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PULP MILL ENVIRONMENTAL IMPACT ASSESSMENT
MACMILLAN BLOEDEL LTD.
ALBERNI PULP AND PAPER DIVISION

Regional Program Report: 79-11

by

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ABSTRACT

In October 1976, the Environmental Protection Service initiated a program to assess the environmental impact of pulp and paper mills in British Columbia. With the cooperation of various other government agencies and the pulp and paper industry, EPS compiled relevant resource data and receiving environment monitoring information. After reviewing and evaluating the existing information, the environmental quality of each area was assessed and the need for additional monitoring studies determined. This report represents the environmental impact assessment for the MacMillan Bloedel pulp mill in Port Alberni, B.C.

RÉSUMÉ

Au mois d'Octobre 1976, le Service de la protection de l'environnement a entrepris de'évaluer les répercussions mésologiques des fabriques de pâtes et papiers de la Colombie-Britannique. Aidé de l'industrie et de divers autres organismes gouvernementaux, il a réuni une documentation concernant les ressources ainsi que certains résultats de contrôles portant sur l'environnement affecté. Après avoir étudié ces données, le Service a évalué la qualité environnementale de chacune des régions et déterminé quelles seraient les études supplémentaires qui resteraient a réaliser. Ce rapport fait connaître les résultats ayant trait à l'évaluation des contrecoups imputables â la fabrique de pâte de la MacMillan Bloedel de Port Alberni, Colombie-Britannique.

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SUMMARY AND CONCLUSIONS

The pollution abatement facilities currently in operation at the MacMillan Bloedel Alberni pulp mill (Alpulp) enable the mill to meet Federal and Provincial (Level B) effluent standards for suspended solids, BOD, and toxicity. Despite the considerable improvements in effluent quality resulting from Alpulp's pollution abatement program certain persistent environmental effects have been identified. These effects are significant due to the sensitivity of the estuarine environment into which the mill discharges. Located near the mouth of a major salmon producing river, the mill's effluent is discharged into surface waters of an area utilized as a rearing ground for juvenile salmonids and a migration route for adult salmon heading up the river system to spawn.

Adverse effects of mill effluent on water quality have been identified as a reduction in phytoplankton productivity in the waters of Alberni Harbour and a depression in dissolved oxygen concentrations in sub-halocline waters of the harbour. Depressed oxygen concentrations restrict salmonid utilization of the estuary by reducing the vertical "living space". Since primary production and salmonid rearing occurs mainly in the surface waters any increase in effluent volume or pollutant loading could further restrict these activities.

1 INTRODUCTION

MacMillan Bloedel's Alberni Pulp and Paper Division pulp mill is situated on the north-east side of the head of Alberni Inlet, Vancouver Island, British Columbia (Figure 1). The mill was built at the mouth of the Somass River and has an aeration lagoon for biological waste treatment located on the river estuary (Figure 2).

Alberni Inlet is a true fjord, typical of the B.C. and Alaska coasts. From the head to Junction Passage, the sides of the inlet are precipitous and rocky. The channel has two openings to the sea, an inner opening at Junction Passage with a depth of about 114 metres, and an outer opening through Trevor Channel into Barkely Sound, with a threshold depth of about 36 metres. The channel also consists of two basins. A large outer basin extends from the mouth of Barkley Sound to Sproat Narrows about 17 km from the head of the inlet. The inner basin, which is much smaller, extends from the shallow sill (37 m) at the Narrows to the head of the inlet (Figure 3).

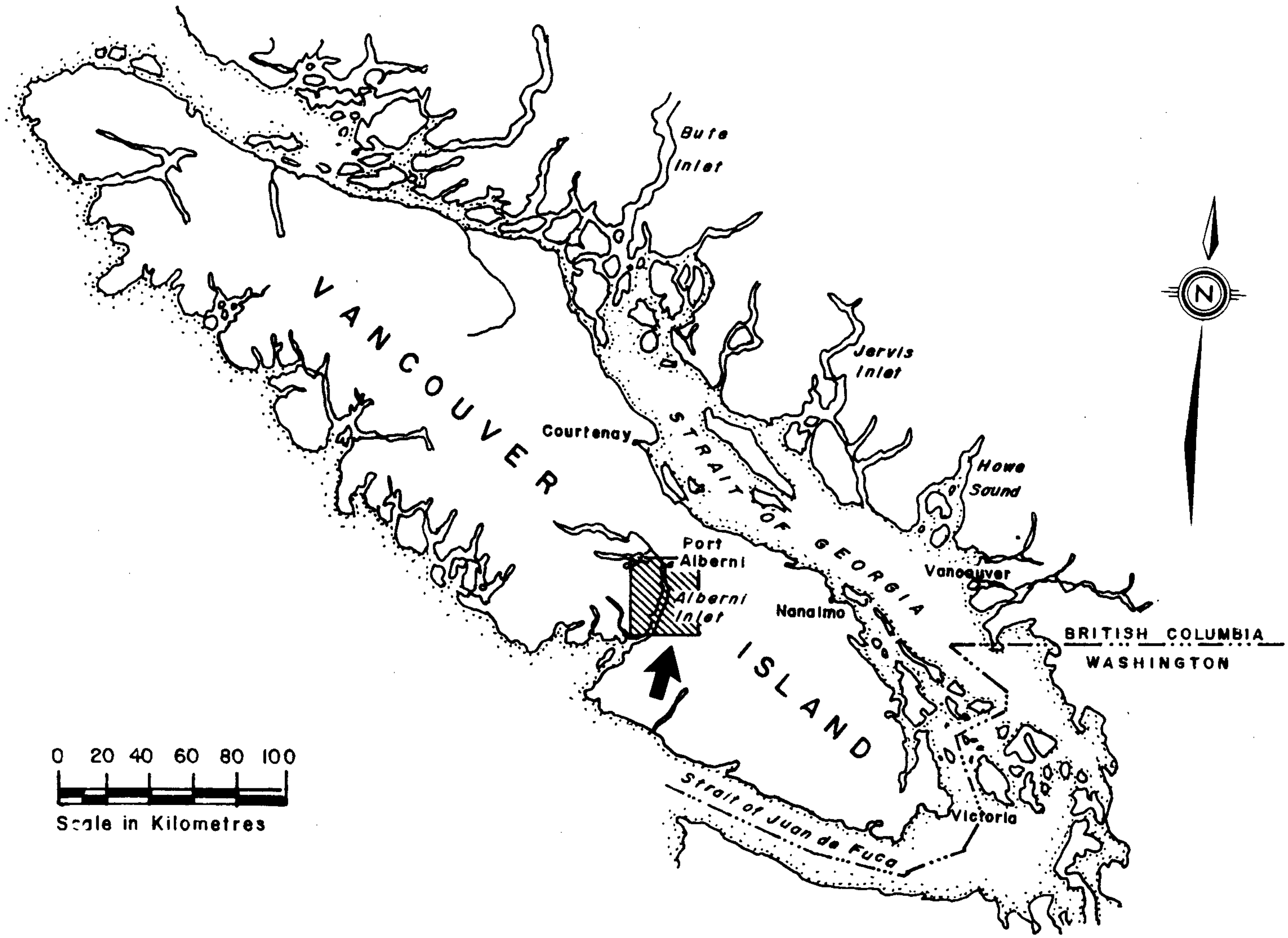

FIGURE I ALBERNI INLET - LOCATION MAP

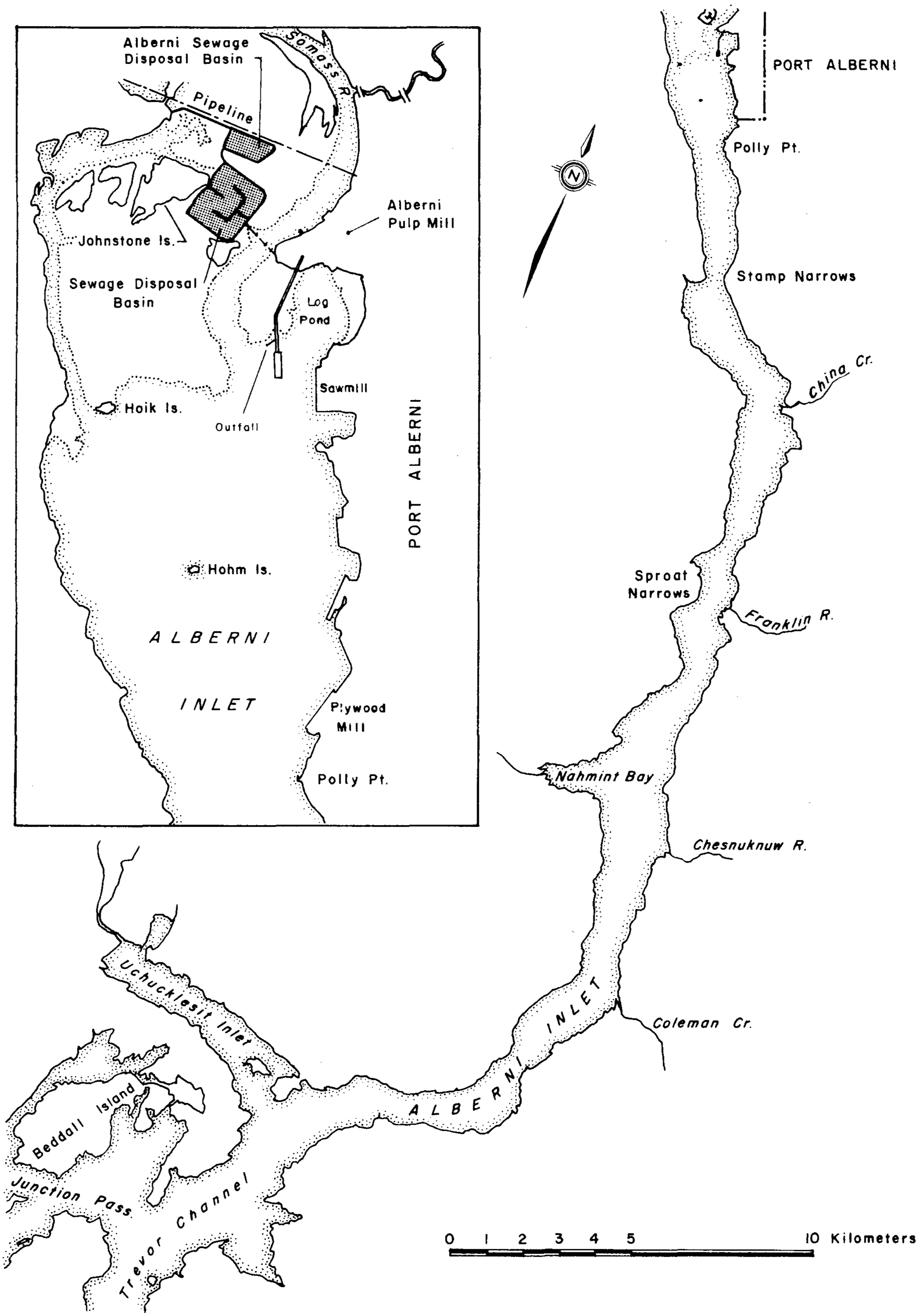

FIGURE 2 ALBERNI INLET

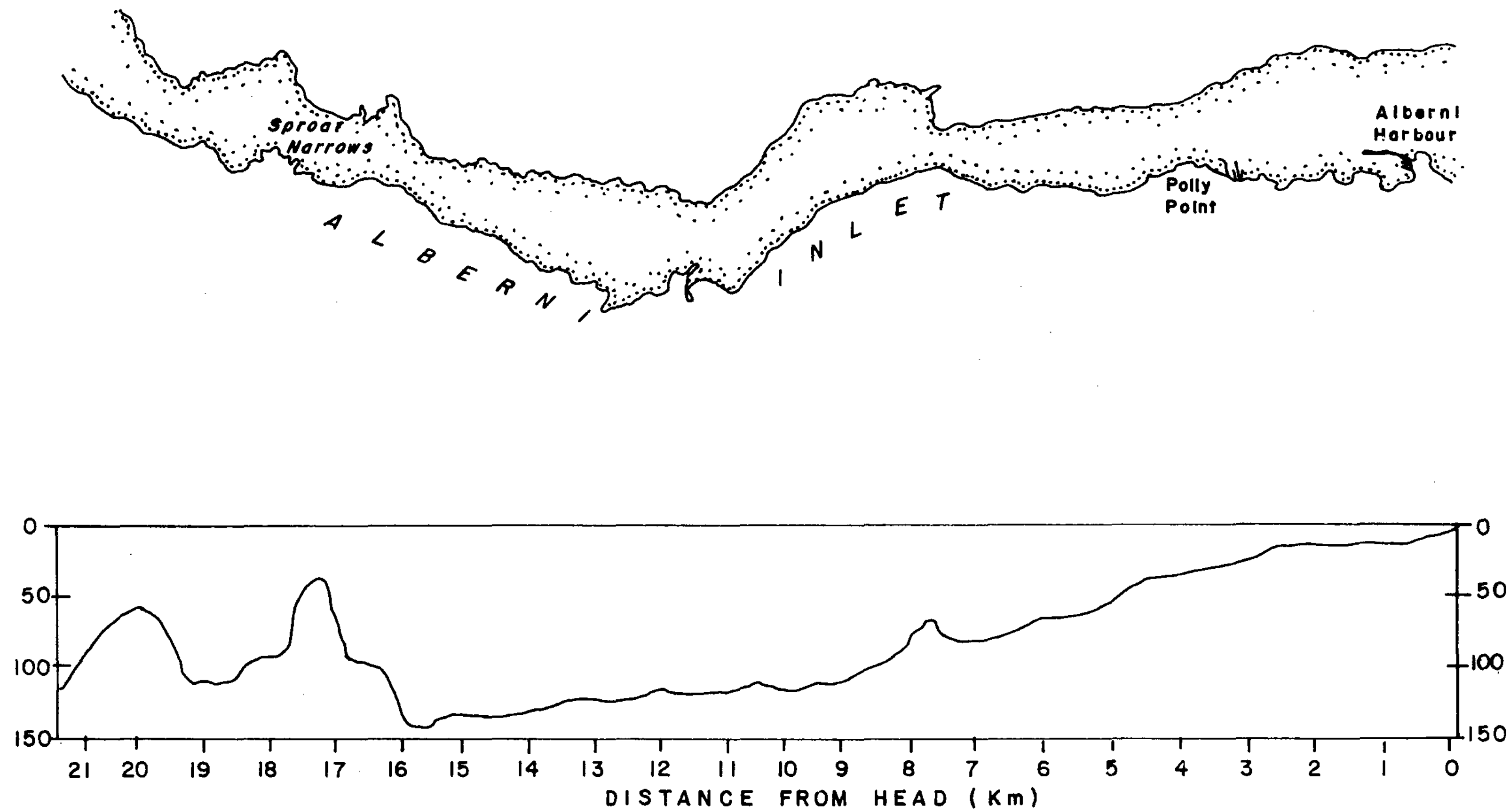

FIGURE 3 PLAN VIEW AND DEPTH PROFILE OF THE INNER BASIN OF ALBERNI INLET (Extracted from Dobrocky Seatech Ltd. 1978a)

2 MILL OPERATIONS

The Alberni pulp mill (Alpulp) began operation in 1947, with a production capacity of 200 air dried tons of pulp per day (ADT/D). The mill was subsequently enlarged, by stages, to become an integrated producer of market unbleached kraft pulp, kraft liner, and newsprint. The daily production approximates 200 ADT/D of market unbleached pulp, 260 tons per day (TPD) of kraft linerboard, and 1000 TPD newsprint for a total production of about 1500 TPD.

The pulping process utilizes about 1300 oven dried tons per day (ODT/D) of wood chips and groundwood blocks with the remainder of the wood requirements being furnished by the adjacent MacMillan Bloedel sawmills and plywood plant. By 1971, in addition to some in-plant treatment, the mill had major external effluent treatment facilities in operation. These consisted of clarifiers for the hydraulic debarker and for groundwood and newsprint effluents and a 12 hectare aeration lagoon for biological waste treatment of groundwood, newsprint, woodmill, and kraft bleach caustic extraction effluents. After receiving primary (clarifier) and secondary (aeration lagoon) treatment these effluents are combined with the untreated kraft mill effluent and discharged via a common surface outfall into the estuary of the Somass River. The discharge point is located along the access ramp to the mills large loading dock (Figure 2). The discharge flow is about 155×10^6 litres per day of process water which is supplied by Sproat Lake located 10 km west of the mill.

3 EFFLUENT QUALITY

3.1 Government Regulations

MacMillan Bloedel is currently authorized to discharge up to 46 x 10^6 Imperial gallons per day (approximately 175 x 10^6 litres) of effluent from their pulp and paper complex at Alberni. Authorization is contained in a permit (PE-266) issued to the company by the Pollution Control Branch (PCB) of the B.C. Provincial Government on April 8, 1969. The permit, which has amendments dated December 6, 1973 and January 22, 1974, stipulates effluent standards shown in Table 1. The mill is presently meeting the effluent standards for biological oxygen demand (BOD), suspended solids (SS), and toxicity as outlined in the Federal Government Pulp and Paper Regulations (Table 2).

3.2 Effluent Characteristics

3.2.1 BOD and SS. Tables 3 and 4 show levels of BOD and SS in Alpulp's combined mill effluent for 1976 and 1977 respectively. The measurements are taken routinely by mill personnel and forwarded to the Federal Department of Fisheries and the Environment, Environmental Protection Service (EPS) and to the Provincial PCB.

3.2.2 Toxicity. In December 1975, an effluent monitoring program was initiated by Fisheries and Environment Canada to determine the range of toxicity associated with the mill effluent. The company participated by sending composite effluent samples on a regular basis to the EPS bioassay laboratory in Vancouver for toxicity testing. The results of these tests are shown in Table 5. Included with the table are the Federal and Provincial bioassay requirements.

3.2.3 Pollution Abatement Program. The Alberni Pulp and Paper mill has had an extensive pollution abatement program in effect for several years. Major in-plant projects have included the conversion of groundwood brightening agents from zinc hydrosulphite to sodium hydrosulphite which largely eliminated zinc from the effluent thereby significantly reducing

TABLE 1 PCB EFFLUENT REQUIREMENTS FOR MacMILLAN BLOEDEL, ALBERNI PULP AND PAPER DIVISION

Parameter	Requirement
Total Suspended Solids	< 20 lbs/ADT
BOD_5	< 35 lbs/ADT
Settleable Solids	< 2.5 ml/l
Floatable Solids	negligible
pH range	6.5-8.5 within 15 ft of outfall
Temperature	< 95°F
Residual Cl_2	< 0.1 ppm
Sulphides	< 1.0 ppm
Mercaptans	< 2.0 ppm
Toxicity	> TLm_{96} - 25%

TABLE 2 FEDERAL EFFLUENT REGULATIONS FOR MacMILLAN BLOEDEL, ALBERNI PULP AND PAPER DIVISION

Process	Allowable Discharge SS	Allowable Discharge BOD_5
Hydraulic Debarking	5 lb/ODT of wood	
Kraft Pulping	7 lb/ADT	64 lb/ADT
Kraft Bleaching	6 lb/ADT	27 lb/ADT
Kraft Sheet Formation (Specialty Single Product)	2 lb/ADT	
Papermaking (Kraft Liner)	6 lb/product ton	
Mechanical Pulping	13 lb/ADT	
Mechanical Pulp Brightening	2 lb/ADT	
Integrated Single Product (Kraft)	3 lb/product ton	
Papermaking (Newsprint) (Groundwood)	5 lb/product ton	

Toxicity - 80% survival at 65% combined effluent concentration (v/v) over 96 hours.

TABLE 3 1976 EFFLUENT QUALITY RESULTS FOR MacMILLAN BLOEDEL, ALBERNI PULP AND PAPER DIVISION

Month	Flow $x10^6$ IG/D	BOD_5 LB/ADT	BOD_5 Tons/Day	Suspended Solids LB/ADT	Suspended Solids Tons/Day
January	39.1	23.6	18.00	18.5	14.11
February	41.0	23.3	19.02	20.4	16.62
March	40.2	18.5	14.41	17.2	13.34
1st Quarter	40.1	21.8	17.14	18.7	14.69
April	38.1	20.4	16.29	15.8	12.61
May	38.3	19.4	16.10	16.7	13.89
June	40.8	21.3	16.68	21.0	16.46
2nd Quarter	39.1	20.4	16.36	17.8	14.32
July	39.1	16.6	12.96	15.7	12.25
August	36.5	18.2	14.15	18.1	14.01
September	37.1	15.8	12.08	14.7	11.25
3rd Quarter	37.6	16.9	13.06	16.2	12.50
October	38.4	14.9	11.38	16.6	12.64
November	38.8	17.7	13.81	14.2	11.08
December	39.3	18.7	13.88	14.2	10.57
4th Quarter	38.8	17.1	13.02	15.0	11.43
Yearly Average	38.9	19.1	14.90	16.9	13.24

TABLE 4 1977 EFFLUENT QUALITY RESULTS FOR MacMILLAN BLOEDEL, ALBERNI PULP AND PAPER DIVISION

Month	Flow	BOD_5		Suspended Solids	
	$x10^6$ IG/D	LB/ADT	Tons/Day	LB/ADT	Tons/Day
January	38.0	19.2	14.81	17.3	13.35
February	39.6	14.6	12.10	13.0	10.78
March	40.4	17.3	14.16	12.4	10.14
1st Quarter	39.3	17.0	13.69	14.2	11.42
April	36.6	13.4	9.42	13.6	9.53
May	39.7	16.1	13.09	14.3	11.63
June	37.8	13.6	10.36	16.6	12.63
2nd Quarter	38.0	14.4	10.96	14.8	11.26
July	40.3	15.1	10.98	15.1	10.98
August	41.3	14.0	9.88	19.6	13.84
September	40.2	14.5	10.52	17.3	12.55
3rd Quarter	40.6	14.5	10.46	17.3	12.46
October	40.3	12.0	9.80	12.1	9.89
November	38.2	16.0	11.84	15.5	11.47
December	39.5	22.6	16.06	26.2	18.64
4th Quarter	39.3	16.9	12.57	17.9	13.33
Yearly Average	39.3	15.7	11.92	16.1	12.12

TABLE 5 BIOASSAY RESULTS FOR MacMILLAN BLOEDEL, ALBERNI PULP AND PAPER DIVISION

Sample Date	% Survival Over 96 Hours, Static Testing Concentration (% v/v) of Combined Mill Effluent			Sample pH
	100	90	65	
December 17, 1975	100	-	100	6.9
January 20, 1976	100	100	100	7.2
February 17, 1976	100	100	100	7.0
March 16, 1976	100	100	100	7.0
April 27, 1976	40	60	100	6.6
July 20, 1976	100	100	100	6.7
November 15, 1976	100	100	100	7.4
January 24, 1977	15	85	-	6.9
March 21, 1977	20	60	-	6.7
April 18, 1977	100	100	-	6.7
August 2, 1977	100	100	-	6.7
September 20, 1977	80	100	-	6.7
October 18, 1977	100	100	-	6.7
November 22, 1977	0	10	-	7.6
January 20, 1977	0	0	-	7.4
January 24, 1978	100	100	-	-
February 21, 1978	20	40	-	7.0
March 21, 1978	100	100	100	6.9

Federal Bioassay Requirement - 80% survival in 65% (V/V) effluent concentration over 96 hours, continuous flow testing.

PCB Bioassay Requirement - 50% survival in 25% (V/V) effluent concentration over 96 hours, static testing.

its toxicity; and improved spill collection facilities which have minimized abnormal discharges which occur periodically due to operation upsets.

External treatment facilities include a large clarifier, 60 meters in diameter, which receives groundwood and newsprint effluents and removes approximately 25 TPD of suspended solids, and a 12 hectare aeration lagoon which provides biological treatment for mill effluent and reduces BOD by about 25 TPD.

The pollution abatement facilities installed over the years have enabled the Alberni pulp mill to meet both Federal standards and Provincial Level B requirements for suspended solids, BOD and toxicity. In an effort to further upgrade its effluent discharge characteristics, Alpulp has expanded its pollution abatement program and anticipates compliance with the more stringent Provincial Level A requirements by 1980 for all parameters with the possible exception of BOD. Provincial Level A and B requirements are discussed in a report on Pollution Control Objectives for the Forest Products Industry of B.C. (1974).

One of the pollution abatement projects conducted at Alpulp was the incorporation of a modified bleach sequence designated HEH which, it was hoped, would significantly reduce effluent color and BOD. Color presents both an aesthetic impact and the biological effect of reducing photosynthetic activity in the receiving environment. A conventional bleach sequence, designated CEH, is a major source of pollution from kraft mill bleach plants by contributing approximately 50% of the BOD and 90% of the color to the total mill outfall. In addition, the effluent is toxic to fish with a 96 hour LC_{50} value of approximately 25% (v/v) effluent concentration. This information is contained in a paper by Moy et al (1974), which outlines a trial study of a modified bleaching process carried out at the Alberni bleach plant over a 24 hour perod. The program was supported by the Cooperative Pollution Abatement Research Program (CPAR) of the Department of Fisheries and Environment.

The results of the short term trial study were very favorable. Monitored effluent properties indicated a 95% reduction in color, a 20% reduction in BOD and a non-toxic effluent. However, more extensive trials at the Alpulp mill between 1974 and 1977 yielded only a 40% reduction in color accompanied by an undesirable reduction in newsprint strength. As a result, the HEH bleach sequence was discontinued in January 1977 and the conventional CEH resumed.

The current pollution abatement program at Alpulp concentrates on in-plant control and recirculation projects such as the collection and treatment of paper machine effluents. A modified toxicity testing program has been instigated with the objective of monitoring the continued state of compliance with the established toxicity criteria.

4 RECEIVING ENVIRONMENT

4.1 Oceanography

The physical oceanography of Alberni Inlet, and particularly its surface waters has been well documented. In 1939 and 1941, the Pacific Oceanographic Group (1957) undertook a series of physical and chemical studies of the area. These formed the basis of an important study by Tully (1949) in which the nature of the water circulation was described with a view to predicting the effects of pollution from a proposed pulp mill. As a result of this study, the original kraft mill was sited at the mouth of the Somass River. The mill sewer was designed to discharge the effluent at the surface so that it would mix with the upper layer of this typical estuarine circulation system while maintaining dissolved oxygen conditions in the inlet at a "satisfactory level" for salmonids.

For the present purposes, circulation in the upper portion of Alberni Inlet can be stylized as a two-dimensional system of three layers. An upper zone originates with the Somass River entering at the head. Vertically, this layer is nearly homogenous because of wind mixing. Horizontally, its salinity increases seaward because of the incorporation of seawater from the lower zone over which it flows. These two layers are separated by a transition zone, the halocline.

In the halocline, the salinity rapidly increases with depth due to entrainment and mixing of water from the lower zone with that of the upper zone. Since any combination of the two waters is less dense than the sea water alone, it "floats", and net transport is upward. Thus the upper zone is continuously added to, and because of the resulting hydrostatic head, it persistently flows seaward. It follows that volume transport is a positive function of river discharge.

Losses to the lower zone are replenished from seaward. The net transport of the lower zone is toward the inlet head and therefore the water of this zone has no further contact with the atmosphere once it is covered by less-dense water. Because of density conditions, materials in solution in the upper zone generally do not enter the lower zone except where the density gradient is sufficiently diminished to allow deep mixing between the two waters. This usually occurs only at the seaward end of Alberni Inlet and in the ocean.

Bell (1976) reports that renewal of the deep water of both the inner and outer basins seems to occur annually beginning in April and May when winds on the coast are predominantly northwest. These winds cause a south-going current divergent from the west coast of Vancouver Island thereby drawing deeper, denser replacement waters upward. Some of this water, which is well oxygenated, will flow up Alberni Inlet and displace bottom waters depleted of oxygen.

Since the initial work by Tully, numerous other surveys have been conducted to assess the effects of effluent from the mill on the water quality (particularly dissolved oxygen) of the inlet. Included are those by Pickard (1963), Waldichuk (1945, 1956a, 1956b, 1960, 1962), Waldichuk et al (1968, 1969), Parker et al (1972a, 1972b, 1972c, 1973a, 1973b, 1973c, 1973d), Parker and Sibert (1973a, 1973b), Sibert and Parker (1972), and MacMillan Bloedel monitoring surveys (Ketcham, 1976, 1977; Young, 1978), plus unpublished information collected by the former Department of Fisheries and the Environmental Protection Service. All revealed basically the same result, namely that the dissolved oxygen content of the water column at the head of the inlet was often less than the desired lower limit of 5 mg/l. This is an unfortunate conclusion considering that in 1970, the mill installed 3.5 million dollars worth of primary and secondary treatment facilities for its effluent in an effort to improve dissolved oxygen conditions in the inlet.

In 1976, during the continuous modified bleaching sequence from July to December, slight improvements in surface water dissolved oxygen levels were recorded at a station near Hohm Island. This was despite the low Somass River flows occurring from September to December. During this period the concentrations below the halocline remained well below 5 mg/l (Sullivan, 1978a).

There seem to be several factors contributing to the low dissolved oxygen levels at the head of the inlet. Parker et al (1972a), Sibert and Parker (1972), and Parker and Sibert (1973b) compared the various known sinks and sources of oxygen in the estuary in a one-dimensional numerical model. This study established that the BOD of the mill effluent alone could not fully account for the apparent loss of dissolved oxygen in the upper mixed layer. Parker and Sibert (1972b) demonstrated that the stain imparted by the effluent to the receiving water also played an important role in the observed dissolved oxygen reductions by adversely affecting primary productivity in the estuary. They hypothesized that in the upper zone and in the halocline, the productivity reduction might result from a variety or combination of causes, among which were direct metabolic poisoning by dissolved chemicals, nutrient (NO_3) limitations, and shading from solar energy by the stain and particulate matter.

Under the halocline, autotrophs (phytoplankton) were not directly subjected to the effluent, and nitrate appeared to be in excess at all times, at least during mill operating conditions. The observed reduction of dissolved oxygen in that stratum as a response to pulp mill effluent in the upper zones was concluded to be either due to an increase in respiration or a decline in photosynthetic activity because of shading. Later, Sibert and Parker (1972) using the numerical model, showed that the large amount of humic stain introduced into the surface waters of the estuary could effectively eliminate primary productivity. As a result the dissolved oxygen remaining in the water column could be rapidly consumed by bacteria and other organisms through respiratory processes.

4.2 Impact Studies

4.2.1 Phytoplankton Productivity. Parker and Sibert (1972b) showed that humic stain in effluent discharged from the Alberni pulp mill was responsible for an oxygen deficiency in Alberni Harbour by blocking subhalocline photosynthesis. In a later study (Parker and Sibert, 1976) these authors found that phytoplankters present below the halocline in the Somass River estuary were incapable of responding to increased light intensity over short terms (less than 5 hours). This was attributed to a physiological state (dormancy) resulting from a light-deprived history of the population. After three days exposure to increased light intensity however, a substantial phytoplankton bloom occurred. The authors concluded that the removal of humic stain from the pulp mill effluent would permit photosynthesis below the halocline and thereby renew oxygen production.

In an attempt to reduce the detrimental effects of humic stain in the effluent, MacMillan Bloedel conducted modified bleaching trials to reduce effluent color. As discussed in Section 3, these trials were of limited success. Under normal mill operations using the CEH bleaching sequence, the zone of pulp mill influence on water quality (as measured by color) extended 22 km down inlet (Ketcham, 1977). During the experimental HEH bleaching sequence, the zone of influence extended 14 km down inlet and color was reduced by about 40% near the head of the inlet. The numerical model presented by Sibert and Parker suggested that primary productivity would not recover to a "normal" rate until the stain content of effluent was reduced by approximately 90%. Another conclusion drawn from the model was that the removal of BOD from mill effluent would have little effect on the dissolved oxygen levels below the halocline since the dissolved fraction of the effluent, which has a high BOD, is contained in the low salinity surface waters and does not penetrate below the halocline as does the larger solids fraction, i.e., fibre.

In surface waters above the halocline, photosynthetic activity may be limited by a reduced standing crop of phytoplankton, shading by the humic stain, or by a nitrate (NO_3) deficiency. Parker _et al_ (1975) explained the NO_3 deficiency by an enhanced heterotrophic population which assimilates this nutrient as a nitrogen source for protein synthesis. Heterotrophic organisms are supported in large numbers in surface waters near the pulp mill by the high organic carbon rich content of the effluent.

Primary productivity studies were conducted by MacMillan Bloedel personnel in 1974 and 1975, utilizing the radioactive carbon (C^{14}) in light-dark bottle technique. Due to technical problems encountered with the procedures the company discontinued productivity and phytoplankton standing crop measurements in subsequent monitoring surveys. Conclusions regarding photosynthetic activity during the 1976 and 1977 surveys (Ketcham, 1977; Young, 1978) are based on chlorophyll "a" measurements alone and therefore should be viewed qualitatively. It was concluded from these studies that phytoplankton productivity was restricted to surface waters in Alberni Harbour with "productive levels" extending into the halocline zone to approximately 3 metres depth. The extrapolation of productivity and standing crop estimates from chlorophyll "a" measurements may be misleading because of the transient nature of plankton, the susceptibility of chlorophyll "a" to rapid breakdown in unfavorable conditions, and the possibility of phytoplankters becoming metabolically inactive when they encountered pulp mill effluent and reduced light conditions and therefore remaining quiescent until light conditions improve (Stockner et al, 1975).

The Environmental Protection Service conducted productivity studies (C^{14}) including standing crop and chlorophyll "a" determinations in Alberni Inlet from 1974 to 1976 (Sullivan, 1978b). The low rates of phytoplankton productivity in Alberni Harbour were attributed to high light attenuation and/or nutrient deficiency. Chlorophyll "a" levels during the studies did not reflect either production rates or phytoplankton standing crop and contrary to the findings of Parker et al, 1975, the populations estimated at the head of Alberni Inlet were similar to those at the control sites. Nitrates were frequently not detectable in the upper zone of the water column both in the harbour and at the control sites and therefore may indicate a growth limiting nutrient deficiency in the inlet. As expected, there was greater light attenuation in the harbour than at control sites.

4.2.2 Intertidal Studies. MacMillan Bloedel personnel have conducted intertidal studies in Alberni Inlet since 1974 as part of their receiving environment monitoring program. The studies involved the placement of artificial substrates (bricks and/or plexiglass plates) in the intertidal zone at stations extending from Alberni Harbour (Hohm Island) to several kilometers down the inlet. After a period of 2 to 3 months the artificial substrates were retrieved and the attached biota identified and enumerated. Invertebrate species commonly found to colonize the substrates included Chironomid larvae, isopods (Gnorimosphaeroma oregonensis), amphipods (Corophium sp. and others) and marine mites (Halacaridae). The fresh water algae Rivularia sp. proliferated at stations near the head of the inlet.

Ketcham (1977) discussed intertidal growth during three periods of variable water quality in Alberni Harbour, i.e., mill shut-down, mill operating with conventional CEH bleaching, and mill operating with modified HEH bleaching. The results indicated that during CEH bleaching the zone of pulp mill influence, as measured by intertidal growth, extended to between 14 and 22 km down inlet where an increase in species diversity and the inclusion of strictly marine species occurred. During HEH bleaching and shut-down periods, intertidal growth appeared to be related more to the fresh water influence of the Somass River than to pulp mill effluent. At these times the total speciation was approximately equal at all stations, however, the dominant organisms varied with the horizontal salinity gradient along the inlet. A comparison of brick versus plexiglass substrates revealed a much greater degree of colonization on the bricks. The dominant brick species were present on the plexiglass plates in very reduced numbers.

4.2.3 Salmonid Studies. Kask and Parker (1972) conducted general fishing surveys in the upper 5 km of Alberni Inlet in 1970 and 1971, concentrating on the distribution of juvenile chinook salmon and their feeding habits. Stomach analyses, together with the catch data, suggested that the juveniles, while in the estuary, exploited food resources generated both in the upper mixed brackish water layer and in the underlying saline layer. It was not possible to determine whether the juveniles penetrated the halocline or whether the food organisms were acquired from within the halocline.

Birtwell's (1977) report on gill net catches and experimental preference studies suggested that chinook salmon rearing in the estuary were predominantly utilizing the upper water layers above the halocline. The absence of juveniles below the halocline was attributed to the low oxygen levels at depths greater than 4 to 5 metres. This oxygen deficiency has been related to inhibition of photosynthetic activity, as discussed previously, and also to the presence of large deposits of decomposing pulp fibre which cover the estuary bottom.

Birtwell determined from benthic invertebrate studies and analysis of chinook stomach contents, that differing habitats within the estuary nearshore area were occupied equally despite the heavy industrialization on the east side of the harbour. Rearing chinook salmonids did show differences in diet related to the availability of food organisms at each sampling site. Oligochaetes and insects provided the main food source on the eastern, more affected side of the harbour and amphipods were the predominant food item selected on the west side of the harbour.

Fourteen day in situ bioassays with juvenile chinook salmon did not shown any relationship between mortality and distance from the pulp mill (Birtwell, 1977). These results substantiate toxicity testing data (Section 3.2.2) which indicated relatively less toxic effluent than encountered at other pulp mills on the B.C. coast. The 100% mortality of test fish held in cages below the halocline at stations near the pulp mill was attributed to oxygen deficiency. The author concluded that the effect of mill effluent was to reduce the vertical "living space" for salmon and also their food supply.

4.2.4 Benthic Studies. The forest products complex at the head of Alberni Inlet comprises chemical and mechanical pulp mills, a sawmill and plywood mill, together with associated log handling and storage facilities. Consequently, the inlet receives considerable quantities of sawdust, wood chips, bark and fibre. Deposits of the wastes are routinely removed from the head of the inlet by dredging operations and dumped in a designated area just to the north of Stamp Narrows (Figure 4). Historically dredgeate had been dumped off Polly Point in Alberni Inlet and for a period was used as landfill on Johnstone Island (Figure 2 inset).

In 1968, the Federal Department of Fisheries carried out studies of benthic fibre deposits in the head of the inlet (Watkins, 1968). Ekman grab samples from various stations indicated that the Somass River flow restricted westward movement and deposition of fibre and that most of the fibre originating at Alpulp was deposited by the time the effluent stream had travelled one kilometer seaward from the outfall. Fibre deposits in the log pond were found to be over one metre in depth.

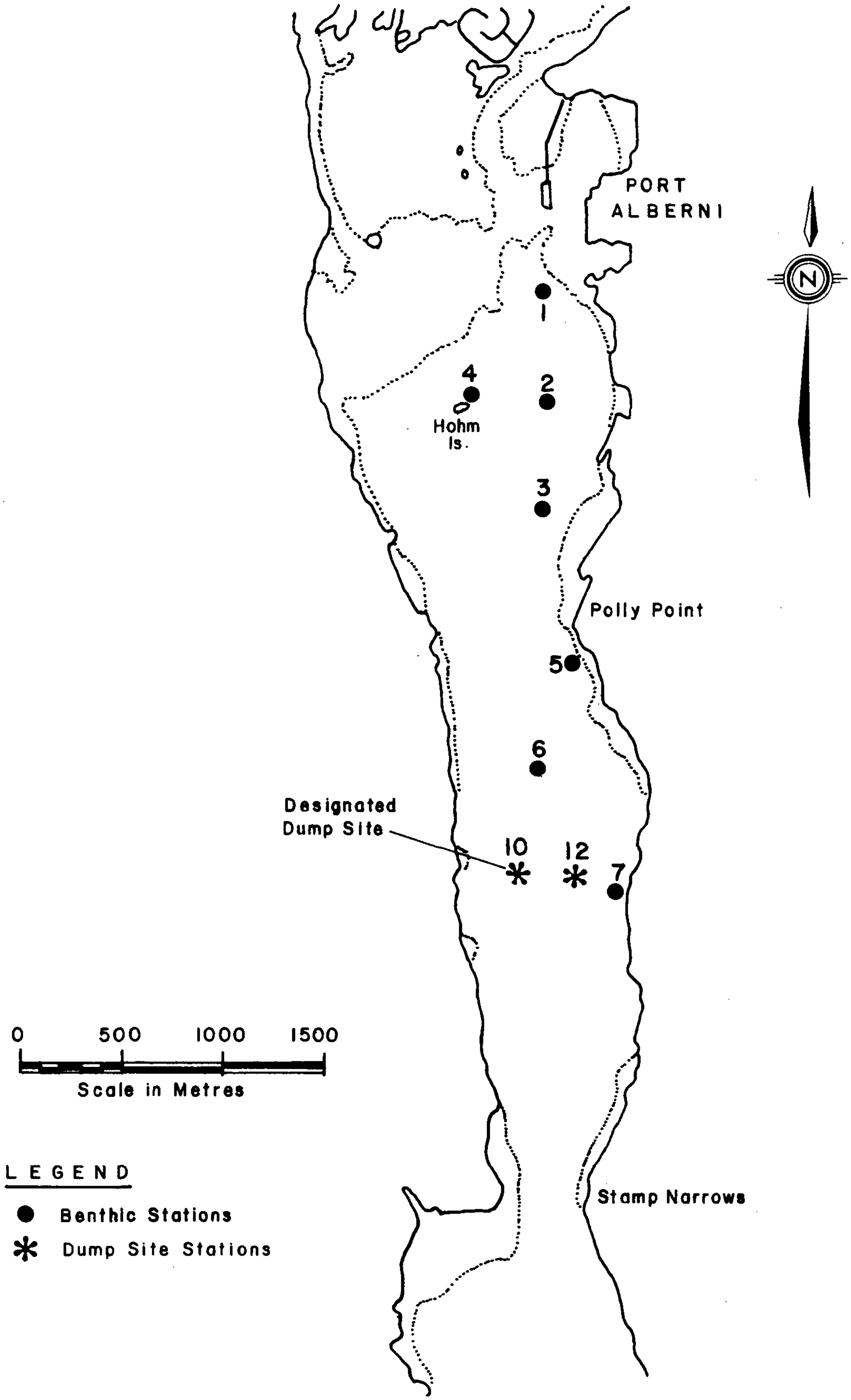

FIGURE 4 MACMILLAN BLOEDEL'S BENTHIC STATIONS (August 1976) AND DESIGNATED OCEAN DUMP SITE

In 1973, the Environmental Protection Service carried out a cursory survey of the nature of the sediment from the head of the inlet to the Nahmint River. Bottom samples obtained using a Ponar grab sampler revealed negligible fibre in all samples with the exception of those taken from the log pond area and directly off the pulp mill outfall. Special attention was given to samples from the Polly Point area where MacMillan Bloedel had deposited their dredge spoil for at least eight years. A considerable number of cedar bark pieces were found but there was no indication of fibre deposits.

Benthic data collected at seven stations (Figure 4) during 1976 by MacMillan Bloedel (Ketcham, 1977) indicated that the area of "highest ecological stress" extended approximately 2 km seaward from the pulp mill outfall to encompass stations 1 and 2. Nematodes and various species of polychaete belonging to the genus Dorvillea were most prolific at these stations. Stations 3, 5, 6 and 7 seaward of station 2 showed increased species diversity with the Dorvillid polychaetes being replaced by the polychaetes Aricidea lopezi and Protodovillea gracilis, the bivalve Axinopsida serricata, the amphipod Eudorella sp. and nematode worms. Station 4, located near Hohm Island to the west of the other benthic stations showed characteristics of both community structures mentioned above and therefore may represent the western edge of the disturbed area.

Visual observations and photographs of bottom conditions in Alberni Inlet have been taken directly from submersibles by EPS (Appendix I for diving observations) and by remote camera by Dobrocky Seatech Ltd. on contract to MacMillan Bloedel Ltd. From the latter study, four basic substrate types were identified in Alberni Harbour and related to nearby industrial activities (Dobrocky Seatech Ltd., 1977). Near the pulp mill outfall the bottom was composed of a dark uncompacted blanket, apparently mostly fibre. In the log pond area fragments of bark, small branches and other wood debris were noted. Near the plywood mill just north of Polly Point the substrate was composed of torn fragments of bark and splintered wood debris but smaller than the material observed in the log pond area. Toward the centre of the inlet a soft mud substrate was encountered with occasional wood debris. This substrate was considered relatively normal.

MacMillan Bloedel have been involved in dredging programs for many years primarily in the vicinity of the log pond pockets, the east and west log storage areas and the deep sea berths. The dredgeate, which recently has ranged from 35 000 cubic metres in 1970-71 to 86 000 cubic metres in 1977-78, has posed a difficult disposal problem. Since the promulgation of the Ocean Dumping Control Act in December 1975, dumping in marine waters has been regulated through a Federal government permit system. Concurrently, the Department of Fisheries and Environment instituted the Regional Ocean Dumping Advisory Committee (RODAC) which, in addition to reviewing permit applications, supports environmental impact studies at existing and proposed dump sites. Recently, Alberni Inlet has been the focal point for such impact studies with respect to both the specific situation at Alberni Inlet and its relationship to dredging and dumping activities elsewhere. The following reports have been prepared for the Federal Department of Fisheries and Environment relative to ocean dumping in Alberni Inlet:

(i) The Effects of Dumping Dredge Spoils Containing Wood Debris on Benthic Communities in Port Alberni, B.C. (Dobrocky Seatech Ltd., 1977).

(ii) A Study of the Characteristics of Alberni Inlet Dredge Spoils Rich in Wood Waste and the Predictive Value of Pre-dump Analyses (Econotech Services Ltd., 1978).

(iii) Study of the Toxicity of Leachates from Dredge Spoils Containing Waste (E.V.S. Consultants Ltd., 1977).

(iv) Alberni Inlet Ocean Dumping Study (Chemex Labs Ltd., 1978).

(v) An Oxygen Budget Study of the Deep Waters in the Inner Basin of Alberni Inlet (Dobrocky Seatech Ltd., 1978a).

(vi) The Role of Wood-borers in the Decomposition of Benthic Wood Debris in Alberni Inlet, British Columbia (Dobrocky Seatech Ltd., 1978b).

Results of the Dobrocky Seatech study on effects of dumping dredge spoils on benthic communities were present at the 41st annual meeting of the American Society of Limnology and Oceanography (Anderson et al, 1978). Twenty stations were sampled in the vicinity of the designated dumpsite and the biota analyzed for species diversity and biomass. By applying cluster analysis to the data, three distinct communities or "biotic provinces" were determined. The less disturbed province, which occupied the centre of the fjord, was characterized by the bivalve Axinopsida serricata and the polychaetes Aricidea lopezi and Paraonis gracilis. A disturbed province found in an area of debris fallout from log handling activities contained the wood boring bivalves Limnoria lignorum and Xylophaga washingtoni, the amphipod Oradarea sp. and the phyllocarid Nebalia pugettensis. The most disturbed province, located directly beneath the dumpsite, was characterized by the polychaete Capitella capitata. Normal infauna at the dumpsite had been obliterated (smothered) and a fringe zone of community alteration extended about 400 metres from the dumpsite. Submersible diving observations obtained by E.P.S. in the dumpsite area are presented in Appendix I (b).

The objective of the study by Econotech Services (1978) was to characterize dredge spoils containing wood debris in Alberni Harbour and relate their characteristics to those of resultant dump site sediments. In addition the liquid or "leachate" associated with the spoils was analyzed to determine its oxygen demand, hydrogen sulphite generation potential and heavy metal content.

Dredge samples were collected by Dobrocky Seatech at stations A to E in Alberni Harbour (Figure 5). The results of the analyses are shown in Table 6. Spoils designated 10 and 12 in the Table were collected at the dump site designated in MacMillan Bloedel's ocean dumping permit (Figure 4). It should be noted that these two stations did not produce the highest surface organic accumulations, i.e., volatile solids, in the study area as might be expected. Stations located to the south of the dump site were higher in volatile solids content. It was suggested that water movements in the channel during dumping may have

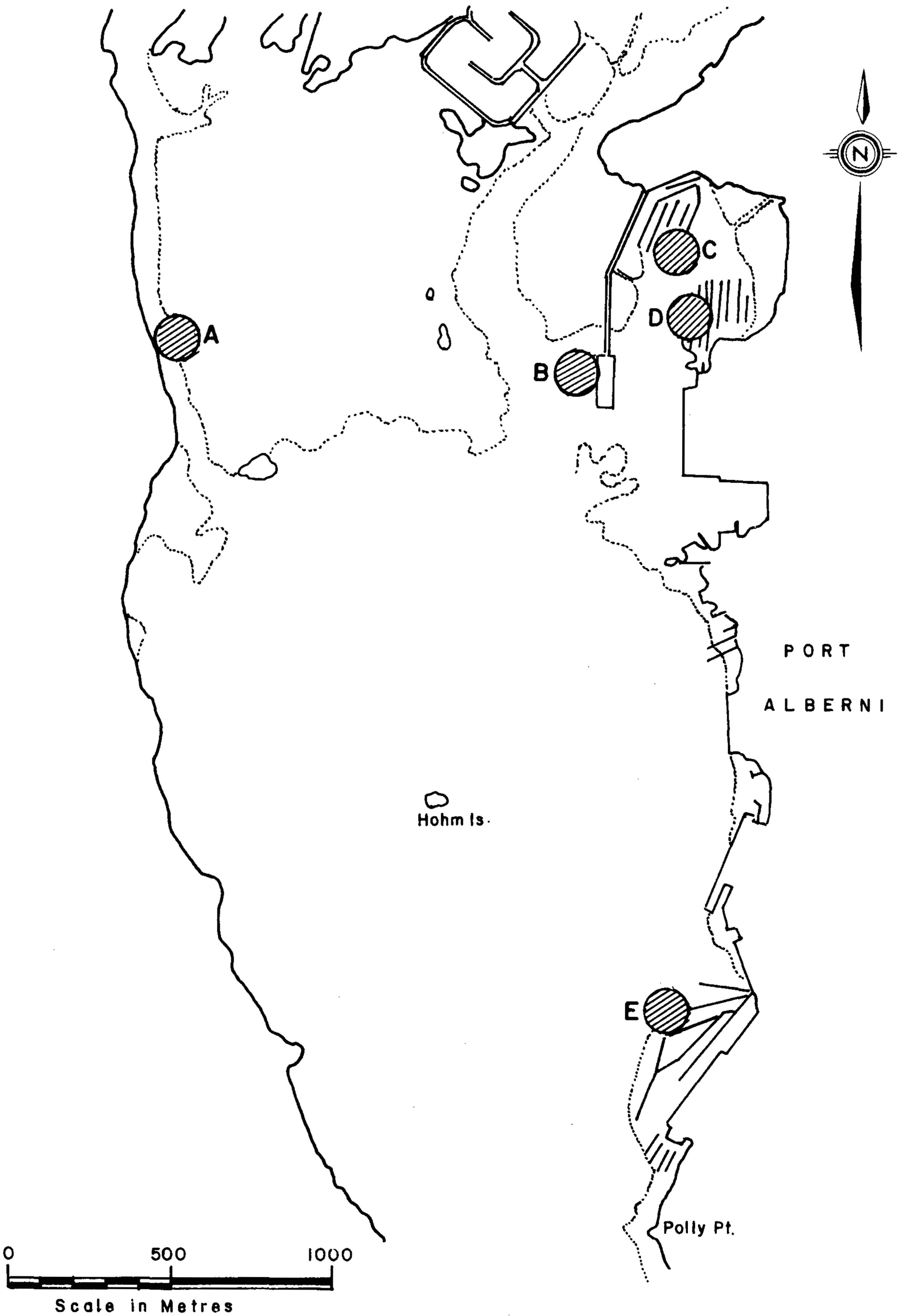

FIGURE 5 BULK DREDGEATE SAMPLING STATIONS
(Dobrocky Seatech 1977)

TABLE 6 ANALYSIS OF DREDGE SPOILS (Extracted from Econotech Services Ltd., 1978)

Spoil Digestion		A	B	C	D	E	10	12
Sawdust (2)	%	2.2	1.9	13.4	2.8	14.2	2.1	0.7
Chips (2)	%	0.5	0	1.7	0.3	2.9	1.6	0.6
Bark (2)	%	7.3	0	13.2	2.7	21.3	0.6	0.3
Fibre Content (1)	%	1	164	66	42	2	10	2
Inorganic Residue (2)	%	90.0	98.1	71.7	94.2	61.6	95.7	98.4
TOC	%	3.5	13.2	15.3	5.4	18.3	5.3	4.8
BOD								
(oxygen uptake) (3)	ppm	955	4185	2965	1990	2865	1250	1730
(no seed)(4)	ppm	508	1101	780	766	895	651	781
Oxygen Uptake from BOD	mg/m2/sec	0.18 x10	0.79x10	0.56x10	0,38x10	0.54x10	0,24x10	0.33x10
Lead	ppm	6.7	8.1	3.3	2.5	3.1	1.9	6.0
Cadmium	ppm	0.38	0.40	0.44	0.34	0.19	0.38	0.60
Copper	ppm	18	32	16	17	21	22	34
Mercury	ppm	0.13	0.96	0.48	0.43	0.18	0.41	0.48
Nickel	ppm	19	30	13	16	18	29	20
Zinc	ppm	59	968	443	309	246	225	153
Lignin (Klason)	%	9.2	21.6	25.5	12.5	31.1	8.4	11.7
Volatile Solids	%	13.5	37.1	49.7	21.2	50.8	13.4	21.1
Volatile Solids	%	14.2	35.5	46.8	21.4	51.5	17.5	20.1
Volatile Solids	%	14.0	35.6	47.4	21.8	51.4	15.5	20.2
Volatile Solids	%	14.0	36.2	48.2	21.1	49.3	12.4	19.0
Volatile Solids	%	13.0	35.7	47.1	22.7	48.2	12.5	19.6
Average Volatile Solids	%	13.7	36.0	47.8	21.6	50.2	14.3	20.0

(1) Relative to a trace in "A" equalling 1.
(2) After wet sieving through 20 mesh screen.
(3) Calculated relative to O.D. solids content.
(4) Calculated relative to wet sample weight.

effected removal of low density organic material to areas further afield or that more recently dumped materials were not high in volatile solids and had covered previous deposits.

The E.V.S. Consultants (1977) toxicity study demonstrated that dredge spoil leachates containing wood waste can be toxic to marine organisms. The test organisms, Crangon communis (shrimp) and Gasterosteus aculeatus (stickleback fish) were both susceptible to leachate in 96 hour laboratory bioassays. However the sticklebacks were found to be 3.3 times more sensitive. Some leachates exerted an oxygen demand sufficient to enhance the toxic action of the leachates. The leachate toxicants were found to be relatively unstable with a decrease in toxic action recorded over time.

5 NATURAL RESOURCES

5.1 Fisheries Resource

A detailed discussion of fisheries resources in Barkley Sound and Alberni Inlet, i.e., Fisheries and Marine Service Statistical Area 23, is contained in a F.M.S. Internal Report (Knapp and Cairns, 1978) and is presented as Appendix II of this report. The following will be a brief summary of this information as related to MacMillan Bloedel's Alpulp mill.

Alberni Inlet is considered one of the major salmon producing areas on the B.C. coast. The Somass River entering the head of the inlet produces 77% of the sockeye, 88% of the chinook, 96% of the coho and 8% of the chum returning to Alberni Inlet waters. Salmon runs remain high despite the effects of pulp mill effluent discharged near the mouth of the river. The high counts can be attributed in large part to salmon enhancement projects being carried out at various locations along the Somass system.

Juvenile salmonids from the Somass system are resident in the estuary for varying time periods. Chum reside in the estuary from early March to June, chinook from about April to late July, sockeye from April to June, and coho from April to July. Juvenile salmon have also been observed in the Alberni Harbour area in late September and October. Adult salmon moving through the estuary may hold at the mouth of the Somass River before migrating upstream. Adult sockeye salmon have a peak migration period between mid-August and September followed by large numbers of chinook and chum. The federal government protects fish stocks in the estuary by generally restricting disruptive activities such as dredging and disposal operations in Alberni Harbour to between October 15 and February 28.

Barkley Sound is one of the major herring rearing grounds on the B.C. coast. Juvenile herring have been found in shallow, sheltered bays, inlets and channels of the system and although observed at the head of Alberni Inlet, spawning does not appear to take place in the inlet itself. Groundfish and shrimp fisheries take place offshore. A limited clam fishery, mainly involving the Japanese littleneck, exists in Barkley Sound, however, the commercial beds are often closed due to paralytic shellfish poisoning.

In 1973, the Environmental Protection Service determined the zinc levels in shellfish in the vicinity of the Alpulp mill in conjunction with its conversion to a new bleaching agent. The only oysters found in the region were in Rainy Bay some 38 km from the mill. Zinc levels in oysters from this area were unexpectedly high (Nelson and Goyette, 1976) however there is known natural mineralization in the area. Clams and mussels collected along Alberni Inlet during the study indicated no zinc contamination.

5.2 Migratory Bird Resource

Migratory bird resources in the Port Alberni area have been summarized by Tretheway (1977, pers. comm.) of the Canadian Wildlife Service (CWS) as follows:

> Forty-six species of birds have been identified at the Somass River estuary which is recognized as an important wintering area and migration staging area for waterfowl. The limited CWS data indicate the most numerous species are trumpeter swans and dabbling ducks, but that the estuary is also used by such waterbird groups as loons, grebes, cormorants, herons, Canada geese, diving ducks, and gulls as well as several species of shorebirds. Most spectacular of the birds that use the area are the relatively large number of trumpeter swans which winter on the opposite side of the estuary from the mill complex. Numbers of swans fluctuate depending on the severity of winter weather elsewhere, but as many as 193 of these huge birds have been counted here. The population of trumpeter swans which winter on Vancouver Island is estimated to range from 1000

to 1200 birds. Of these, nearly 20 percent winter at the Somass River estuary, making it the single most important area for this species on Vancouver Island. The shoreline of Alberni Inlet is known to be used as wintering habitat by diving ducks and other waterbirds but their relative numbers have not been documented.

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APPENDIX I

SUBMERSIBLE DIVING OBSERVATIONS - PISCES IV
(Environmental Protection Service, 1977)

a) Alberni Inlet - March 11, 1977 (Dive 593)

b) Alberni Inlet - March 11, 1977 (Dive 594)

APPENDIX I SUBMERSIBLE DIVING OBSERVATIONS - PISCES IV

a) Alberni Inlet - March 11, 1977

DIVE : 593
LOCATION : Centre Channel Opposite Nahmint Bay
OBSERVERS : R. Hoos and G. Packman
PILOT : F. Chambers
POSITION : Submerge
49°2.75 N
124°40.9 W
DURATION : 2.7 hours
TIME : Submerged at 0947
PHOTOGRAPHY : 70 mm series: (Hasselblad) series - up to 47, 48
16 mm rolls
DEPTH : 300 m

OBSERVATIONS: Descending

- Brown surface water, possibly attributable to the pulp mill complex at Alberni.
- Visibility poor at 20 m.
- A few euphausids at 60 m.
- Euphausid layer ceases by 90 m. Ctenophores, copepods present.
- *Pasiphaea pacifica* concentrated at 175 m. A few very large ctenophores and lantern fish in the background.
- Greater concentration of lantern fish (myctophidae) at 225 m.

Bottom

- Bottom at 270 m. Ratfish, some shrimp. Dropped into a school of hake. The hake stirred up dust. Took about 15 minutes maneuvering to get away from the poor visibility created.

- Sediment very fine and soft. Visibility 10-12 ft. A few smelt, Crangon present.
- Ratfish, hake, dogfish, sole, red snapper, eel pouts seen from time to time.
- 295 m. Visibility approximately 10 ft. Sole and turbot seen. Several "PMT" type prawns noted.
- Position fixed at 300 m - 49°3.0 N, 124°50.7 N.
- Ascend from 300 m to surface.

APPENDIX I SUBMERSIBLE DIVING OBSERVATIONS - PISCES IV

b) Alberni Inlet - March 11, 1977

DIVE : 594

LOCATION : Alberni Inlet near ocean dump site north of Stamp Narrows.

OBSERVERS : R. Hoos and V. Bradshaw

PILOT : F. Chambers

POSITION : Submerge
49°12.1 N
124°49.1 W

DURATION : 2.1 hours

TIME : Submerged at 1421

PHOTOGRAPHY : 70 mm series: 48-71
16 mm rolls

DEPTH : 55 - 60 m

OBSERVATIONS: Descending

- Fresh water interference down to 5 m. Pisces was stopped at 5 m by pycnocline. More ballast required.
- No plankton observed down to 55 m (bottom). Herring and smelt observed on arrival at bottom.

Bottom

- Flat bottom at point of descent. Soft silt, no indication of dumping at this point. Variety of small eelpouts, poachers, small flatfish, smelts and rockfish noted.
- Cables and wires found at one point.
- Direct quote from Chambers -
  "Surface, Pisces, its just teeming with smelt down here; 100's of smelt, over".
- Eelpouts approximately $1/m^2$. Dominant fish outside of schools of smelt, herring.

- Ten minutes into dive and have run into some dumped material covered in fine film of sediment. Bottom is "lumpy" up to 6-8" above bottom. Considerable wood debris incorporated into lumps. Surface only disrupted where debris lands. Fewer shrimp in area of concentrated wood debris.
- Small logs, lots of branches, pieces of wood. Over dumpsite includes the above and some large logs. Eelpouts and a few ratfish only animals noticed in area of concentrated dumping. While stationary, smelt were attracted to lights.
- Ran Pisces into tree trunk with complete root system. Bottom littered with wood debris. Eelpouts, a few smelt and a few small sole present.
- One brittlestar. No sign of shrimp, but only few were present on "unaffected" bottom.
- Near southern extremity of dumpsite, ran into large numbers of large logs, probably constituting fall-out from log booming area above. Bundle straps noted.
- F. Chambers quote, "Dangerous area, there are a great many huge logs standing up and lying down, and I do not like this whatsoever".
- Course changed to get away from this area, and Pisces surfaced at 1617 pm.

APPENDIX II

MacMILLAN BLODEDEL PULP MILL, PORT ALBERNI, B.C.
FISHERIES RESOURCES OF FISHERIES AND MARINE SERVICE
STATISTICAL AREA 23

(Knapp and Cairns, 1978, F.M.S. Internal Report)

The information presented in this document was collated solely for use within the Pacific Region (DFE) "Pulp Mill Review Process": a process designed to determine effluent characteristics, degree of treatment, and effects upon the receiving environment. This task was carried out to identify current and potential conflicts between aquatic resources and effluent disposal in order to priorize pollution abatement efforts.

Opinions expressed in the text reflect the judgement of the authors and contributing personnel.

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DEPARTMENT OF FISHERIES AND THE ENVIRONMENT
FISHERIES AND MARINE SERVICE

MacMillan Bloedel Pulp Mill - Port Alberni
Fisheries Resources of Fisheries and Marine Service Statistical Area 23

by
W. Knapp
I. Cairns

Water Quality Division
Habitat Protection Unit
Resource Services Branch
1978

TABLE OF CONTENTS

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MACMILLAN BLOEDEL PULP MILL - PORT ALBERNI
FISHERIES RESOURCES OF
FISHERIES AND MARINE SERVICE STATISTICAL AREA 23

I INTRODUCTION

The Port Alberni pulp mill is situated in Fisheries and Marine Service Statistical Area 23 (Figure 1) on the southwest coast of Vancouver Island. The area extends from Pachena Point in the south to Amphitrite Point in the north. The area incorporates 150 miles of coastline, not including islands, and has 41 known salmon spawning streams plus their tributaries.(1)

II SALMON

A. Stocks

Area 23 contains all five species of Pacific salmon *(Oncorhynchus* sp.). Since 1972, sockeye salmon have been the largest stock closely followed by chum, coho, chinook and pink salmon. Sockeye comprise about 50% of the stock while chum, coho and chinook salmon comprise about 25%, 15% and 5% respectively. Stocks of pink salmon are small, despite attempts in the past to enhance this species at the Robertson Creek hatchery and rearing facility in the Somass River system.

TABLE I

Total Salmon Stocks - Area 23(2,3)

YEARS	SOCKEYE	CHINOOK	COHO	CHUM	PINK Even/Odd	STEELHEAD
1956-60	64,628	18,497	45,178	245,994	1,212/331	6,517
1961-65	75,900	15,781	48,778	77,030	568/3,180	6,826
1966-70	175,330	19,152	77,737	139,266	1,057/146	2,002
1971	108,653	36,549	106,800	120,506	986	4,320
1972	257,310	16,523	45,071	249,789	1,082	3,229
1973	536,396	24,371	156,288	245,307	601	1,301
1974	326,865	32,306	137,797	152,009	1,359	419
1975	434,938	54,458	54,341	117,707	1,405	278
1971-75	332,832	32,441	100,059	177,064	1,220/997	1,909
1956-75	162,172	21,468	67,938	166,338	1,038/1,348	4,313

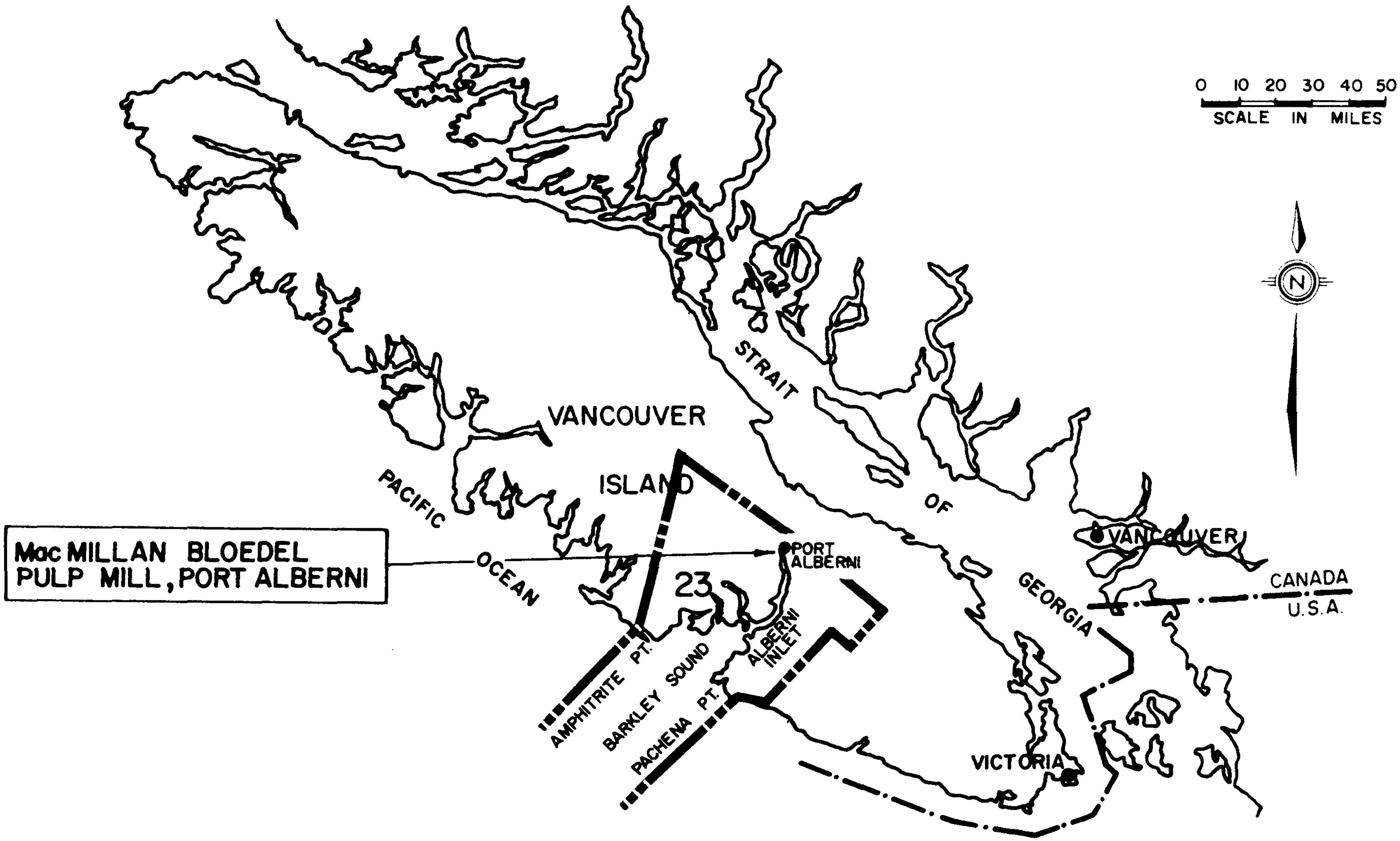

FIGURE I—LOCATION OF MacMILLAN BLOEDEL PULP MILL (PORT ALBERNI) IN STATISTICAL AREA 23

B. Salmon Enhancement

There are five fishways within Area 23. They are located at Stamp Falls, Sproat Falls, Great Central Lake, Macleans Mill Dam, and Maggie River.(1) Except for the Maggie River fishway, all are located within the Somass River system. The Stamp Falls fishway was constructed in 1927, and replaced in 1954.(4) The Sproat Falls fishway was constructed in 1951 following a period of low flow in 1950 which made the falls impassable to a large run of sockeye salmon.(4) The Great Central fishway was constructed in conjunction with the Great Central Lake dam. The dam was intended to permit sufficient flow at times of low Somass River discharge. This prevented Alberni pulp mill effluent from reducing dissolved oxygen levels in Alberni harbour below "safe" levels for fish.(4) Maclean Mill Dam was constructed as a flood control project in the lower Somass River tidal area; salmon pass the dam via flap gates.(2) The Maggie River fishway was constructed in 1939, a half mile above the river mouth and was originally intended to allow transplanted sockeye easier access to the upper river. Although several attempts were made to transplant sockeye eggs to the system no appreciable returns developed. Coho salmon also remained at relatively low levels. A tenfold increase in coho escapement was reported in 1951, however, heavy mortality occurred due to blockage of the run by the then inoperable fishway. Since coho continued to return at the high levels (2,000-5,000 per annum) the fishway was eventually rebuilt in 1972.(2)

The Robertson Creek hatchery and rearing facility is located on the Somass River system. Robertson Creek was developed in 1958-1959, by the Fisheries Research Board (FRB) for use as a pink salmon spawning stream. It now has spawning areas over 61% of its length (1280 m) as well as ponds for holding adults and rearing juveniles.(5)

The first planting of pink eggs (1.6 million) at Robertson Creek occurred in 1959.(5) Plantings continued through 1964, but despite good egg-to-fry survival, returns were generally poor.(6) The pink salmon returns to Robertson Creek ceased after 1966 and Robertson Creek was converted to a coho-chinook-steelhead experimental hatchery and rearing facility with production beginning in 1972.(6) The first return of adult (4 year-old) chinook occurred in 1976.(7) Adult returns in 1976 reached approximately 2,000 coho and 2,500 chinook (not including jacks). The number of returning adults is expected to increase as the runs become established.(6)

The Nahmint River, which flows into the lower half of Alberni Inlet (Figure 2), was scrutinized for its enhancement potential in 1929-1930, and again in 1967.(8) The Nahmint has severe blockages that prevent salmon from ascending past a point 3½ miles above the mouth of the river.(2,4) Coho escapements can be increased by a factor of ten and the chinook by a factor of five, to 10,000 and 3,000 spawning adults respectively if the obstructions can be bypassed.(4) In addition, an escapement of 15,000 "introduced" sockeye might be supported in Nahmint Lake.(8) The bypassing or removal of the Nahmint River obstructions appear to be too costly and, though enhancement has not taken place, a chinook-coho-steelhead hatchery facility may be built in 1984-1986.(9)

The FRB initiated an experimental program of controlled fertilization of Great Central Lake in 1969 to increase sockeye production. From 1970 to 1973 and 1975, commercial inorganic fertilizer (nitrogen, phosphorous, potassium - 27-14-0) plus a small quantity of organic material (fish solubles) was added to the lake at the rate of 5 tons/week for five months, spread over 8km^2 in the center of the lake.(10) Mean zooplankton concentrations were increased by a factor of 10,reaching values commonly reported for some of the larger sockeye producing lakes.(11) In 1970, juvenile sockeye were found to have increased in weight by 30% over the previous year's stock of the same age. The increased size of juveniles was expected to increase the percent survival of the stock.(12) The first returns from the 1970 fertilization occurred in 1972. The sockeye stock (Table I) increased by an average of two and a half times the 1956-1971 average, and the commercial sockeye catch (Table II) increased by an average of eight times this average in the same period. Fertilization was not carried out in 1974, but the program was resumed in 1975 and is planned to continue in the future.(9) In addition, Henderson Lake will be included in the fertilization program with the first year of fertilization occurring in 1976.(9)

Future plans in Area 23 include chum-coho-chinook enhancement beginning 1984-1986 in the Sarita River, and chum enhancement beginning in 1988 in the Toquart River.(9)

C. Commercial Fishery

The major commercial troll fishery is located offshore, concentrating mainly on stocks migrating past Area 23.(13) However a small winter (November-December) chinook troll fishery does exist inside Barkley Sound around Bamfield (1,7,13).

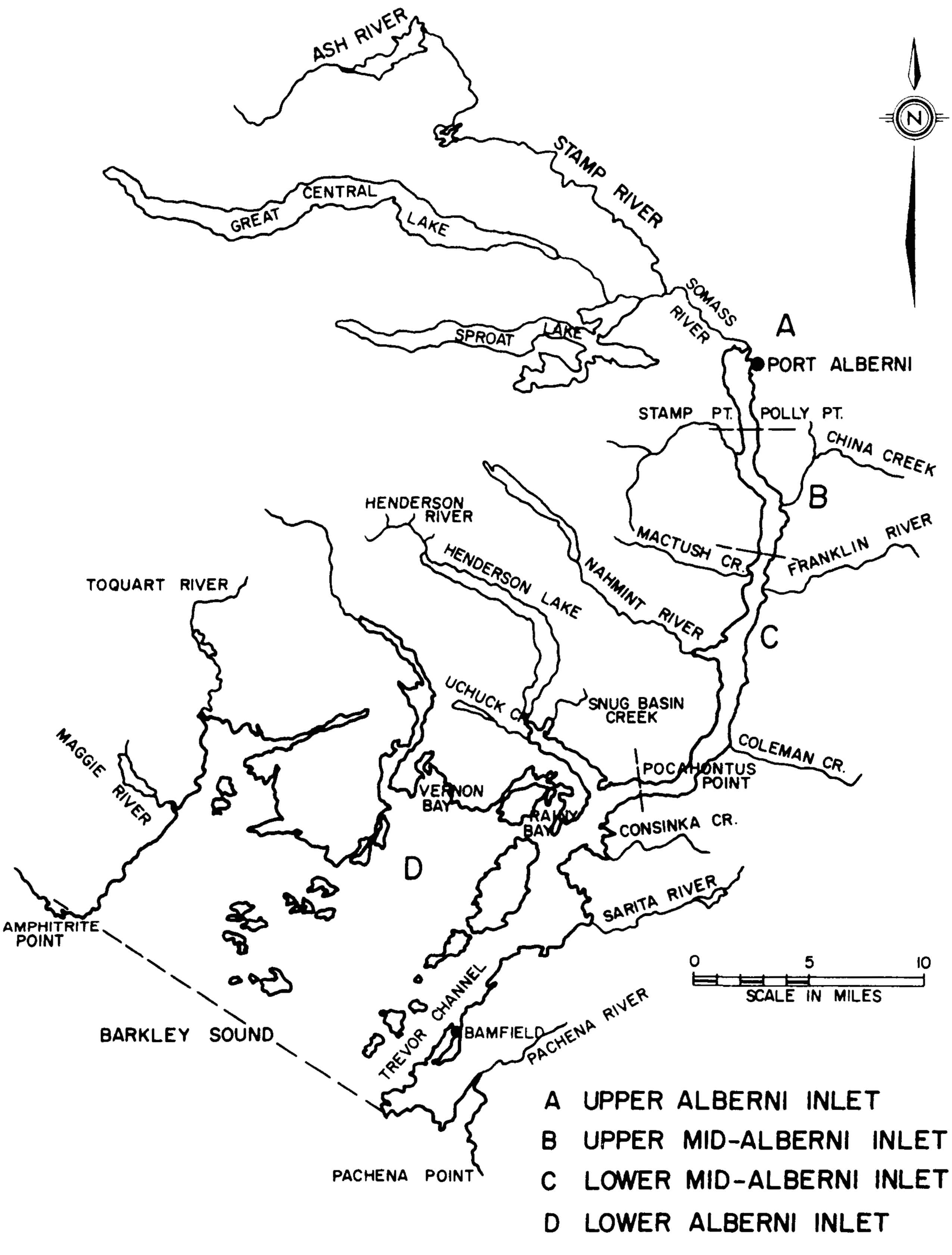

FIGURE 2 — SALMON SPAWNING STREAMS OF AREA 23

TABLE II

Area 23 - Commercial Harvest of Local* Stocks(3)

	YEARS	SOCKEYE	CHINOOK	COHO	CHUM**	PINK Even/Odd	STEELHEAD
Avg.	1956-60	9,018	4,052	6,136	124,496	11/276	325
Avg.	1961-65	15,621	1,922	766	35,314	18/673	402
	1966-70	38,258	2,199	1,573	20,429	268/18	706
	1971	28,578	7,321	9,288	25,042	786	575
	1972	112,158	3,234	6,693	40,366	162	904
	1973	228,393	7,770	11,469	95,703	411	416
	1974	223,215	10,495	3,180	2,464	196	419
	1975	225,226	27,752	4,592	1,602	1087	278
Avg.	1971-75	163,514	11,314	7,044	33,035	179/761	518
Avg.	1956-60	56,603	4,872	3,968	67,593	127/474	488

* Includes net catches and Nov.-Dec. troll catches (troll catches in Nov.-Dec. are conducted inshore, at other times, they are conducted offshore on stocks not native to Area 23).

** Net closures to protect chum salmon 1963 to 1969. Averages for 1961-1965, 1966-1970, and 1956-1975 are 2 yr., 1 yr., and 13 yr. respectively.

The inside fishery is principally conducted with nets. The summer net fisheries concentrate in Trevor Channel from Bamfield to Rainy Bay and Vernon Bay and Alberni Inlet as far up as Pocahontas Point.(13) The commercial net fishery concentrates on sockeye heading to the Somass and Henderson rivers(1) and chum dispersing to rivers throughout Barkley Sound. Chinook have recently (1973-1975) become an important commercial catch, with coho being of secondary importance to chinook and chum. Pink salmon provide a very minor catch. The commercial catch from 1958 to 1975 is given in Table II.

Strategic closures are extensively utilized in Area 23 to prevent over-exploitation of various stocks. Since 1956, there has been a total closure of net fishing in Barkley Sound after mid-October in order to protect local chum and coho stocks. In addition September to end-of-season net closures were employed from 1963 to 1969 inclusive, in order to protect chum escapements along the west coast of Vancouver Island.

D. Escapement

Sockeye are found in only two lake and river systems in Area 23; the Henderson system near the mouth of Alberni Inlet, and the Somass system at the head of Alberni Inlet (Figure 2). Sockeye arrive in the Henderson system from mid-August to late September, while those of the Somass system arrive in early May. In both systems, sockeye spawning begins in mid-October, peaks in mid-November, and ends in mid-January. Chinook begin to spawn from early September to early October, peak in mid-October and end in mid-November. Coho commence spawning from late September to mid-October, peak in mid-November and end in mid-January. Chum start spawning from mid to late October, peak in late October to early November and end in late November.(2)

Juvenile salmonids from the Somass system are resident in the estuary for varying time periods. Chum reside in the estuary from early March to June, chinook from about April to late July, sockeye from April to June, and coho from April to July. Some juvenile salmonids may appear in the Somass estuary at later times during the year. For example, in 1975 juvenile salmonids were observed in the harbour area in late September and October.(14)

There are 39 known salmon spawning streams and their tributaries in Area 23 inside waters (the escapements to two streams in outside waters are not considered. (Figure 2). These waters produce large escapements of all salmon species except pink salmon (Table III). The waters running into Alberni Inlet produce 100% of the sockeye, 95% of the chinook, 86% of the coho, and 31% of the chum, as well as most of the few pink salmon returning to inside waters of Area 23.(1)

AREA 23 SALMONID ESCAPEMENTS

TABLE III

Total Escapements to Streams of Barkley Sound and its Inlets(2)

YEARS	SOCKEYE	CHINOOK	COHO	CHUM	PINK Even/Odd	STEELHEAD **
1956-60 *	53,400	12,900	38,000	118,000	1900/50	6,200
1961-66 *	58,000	11,800	47,400	60,000	500/2400	6,400
1966-70 *	127,600	13,400	74,600	160,000	700/100	600
1971	75,000	16,300	92,100	95,000	200	3,700
1972	141,000	10,600	35,800	208,000	800	2,300
1973	301,000	12,300	143,600	148,000	100	900
1974	99,000	14,100	132,200	147,500	750	-
1975	201,000	16,700	47,700	115,000	200	-
1971-75 *	163,400	14,000	90,300	143,000	800/200	-
1956-75 *	100,600	13,000	62,600	120,000	800/800	-

TABLE IV

Total Escapements to Alberni Inlet Streams(2)

1956-60	53,400	12,500	29,300	32,500	400/30	5,400
1961-65	58,000	11,100	38,000	24,700	500/2400	5,300
1966-70	127,600	12,700	80,200	54,200	700/100	500
1971	75,000	15,500	86,400	24,100	200	2,700
1972	141,000	10,000	31,000	52,500	800	2,200
1973	301,000	12,000	132,300	51,600	-	800
1974	99,000	13,300	126,800	35,800	400	-
1975	201,000	16,200	41,500	29,300	100	-
1971-75 *	163,400	13,400	83,600	38,700	600/200	-
1956-75 *	100,600	12,400	57,800	37,500	500/800	-

* Averages

**Steelhead enumerations are made incidental to salmon escapements and are therefore not reliable figures.

Alberni Inlet, as well as being the major salmon-producing area (Table IV), is also the recipient of effluent from the Port Alberni pulp mill located on the east side of Alberni Inlet, at the mouth of the Somass River.

To facilitate documentation of the fisheries resources in relation to the pulp mill, Alberni Inlet can be divided into four arbitrary areas (Figure 2), (Tables V, VI, VII, VIII).

Upper Alberni Inlet, above Stamp and Polly Points is the most studied portion of Area 23 (with respect to pulp mill pollution). The only salmon stream entering the head of the Inlet is the Somass River, which produces 77% of the sockeye, 88% of the chinook and 96% of the coho, but only 8% of the chum returning to Alberni Inlet waters (Table V). The waters of this upper inlet area would probably be the most adversely affected in terms of pulp mill pollution. At present, salmon runs are still high despite the effects of the pulp mill on the estuary, however, there has been much enhancement work carried out at various locations along the Somass system.

In the Somass estuary (upper Alberni Inlet) phyto-plankton production below the halocline is severely reduced. This has probably been caused by inhibition of photosynthesis due to discolouration of the water by pulp mill effluent.(15) In addition large deposits of pulp fibre, which cover the bottom of the estuary also contribute to the depletion of oxygen in the water below the halocline. Juvenile chinook in the estuary are found only in the upper water layers above the halocline, probably due to the low oxygen levels that occur at depths greater than about 4 to 5 metres (i.e. below the halocline).(14) The pulp mill effluent is not as toxic as effluent from some other pulp mills. Fourteen day in-situ bioassays with juvenile chinook salmon did not show a relationship between mortality and distance from the pulp mill.(14)

Studies showed that beneath the halocline, oxygen depletion probably caused 100% mortality of juvenile chinook held at this depth. The effect of the mill effluent has been not only to reduce the vertical "living space" for salmon, but also to cause a reduction in the food supply of juvenile salmon. The juvenile chinook feeding pattern has changed in the area below the pulp mill outfall on the east side of the harbour, from a diet of amphipods to a diet of insects and oligochaetes.(14)

TABLE V

Escapements to Upper Alberni Inlet(2)
(Somass River System)

YEARS	SOCKEYE	CHINOOK	COHO	CHUM	PINK Even/Odd	STEELHEAD**
1956-60*	42,600	10,800	28,000	4,500	300/5	3,500
1961-65*	35,000	9,400	35,000	2,200	400/2400	3,500
1966-76*	84,000	11,400	77,000	2,400	700/100	300
1971	67,000	13,500	85,000	1,500	200	1,500
1972	137,000	9,000	30,000	4,000	400	-
1973	261,000	11,000	130,000	7,000	-	-
1974	93,000	12,500	125,000	3,500	400	-
1975	191,000	15,000	40,000	700	100	-
1971-75	149,800	12,200	82,000	3,300	400/100	-
1956-75	77,800	10,900	55,200	3,100	500/800	-

* Averages

TABLE VI

Salmonid Escapements to Upper-Mid Alberni Inlet
(Cous and China Creeks)

1956-60*	Nil	-	100	350	Nil	500
1961-65*	-	75	200	175	-	575
1966-70*	-	50	800	1,150	-	400
1971	-	35	225	200	-	1,000
1972	-	25	275	1,525	-	1,000
1973	-	50	225	825	-	750
1974	-	25	150	425	-	-
1975	-	35	225	400	-	-
1971-75*	-	35	225	675	-	-
1956-75*	-	40	325	600	-	-

*Averages
**Steelhead enumerations are made incidental to salmon escapements and are therefore not reliable figures

TABLE VII

Salmonid Escapements to Lower-Mid Alberni Inlet(2)

(Mactush Cr., Franklin R., Nahmint R., Coleman Cr.)

YEARS	SOCKEYE	CHINOOK	COHO	CHUM	PINK Even/Odd	STEELHEAD**
1956-60*	Nil	800	400	16,400	113/25	675
1961-65*	-	875	350	17,825	-	800
1966-70*	-	800	800	40,000	-	-
1971	-	1,250	300	12,075	-	1,100
1972	-	925	350	36,725	-	275
1973	-	825	950	35,050	-	1,225
1974	-	650	600	15,175	25	50
1975	-	800	500	29,075	25	-
1971-75	-	900	550	23,825	-	-
1956-75	-	850	525	24,500	50/25	-

TABLE VIII

Salmonid Escapements to Lower Alberni Inlet(2)

(Uchuk Cr., Consinka Cr., Snug Basin Cr., Henderson Lk.)

1956-60*	10,800	870	1,800	11,325	-	525
1961-65*	14,900	780	2,500	4,550	-	490
1966-70*	43,600	400	1,250	10,660	-	-
1971	8,000	750	875	10,350	-	-
1972	4,000	400	450	10,300	400	-
1973	40,000	250	1,200	8,750	-	-
1974	6,000	150	1,025	16,750	-	-
1975	10,000	400	675	8,050	-	-
1971-75*	13,600	400	825	10,850	-	-
1956-75*	22,750	600	1,600	9,350	-	-

* Averages

** Steelhead enumerations are made incidental to salmon escapements and are therefore not reliable figures.

Salmon returning to the upper-mid Alberni Inlet streams (Figure 2, Table VI) would be subjected to less severe water quality conditions than those encountered by salmon in the upper Inlet. The two creeks in this area produce 20 year annual average runs of 325 coho, 600 chum and 40 chinook salmon.

Similarly, salmon returning to lower-mid Alberni Inlet streams (Figure 2, Table VII) would be subjected to much less severe water quality conditions than those which occur further up the Inlet. The four salmon-producing streams in this area produce 20 year average annual runs of 850 chinook, 525 coho and 24,500 chum salmon and 1,000 steelhead trout.

Salmon returning to the streams of lower Alberni Inlet (Figure 2, Table VIII) would probably be subjected to the least severe water quality conditions of Alberni Inlet. The four salmon-producing streams in this area produce 20 year average annual runs of 600 chinook and 1,600 coho as well as producing 9,350 chum and 22,750 sockeye salmon.

E. <u>Sport Fishery</u>

The Area 23 salmon sport catch increased approximately five-fold from 1956 to 1975; peak catches were recorded in 1971 (Table IX).(16) The ten year average (1966 to 1975) indicates a mean annual catch of 5,100 chinook and 2,000 coho plus incidental (up to 400/year) pink salmon. The chinook fishery concentrates in Nahmint Bay and the head of Alberni Inlet.(1) A small fishery near Bamfield produces significant numbers of coho.(1)

In order to preserve chinook and on occassion coho stocks it has been necessary in the past to close certain areas to sport fishermen.(7) From 1957 to 1965, Nahmint Bay and Alberni Harbour (above Stamp and Polly Points, Figure 1) were closed almost every year from the end of September to the end of December to conserve chinook stocks. From 1966 to 1975, the length of the closed season was gradually decreased from 4 months to 1.5 months (mid-September to late October), although at times the areas were open to sport fishing all year round (Alberni Harbour in 1971 and 1975, Nahmint Bay in 1969). Sarita Bay, in the northeast corner of Trevor Channel (Figure 2) was closed to the sport fishery for 1 to 4 months (September to December), from 1961 to 1969 inclusive, to protect the chinook stocks of the streams flowing into Sarita Bay. The only non-tidal closure to sport salmon fishing has been the Sproat River, from June 15 to November 15, in order to conserve runs of coho and chinook salmon.(7)

TABLE IX

Salmon Sport Catch - Area 23**(16)

YEARS	CHINOOK	COHO	PINK
1956-60*	1,465	464	-
1961-65*	2,050	540	36
1966-70**	3,427	1,393	42
1971	11,152	5,263	-
1972	2,674	2,528	120
1973	4,273	1,130	89
1974	7,640	2,414	386
1975	7,981	2,020	88
1971-75*	6,744	2,671	137
1966-75*	5,085	2,032	89

* Averages

** Also includes insignificant Area 22 (Nitinat Lake) sport catches.

TABLE X

Indian Food Fishery - Area 23 (1,7)

YEARS	SOCKEYE	CHINOOK	COHO	CHUM	PINK	STEELHEAD
1956-60*	2,210	60	180	3,540	0	0
1961-65*	2,279	29	101	3,012	9	0
1966-70*	3,352	172	179	1,202	18	7
1971	5,075	1,796	124	1,194	0	0
1972**	4,152	20	70	1,223	0	0
1973	6,978	3	39	1,679	1	0
1974	4,650	26	28	2,000	22	0
1975	8,712	0	0	1,000	0	0
1971-75*	5,913	369	52	1,199	7	0

* Averages

** Calculated from the number of fish reported from combined Areas 22 and 23 in 1972, and the percent contribution of Area 23 to the total Area 22 and 23 harvests of 1973-75 inclusive.

F. Indian Food Fishery

Recent Indian food fish catches have increased mainly due to larger sockeye harvests (Table X). Chum salmon captures have fluctuated, but are also a major part of the harvest. Pink and steelhead catches are intermittant and insignificant. Chinook were taken in large numbers from 1968 to 1971, but otherwise were not a significant part of the catch. Coho have been declining in importance since the mid 1960's.

Food fisheries occur at the Somass River (Sockeye, coho, chinook, pink), the Henderson River (Sockeye,) and the Sarita River (chum).(7)

III HERRING

The Area 23 commercial herring fishery concentrates in Macoah Passage (seine and gill-net), Dutch Harbour (gill-net), Lyall Point (gill-net), the eastern side of Imperial Channel (seine), Vernon Bay (seine), and Ucluelet Harbour (gill-net).(1,17) Historical herring catches have fluctuated widely (Table XI). The mean catch from 1972 to 1975 was 45.5 million pieces. The mean (1956 to 1975) commercial harvest is 44% of the stock (catch and spawners).

The desired number of spawning herring for Area 23 is 59.2 million fish.(18) This was achieved only 30% of the time between 1956 and 1968, but has been well over this level since 1969. There was a four year closure of the herring fishery from 1968 to 1971 to protect declining stocks. Herring spawning areas are indicated in Figure 3. Spawning occurs from late February and early March to early April.(18)

Barkley Sound is one of the major herring rearing grounds on the British Columbia coast.(22) A study of juvenile herring conducted in Barkley Sound in the early 1950's concluded that most of the juveniles were spawned on the northwest side of the sound, then migrated to the southeast side where they formed large schools. Juveniles have been found in shallow, sheltered bays, inlets and channels(22) and also at the head of Alberni Inelt.(23) Spawning, however, does not take place in Alberni Inlet.(17)

IV GROUNDFISH

The groundfish fishery of Area 23 is conducted offshore.(13) Commercial catch statistics are given in Table XII.

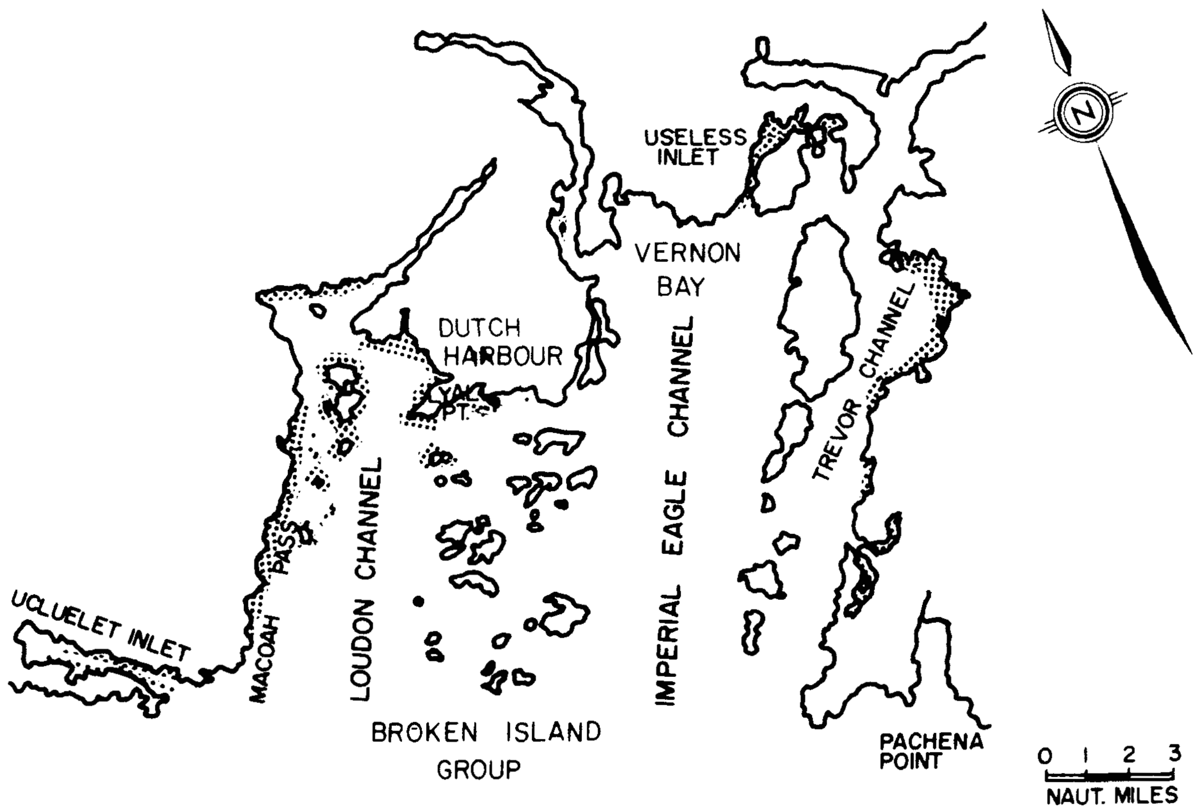

FIGURE 3 — LOWER ALBERNI INLET AND ITS HERRING SPAWNING GROUNDS (17,22)

TABLE XI

Area 23 Herring Catch, Spawners Stock and Miles of Spawn(17,18,19,20)

	MILLIONS OF PIECES			
	COMMERCIAL CATCH	SPAWNERS	TOTAL STOCK	SPAWN-STATUTE MILES AT MEDIUM DENSITY
1956-60*	169.4	53.4	222.8	7.54
1961-65*	85.8	77.6	163.4	4.15
1966-70*	10.2	71.1	81.3	5.24
1971	0.0	192.2	192.2	17.70
1972	26.1	158.6	184.7	13.60
1973	55.5	89.0	144.5	6.92
1974	35.0	327.0	362.0	25.50
1975	65.4	132.7	198.1	10.40
1971-75*	36.4	179.9	216.3	14.82
1956-60*	75.5	76.4	151.9	7.94

* Averages

TABLE XII

Area 23 ¬ Mean Commercial Harvest of Groundfish(3)

Hundredweight (cwt)

YEAR	FLOUNDER & SOLE	HALIBUT	COD	PERCH	TUNA	SALMON ROE	SKATE	NON-FOOD OTHER FISH
1956-60	4,382	2,617	15,807	10	9	-	50	3,482
1961-65	2,454	2,793	10,549	18	6	-	68	2,454
1966-70	3,910	3,676	23,194	651	1,404	-	171	1,369
1971-75	8,866	1,819	54,310	1,028	2,748	257 (3 yr avg.)	181	1,097

TABLE XIII

Area 23 - Commercial Harvest of Shellfish(3)

Hundredweight (cwt)

YEAR	CRAB	SHRIMP	BUTTER CLAM	LITTLENECK JAPANESE	LITTLENECK NATIVE	MIXED CLAM	ABALONE	SHUCKED OYSTER (U.S. GAL.)
1956-60 *	117	87	1	0	0	0	0	0
1960-65 *	51	4,794	44	260	228	0	15	0
1965-70 *	55	5,454	36	834	509	0	22	0
1971	42	1,625	0	0	40	0	136	0
1972	31	306	0	0	97	0	882	0
1973	30	60	< 5	0	< 5	0	190	0
1974	30	360	0	420	0	0	40	0
1975	60	1,120	0	1,616	140	60	20	145
1971-75 *	39	694	< 1	407	56	12	254	29
1956-75 *	66	2,757	20	375	198	3	73	72

* Averages

V CRUSTACEANS

Commercial and recreational crab fishing occurs in Sarita and Toquart Bays. The commercial crab fishery has declined from 1956 to 1960 levels (Table XIII).

The most important crustacean fishery is for shrimp, with a mean harvest (1966-1975) of 3074 hundred weight (cwt). This fishery is conducted offshore and has declined somewhat from 1965-1970 levels (Table XIII).

Stocking experiments were carried out with Atlantic lobsters at Fatty Basin, Useless Inlet in 1965. In 1966, a hatchery was built at Fatty Basin and in 1967, a rearing installation was built and juvenile lobsters were transplanted to areas in Barkley Sound.(1) The project was later abandoned.

VI MOLLUSCS

A clam fishery existed in Barkley Sound from 1964 to 1969. More recently (1974) this fishery appears to be reviving, especially for the harvest of Japanese littlenecks (Table XIII). Commercial beds are often closed, due to paralytic shellfish poisoning.(13) A new oyster fishery started in 1975, and produced 145 shucked U.S. gallons from commercial oyster leases in Toquart Bay (Figure 3).

Abalone harvesting began in 1970 in the Broken Island group. Maximum harvests were made in 1972 but have been declining since (Table XIII).(13)

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