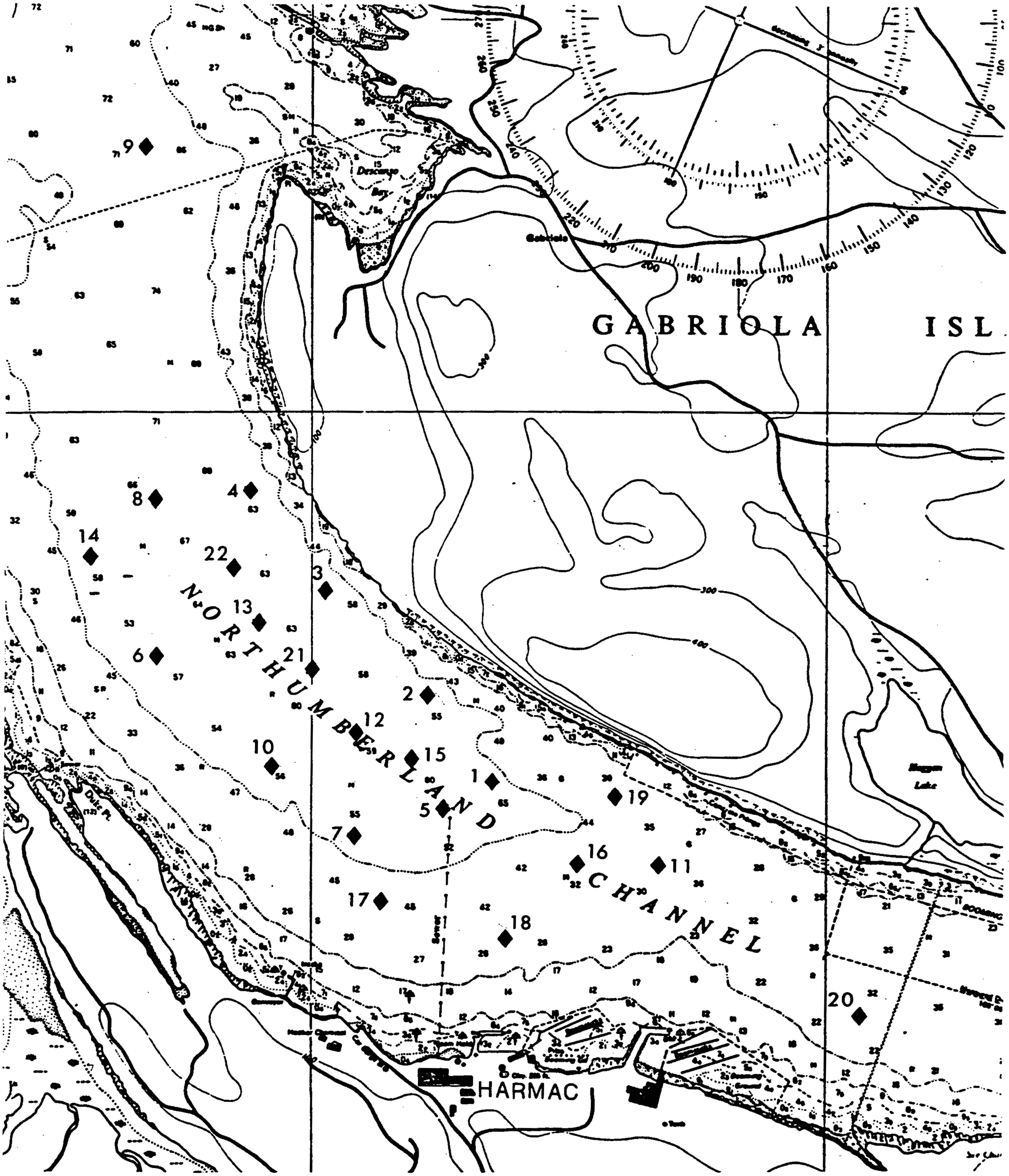

FIGURE 3: HARMAC SAMPLE SITES

APPENDICES

APPENDIX I: PACIFIC REGION PULP AND PAPER INDUSTRY EFFLUENT SUMMARY

Company: MacMillan Bloedel Limited
Mill: Harmac
Location: Nanaimo

Year: 1987

	===FLOW===		=PRODUCTION=		===TSS (FED)===			==TSS (PROV)==		===BOD5 (FED)===			==BOD5 (PROV)==		==TOXICITY (PROV)==	
	Aver. (m3/d)	# of days	Av. (ADt/d)	# of days	Av. (kg/ADt)	# of Tests	% Comp.	Av. (tonne/d)	# of Tests	Av. (kg/ADt)	# of Tests	% Comp.	Av. (tonne/d)	# of Tests	# of Tests	% Comp.
Yearly Values	237,526	342	1,042	342	8.67	339	80%	9.03	339	21.12	44	100%	21.68	44	4	100%

EFFLUENT QUALITY REQUIREMENTS

	FLOW (m3/d)	TSS	BOD5	TOXICITY (%v/v)
Federal (kg/ADt)	---	10.30	47.90	96LC20 = 65
Provincial (tonne/d)	265,000	12.00	27.00	96LC50 = 30

APPENDIX II: HARMAC SAMPLING STATION LOCATIONS, NORTHUMBERLAND CHANNEL, APRIL 10, 1986

STATION	LATITUDE	LONGITUDE
1	49°9.30′N	123°51.31′W
2	49°9.27′N	123°51.48′W
3	49°9.56′N	123°51.95′W
4	49°9.77′N	123°52.19′W
5	49°8.99′N	123°51.55′W
6	49°9.40′N	123°52.60′W
7	49°8.94′N	123°51.80′W
8	49°9.72′N	123°52.45′W
9	49°10.66′N	123°52.66′W
10	49°9.12′N	123°52.14′W
11	49°8.82′N	123°50.65′W
12	49°9.15′N	123°51.80′W
13	49°9.48′N	123°52.19′W
14	49°9.60′N	123°52.70′W
15	49°9.11′N	123°52.58′W
16	49°8.90′N	123°51.01′W
17	49°8.75′N	123°51.72′W
18	49°8.64′N	123°51.21′W
19	49°8.99′N	123°50.86′W
20	49°8.48′N	123°49.80′W
21	49°9.40′N	123°52.03′W
22	49°9.61′N	123°52.27′W

APPENDIX III: HARMAC SAMPLING STATION LOCATIONS, NORTHUMBERLAND CHANNEL, APRIL 26, 1989

HYDROCASTS AND CTD			
STATION	DEPTH (m)	LATITUDE	LONGITUDE
NC-5	105	49°9.00'N	123°51.49'W
NC-9	130	49°10.65'N	123°52.67'W
NC-20	62	49. 8.46'N	123°49.88'W
TRAWLS			
STATION	DEPTH (m)	LATITUDE	LONGITUDE
NC-9: START FINISH	130	49°10.98'N 49°10.65'N	123°53.10'W 123°52.68'W
NC-15: START FINISH	115	49°9.39'N 49°9.00'N	123°51.95'W 123°51.40'W
SEDIMENT STATIONS			
STATION	DEPTH (m)	LATITUDE	LONGITUDE
1	127	49°9.30'N	123°51.31'W
2	111	49°9.27'N	123°51.48'W
3	117	49°9.56'N	123°51.95'W
4	124	49°9.77'N	123°52.19'W
5	109	49°8.99'N	123°51.55'W
6	97	49°9.40'N	123°52.60'W
7	110	49°8.94'N	123°51.80'W
8	126	49°9.72'N	123°52.45'W
9	130	49°10.64'N	123°52.65'W
10	112	49°9.12'N	123°52.14'W
11	75	49°8.84'N	123°50.65'W
12	116	49°9.15'N	123°51.80'W
13	125	49°9.48'N	123°52.19'W
14	109	49°9.60'N	123°52.70'W
15	116	49°9.11'N	123°52.58'W
16	73	49°8.79'N	123°51.12'W
17	86	49°8.75'N	123°51.72'W
18	58	49°6.80'N	123°51.26'W
19	72	49°9.05'N	123°50.83'W
20	54	49°8.47'N	123°49.88'W
21	119	49°9.40'N	123°52.03'W
22	122	49°9.61'N	123°52.27'W