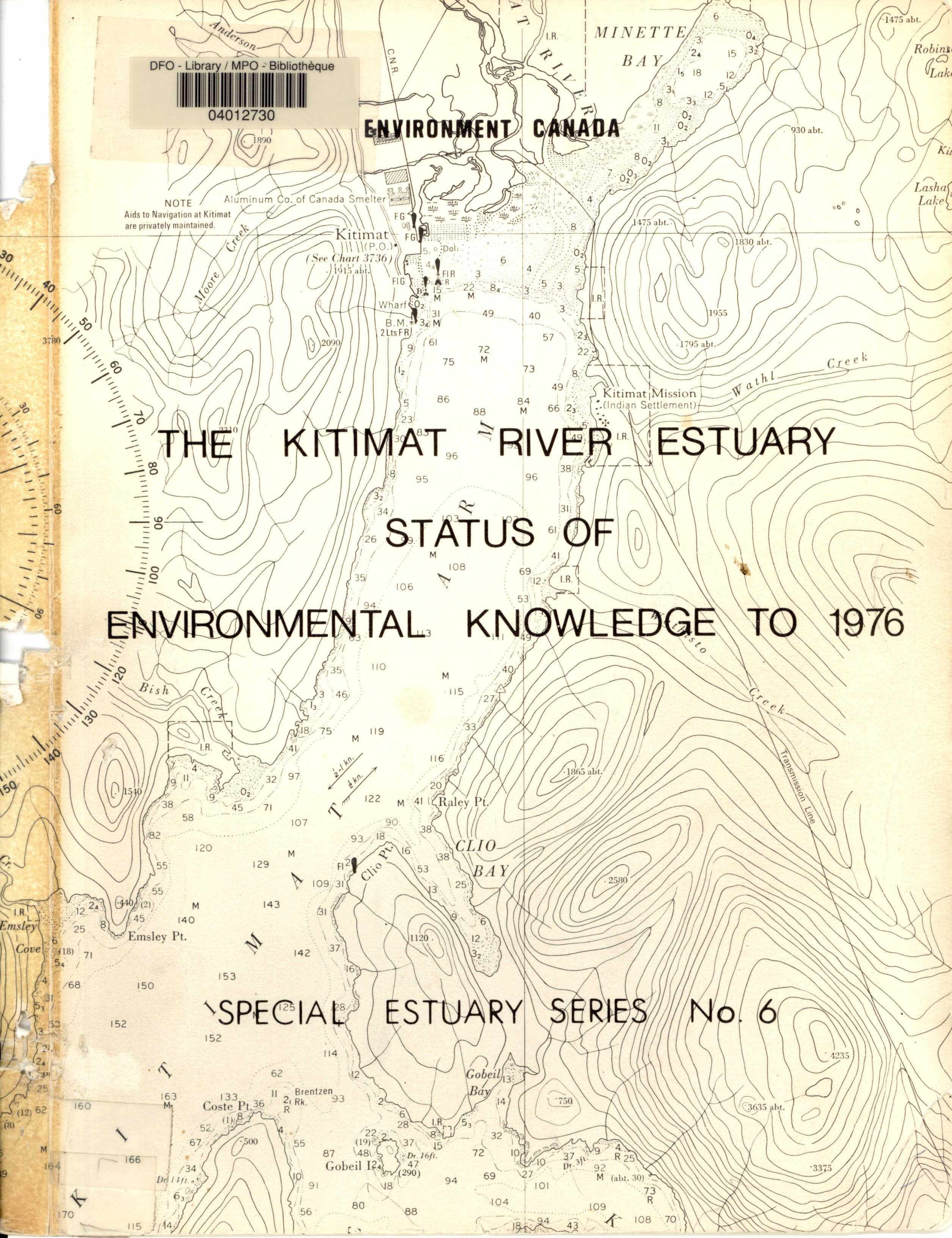
ENVIRONMENT CANADA

THE KITIMAT RIVER ESTUARY

STATUS OF ENVIRONMENTAL KNOWLEDGE TO 1976



SPECIAL ESTUARY SERIES No. 6

ENVIRONMENT CANADA

THE KITIMAT RIVER ESTUARY STATUS OF ENVIRONMENTAL KNOWLEDGE TO 1976

REPORT OF THE ESTUARY WORKING GROUP
DEPARTMENT OF THE ENVIRONMENT
REGIONAL BOARD PACIFIC REGION

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Kitimat River Estuary - August 1974.

Courtesy of Alcan, Kitimat. Photography by McElhanney Surveying & Engineering Ltd., Vancouver, B.C.

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ABBREVIATIONS AND SYMBOLS

asl	above sea level
ac.	acre(s)
A.L.R.	Agricultural Land Reserve
ADt(ADT)	air dried tonne (short ton)
ADUt(ADUT)	air dried unbleached tonne (short ton)
Al	aluminum
et al.	and others
Atmos Environ. Serv. (AES)	Atmospheric Environment Service
av.	average
BOD(BOD_5)	biochemical oxygen demand (5-day BOD)
B.C.	British Columbia
B.C.L.I.	British Columbia Land Inventory
bull.	bulletin
Can. Dept. Env.	Canada Department of the Environment
C.L.I.	Canada Land Inventory
CASAW	Canadian Association of Smelter and Allied Workers
CNR	Canadian National Railway
cm	centimetre(s)
cm/s (cm/sec)	centimetres per second
cont'd	continued
Corp.	Corporation
cfs	cubic feet per second
m^3(cu.m)	cubic metre(s)
m^3/s	cubic metres per second
dm^3	cubic decimetre(s)
^oC	degrees Celsius (centigrade)
^oF	degrees Fahrenheit
σ_τ	density (sigma-τ)
D.O.	dissolved oxygen
Dist.	District
E	east

ed.	editor or edition
EEB	Environmental Emergency Branch
ELUCS	Environment and Land Use Committee Secretariat
EPS	Environmental Protection Service
pH	expression for acidity or alkalinity of a solution
fm	fathom(s)
fig.	figure
Fish. Res. Board Can.	Fisheries Research Board of Canada
F	fluorine
ft.	foot (feet)
fbm	foot board measure
e.g.	for example
gal.	gallon(s)
g	gram(s)
g/m^2	grams per square metre
GSC	Geological Survey of Canada
>	greater than
ha	hectare(s)
h.(hr.)	hour(s)
HF	hydrogen fluoride
H_2S	hydrogen sulfide
IGD	Imperial gallons per day
Ibid.	in the same place
in.	inch
IR	Indian Reserve
IUTC	industrial, utility and transportation corridor
IWD	Inland Waters Directorate
IEC	International Environmental Consultants Limited
kg	kilogram
km	kilometre
km/hr.	kilometre per hour
KME	kraft mill effluent

kn	knot(s)
Lat.	latitude
<	less than
l	litre(s)
Long.	longitude
MS	manuscript
max.	maximum
mem.	memoir
m	metre(s)
mhos	mhos (conductance; SI unit-siemens)
μg	microgram(s)
μmhos	micromhos (conductance; SI unit-micro-siemens)
mi.	mile(s)
m.p.h.	miles per hour
meq/l	milliequivalents per litre
mg/l	milligram per litre
mg/mol	milligram per mole
mm	millimetre(s)
MMbm	million board feet
Mm^3	million cubic metres
Mdm^3	million cubic decimetres
min.	minimum
m.(')	minute
misc.	miscellaneous
mol	mole
NAS	National Academy of Sciences (USA)
n.mi.	nautical mile(s)
NKK	Nippon Kokan Kaisha Limited
NO_3	nitrate
NO_2	nitrite
N	north
No.(#)	number
OECD	Organization for Economic Co-operation and Development
oz.	ounce

PBS	Pacific Biological Station
PEI	Pacific Environment Institute
p.	page
pp.	pages
ppm	parts per million
$^{o}/_{oo}$	parts per thousand
%	percent
pers. comm.	personal communication
PCB	Pollution Control Branch
lb(s)	pound(s)
rept.	report
ser.	series
S	south
sp.	species (singular)
spp.	species (plural)
cm^2	square centimetres
sq.ft.	square feet
m^2	square metre(s)
sq.mi.	square mile(s)
STD(std.)	standard
SCF	standard cubic foot (air pollution)
SCFM	standard cubic foot per minute (air pollution)
S	sulfur
SO_2	sulfur dioxide
SS	suspended solids
temp.	temperature
i.e.	that is
Mbm	thousand board feet
TA	total alkalinity
TDS	total dissolved solids
TIC	total inorganic carbon
TOC	total organic carbon
TS	total solids
TSS	total suspended solids

UBC	University of British Columbia
U.S.	United States (of America)
U.Vic.	University of Victoria
var.	variety (biology), variance (statistics), variation (navigation)
VSS	vertical-stud Södenberg (type of electrolytic pot design)
vol.	volume
W	west
yr.	year

PREFACE

. This is the sixth estuarine system on the coast of British Columbia examined by the Estuary Working Group of the Regional Board Pacific Region of Environment Canada. There are considered to be 18 estuaries on the British Columbia coast which are regarded as critical by the Estuary Working Group, and seven of these have now been covered in this series of reports: (1) Fraser; (2) Squamish; (3) Skeena; (4) Cowichan and Chemainus; and (5) Nanaimo. Priority will be given to the Campbell, Courtenay, and Somass Rivers in the next reports of this series. To complete the series it is planned to compile and summarize environmental information on the estuaries of the Indian, Homathko, and Bella Coola Rivers on the British Columbia mainland and of the Quatse, Salmon, Gold, Wannock and Nimpkish Rivers on Vancouver Island.

The first estuaries in this series had a substantial amount of environmental information to be reviewed, and this is understandable, since they were generally in the areas of major development near the population centres of the lower mainland of British Columbia and on Vancouver Island. The last half of the series of estuaries being reported has far less environmental coverage than the others, and this will be reflected in the brevity of these reports. Hopefully, these reports are meeting the needs of users in the field for any prospective development, as well as in research, where the first stage must always be the adequate coverage of existing information.

Kitimat and the Kitimat River estuary came into prominence during the early 1950's when the aluminum smelter of the Aluminum Company of Canada was being planned for the mouth of the Kitimat River, at the head of Kitimat Arm extending from Douglas Channel. The plan was to use the vast amounts of hydroelectric potential that was available in the Kemano project nearby, for the electrolytic reduction of the aluminum, and to import the aluminum ore (bauxite) from the Caribbean for this purpose. It was planned to have "an instant city" of considerable size within 10 years adjacent to the aluminum smelter, and Kitimat was to be a model townsite development. Indeed the planning achieved a unique townsite with all the amenities and facilities for modern living. Unfortunately, as most plans usually go, the goal of full production from the Kitimat aluminum smelter was never fully reached, and the town of Kitimat never became the sizeable city initially conceived. However, production of aluminum was ultimately at a level to give the Alcan Works the claim of being the second largest aluminum smelter in the free world, albeit not fully utilizing the hydroelectric potential of the Kemano power project. The town of Kitimat did become a substantial planned community of 12,000 people within the next 20 years.

There was little environmental investigation of the type carried out nowadays, prior to installation of the ALCAN works in 1954. However, there have been concerns expressed from time to time since the plant went into operation, both as a result of atmospheric emissions and their effect on vegetation in the area, and the discharge of water-borne wastes into the mouth of the Kitimat River and its possible effects on fisheries. Some of these concerns have been followed up with investigations by appropriate authorities.

The next major development on the Kitimat River estuary at the head of Kitimat Arm was the Eurocan Pulp Mill, which was planned in the mid 1960's and finally went into operation in 1970. Unlike the aluminum smelter, the pulp mill was considered to have certain potential environmental risks, partly because of known adverse environmental effects of pulp mills by this time and mainly because of changing attitudes on environmental matters. It was felt that the mill could affect the salmon runs up the

Kitimat River. Therefore, a considerable study went into the design of the pulp mill for proper in-plant control of waste output and effluent quality, as well as for out-plant effluent treatment, and for suitable siting of the outfall for effluent disposal with minimum ecological damage. The Resource Development Branch of the Department of Fisheries in Vancouver became actively engaged in assessment of the problems and development of solutions, along with cooperation from the Fisheries Research Board's Biological Station in Nanaimo, in order to select the most suitable system of effluent treatment and waste disposal. Several options were considered in siting the mill, which included a number of locations on the west shore of Kitimat Arm, as well as on the banks of the Kitimat River. The final decision taken by the Eurocan consortium was to build on the west bank of the Kitimat River some distance upstream from the aluminum smelter, and to provide a certain degree of effluent treatment before discharge. The latter involved the installation of primary and secondary treatment in a lagoon system to provide a settling basin for wood solids as well as 5-day biological treatment with 70-80% removal of BOD (biochemical oxygen demand).

Although the Kitimat River has a substantial flow, especially during the freshet period in the spring, when a considerable amount of snow-melt adds to the normal runoff, and during heavy runoff in autumn the Kitimat River estuary was not without its problems. The Indian community on the reserve bordering the Kitimat River has relied traditionally on the fishery in the Kitimat River, including the spring run of eulachons (oolichans), which have always provided the Indians with a source of food and oil, and in earlier days, a means of illumination (these fish are sometimes known as "candle-fish" because at one time they were dried, fitted with a wick and used as candles). Soon after the pulp mill went into operation, the eulachons were found to have a taint, possibly from the kraft pulpmill effluent discharging into the river, and this was a cause for considerable concern from both the Indians and the conservation agencies. Sewage from the city of Kitimat was allegedly affecting some of the fish, according to the native fishermen, and this was a further problem of conflict in resource use.

Even though no fish or bird kills had been reported from Kitimat prior to installation of the pulp mill, the aluminum smelter is known to introduce certain wastes, particularly fluoride, which can be toxic to living resources. In 1974, a temperature-induced fish kill occurred downstream from the Eurocan pulp mill and a successful prosecution was made under the Fisheries Act. The combined effects of effluents from the pulp mill and the smelter, add to the stress that fish are subjected to normally in the Kitimat River estuary. It has been reasonably well established that the northwest corner of Kitimat Arm, between the ALCAN and Eurocan docks is comparatively poor in benthic organisms normally used as food by juvenile salmon. In contrast, the eastern part of the delta, including Minette Bay, is quite rich in food organisms for salmonids.

The Kitimat area is one of two principal sites chosen as potentially suitable for the development of a steel mill in the northwestern part of British Columbia. It is now being subjected to further scrutiny as a terminal for the Kitimat-Edmonton Pipeline, designed to take oil transported by tanker from Alaska and pipe it to the mid-western U.S. states. Although Kitimat Arm is quite deep and fairly well flushed, man's disturbance of the estuary can result in problems which have been recognized in other estuaries along the British Columbia coast where development is either already under way or being planned. Some of the effects of industrial development on habitats used by juvenile salmonids identified in the Fraser and Squamish River estuaries could also affect the Kitimat. The problem of conflict of development with renewable resources merits close examination in this rather vital estuary of the north.

 Preface

I should like to thank all those who have provided information for this report, particularly Alcan Smelters and Chemicals Limited (Kitimat Works), Eurocan Pulp and Paper Company and the District of Kitimat. The continued dedication of the contractors, Messrs. Bell and Kallman, has ensured a thorough coverage of available information from various sources. To the members of the Estuary Working Group (see Preface Table (i)) and their colleagues, who reviewed the drafts of the report, goes my sincere appreciation for their time and effort.

We hope that the report will fulfill its objectives in providing an examination and review of available environmental data for users at various levels of government, in academic institutions and in the private sector.

M. Waldichuk

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Once again we would like to thank the members of the Estuary Working Group for reviewing the draft manuscript, as well as all the individuals who contributed reports and data used herein.

To Dr. M. Waldichuk, the author of the Oceanography Section, mentor and director of this special series of estuary reports,goes our continued appreciation for his guidance and constructive advice during the preparation of the manuscript.

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SUMMARY

The Kitimat River estuary, 715 kilometres northwest of Vancouver on the British Columbia mainland coast, is typical of the highly stratified deep basin estuaries found at the head of the Canadian west coast fjords.

A relatively undeveloped area with few natural resources, but with an abundant source of hydro-power at nearby Kemano and sea access to Hecate Strait and the Pacific Ocean, the estuary provided a good site for the Alcan aluminum smelter, which in 1954 was one of the largest in the world. The new town of Kitimat, built in 1950 to house the employees of Alcan and its associated service industries, now has a population in excess of 13,000. Incorporating many features of modern town planning technology, the townsite has been designed to expand with industrial development, and to ultimately accommodate some 50,000 inhabitants.

The Kitimat River and its main tributaries drain an area of the Kitimat Ranges encompassing about 200,000 ha (768 sq. mi.) of the granitic mountains of the Coastal Mountains of the Western Cordillera. The Kitimat River with a mean annual discharge of 134 cms (4,740 cfs), rises on the slopes of Mt. Davies (2,089 m) and flows northwesterly for about 43 km (27 mi.), at which point it enters the Kitimat Valley. It continues with a southerly flow for 32 km (20 mi.) before discharging into the estuary, west of Minette Bay. The river delta comprised mainly of coarse sediments (sand and gravel) is less than 3 km (2 mi.) wide and extends southwards for approximately 1.5 km (1 mi.). Beyond the delta front the estuary rapidly deepens to 30 fathoms or more.

The climate of the estuary exhibits many of the characteristics of a continental climate. It is largely influenced,

during most seasons, by low-pressure systems that have moved eastward across the Pacific Ocean. These occur with the greatest intensity in the fall, producing an October peak in the distribution of precipitation at Kitimat. Winds are predominantly from the north and the south. During the summer months southerly winds prevail, while northerly winds, associated with outflowing Arctic air are prevalent during the winter months.

Kitimat Arm is characterized oceanographically as a comparatively deep (220 m or 120 fm) fjord system with freshwater inflow at the head. The salinity of deep water exceeds $33^{o}/_{oo}$, which is somewhat higher than that of inlets tributary to the Strait of Georgia (e.g. bottom water in Howe Sound is just under $31^{o}/_{oo}$). Freshwater inflow causes a thin brackish layer of low salinity usually less than 5 m deep. Thus the pycnocline, where density changes rapidly vertically, is at a comparatively shallow depth.

Surface waters of Kitimat Arm are amply aerated with dissolved oxygen levels near saturation. Dissolved oxygen in deep water of Kitimat Arm proper appears to seldom drop below 4 mg/l (about 42% saturation), indicating that the bottom water in this inlet, lacking a shallow threshold sill, is regularly replaced. However, the Minette Bay extension of Kitimat Arm has a shallow sill at its entrance caused by deposition of sediment from the Kitimat River, and it undergoes seasonal depletion of oxygen in its bottom water.

Tides in Kitimat Arm are mixed mainly semi-diurnal (MSD), giving two highs and two low waters in a tidal day, with irregularities in height and time of succeeding tidal oscillations. The tidal range is substantially larger at Kitimat than at more southern locations on the British Columbia coast, with a mean tidal amplitude of 4.2 m (13.8 ft.) and a large tidal amplitude of 6.5 m (21.4 ft.).

xxv. Summary

Surface currents in Kitimat Arm are largely wind-induced. Tidal currents are comparatively small at the head of the inlet, although they increase substantially down inlet in Douglas Channel. However, surface currents seldom exceed 50 cm/sec (1 kn.). Deeper currents are considerably more sluggish. The configuration of the coastline lends itself to formation of eddies.

Wind waves are best developed with southerly winds of winter. The longest fetch for wind wave action to develop is from the south and southwest, approximately 37 km (20 n. mi.) of unobstructed channel. Although they probably seldom exceed 1.5 m (5 ft.) in height, these waves make anchorage in mid-channel at the head of Kitimat Arm undesirable during these conditions. They also have an ecological impact on the deltaic populations of flora and fauna, rendering the substrate for attachment of these organisms relatively unstable.

Forests in the Kitimat Valley have been subject to infestations of saddle-backed loopers (*Ectropis crepuscularia*), spruce budworm (*Choristoneura orae*) and bark beetles (*Pseudohylesinus* sp.), which have caused moderate to severe tree mortality along the western slope of the valley. Chemical control measures were implemented in 1960 and 1961 to limit the extent of looper defoliation. The spruce budworm experienced a similar cycle of abundance from 1960 through 1963. Bark beetles subsequently attacked the defoliated and weakened trees. Looper and budworm concentrations remained light until 1969 when they again defoliated trees in the lower valley.

The macroinvertebrate fauna of the lower Kitimat River has been sampled regularly since 1969 as part of Eurocan's monitoring program. The benthic community is characterized by a standing crop and diverse species composition, that is subject to large fluctuations and indicative of clean water conditions. The municipal sewage outfall and the Eurocan effluent outfall increased the benthic standing crop and altered benthic community composition in the lower river.

Both intertidal and benthic invertebrate faunas in Kitimat Arm are diverse and may be considered typical of "healthy" northern fjords. Benthos of the western delta is characterized by the bivalve *Macoma inconspicua*, while that of the middle and eastern sectors is dominated by gammarid amphipods. Low species diversity on the delta suggests the predominance of fresh-water influence. Invertebrate fisheries in the immediate area are limited to a crab fishery in Kitimat Arm.

Five species of Pacific salmon (chum, coho, chinook, pink and sockeye) and two species of migratory trout (steelhead and coastal cutthroat) occur in the Kitimat River system. The substantial salmon escapements to the system have trended smaller in recent years owing to fishing pressures and adverse riverine conditions (floods). A salmon hatchery on the Kitimat River system is being considered as part of the Salmon Enhancement Program. Moderate stocks of herring and groundfish occur in the area but are not exploited commercially. Commercial fishing is for the most part located in outside waters of Area 6 (at the mouths of inlets leading to Kitimat). Tidal sport fishing in Kitimat Arm and the inside waters of Area 6 is becoming more popular annually as people bring more and better boats to Kitimat. Freshwater sports fishing is highly popular with residents of Kitimat and the river is one of the most heavily sport fished rivers in Canada. Salmon and herring are taken for food by the local Indian Bands; however, eulachons are no longer fished from the Kitimat River because of their alleged tainting.

Little work has been conducted on the aquatic vegetation of the area; however, a recently completed report documents both deltaic and terrestrial vegetation. Salt marsh vegetation is found over much of the central and eastern delta with extensive

rockweed and eelgrass beds in the Minette Bay Channel. Descriptions and the distribution of floral community types, defined as land units, are documented under Terrestrial Flora. The Kitimat River valley has been actively logged over the past decade leaving much of the lower valley in the early stages of regrowth.

The Kitimat area is only moderately important in terms of overall numbers of wildlife; however, the estuary and lower river course are the most important habitats in terms of valued and abundant avian populations, especially during winter when heavy snowfalls blanket terrestrial food sources. Portions of the study area attractive to birds and mammals are described. The estuary and watershed offers considerable wildlife-oriented recreation, much of which has not yet been realized. Nature observation and hunting are moderately popular pastimes with Kitimat residents.

The Kitimat District Municipality incorporated in 1953 is supported by two major industries. The Alcan aluminum reduction plant with an installed capacity of 300,000 tons a year, employs about 2,500 people, while the Eurocan Pulp and Paper Company Ltd., employs an additional 1,200 local inhabitants, in its mill, logging and other operations. Harbour facilities for these two industries have been developed on the western side of the delta, and have involved a certain amount of dredging and filling of the tidal flats.

Fairly extensive water quality data are available for the Kitimat River, estuary and Kitimat Arm as a result of observations by the industry located there. Water pollution sources include treated municipal sewage which causes minor enrichment of Kitimat river waters; treated pulpmill effluent which causes more significant enrichment and has allegedly tainted the annual eulachon run; smelter wastes whose fluoride content is being reduced with the substitution of dry scrubbers over wet scrubbers; logging within the watershed which allegedly keeps the silt load of the river higher than normal; log handling and storage in estuarine waters, whose facilities are being reduced in number; and shipping in and out of Kitimat Harbour, which is likely to increase with increasing development. Major air pollution sources include the Alcan smelter, whose emissions have caused visible vegetation damage in the path of the emissions plume, the Eurocan pulp mill and broadcast slash burning in the Kitimat Valley.

Plans for future development within the District of Kitimat include the phasing out of log storage facilities in Minette Bay and the development of the area for recreational uses. The establishment of an industrial, utility and transportation corridor linking the Port of Kitimat with the Canadian National Railway and potential industrial areas is currently under review of the District of Kitimat Planning Department and Alcan. Studies to evaluate the feasibility of an oil pipe line terminus on the west shore of Kitimat Arm are being carried out in conjunction with assessments of environmental impact.

1. INTRODUCTION

1 (i) GENERAL

The Kitimat River estuary located at the head of Douglas Channel (Latitude 54° 00' N and Longitude 128° 40' W), is 145 kilometres (90 miles) inland from Hecate Strait and 715 kilometres (444 miles) northwest of Vancouver by water, via the "inside passage".

For the purpose of this report the boundaries of the study area are defined as follows: On the landward side, the northern limit is delineated by the northern end of Lakelse Lake, latitude 54° 25' north and longitude 128° 32' west; the southern limit is marked by the Kitimat Harbour limit and the south end of Coste Island, latitude 53° 49' north and longitude 128° 50' west. Mount Davies (2,028 m) and the headwaters of the Kitimat River mark the eastern limit of the study area, while Jesse Lake (to the south) and Larsen Ridge (1,340 m) (to the north) roughly define the western limit, (Figure 1.1).

The Kitimat River with an average annual discharge of 134 cms (4,740 cfs), provides the main source of freshwater inflow to the estuary. Additional, but lesser amounts are contributed by a series of small creeks emptying into Minette Bay, and Wathl Creek, Bish Creek, Emsley Creek and Jesse Lake, all discharging into Kitimat Arm.

Kitimat, a planned community with a present day population of 13,000, was built in the early 1950's to accommodate the employees for the new Alcan aluminum smelter, capable of producing 300,000 tons of aluminum a year. Utilizing all the modern techniques of town planning available, Kitimat was planned as a model town, incorporating the natural physical features of its surrounding environment for recreational amenities, without losing

2. Introduction

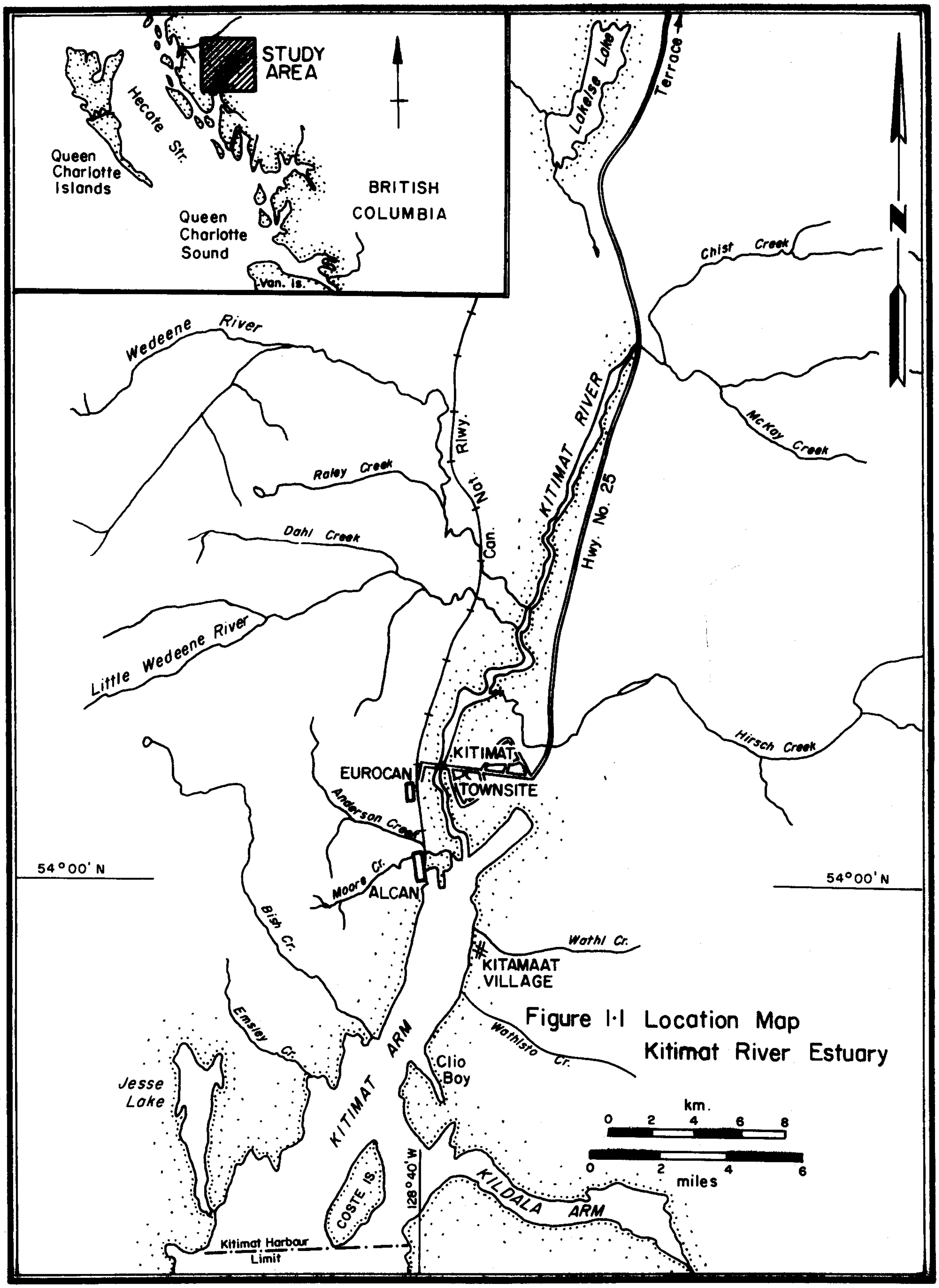

Figure 1·1 Location Map
Kitimat River Estuary

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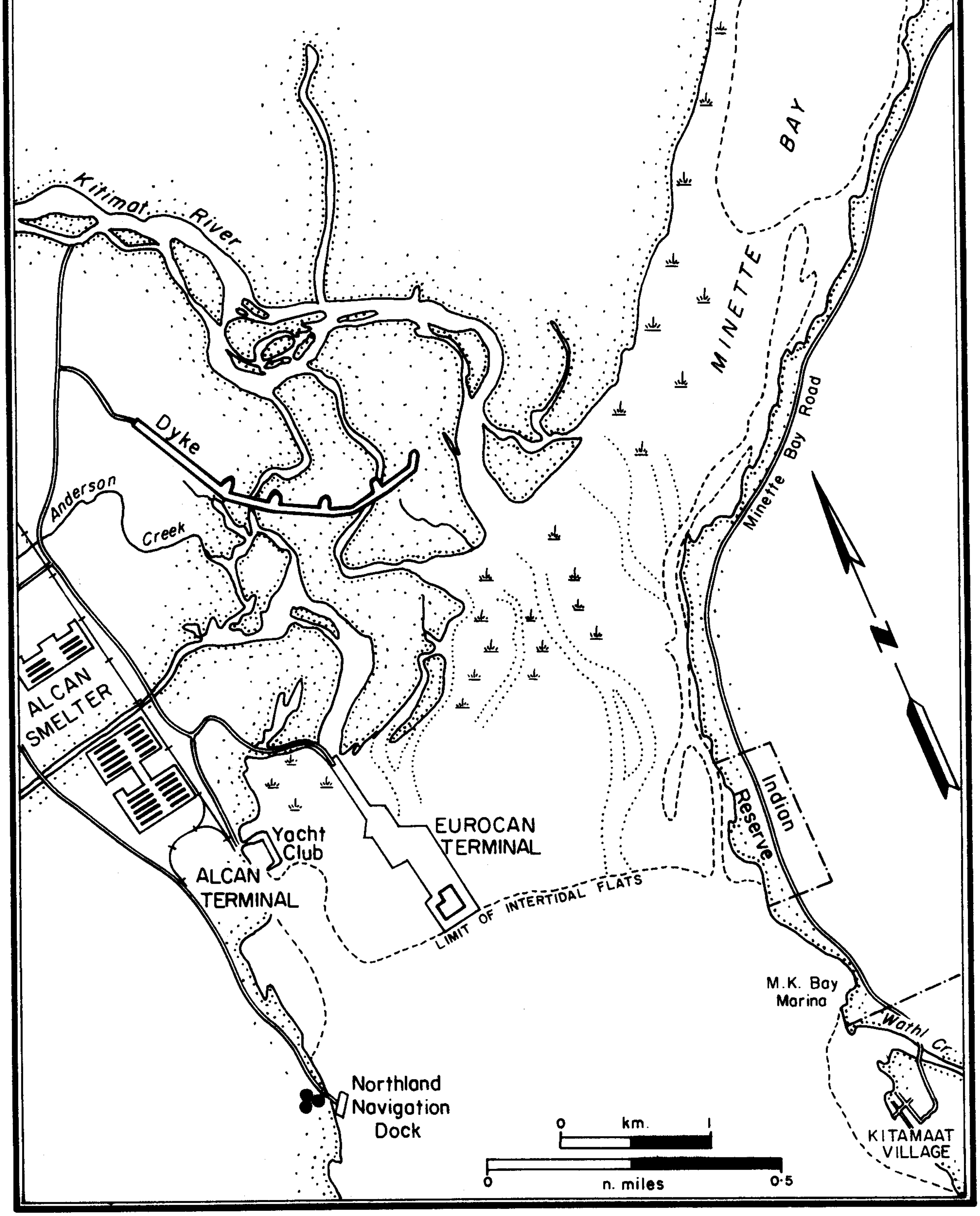
Figure 1·2 The Kitimat River Estuary (based on Can. Hydrographic Chart No. 3736)



the historical significance of the area and its Indian folklore.

Designed for an ultimate population of 50,000 people by 1990 (Stein, 1952), Kitimat is currently supported by two major industries (Alcan and Eurocan) employing a total of almost 4,000 persons, and a logging industry utilizing the available natural timber resources of the Terrace - Kitimat Valley. While the soils in the area are generally only suitable for farming in the vicinity of Lakelse Lake, extensive deposits of sand and gravel in the valley provide an economically beneficial natural resource to the region

Development on and adjacent to the estuary has been confined to the northwestern sector (Figure 1.2). Log storage and booming operations in Minette Bay are being phased out, and plans to develop the recreational potential of the eastern sector of the estuary (including Minette Bay) are currently being formulated by the District of Kitimat Planning Department. These and other aspects of the use of the estuary by man and animals are discussed in the subsequent sections of this report.

1 (ii) HISTORICAL PERSPECTIVE

According to Indian folk lore, the Haisla Indians have been living in Kitamaat Village for nearly 600 years. The Haisla, one of three dialect groups of the Kwakiutl Indians, separated by geographical divisions, live in the region surrounding Douglas Channel and Gardner Canal. The northernmost of the Kwakiutl group, the Haisla are best known by their Tsimshian names Kitimat and Kitlope. The name Kitimat comes from the Haisla spelling "Kitamaat", meaning "people of the ever snowing valley".

The Indian legendary history of the area has been documented by Holland (1954), in an article based on an interview with Guy Williams (WAH - TAH) a member of the Eagle Clan of the Kitamaat

Tribe, and in the "Tales of Kitamaat" by Robinson (1961). Kitamaat Village was little influenced by European culture until 1876, when one of the village inhabitants travelled to Victoria and was converted to Christianity. On his return to Kitamaat, he spread his new found beliefs, with much opposition from the village shamans (Robinson, 1961). In 1893 the first ordained minister came to Kitamaat, and a residential school, a new church and a new mission house was erected. Details of the work of the early missions has been described by Large (1957).

The first detailed survey of the Kitimat Estuary was made by Captain Vancouver during his expedition to British Columbia in the years 1792, 1793 and 1794. The following is an account of his expedition from Endersby (1954).

"The first year [1792] he worked up as far as Burke Channel and the following year he surveyed much of the area further north, including Douglas Channel, the Skeena River estuary (though the river itself was missed), Observatory Inlet, and the Portland Canal. A party under Mr. Whidbey, the Chief Officer of Captain Vancouver's ship "Discovery", spent a little over a week in the channels and inlets just south of Kitimat. Arriving at the junction of the Gardner Canal and Devastation Channel on June 25th, 1793, they proceeded to explore the Gardner Canal, after which they made their way up toward the present site of Kitimat. They explored Kildala Arm on June 29th and Kitimat Arm on June 30th, after which they rejoined the "Discovery" and travelled northward toward the Skeena, reaching a point near its mouth on July 9th."

One hundred years later (1894), the first white settler, George Anderson, cleared a small piece of land for farming near what is now known as Anderson Creek. Some of the logs obtained from the clearing of this land were used to construct buildings, while the remainder were burnt, as was the practice of the day. This is the first known operation of logging in the Kimimat Valley.

The first recorded logging operation in the Kitimat Area was that of Rudolph Braun, who towed his logs to the Swanson Bay Pulp Mill, some 129 km (80 mi.) south of Kitimat in Graham Reach. The "mill", established by Pacific Mills of Vancouver in 1906, operated until 1923, when it closed and moved to Ocean Falls (Holland, et al., 1972).

The annual eulachon run provided a major source of food for the Indians of the area. Eulachon grease, extracted from the fish by boiling, was considered a gourmet's delight by neighbouring bands. This resulted in the establishment of "grease" trails by which this commodity was transported from the coast to the interior. At least five such trails existed in northern British Columbia. The following is a description of the Kitimat grease trail from Kaser (1974).

"The Kitimat grease trail provided southerly communication running from Copper River down to Onion Lake and to Kitimat via the Kitimat River. The Kitimat Trail was used in the early part of the century as a mail run during winter and later became a tote road along the survey of the proposed Kitimat Omineca Railway."

In 1900, the British Columbia Provincial Legislative granted a charter to a group of Victoria and Vancouver businessmen to build a railroad from Kitimat to Omineca (named after the Omineca Mountain Ranges). Their Company was known as the Pacific, Northern and Omineca Railway. The railway was not built, and the Companys' charter was purchased in 1905 by the Grand Trunk Pacific Railway. As early as 1902 Kitimat was favoured as the western terminus of a second trans-continental railway, but lost out to the more favoured Kaien Island (Prince Rupert) location. Prior to the final decision on the Prince Rupert site the Grand Trunk Railway surveyed an alternative route through the valley to Kitimat This and the previous Pacific, Northern and Omineca Railway proposal caused considerable land speculation along the proposed route.

"A wharf and a hotel of sorts were built on the shore of Kitimat Arm, a "tote" road was hacked through to Terrace, a grid subdivision plan was registered, a score of lots was sold, and a number of homesteads developed. Most of the settlers drifted away when Prince Rupert instead of Kitimat was chosen as the rail terminus, although a number remained for some years and made their living hand logging, trapping, fishing and farming (Endersby, 1954)."

From a list of settlers in Kitimat between 1911 and 1915, obtained from one of the settlers living there at that time, it appeared that there were about 35 people living in the area (Northern Sentinel, 1964). However, the lack of a road to Terrace, enlistment for World War I, accidents, and a lack of education facilities soon decreased their numbers, and by 1941 all were gone.

In April, 1951, the general contractor for the Alcan aluminum smelter to be built at Kitimat, chartered a 72-foot coastal boat and moved into the area with 10 men to establish the first beach camp (Aluminum Company of Canada, 1954). On August 3, 1954, H.R.H. the Duke of Edinburgh watched the pouring of the first aluminum ingot at the Kitimat smelter.

2. GEOLOGY AND SOILS

2 (i) GENERAL GEOLOGIC HISTORY

The Kitimat River system and its estuary lie within the Kitimat Ranges of the Coastal Mountains of the Western Cordillera (Holland, 1964). The granitic mountains of the Kitimat Ranges, form the central section of the Coast Mountains, and extend for more than 300 kilometres from the Nass River in the north, to the Bella Coola River in the south. Generally the peaks are between 2,000 and 2,200 metres in elevation. Many overridden in the past by ice,are round topped, with cirques on their north and northeastern sides. The higher peaks and ridges are sharp crested with remnants of glaciers and some permanent snowfields. Major rivers cross the ranges in valleys less than one hundred metres above sea level. The highest mountain in the ranges, Atna Peak (2,755 metres), is located 40 kilometres southeast of Kitimat.

It has been suggested that in pre-glacial times the Nass and Skeena Rivers flowed through the Kalum-Kitimat Valley to Kitimat Arm, but were subsequently diverted to their present westward course by headward erosion. The time of this event has not been determined, though it is believed to have occurred some time prior to the formation of the Cordilleran ice-sheet (Duffell and Souther, 1964). Ice, that filled the valley during the Pleistocene period, moved southward down Kitimat Arm. As the ice receded northward, toward the end of the period of glaciation, it was followed by an arm of the sea that drowned the valley up to at least the 183 m (600 ft.) contour. It is not known how far the glacier retreated up the Skeena Valley, as no marine deposits have been recognized beyond Williams Lake (northeast of Lakelse Lake).

2 (ii) BEDROCK GEOLOGY

The first geological report on the Kitimat area was made in 1876 by James Richardson of the Geological Survey of Canada. Following a visit to the area with a Canadian Pacific Railway surveyor, he described briefly the features of the Kitimat Valley and some of the surficial deposits associated with them.

Geological mapping of the area of the Coast Mountains, between latitudes 52°N and 55°N (including Kitimat and Douglas Channel), has been carried out on a reconnaisance scale of one inch to four miles, by Souther (1964) and Roddick, Baer and Hutchison (1970). For a detailed description of the general and economic geology of the Kitimat area, the reader is referred to Duffell and Souther (1964). Following three years (1953 to 1955) of field work in the Terrace - Kitimat area, they concluded that "the main body of the Coast Intrusions in the Terrace map-area is a composite batholith of granitoid rock that resulted from separate emplacements of granitic material over a long period of time. The exact limits of this period are unknown, but it is indicated that intermittent emplacement occurred throughout a large part of the Mesozoic era" (Appendix 2.1).

In the Douglas Channel - Hecate Strait map-area, granitic rocks underlie about 88 percent of the land area (Roddick 1970). The general geology of the Terrace (Kitimat) map-area has been described by Duffell and Souther (1964) as, "that of a part of the eastern contact of the Coast Range batholith, and the flanking metamorphosed sedimentary and volcanic rocks that range in age from late Paleozoic to early Cretaceous". The latter may be seen in the localized outcrops visible to the north and west of Kitimat Townsite, and on the east side of Iron Mountain. In general the eastern side of the Kitimat Valley is flanked by the granitic rocks of the Coast Mountains, while to the west of the valley a ridge of

Jurassic rocks composed mainly of andesite, breccia, tuff, greywacke and argillite separates the unconsolidated deposits in the valley from the Cretaceous igneous intrusions. Small areas of Triassic limestone-boulder conglomerate are exposed on ChistCreek, and HirschCreek in the vicinity of Fire Mountain, and at the head of McKay Creek.

Fossil evidence has been obtained to prove the existence of rocks of Permian, Triassic, Jurassic and Cretaceous age, but their boundaries are difficult to establish. Duffell and Souther (1964) in their description of the area suggest an unconformity between volcanic rocks, referred to by them as the Hazelton Group and the overlying sedimentary sequence referred to as the Bowser Group (Table 2.1).

2 (iii) SURFICIAL GEOLOGY

A description of the unconsolidated sediments (surficial deposits) in the Kitimat area, and in particular those underlying the Alcan Smelter site and Kitimat townsite, is contained in an unpublished report prepared for the Aluminum Company of Canada Limited, by V. Dolmage (1956).

Dolmage states that "during the Glacial Period the land was depressed, presumably by the weight of the ice, as much as 1,000 feet [305 m]. Isostatic rebound at the end of the period of glaciation, about 10,000 years ago, resulted in a land rise in the order of 183 m [600 ft.]. Prior to the rise of the land Douglas Fjord extended inland at least as far as Kitsumkalum Lake and, in the vicinity of Kitimat was about 183 m [600 ft.] deep".

Studies of the post-glacial and glacial deposits in the Kitimat-Terrace area (Armstrong, 1966) produced evidence that the withdrawal of the Cordilleran ice was followed by an invasion of the sea for at least 80 km (50 mi.) inland from its present location.

Table 2.1 Table of Geologic Formations - Kitimat Area (From Duffell and Souther, 1964)

Era	Period or Epoch	Formation	Lithology
Cenozoic	Pleistocene and Recent		Sand, gravel, clay, silt
			Unconformity
Mesozoic or Cenozoic	Cretaceous	Coast Intrusions	Mainly biotite granodiorite and adamellite, with border zone of hornblende granodiorite, quartz diorite, diorite, and migmatite. Outlying stocks of pyroxene-quartz diorite and gabbro
			Intrusive Contact
Mesozoic	Upper Jurassic and Cretaceous	Bowser Group	Fossiliferous marine and terrestrial conglomerate, greywacke, and shale
			Unconformity
	Jurassic	Hazelton Group	Porphyritic and amygdaloidal andesite flows; minor basalt, dacite, and rhyolite. Porphyritic andesite breccia, tuff, greywacke, argillite.
			Conformable Contact
	Triassic?		Limestone-boulder conglomerate, greywacke, shale
			Unconformity
Palaeozoic	Carboniferous and Permian		Fossiliferous white limestone, argillaceous grey limestone, shale; greenstone

Armstrong reported that "extensive marine deposits containing shells were found up to elevations of 400 feet (122 m) or more. These are overlain by outwash sand and gravel up to elevations of 750 feet (229 m) and probably represent marine deltas. In several places a glacial till was also found overlying marine clay, possibly representing a late advance of Cordilleran ice. The evidence suggests the land in Kitimat-Terrace Valley was depressed at least 1,000 feet (305 m) below its present elevation during Cordilleran glaciation".

Between Lakelse Lake and Kitimat Arm, Pleistocene and Recent deposits of alluvial sand, gravel and marine or glacio-marine clay cover most of the Kitimat Valley. These unconsolidated sediments are in some cases up to 152 m (500 ft.) thick (Duffell and Souther, 1964), and are generally restricted to elevations below 300 m (984 ft.) in the Kitimat Valley, and some of the larger tributary valleys, such as the Wedeene (Clague and Hicock, 1976).

Estuarine and/or marine deposits of silt and sandy blue-grey clay containing shells are exposed along the banks of the Kitimat River from its mouth up to the point where it turns eastward out of the main valley. Extensive deposits of marine clay, resting directly on glacially polished bedrock, are exposed in road-cuts along the east side of Lakelse Lake and along the railway west of Lakelse Lake. "The most northerly exposure of marine clay was noted near the bridge across Williams Lake where about 65 feet (19.5 m) of clay is exposed at an elevation of 400 feet (122 m) above sea level (Duffell and Souther, 1964)." The presence of marine clays and raised delta sediments, as represented by local landforms such as the sand hill east of the Townsite and gravel terraces south of Hirsch Creek, provide good evidence that sea level is at least 183 m (600 ft.) lower than at the close of the Pleistocene. The flat top of the sand hill and the highest of the terraces near Hirsch Creek, presently stand at about 183 m (600 ft.) in elevation.

Fossil evidence suggesting a marine origin for the clays found in the vicinity of Lakelse Lake has been reported by Wagner (1959), Duffell and Souther (1964), and Smith (1965). Exposures of clay near Furlong Creek (northeast corner of Lakelse Lake) have been described by Duffell and Souther as containing marine shells. These were identified as a marine bivalve *Mytilus edulis*, indicating a marine origin for the clay.

Dolmage (1956) described the sedimentary formations in the Kitimat area (from oldest to youngest) as glacial drift and till, marine silts and clays, raised deltas, and presently forming deltas. He also described their distributions, thicknesses and relations to one another. Marine silts and clays are the dominant sediments in the general area of the Kitimat Townsite and Alcan smelter site. They extend from 91 m (300 ft.) above sea level to more than 91 m (300 ft.) below sea level, and are exposed to view in the residential area of the Townsite (Dolmage, 1956). They have been explored by drilling, both in the Townsite and the smelter site.

In the residential area of the Townsite, they consist of an upper stratum of clay about 21 m (70 ft.) thick resting on a thicker series of fine sands. These sand beds have been observed in road cuts in the Hirsch Creek Valley. Beds up to 14 m (45 ft.) thick have been encountered by drilling. The clay has been described by Dolmage (1956) as medium hard on top but becoming softer with depth. The high impermeability of the clay results in a rapid run-off during periods of heavy rain. This combined with the softness of the clay and its close association with seams of sand and silt, has resulted in numerous instances of gullying and minor mud slides.

The smelter site is underlain by sedimentary deposits varying in depth to a maximum of 107 m (305 ft.). They are of a complex nature including sand, gravel, silt and marine clays (Hardy and Ripley, 1954). The necessity of using fill varying in depth to a maximum of 9 m (30 ft.) and covering an area 366 m (1200 ft.) by 488 m (1600 ft.) in order to raise the smelter site to a working level prior to construction, presented major problems in the forecasting of the amount and rate of settlement, below the fill, in the irregular natural soil deposits. About 80 holes were drilled in the smelter site in conjunction with a program of foundation investigations. Subsequent drilling programs were undertaken at the Alcan dock and plant site areas for the purpose of obtaining more detailed subsoil information at specific locations after the general plant layout had been determined.

The location of these test holes and the subsoil conditions have been documented by Hardy and Ripley (1954). The log of a typical test hole, from this program of foundation investigations, shows about 5 m (15 ft.) of overburden overlying 27 m (90 ft.) of gravel, on top of a thin layer of sand 5 m (15 ft.) thick and a bed of sand-silt 61 m (200 ft.) thick. These in turn overlie clay 18 m (60 ft.) thick resting on bedrock, or in some instances on glacial sediments.

A number of events associated with marine clay have been observed in the Kitimat area, and have been documented by Golder, Brawner and Associates Limited (1975). A summary of these events is contained in Appendix 2.2.

On April 27, 1975 a submarine landslide in the order of 2.3 million cu.m (3 million cu. yds.) of soft marine clay occurred at Moon Bay on the eastern side of Kitimat Arm.
At the request of the B.C. Water Resources Service the slide was investigated by Golder, Brawner and Associates Limited (1975). Their report concludes that the submarine slide occurred as a result of shearing failure in the soft marine clay that forms

part of the bottom sediments in Moon Bay. Investigations indicated that the slide was triggered by relatively minor construction operations on soil deposits that were in a state of critical equilibrium. It occurred during the construction of a breakwater made of rockfill and sand dredged from the bottom of the inlet.

Little is known about the sediments composing the Kitimat Delta. Sediment sampling of the intertidal zone was carried out in conjunction with a preliminary survey of the intertidal invertebrates of the Kitimat River estuary (Levings, 1976). Grain size analyses of these sediments have, at the time of writing, not been completed. Test holes, drilled by Alcan in 1954 on the eastern side of the delta, indicated the thickness of the beds of silt, sand and gravel forming the delta, are a minimum of 45 m (150 ft.) thick (C.D. Howe Western, 1971). Although no data are available to quantify the rate of growth of the delta, Dolmage (1956) has stated that "the present Kitimat delta is growing rapidly", and has a steep submarine slope on the delta front. Calculations based on contour levels shown on hydrographic charts show the slope of the delta front to be in the order of 10 degrees.

Analyses of sediment samples collected south of the Eurocan loading dock, during an environmental surveillance survey of Kitimat Arm (Bradshaw, 1976), showed that the seabed of the estuary in this area was covered with fine sand and silt. A summary of the grain size analysis for samples taken at fourteen stations is contained in Table 2.1. A comparative scale of sediment types and sizes is shown in Table 2.2.

2 (iv) ECONOMIC GEOLOGY

While mining has played a major role in the development of the Terrace map-area, few economic deposits of metallic ores

Table 2.2 Summary of grain size analysis for sediment samples taken at Kitimat Arm, June 24, 1975 (Bradshaw, 1976)

Station	% Coarse Sand >0.5mm	% Medium Sand 0.25-0.5mm	%Fine Sand 0.0625-0.25mm	% Silt <0.0625mm
1	1.2	4.2	34.5	60.1
2	0.4	0.2	16.4	83.0
3	0.6	3.5	17.2	78.7
4	0.1	0.2	16.6	83.1
5	1.8	9.4	35.0	53.8
6	97.0	0.8	1.8	0.4
7	3.7	40.0	2.0	54.3
8	1.5	0.2	11.7	86.6
9	0.6	2.5	56.0	40.9
10	0.8	1.0	35.1	63.1
11	0.1	0.2	2.2	97.5
12	0.1	0.1	24.5	75.3
13	0.3	4.1	54.0	41.6
14	0.1	0.4	3.8	95.7

Table 2.3 Grain size scale for sediments

GRAVEL	-	coarser than 2.00 mm	
SAND	-	very coarse	2.00 - 1.00 mm
	-	coarse	1.00 - 0.50 mm
	-	medium	0.50 - 0.25 mm
	-	fine	0.25 - 0.125 mm
	-	very fine	0.125 - 0.0625 mm
SILT	-	0.0625 - 0.0039 mm (62.5 - 3.9 microns)	
CLAY	-	finer than 0.0039 mm (<3.9 microns)	

have been discovered in the Kitimat region. The Drum Lummon Copper Mines Limited, incorporated in 1915, and situated on the west shore of Douglas Channel, approximately 35 km (22 mi.) south of the head of Kitimat Arm, were closed in 1930 (B.C. Minister of Mines, 1930). This mining property has been described under the historical development of the area in Section 1 (ii) of this report.

The possibility of mining concentrating-grade magnetite deposits from Iron Mountain, 16 km (10 mi.) north of Kitimat, is now more feasible than in the past, because of the availability of rail and port facilities.

Between Lakelse Lake and Kitimat Arm, Pleistocene and Recent outwash and stream deposits of sand and gravel, up to 152 m (500 ft.) thick, provide an excellent source of materials for use by the construction industry in buildings, roads and in fill. These deposits have been described briefly by Duffell and Souther (1964).

A more detailed investigation of the sand and gravel resources of the Kitimat-Terrace area was recently undertaken by the Geological Survey of Canada (Clague and Hicock, 1976). The largest deposits in the area are located north of Terrace and north and south of Lakelse Lake. Representative sediment samples were analyzed for grain size. The results showed that gravel constituted 54 to 91 percent, sand 9 to 44 percent and silt and clay 0 to 2 percent. These deposits presently supply most of the aggregate used in the Terrace-Kitimat area, and together represent a volume of sand and gravel in the order of $10^{10} m^3$.

River gravel bars have also been used as a source of construction materials. A record of the river areas subjected to gravel removal is contained in the annual narrative report prepared by the Environment Canada fishery officer for the Kitimat

District (Christiansen, 1971, 1972, 1973; MacDonald, 1974, 1975).

In 1975, three gravel removal permits were issued under the British Columbia Gravel Removal Order (Fisheries Act, Canada, 1974) to remove gravel in the Kitimat River, Hirsch Creek and Chist Creek. A permit to displace 612 m^3 (800 cu.yds.) of gravel was issued to Eurocan Pulp and Paper Company Limited in connection with work done to modify their mill effluent outfall on the Kitimat River. A permit was issued to the District of Kitimat to displace a maximum of 382 m^3 (500 cu. yds.) of gravel from Hirsch Creek for the purpose of flood control in Hirsch Creek Park, and another permit was issued to Eurocan Pulp and Paper Company Limited to displace a maximum of 382 m^3 (500 cu.yds.) of gravel near the mouth of Chist Creek.

2 (v) SOILS

Little data is available to describe the soils of the Kitimat area. The main sources of soils information are (1) a soil survey of the Bulkley-Terrace area (Farstad and Laird, 1954); (2) a description of soils underlying an area of the town of Kitimat, proposed for residential expansion (Associated Engineering Services Limited, 1976); (3) Soils of the Prince Rupert - Smithers bulletin area (B.C. Dept. of Lands, Forests and Water Resources, 1974); and (4) landform mapping of the Kitimat Valley for reforestation purposes, B.C. Forest Service Research Division (Keser and St. Pierre, 1972).

Alluvial soils occur on terraces, pans and flood plains in the valleys of the main rivers and their tributary streams. In the Coast Mountain valleys glacial till deposits are limited in extent. In the Kitimat Valley they commonly have been buried to depths in excess of 100 m (328 ft.) by alluvial deposits of sands, silts and marine clays.

19. Geology and Soils

Organic soils have developed in areas where there is poor drainage and a build up of organic material associated with decaying vegetation. This has resulted in the formation of peat (Fibrosols) and muck soils (Humisols). A layer of peat, varying in depth from 15 cm (6 in.) to over 3 m (10 ft.), covers the silts and clays underlying an area between the Town of Kitimat and Minette Bay, which has been proposed for residential expansion.

The main soil groups found in the Kitimat Valley and lands adjacent to the estuary are Podzols and Brown Podzolic soils associated with the forested areas, Chernozems found in patches of semi-open grassland, Regosols on recently deposited river alluvium and Organic soils associated with decaying vegetation (B.C. Dept. Lands, Forest and Water Resources, 1974).

Podzols are the dominant soils of the area, and because of their association with heavy rainfall and a long, cool growing season they occur only where the maritime influence is strong. For a detailed description of these and the other soils found in the Kitimat Valley and adjacent areas, the reader is referred to Report No. 4 of the British Columbia Soil Survey (Farstad and Laird, 1954).

3. CLIMATOLOGY

3 (i) GENERAL

The climate of the Kitimat River estuary, during most seasons, is influenced by low-pressure systems that have moved eastward across the Pacific Ocean, along with their associated frontal systems. These impinge upon the Northwest Coast with greatest intensity in the fall producing an October peak in the distribution of precipitation at Kitimat. The north-south trending Kitimat Valley extending from Terrace to Kitimat Arm, provides a pathway for the flow of cold arctic air during the winter season. The climate of the estuary, while modified throughout the year by its proximity to Kitimat Arm and Douglas Channel still exhibits many of the characteristics of a continental type climate.

The town of Kitimat and the estuary, under the maritime influence of the west coast, experience mild winters and cool summers. Periods of heavy precipitation are prevalent in the fall. Winter snowstorms, both in the valley and on the surrounding mountains bear out the impression of the "ever snowing valley", as observed by the native Indian population.

Overcast skies, intense rain and strong winds are frequent during the period from October to March, but are less frequent during the summer months when periods of high pressure are more common. During the winter, deep masses of cold Arctic air are occasionally impounded on the east side of the Coast Mountains. These may rush down the narrow fiords at high speed, producing a sudden drop in temperature accompanied by high winds called "Williwaws" (B.C. Dept. of Lands, Forests and Water Resources, 1974) or "Squamishes", the strong northerly winds which flow down Howe Sound during the cold winter months (Hoos and Vold, 1975).

3 (ii) CLIMATOLOGICAL STATIONS

The Kitimat River estuary is one of the few estuaries on the British Columbia Coast for which long-term climatological records are available. Irregular measurements of temperature and precipitation have been taken since 1902 (Can. Dept. Env., 1973).

Regular measurements of temperature and precipitation began at the Alcan smelter site (Kitimat 2) in 1951, and at the new Kitimat Townsite in 1954. Since then the meteorological observations have been expanded to include the measurement of rate of rainfall, wind mileage and hours of bright sunshine.

Irregular measurements of temperature and precipitation were made at the Kitimat Station (Kitimat Mission site), south of Minette Bay, from 1902 to 1907 and precipitation measurements only from 1931 to 1948. The location of this inactive station and the active recording stations, Kitimat 2 and Kitimat Townsite are shown in Figure 3.1. The available weather data recorded at these stations, and a climate summary for the Kitimat Estuary area, are listed in Tables 3.1 and 3.2.

3 (iii) PRECIPITATION

The 1941-1970 precipitation normals for British Columbia (Can. Dept. Env., 1975) show that for the Kitimat area the month of October has the most precipitation (over 450 mm at the smelter site) and also the greatest number of days with measurable precipitation (23 days at the smelter site). June and July are the driest months, experiencing precipitation on an average of only 10 to 12 days. The distribution of precipitation throughout the year follows the pattern common to the North Coast of British Columbia with May to August being relatively dry months (approximately 50 mm to 80 mm per month in the Kitimat area) and October to February being excessively wet months (approximately 250 mm to 450 mm per

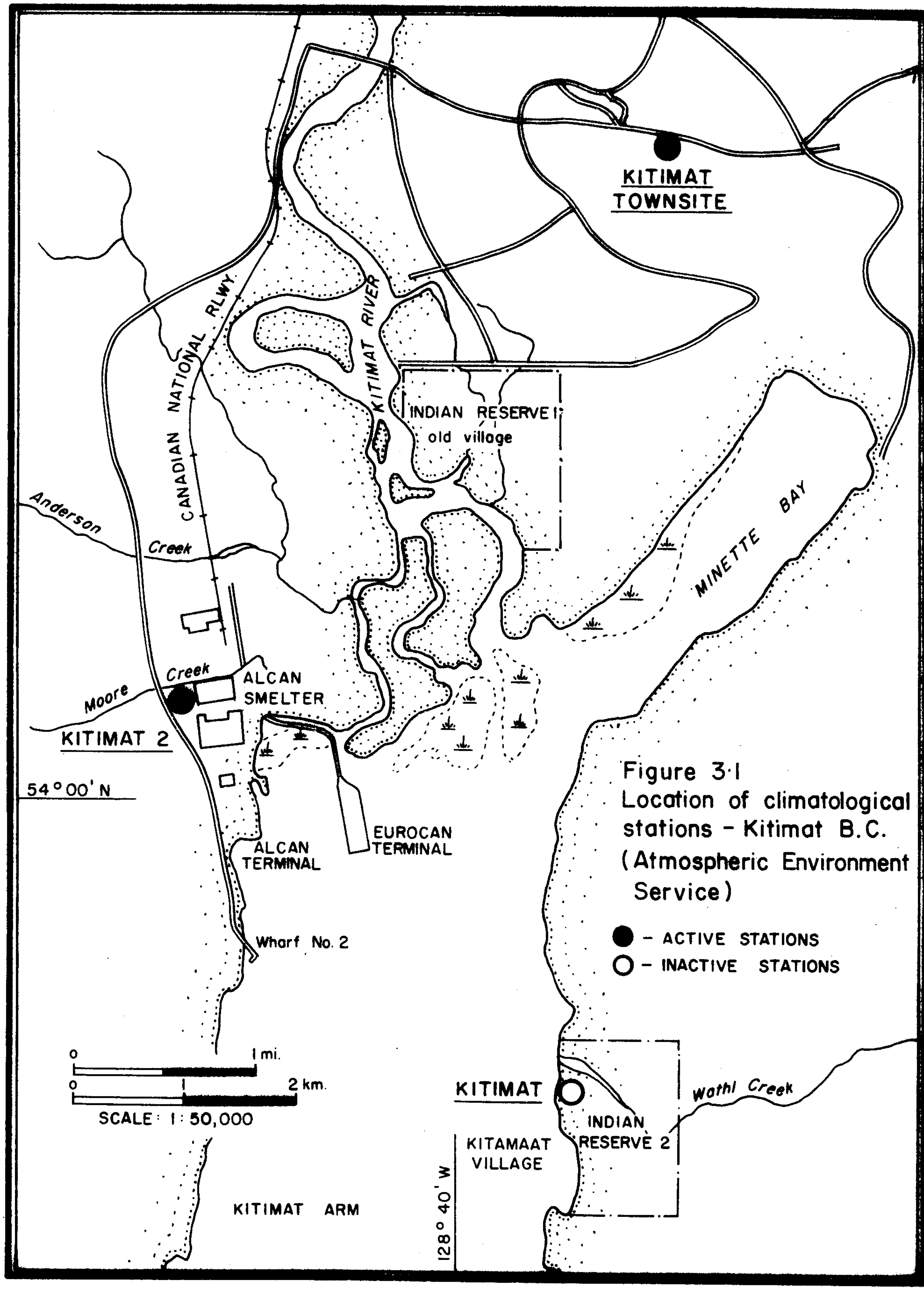


Figure 3·1
Location of climatological stations - Kitimat B.C.
(Atmospheric Environment Service)

Table 3.1. Kitimat River Estuary - available weather data (Canada Department of the Environment - Atmospheric Environment Service, 1975).

KITIMAT RIVER ESTUARY

Available Weather Data

Kitimat 2 $54^{o}00'$N $128^{o}42'$W 17m asl (Alcan smelter site)

Temperature & Precipitation	June 1951 - Continuing
Rate of Rainfall	February 1966 - Continuing
Wind Mileage	February 1966 - Continuing
Sunshine	February 1966 - August, 1973

Kitimat Townsite $54^{o}03'$N $128^{o}38'$W 128m asl (present Townsite)

Temperature & Precipitation	January 1954 - Continuing
Rate of Rainfall	January 1960 - December 1960 September 1961 - March 1962
Wind Mileage	January 1960 - March 1960 November 1967 - Continuing
Sunshine	February 1954 - April 1955 July 19 1957 - August 1961 April 1962 - January 1973 August 1973 - Continuing

Kitimat $53^{o}59'$N $128^{o}38'$W 6m asl (old Kitimat Mission site)

Temperature & Precipitation	October 1902 - September 1907
Precipitation	December 1931 - December 1937 January 1939 - June 1948 (some omissions)

Table 3.2. Kitimat River Estuary - climate summary (Canada Department of the Environment - Atmospheric Environment Service, 1975).

Temperature (adjusted to 1941 - 1970 Normal Period)	Kitimat Townsite	Kitimat 2
Mean temperature - Annual	6.6°C	6.9°C
Mean temperature - January	-4.2°C	-3.9°C
Mean temperature - July	16.2°C	16.8°C
Extreme maximum temperature	36.1°C	39.4°C
Extreme minimum temperature	-25.0°C	-24.4°C
Precipitation (adjusted to 1941 - 1970 Normal Period)		
Mean annual total precipitation	2,377 mm	2,826 mm
Mean annual rainfall	1,840 mm	2,399 mm
Mean annual snowfall	537 cm	426 cm
Wind		
Prevailing wind directions by hours	south(43%) north(27%)	south & southwest (43%) northwest(25%)
Mean annual wind speed	12.2 km/hr	9.0 km/hr
Strongest wind	N 56.3 km/hr	S 40.2 km/hr
Mean Annual Number of Days with:		
Measurable rain	165	168
Measurable snow	48	39
Measurable precipitation (rain and/ or snow)	195	195
Frost	129	111
Average Annual Hours of Bright Sunshine	1,447	1,065

month in the Kitimat area).

It should be noted that there is a considerable variation in recorded precipitation between recording stations and these must be taken into consideration when extrapolating for the estuary. For example, the mean annual precipitation measured at Kitimat Townsite is only 2,377 mm, compared to 2,826 mm measured at station Kitimat 2 (Table 3.2). This difference is most likely related to the contrast in local topographic factors between the two sites. Kitimat 2 is in close proximity to the mountain slopes to the west and north-northwest, whereas Kitimat Townsite enjoys a more open exposure in the centre of the valley. The Kitimat River estuary would be expected to receive an amount of precipitation lying between these two extremes.

While snowfall on the outer coast is generally light near sea level elevations, the Kitimat Townsite area averages between 400 cm and 600 cm of snow most winters (Can. Dept. Env., 1975). Measurable snowfall occurs on an average of 40 to 50 days a year with over 50 percent of the total seasonal fall occurring during the months of December and January (Landsberg, 1952).

Snowfall amounts are significantly influenced by local topographic features, primarily elevation, and are highly variable from year to year. While Kitimat Townsite receives a smaller amount of precipitation than the Alcan smelter site (Kitimat 2), it receives a considerably greater snowfall (Table 3.2), primarily due to its greater elevation. Annual snowfall amounts at Kitimat 2, nearest the estuary, have ranged from 846.3 cm in 1972 to a low of 193.5 cm in 1962. By way of contrast as much as 1003.6 cm have fallen in one year (1972) at Kitimat Townsite, and as little as 63.8 cm at Kitimat Mission (1940).

Mountain slopes in the area adjacent to the Kitimat Valley receive much greater average snowfall amounts. Over 2200 cm of snow were recorded in 1956 at the Kemano Kildala Pass climatological station, located at an elevation of 1610 m in the pass between the Kemano and Kildala Rivers, approximately 40 km southeast of Kitimat.

3 (iv) TEMPERATURE

Temperature records (Table 3.2) indicate little difference between values at Kitimat Townsite and Kitimat 2. The slightly higher mean annual temperature shown for Kitimat 2 is primarily the result of minimum temperatures which average about 0.5^{o}C greater there than at the Townsite. Differences in elevation (111 m) and proximity to the water appear to have had little effect on average temperatures at the two sites.

As indicated in Table 3.2, extreme temperatures over the period of record at the two stations are also in fairly good agreement. If one includes early records from Kitimat Mission, a temperature of 41.1^{o}C (106^{o}F) was recorded on July 20, 1907. It is difficult to verify such early records, since thermometer calibrations and reports on the condition of the Stevenson screen are lacking. However, even without that particular value, extremes at Kitimat reflect continental modification to the extent that extreme maxima are higher than those associated with many of the more exposed coastal sites, whereas extreme minima are lower. In both cases an outflow of air from the interior is associated with such extremes. In summer it is of a hot, dry type which permits temperatures to rise much above those of surrounding waters; in winter it is of the cold Arctic type, modified to some extent by its descent to sea level.

3 (v) WIND

Continuous records of wind speed and direction have been kept at climatological stations at Kitimat 2 and Kitimat Townsite since February 1966 and November 1967, respectively. The annual wind rose for Kitimat Townsite (Figure 3.2) shows the overriding influence of the orientation of Kitimat Arm and the Kitimat River Valley. Winds from the north and south are heavily predominant, accounting together for 70 percent of hourly winds. The mean wind speed is 11.8 km/hr with calms recorded on only 1 percent of all hours. The lower mean wind speed at Kitimat 2 (9.0 km/hr) (Table 3.2) primarily reflects the fact that the anomemeter there is closer to the ground (10 m compared to 14 m at Kitimat Townsite), although some part of the difference may be due to differences in exposure to the regional winds as a result of the elevations of the two stations involved. Strongest winds are from the north and are associated with outflowing Arctic air during winter months, although strong southerly winds generated by active Pacific storms also occur. In summer months strongest winds are from southerly directions.

Complexities in the wind regime of the Kitimat area introduced by seasonal progression, local topography, drainage winds and land and sea breeze circulations are revealed to some extent in Figures 3.3 and 3.4, which present percentage frequencies by direction for each month of the year at Kitimat Townsite and Kitimat 2 respectively. Figure 3.3, for Kitimat Townsite, clearly indicates that northerly winds are dominant during winter while southerly winds predominate in summer months.

Figure 3.4 reveals the somewhat different, although related, pattern at Kitimat 2. In this case, northwest winds are more frequent than north winds, and winds from the southwest and southeast augment those from the south. A closer examination based on detailed hourly distributions for each month (pers. comm. J. Emslie, AES) shows that these northwest winds are relatively light drainage winds flowing down Anderson Creek. During summer, northwest, west and southwest winds occur predominantly overnight and in the early morning to be replaced by a sea breeze circulation from the south or southeast during the afternoon. At Kitimat

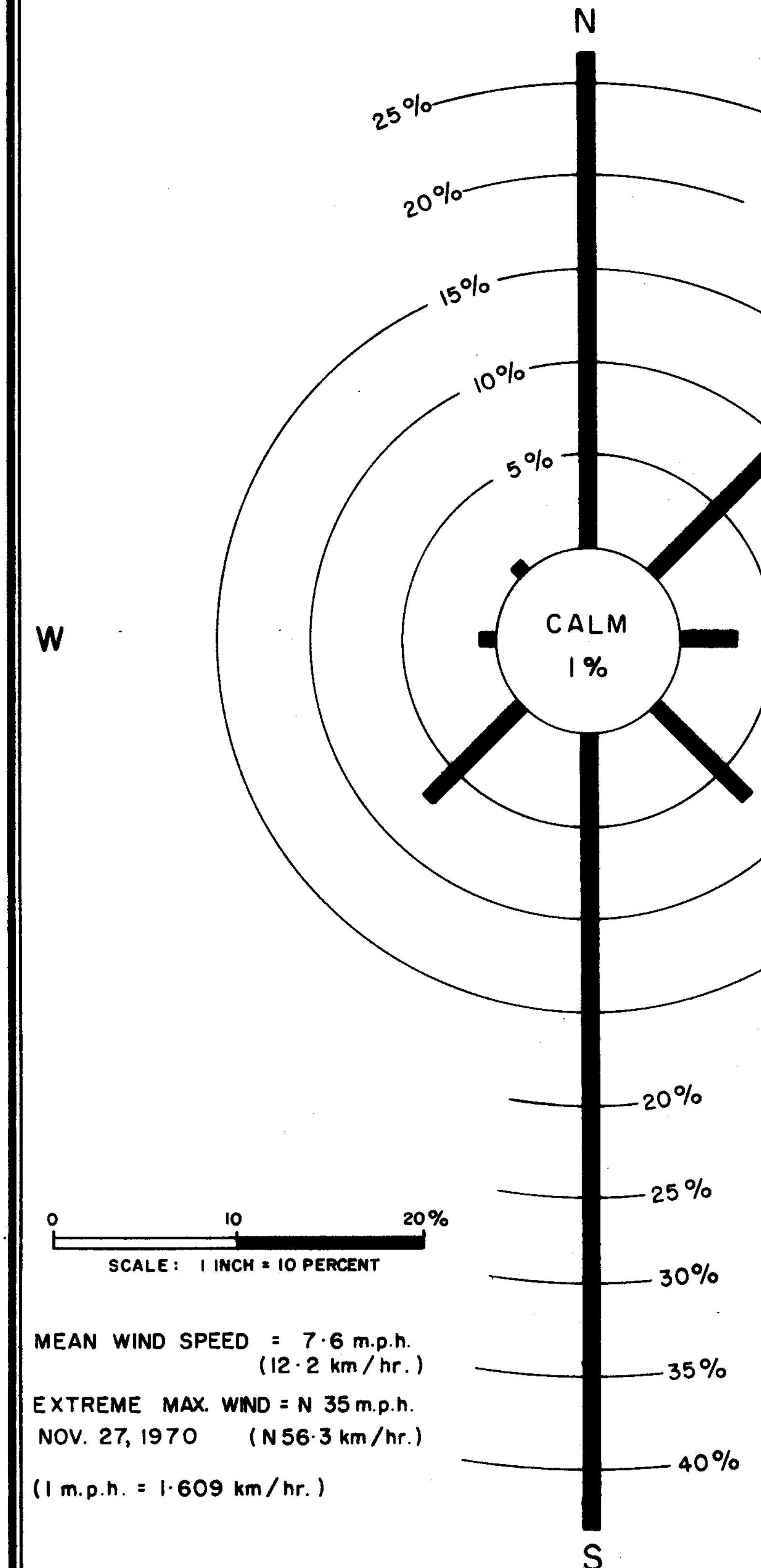


Fig. 3·2 Annual Wind Rose Kitimat Townsite Percentage Frequency and Mean Wind Speed by Direction — November 1967 to December 1972 (Canadian Atmospheric Environment Service)

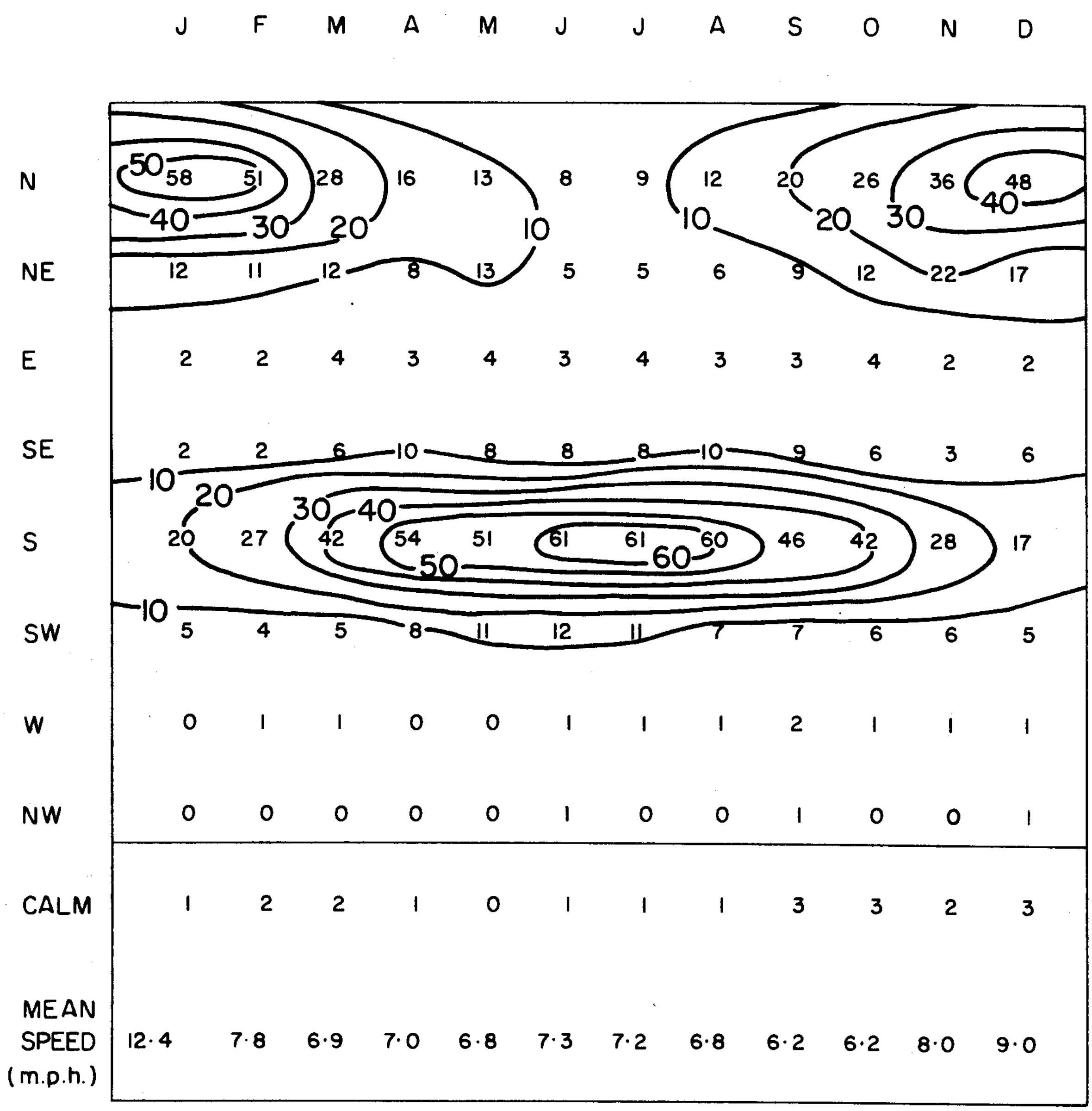


Figure 3·3 Kitimat (Townsite) - Percentage Frequency Wind Direction (and Calms) and Mean Wind Speed by Months - November 1967 to January 1974.
(Canadian Atmospheric Environment Service)

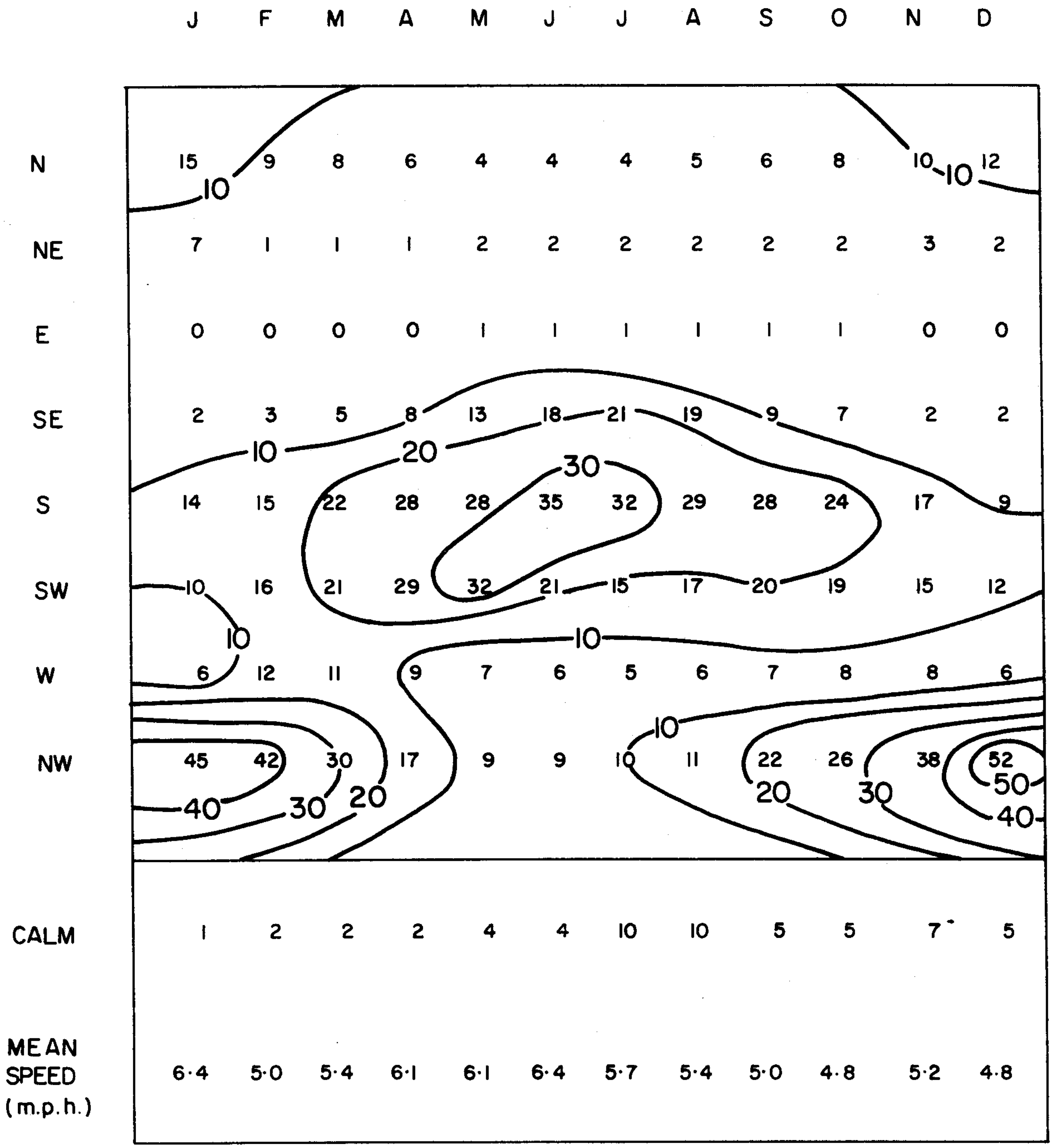


Figure 3·4 Kitimat 2 (Smelter) – Percentage Frequency Wind Direction (and Calms) and Mean Wind Speed by Months – February 1966 to January 1974.
(Canadian Atmospheric Environment Service)

Townsite these land and sea breezes are reflected in summer months by an increased frequency of north to northeast winds during the early morning and south to southwest wind during the afternoon.

3 (vi) OTHER PARAMETERS

For other parameters such as atmospheric pressure, vapour pressure, cloud cover and visibility, the closest observations to the Kitimat River estuary are those made at Terrace Airport, 60 km to the north. Detailed data summaries are available from the Atmospheric Environment Service.

Hours of bright sunshine, recorded at Kitimat 2 from 1966 to 1973, and at Kitimat Townsite since 1954, continue to be recorded at the Townsite climatological station (Table 3.1). The records show considerably more sunshine recorded at the Townsite (1,477 hours per year) than at Kitimat 2 (1,065 hours per year), reflecting the fact that the mountain ridge just west of the Kitimat 2 station cuts off the direct rays of the sun earlier in the afternoon than in areas further from the mountains.

Frost records for the Kitimat area indicate an average frost free period from May 3 to October 18 at the Kitimat Townsite and from April 28 to October 26 at the Alcan smelter site (Kitimat 2). The mean annual number of days with frost measured at Kitimat Townsite is 129 and at Kitimat 2 is 111 (Table 3.2).

3 (vii) AIR POLLUTION POTENTIAL

The potential for air pollution is a product of the topographical features of the surrounding area and of the various meteorological parameters. Surface-based inversions are frequent in north coastal inlets. In spring and summer, these are due to milder Pacific air overrunning the surface air layers, which have been cooled by the cold sea surface, and the effect is carried inland by the onshore prevailing wind. In winter they are due to the cold surface layers of outflowing Arctic air in the valley bottom. The seasonal percentage frequency of surface-based inversions at Kitimat in the late afternoon and early morning is shown in the following table:

	Winter	Spring	Summer	Fall
P.M.	40	55	50	40
A.M.	65	67	62	57

It thus appears that surface-based inversions are quite frequent both overnight and in the early morning in all seasons, as well as through the day in spring and summer.

Climatological summaries for the meteorological stations Kitimat 2 and Kitimat Townsite show that with approximately 2,500 mm of precipitation annually and measurable precipitation on 53% of days, the effects of rainout and washout of airborne pollutants should be quite effective. In summary, with a high percentage frequency of ground-based inversions in all hours and seasons, and winds which prevail in one direction for extended periods, either up or down the valley, it is expected that local episodes of high pollution concentration could be expected during periods of non-precipitation.

4. HYDROLOGY

4 (i) GENERAL

The Kitimat River (Figure 4.1), with its main tributaries drains an area of almost 200,000 ha (768 sq. mi.) (Can. Dept. Env., 1974). The major portion of the drainage basin lies to the east of the Kitimat Valley and is drained by the Kitimat River, Chist Creek, Hirsch Creek, Davies Creek and McKay Creek. The west side of the valley is drained principally by the Wedeene and Little Wedeene Rivers, Anderson Creek and Moore Creek.

The Kitimat River rises on the southwestern slopes of Mt. Davies (2,089 m) and flows in a northerly direction for approximately 24 km (15 mi.), at which point it turns and flows in a westerly direction for another 19 km (12 mi.) towards the Kitimat Valley. Entering the valley northeast of Iron Mountain (700 m), it is joined by Chist Creek and McKay Creek. The river then broadens, and flows southwards for 32 km (20 mi.), in a series of meandering channels, with an average grade of 2.6 m per km (15 ft. per mi.) (Ross, 1952), before discharging onto the tidal flats of the northwest portion of Kitimat Arm. South of Iron Mountain the Kitimat River is joined by its main tributaries the Wedeene River, the Little Wedeene River and Hirsch Creek. Anderson and Moore Creeks cross the Alcan smeltersite in "improved" channels, before joining the river close to its mouth.

Minette Bay, at the northeastern end of Kitimat Arm is fed by 7 small streams ranging from 1.6 km (1 mi.) to 4.8 km (3 mi.) in length and originating predominantly in the steeply sloping land to the east and southeast of the bay at elevations up to 427 m (1,400 ft.) (Acres Western Limited, 1967).

An additional source of freshwater inflow to the estuary south of Kitimat, is provided by Wathl Creek and Wathlsto Creek,

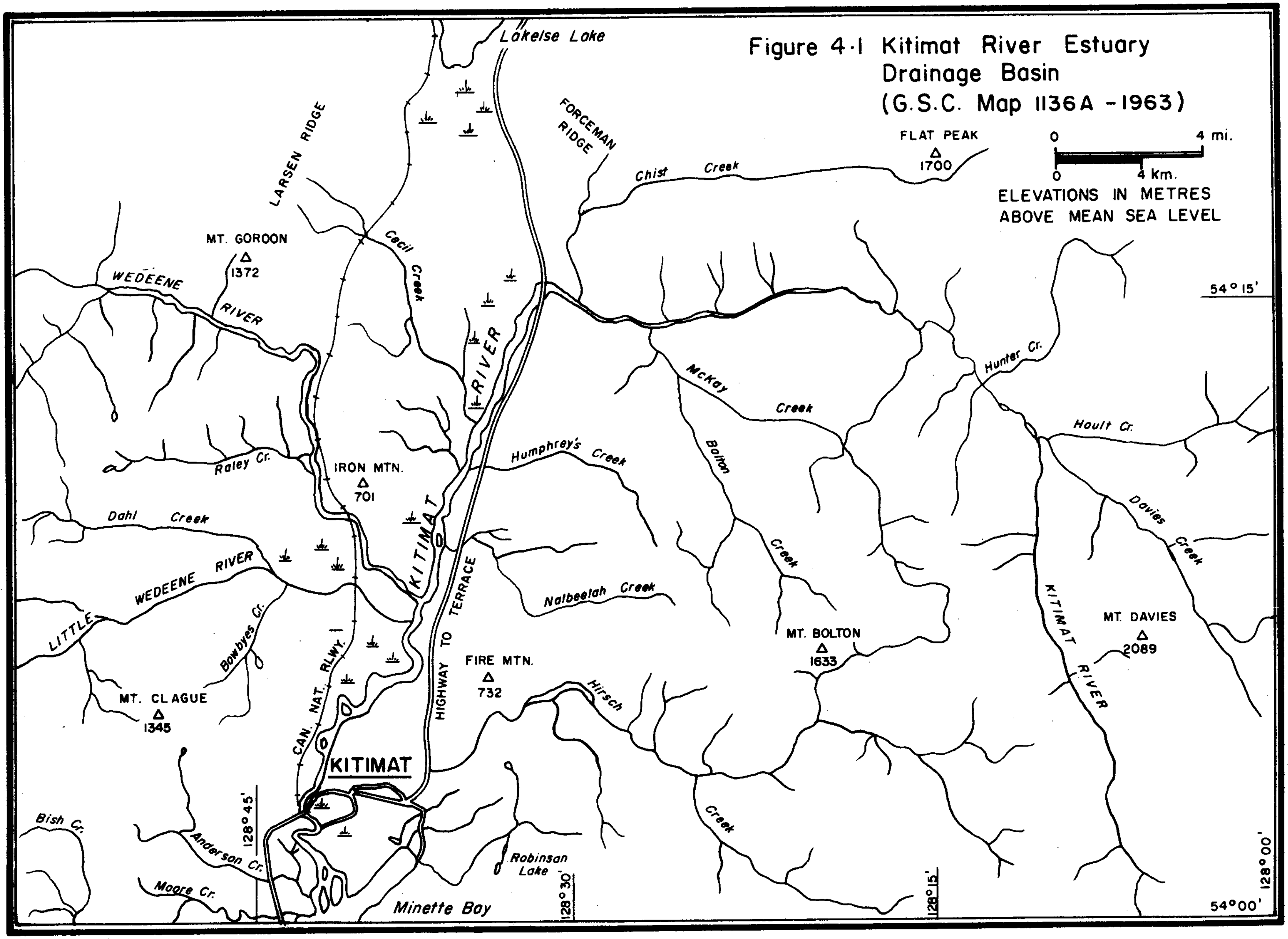


Figure 4·1 Kitimat River Estuary Drainage Basin (G.S.C. Map 1136A - 1963) which discharge on the east side of Kitimat Arm, between Minette Bay and Clio Bay. On the west side of Kitimat Arm, the major freshwater inflow to the estuary is provided by Bish Creek, Emsley Creek and Jesse Lake. The latter is fed by Jesse Creek, which drains an area 27 km (17 mi.) long by 8 km (5 mi.) wide. Jesse Lake, although surrounded by steep mountains, has a lake level of only 5 m (17 ft.) above high tide in Douglas Channel (Acres, H.G. and Company Limited, 1964).

4 (ii) STREAMFLOW GAUGING STATIONS

Continuous streamflow measurements have been made by the Water Survey of Canada on the Kitimat River (below Hirsch Creek), since 1964, and on Hirsch Creek (near the mouth) and Little Wedeene River (below Bowbyes Creek), since 1966. For additional information on these gauging stations the reader is referred to Appendix 4.1 and the Water Survey of Canada, surface water data records for British Columbia (Can. Dept. Env., 1976a).

Prior to these dates, flow measurements were obtained from a series of stage gauges established by Alcan below the Haisla Boulevard Bridge. Hydrologic data is available for the Kitimat River for the period 1957 to 1960, from a station above Hirsch Creek, and for the period 1960 to 1965 from a station at Sandhill (B.C. Dept. Lands, Forests and Water Resources, 1971).

The mean annual discharge for the Kitimat River from 1964 to 1973, was 134 cms (4,740 cfs), measured at Station 08FF001 below Hirsch Creek. The maximum mean annual flow for this period was 160 cms (5,650 cfs) and the minimum was 108 cms (3,820 cfs). The mean annual discharges, for the period 1966 to 1973, for Hirsch Creek (Station 08FF002) and Little Wedeene River (Station 08FF003), were 22 cms (776 cfs) and 17 cms (601 cfs) respectively.

The maximum instantaneous discharge for the Kitimat River was recorded during the 1974 flood. A flow of 2,020 cms (71,400 cfs) was recorded at Station 08FF001 at 0810 PST on October 15, 1974. Other record - flow data measured at Station 08FF001 on the Kitimat River are listed in the following table:

Table 4.1. Kitimat River record - flow data (Can. Dept. Env., 1976b,unpublished surface water data).

	cms	cfs	date
Maximum daily flow	1,647	58,200	Oct. 15, 1974
Minimum daily flow	9	325	Dec. 22, 1973
Largest mean annual flow	160	5,650	1967
Smallest mean annual flow	108	3,820	1970
Maximum mean monthly flow	385	13,600	June, 1967
Minimum mean monthly flow	14	485	Feb., 1972

Peak river flows generally occur during the Fall months of October and November, and during the months of May and June, following the snowmelt and subsequent spring runoff. High river flows have also been recorded during January and February during periods of abnormal weather conditions. In 12 years of record (Can. Dept. Env., 1964 to 1975), the peak flows occurred between January 23 and February 18, May 13 and June 3, and October 12 and November 30. A hydrograph of the daily discharge for the Kitimat River below Hirsch Creek, for a typical year (1970), is shown in Figure 4.2.

4 (iii) FLOODS AND FLOOD CONTROL

Weather and ground conditions at Kitimat are conducive to heavy runoffs and flash flooding. Early frosts followed by

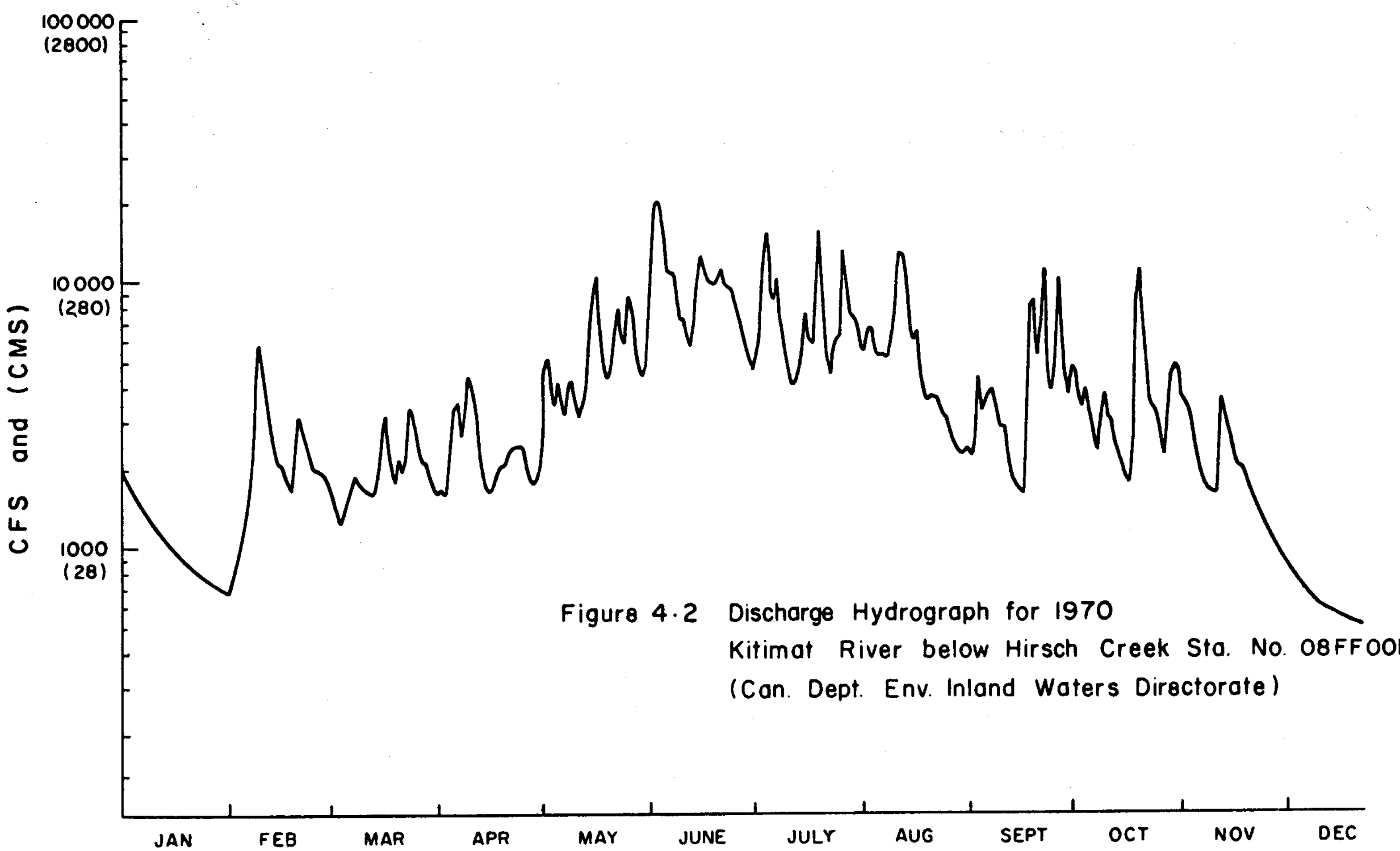


Figure 4·2 Discharge Hydrograph for 1970
Kitimat River below Hirsch Creek Sta. No. 08FF001
(Can. Dept. Env. Inland Waters Directorate)

heavy snowfalls, in turn followed by mild temperatures and warm rains lead to the rapid runoff of surface water, unable to permeate the frozen ground. Extensive logging in the watershed may also contribute to rapid runoff. Banyay (1966) reported that, in an area north of the Town of Kitimat, mostly on the valley floor, approximately 4,046 ha (10,000 ac.) had been clear felled and deforested, and that this amount was rapidly increasing each year. However, in recent years, improved logging practices and a slow down in the rate of removal of timber within the watershed have helped to alleviate this situation (see Pollution Section, P. 150).

On October 24, 1966, the Kitimat River reached one of its highest peaks in its recorded history, when a flow of 1,684 cms (59,500 cfs) was recorded at 1810 PST at Station 08FF001, below Hirsch Creek (Can. Dept. Env., 1974). Extensive flooding caused a considerable amount of damage to the Service Centre, erosion to the west bank of the river north of the Kitimat River bridge, and erosion to the east bank of the river both north and south of the bridge. At the Kitimat River bridge (Haisla Blvd.) the water had risen to a record high water level of elevation 16.8 m (55.2 ft.), approximtely 4 m (13 ft.) above the normal level of the river measured by the Alcan datum at the Haisla Boulevard stage.

The behaviour of the Kitimat River during this flood has been described by Banyay (1966), who included in his report an account of the pre-flood local weather conditions. The following is an extract from his report. "The first snow appeared on the 10th September, 1966 on the Summit of Mount Elizabeth. From the first of October on, the snowline started to move steadily downwards on the neighbouring mountain sides. On 18th October the first snowfall was recorded in the Townsite, a low pressure area was moving into the valley and region. The weather forecast predicted more rain and mild temperatures."

A subsequent report by the Kitimat Municipal Engineer (Stewart, 1967) stated that "From October 22nd to October 24th, 1966, in a 34-hour period, better than 7 inches [178 mm] of rain fell on Kitimat and similar conditions existed throughout the whole of the Kitimat drainage basin."

Following the 1966 flood, representation was made by the District of Kitimat to the Deputy Minister of Water Resources for flood protection assistance under the Canada Water Conservation Assistance Act. An evaluation of flooding problems in the Kitimat Valley was undertaken by the British Columbia Water Resources Service (Tutt, 1971, unpublished report). This report presented recorded facts concerning the flooding, an analysis on probable future floods and the cost of providing protection from these events. Meteorological and flood data contained in the report has since been updated to December, 1974 (B.C. Dept. Lands, Forests and Water Resources, 1975). A flood frequency analysis, based on annual flood data for the Kitimat River for the years 1958 to 1974, showed that a 1 in 200 return period flood would have a peak discharge of 2,830 cms (100,000 cfs), corresponding to a stage of 17.7 m (58 ft.) measured by the Alcan datum at Haisla Boulevard. This estimate of a 1 in 200 year river flood has been used by the Planning and Survey Branch (B.C. Water Resources Service) in the computation of the 200 year flood plain limits for the Kitimat River.

OCEANOGRAPHY

5 (i) INTRODUCTION

Little detailed oceanographic study has been conducted on Kitimat Arm and the Kitimat River estuary. Most of the work done there has been of a survey nature related to installation of the pulp mill in Kitimat and the siting of a suitable outfall system for effective dispersion of effluent from the mill. Although the aluminum smelter was brought into operation in Kitimat during 1954, there was actually little prior oceanographic work related to dispersion and on potential effects of discharge of wastes from this plant into Kitimat Harbour.

The status of hydrographic and oceanographic information to 1973 for Kitimat Arm and the Kitimat River estuary, among other estuaries along the British Columbia coast, has been reported by Marles et al.(1973). There have been eight oceanographic surveys of Douglas Channel and Kitimat Arm: (1) Summer 1951; (2) 11-13 April, 1962; (3) 16-19 October, 1964; (4) 27-28 September, 1967; (5) 19-20 September, 1969; (6) 11-23 June, 1971; (7) 22-23 July, 1972; and (8) 23-28 June, 1975. Data for the first four surveys have been published (Anon, 1951; Pickard, 1961; and Waldichuk, et al., 1968), while the data for the 1969 and 1972 surveys are on file at the Pacific Environment Institute (Waldichuk and Meikle, MS, 1972, unpublished data), and those for the 1971 and 1975 surveys are on file at the Environmental Protection Service, Pacific Region (Goyette, MS, 1971; Bradshaw, MS, 1976).

In connection with siting of the outfall for the Kitimat pulp mill, float studies were conducted in Kitimat Arm in the vicinity of Emsley Cove during 14-22 July, 1966 and near Halfmoon Bay during 7-14 July, 1967 by staff of the Department of Fisheries, Vancouver (Schouwenburg and Jackson, MS, 1966; Can. Dept. Fish, MS, 1967). Technical staff of Eurocan Pulp and Paper Company Ltd. also conducted some observations at the head of Kitimat Arm during the summer of 1967 (King and Koistinen, MS, 1967), in an endeavour to obtain the information required for designing an outfall system for the pulp mill (H.A. Simons Limited, 1967). The salinity distribution in the surface layer of Kitimat Arm as a basis to predict movement of pulpmill effluent from a number of proposed pulpmill sites (Waldichuk, 1967a), and the availability of dissolved oxygen in the surface layer for oxidation of pulpmill effluent (Waldichuk, 1967b), were used in early discussions of suitable siting of the outfall from the Eurocan pulp mill.

As part of a program to measure the deposition of natural and man-made substances introduced into coastal waters of British Columbia receiving wastes from pulp mills, or designated to receive such wastes, settling materials were collected in sediment traps at 4 stations in Kitimat Arm during June 16 to September 15, 1966 (Werner and Hyslop, 1968).

More recent studies in Kitimat Arm have been related to the ecology of the estuary in connection with future developments at Kitimat, e.g. expansion of port facilities, and possible steel mill construction. Some of this work has been conducted by the Environmental Protection Service (Bradshaw, MS, 1976) and by the Northern Operations Branch of Fisheries Operations in the Fisheries and Marine Service, Pacific Region, of Environment Canada (Higgins and Schouwenburg, MS, 1976). Other studies have included Kitimat Arm for studies of fluoride distribution in the sea (Harbo, et al., MS, 1973, 1974) and for comparison of ecological characteristics of different estuarine systems on the British Columbia coast (Levings, et al., 1975). Consultants have also examined ecological characteristics of Kitimat Arm in relation to prospective developments in the Kitimat River Estuary (Howard Paish and Associates, Limited, 1973, 1974).

The most recent hydrographic survey in Douglas Channel and Kitimat Arm was conducted by the Canadian Hydrographic Survey in 1952. Hydrographic charts for the area are: No.3743-DOUGLAS CHANNEL on a natural scale of 1:73,032; and No. 3736-KITIMAT AND KEMANO BAY on a scale of 1: 12,165. The changes at the northwest corner of Kitimat Arm, as a result of Eurocan Terminals installations, have been surveyed by Eurocan Pulp and Paper engineers and incorporated by the Canadian Hydrographic Survey into the harbour chart No. 3736. Topographic changes along the western shore of Kitimat Arm 0.6 km (0.30 n.mi.) south of Kitimat Wharf No. 2 (53^0 59.1'N; 128^0 41.8'W), as a result of a land slide in April 1975, apparently only affected the submarine topography within the 2 m (1 fathom) line, and it was not considered necessary to make a chart correction following that incident (R.W. Sandilands, Canadian Hydrographic Service, personal communication).

5 (ii) GENERAL OCEANOGRAPHIC CHARACTERISTICS

Kitimat Arm might be classed as a typical British Columbia fjord. It is an extension of the Douglas Channel system, although it is also connected to Gardner Canal through Devastation Channel. Kildala Arm is also a tributary of the Douglas Channel system, and is contiguous with Kitimat Arm in the region of a confluence of these channels some 18 km (10 n.mi.) from the head. The main connection of Kitimat Arm with the open waters of Hecate Strait and Queen Charlotte Sound is through Douglas Channel, Whale Channel and Caamaño Sound.

Kitimat Arm drops off rather steeply from the delta at the head into deep waters reaching over 200 m (120 fathoms) at 9-11 km (5-6 n.mi.) from the head. There is no apparent threshold sill at the entrance to Kitimat Arm, but there is a sill to the Douglas Channel system from Hecate Strait through Caamaño Sound. Kitimat Arm has an extension to the northeast of the Kitimat River estuary in a narrow inlet only about 5.5 km (3 n.mi.) long with a maximum depth of 32 m (18 fathoms) in Minette Bay. This bay has a shallow entrance as a result of the deposition of silt from the Kitimat River, and the entrance is passable only to shallow draught vessels at high tides. Minette Bay has always been a popular log storage area because it is well sheltered. At one time there was a proposal to enclose the bay by a dyke at the entrance and make it essentially into a fresh water lake (Acres Western Limited, 1967). However, it is now recognized as a productive intertidal area utilized by juvenile salmonids from the Kitimat River system, and efforts are being made to protect it.

The main section of Kitimat Arm from Clio Point to the Kitimat River delta is quite wide, having a breadth of approximately 3 km (1.7 n.mi.), so that surface water outflow in this part of the inlet is not too constricted laterally. Also, because of the great depth, there is a large volume of water in the system which buffers any tidal exchange. The Kitimat River water flowing into Kitimat Arm mainly via the eastern half of the delta, fans out over Kitimat Arm in typical estuarine fashion forming a relatively thin layer of fresh water. The Kitimat River water is supplemented by fresh water from Anderson and Moore Creeks draining into the northwest corner of Kitimat Arm. The surface layer entrains sea water from below as it progresses towards Douglas Channel, and therefore, the volume of water in the upper layer moving seaward gradually increases with distance from the head of Kitimat Arm. Because the brackish layer does not substantially deepen seaward, the flow through the surface layer, and hence the current velocity, increases with distance from the Kitimat River. Although there is no clearly defined jet stream of fresh water from the Kitimat River in Kitimat Arm, as one might anticipate, there is evidence of fresh water hugging the western shore as far south as Bish Creek. The northwestern corner of Kitimat Arm appears to be occupied by an eddy with a clockwise circulation.

Making some simplifying assumptions, an attempt was made to estimate the amount of oxygen available in the upper layer of Kitimat Arm for oxidation of wastes. Assuming a 100-year minimum flow of the Kitimat River of 9.0 m^3/sec (321 cfs), and a demand of 3.4 m^3/sec (120 cfs) by the Eurocan pulp mill, a net minimum river flow for dilution and oxidation of effluent was estimated at 5.6 m^3/sec (201 cfs). Taking a 50% dilution of fresh water by sea water of equal dissolved oxygen concentration, the total amount of oxygen available daily from the water for waste oxidation was estimated at 5.92 tonnes (1.31×10^4 lb.) (Waldichuk, MS, 1967b).

Because there is no threshold sill at the entrance to Kitimat Arm, the deep water tends to be replaced quite regularly. Even during the latter part of summer when deep water conditions can be considered to be at their worst, as far as oxygen content is concerned, there is usually dissolved oxygen exceeding 3 mg/l at depths of 300 m. This is not true, however, of bottom water in Minette Bay, which is isolated from the main body of Kitimat Arm water. During the course of summer, it may be totally depleted of dissolved oxygen at a depth of 30 m. This was observed during the cruise in September 1964.

Surface waters may be affected in clarity by turbid run-off at almost any time of year. For example, stations occupied during the survey in September 1967 (see Fig. 5.1) exhibited comparatively turbid water even at stations K-1 to K-4, with Secchi disc readings of 0.6 - 1.8 m (2-6 ft). At stations K-5 to K-11 the Secchi disc readings were less than 0.6 m (2 ft). During the survey in April 1962, Secchi disc readings ranged from 4.6 m (15 ft) at the outer stations in Douglas Channel to 1.5m (5 ft) at the head of Kitimat Arm. On the other hand, during the survey conducted in October 1964, the Secchi disc reading at station K-1 was 5.5 m (18 ft), at K-4, 2.4 m (8 ft) and at K-5 to K-11 about 0.9 m (3 ft). During the survey of July 1972, Secchi disc values ranged from 3.8 m (12.5 ft) at K-6 to 2.0 m (6.5 ft) at station K-10 at the head of Kitimat Arm. The large seasonal turbidity is expected during June when the Kitimat River is in spring freshet, but heavy rains in the autumn and winter may cause large local runoff contributing to much turbidity in the Douglas Channel-Kitimat Arm system at that time.

The turbidity in Kitimat Arm and the Kitimat River estuary affects light penetration, and as in other inlets with turbid runoff, inhibits primary production. The summer period is one characterized by comparatively low turbidity, so that photosynthesis can occur relatively unimpeded. However, a late spring freshet of the Kitimat River and/or early autumn rains can reduce the period available for effective production of phytoplankton. Minette Bay suffers from the brown colour of humic substances introduced from local runoff through marshy areas, as well as leachates from bark in logs held in log booms in the area.

(iii) TIDES

Tides in Kitimat Arm are typical Pacific coast mixed tides with a semi-diurnal component giving two high and two low waters during a tidal day, with inequalities in height and time of succeeding tidal oscillations, reaching their greatest values when the declination of the moon has passed its maximum. It is considered a mixed, mainly semi-diurnal, tide (MSD) in the Tide Tables (Canada Department of the Environment, 1976).

Tidal measurements were made in Kitimat Arm during two periods: (1) 1 July 1909 - 1 November 1909; and (2) 1 August 1951 - 1 August 1954. The latter series was carried out prior to the installation of the new Alcan smelter so that vessels could have reliable tidal predictions on entering this port. The tidal range for Kitimat is considerably greater than that for the southern coast of British Columbia, with a mean tide amplitude of 4.2m (13.8 ft) and a large tidal amplitude of 6.5m (21.4 ft). The tidal predictions for Kitimat are based on Bella Bella about 250 km (140 n.mi.) to the south, as the reference port. Data for both the reference port and secondary port are given in Table 5.1. Differences in time and height of tides between Kitimat and Bella Bella are given in Table 5.2

Table 5.1 Tidal characteristics at the reference and secondary ports for the Kitimat River estuary (From Canada Department of the Environment, 1976)

PORT	POSITION	DURATION OF TIDAL RECORDS	MEAN TIDAL RANGE		LARGE TIDAL RANGE	
Reference Port			m	ft	m	ft
Bella Bella	52°10'N; 128°08'W	1 January 1962-Present	3.4	11.2	5.3	17.4
Secondary Port						
Kitimat	53°59'W; 128°43'W	1 July 1909 - 1 November 1909; 1 August 1951 - 1 August 1954	4.2	13.8	6.5	21.4

Table 5.2 Differences in time and height for tides at Kitimat in relation to the reference port, Bella Bella. (From Canada Department of the Environment, 1976)

Higher High Water					Lower Low Water				
Time h.m.	Mean m.	Tide ft.	Large m.	Tide ft.	Time h.m.	Mean m.	Tide ft.	Large m.	Tide ft.
+0.17	+0.85	+2.8	+1.07	+3.5	+0.12	+0.06	+0.2	-0.15	-0.5

As it can be seen in Table 5.2, the time difference between Kitimat and Bella Bella for higher high water is +17 minutes and for lower low water, +12 minutes, which is not a large variation in the time of these tidal stages, considering the comparatively long distance between these two ports. However, there is a considerably higher tide at Kitimat than at Bella Bella during higher high water with a difference of about 1 m (3.5 ft), although the lower low water for mean tides is only .06 m (0.2 ft) higher and for large tides 0.15 m (0.5 ft) lower. The higher sea level at Kitimat than at Bella Bella during large tides is related to the increasing tidal range as one proceeds northward up the British Columbia coast. In general, the lack of constricting channels between Caamaño Sound and Kitimat Arm means that there is little delay for the tidal wave to reach the head of the inlet from Hecate Strait and the open Pacific Ocean.

5 (iv) WATER PROPERTIES

Water properties in Kitimat Arm exhibit a large marine influence compared to those in British Columbia inlets tributary to a semi-confined inland sea such as the Strait of Georgia. This means that salinities are substantially higher in the deep water of Kitimat Arm than those of Howe Sound for example. Inasmuch as the flushing of Kitimat Arm appears to be fairly regular, estimated as at least once per year in the deeper waters, the salinity and temperature of the deep waters of Kitimat Arm are closely related to those of the sea water on the continental shelf in Caamaño Sound and Hecate Strait.

The effects of the Kitimat River are confined to a rather thin surface layer, as observed in the several oceanographic surveys, although this may change seasonally. Heavy autumn and spring runoff accompanied by intensive wind mixing, for example, may be more effective in producing a deeper brackish layer than noted in summer and early autumn oceanographic surveys. The strong southerly winds during some periods must cause temporary deepening of the surface layer at the inlet head; this might have implications for the benthic ecology.

Station locations occupied in an oceanographic survey during September 1964 are shown in Figure 5.1. A series of closely-spaced stations with *in situ* salinometer profiling was occupied at this time to obtain as nearly a synoptic picture of distribution of salinity in the surface layer as possible. The rapid changes in salinity in Kitimat Arm with depth are shown in Figures 5.2 - 5.4, where horizontal distributions of salinity are shown at the surface, 2 m and 4 m depth. Kitimat River water

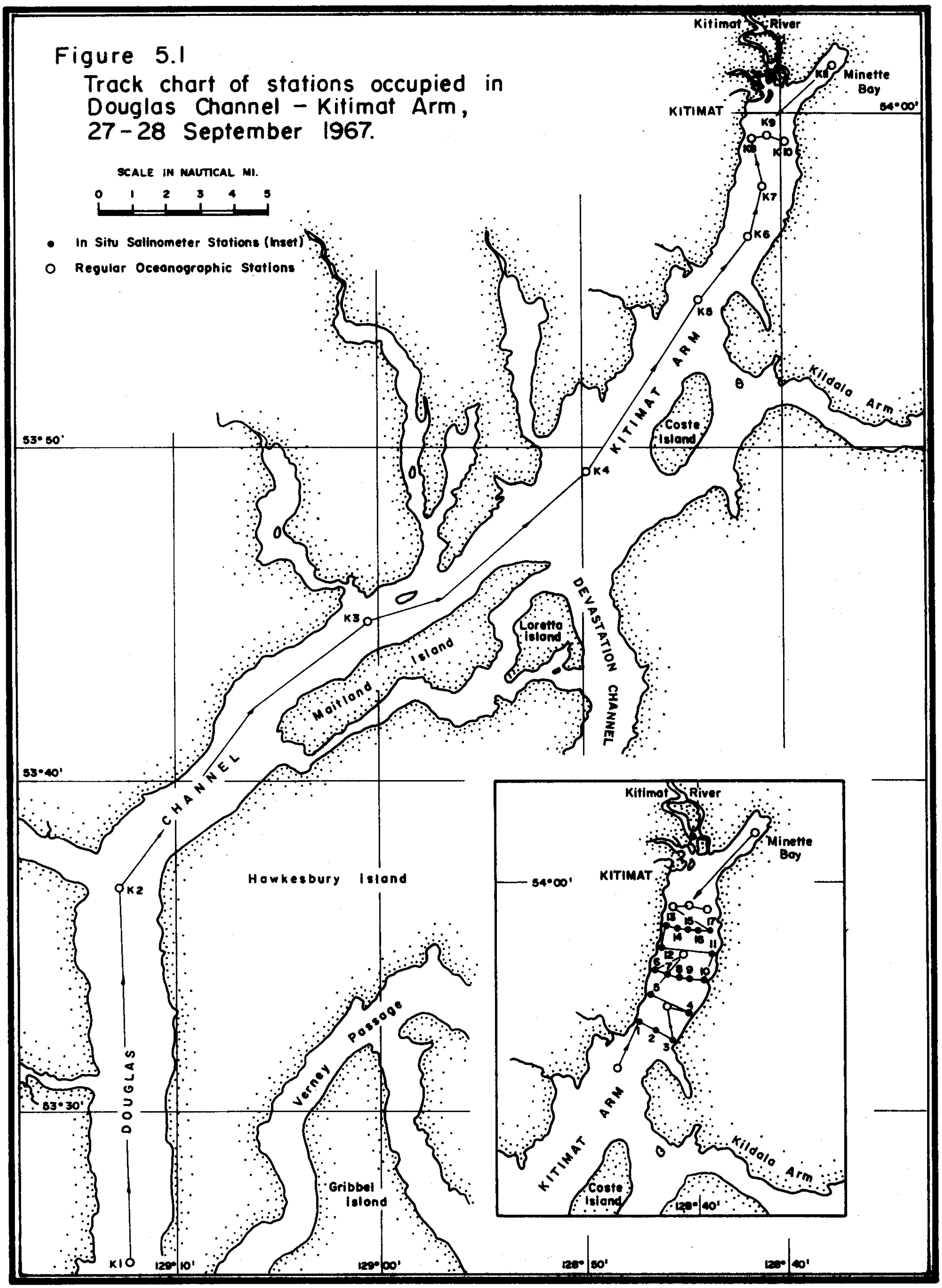


Figure 5.1
Track chart of stations occupied in Douglas Channel - Kitimat Arm, 27-28 September 1967.

was clearly confined to a rather thin surface layer. Large vertical changes in salinity were apparent between the surface and 5 m during this survey (Waldichuk, 1967a).

The surface distribution of salinity shown in Figure 5.2 exhibits a number of cells of low-salinity and tongues of intruding high-salinity water. These are largely manifestations of the geography of the system and the tide, wherein extrusions of fresh water are cut off on succeeding flood and ebb tides along the curved and irregular configuration of the coastline. However, the fresh water appears to hug the western shoreline, as shown by the lower salinity on that side, north of the high-salinity intrusion above Bish Creek. It should be noted that internal waves could be present in such a stratified system, and part of the irregular salinity distribution may be due to spatial aliasing of internal waves.

The distribution of salinity at 2 m (Fig. 5.3) is more representative of the horizontal salinity pattern in the thin brackish upper layer. Again, the lower salinities were adjacent to the western shoreline, but at this depth they extended right to Bish Creek. One exception to this general cross-channel salinity trend was at the north end, where comparatively high salinities existed just south of the Kitimat wharf area. This suggests that an eddy in the northwest corner of Kitimat Arm retained some of the mixed higher-salinity water in the area, while the river flushed similar mixed water seaward from the section further south. With the large vertical salinity gradient in the pycnocline (see Fig. 5.5), it could be reasonably expected that some anomalies in horizontal salinity distribution are due to small errors in instrument depth or to very small vertical movements in pycnocline.

In the horizontal distribution of salinity at 4 m (Fig. 5.4), there was apparently the greatest downward penetration

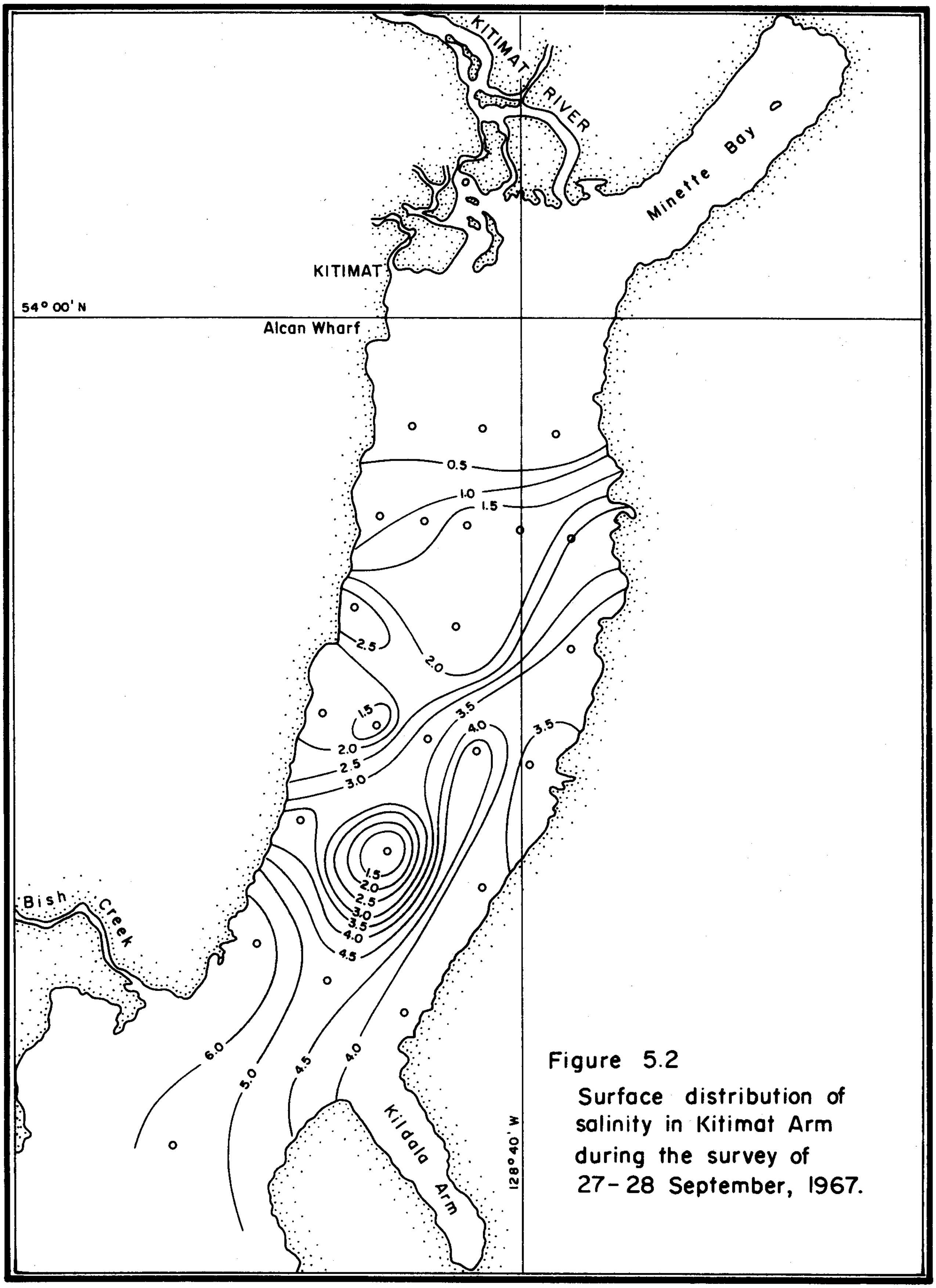


Figure 5.2
Surface distribution of salinity in Kitimat Arm during the survey of 27-28 September, 1967.

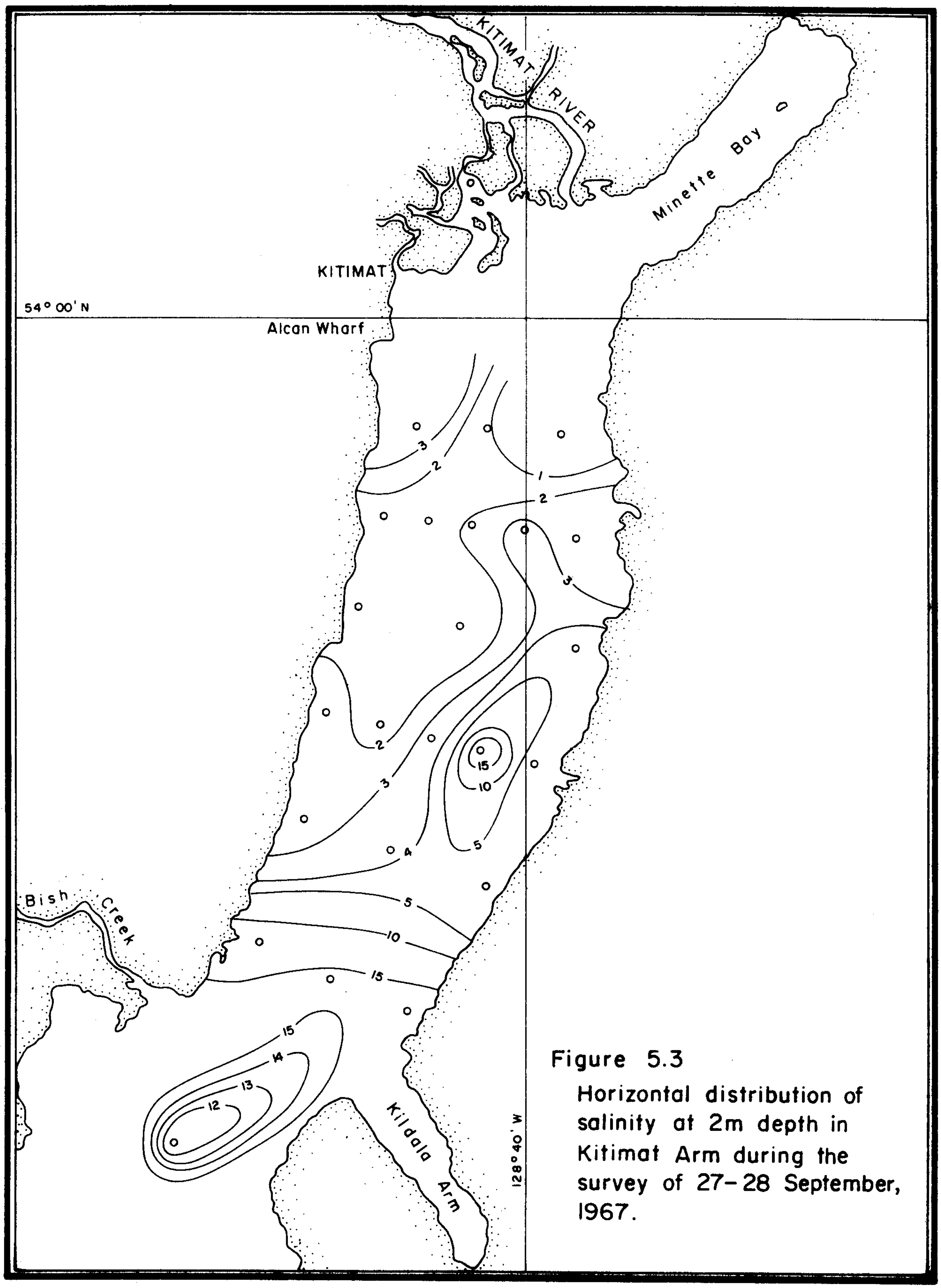


Figure 5.3
Horizontal distribution of salinity at 2m depth in Kitimat Arm during the survey of 27–28 September, 1967.

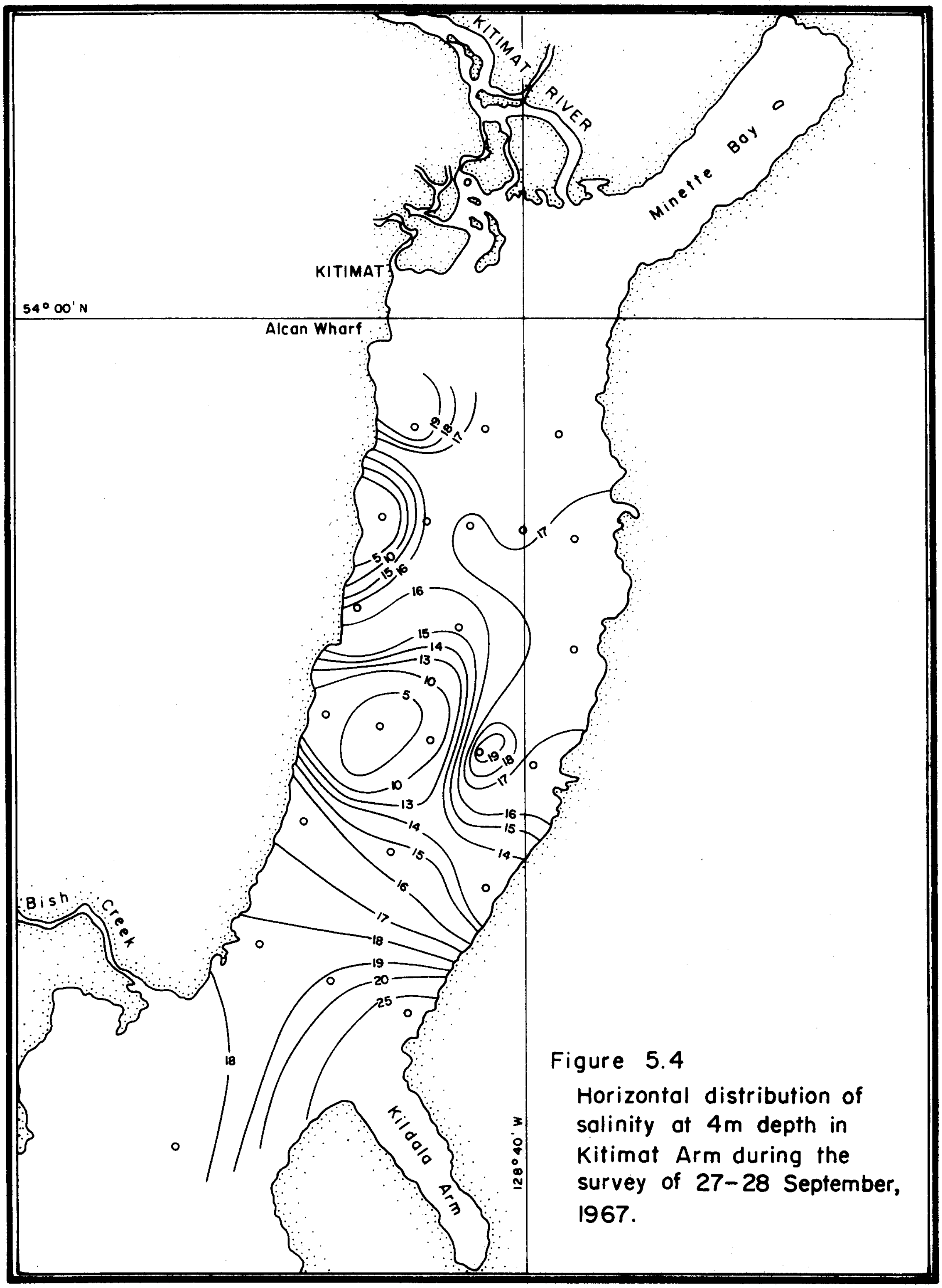


Figure 5.4
Horizontal distribution of salinity at 4m depth in Kitimat Arm during the survey of 27-28 September, 1967.

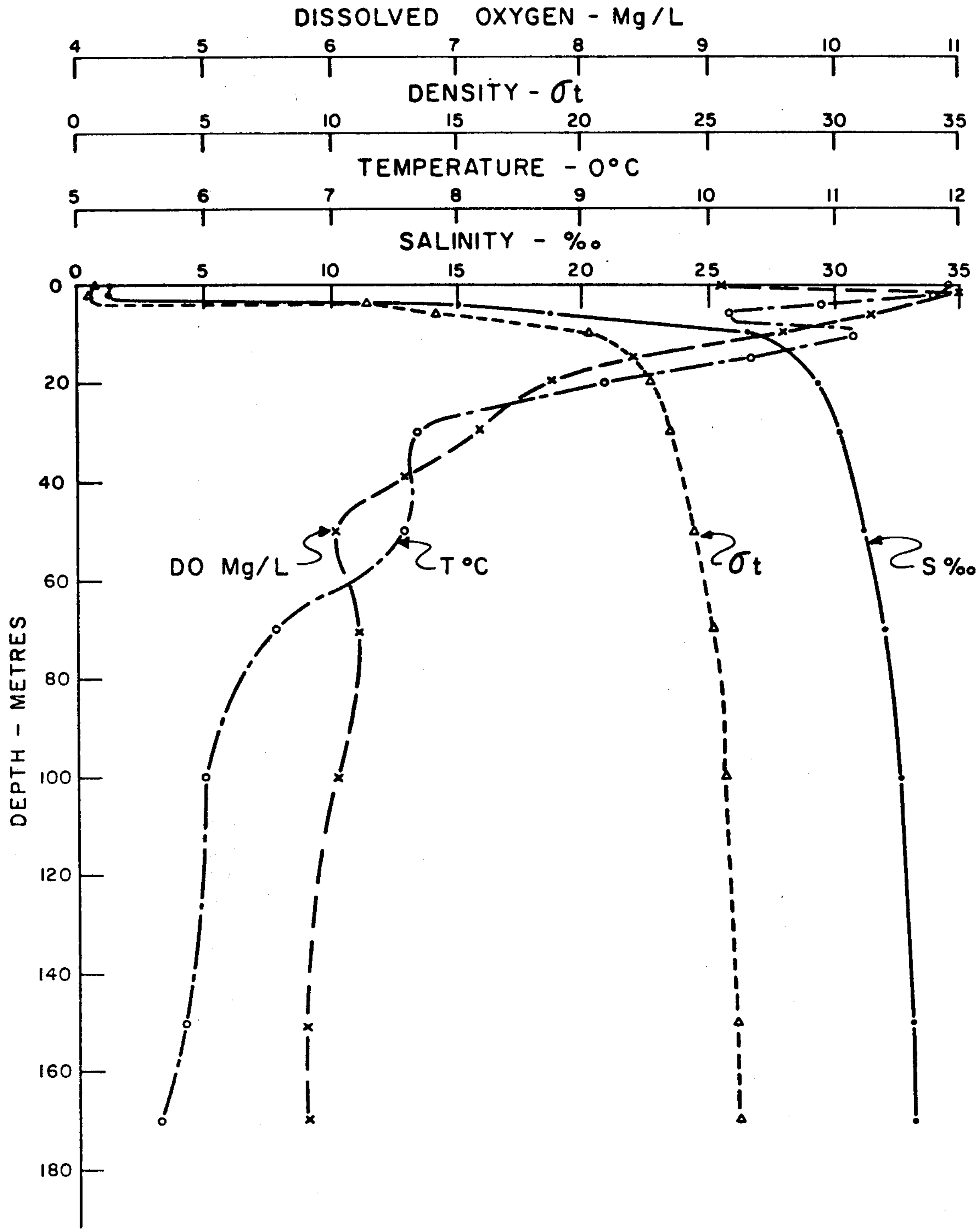


Fig. 5·5 Profiles of salinity, temperature, density (σ_t), and dissolved oxygen at station K-7 (see Fig. 5·1) on September 28, 1964.

of fresh water along the western shore of Kitimat Arm. At this depth, there was probably the greatest entrainment of sea water into the seaward-flowing brackish surface layer.

Profiles of salinity, temperature, density (σ_τ) and dissolved oxygen are shown in Figure 5.5 for Station K-7, at the upper end of Kitimat Arm during the survey of 27-28 September 1967. The sections of salinity, temperature and density (σ_τ) taken along the axis of Douglas Channel and Kitimat Arm during the survey of September 1967 are shown in Figure 5.6. The thin layer of brackish water is clearly evident in these sections. The non-conservative properties in the same section during the same survey are shown in Figure 5.7. These sections make it quite obvious that the bottom water of Kitimat Arm is not as depleted of dissolved oxygen as one might expect, but that the bottom of Minette Bay may be devoid of oxygen at this time of year. Comparing this oxygen distribution with that of Muchalat Inlet on the west coast of Vancouver Island, at about the same time of year (Waldichuk, et al., 1968), indicates that either the deep water of Kitimat Arm is more actively flushed than Muchalat Inlet, or else the oxygen consuming processes are not quite as active in the Douglas Channel-Kitimat Arm system.

5 (v) CURRENTS AND CIRCULATION

Surface currents at the upper end of Kitimat Arm are mainly attributable to the runoff and wind effects. Tidal currents become more pronounced in the narrow section of Kitimat Arm between Clio Point and the Bish Creek delta. The ebb current is of the order of 25-50 cm/sec (0.5 - 1.0 kn.), while the flood current is about 25 cm/sec (0.5 kn.) in this region. It is not until one reaches Pt. Ashton 32 km (17 m.mi.) seaward of Kitimat that the ebb current tends to be somewhat stronger than the flood at the surface, at about 50 cm/sec (1 kn.), compared to the flood at about 25 cm/sec (0.5 kn.).

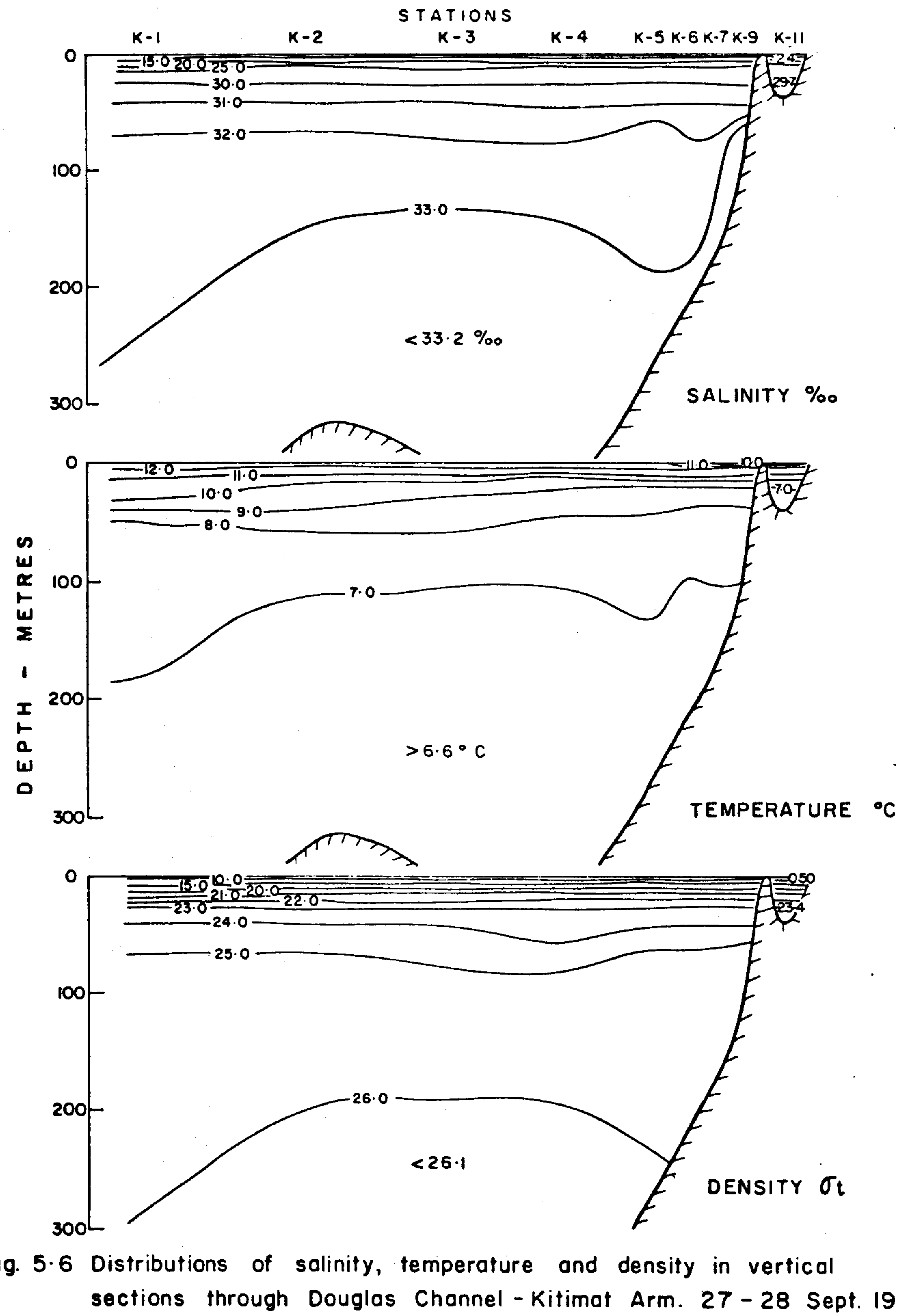


Fig. 5·6 Distributions of salinity, temperature and density in vertical sections through Douglas Channel - Kitimat Arm. 27 - 28 Sept. 1967 (see Fig. 5·1 for station locations).

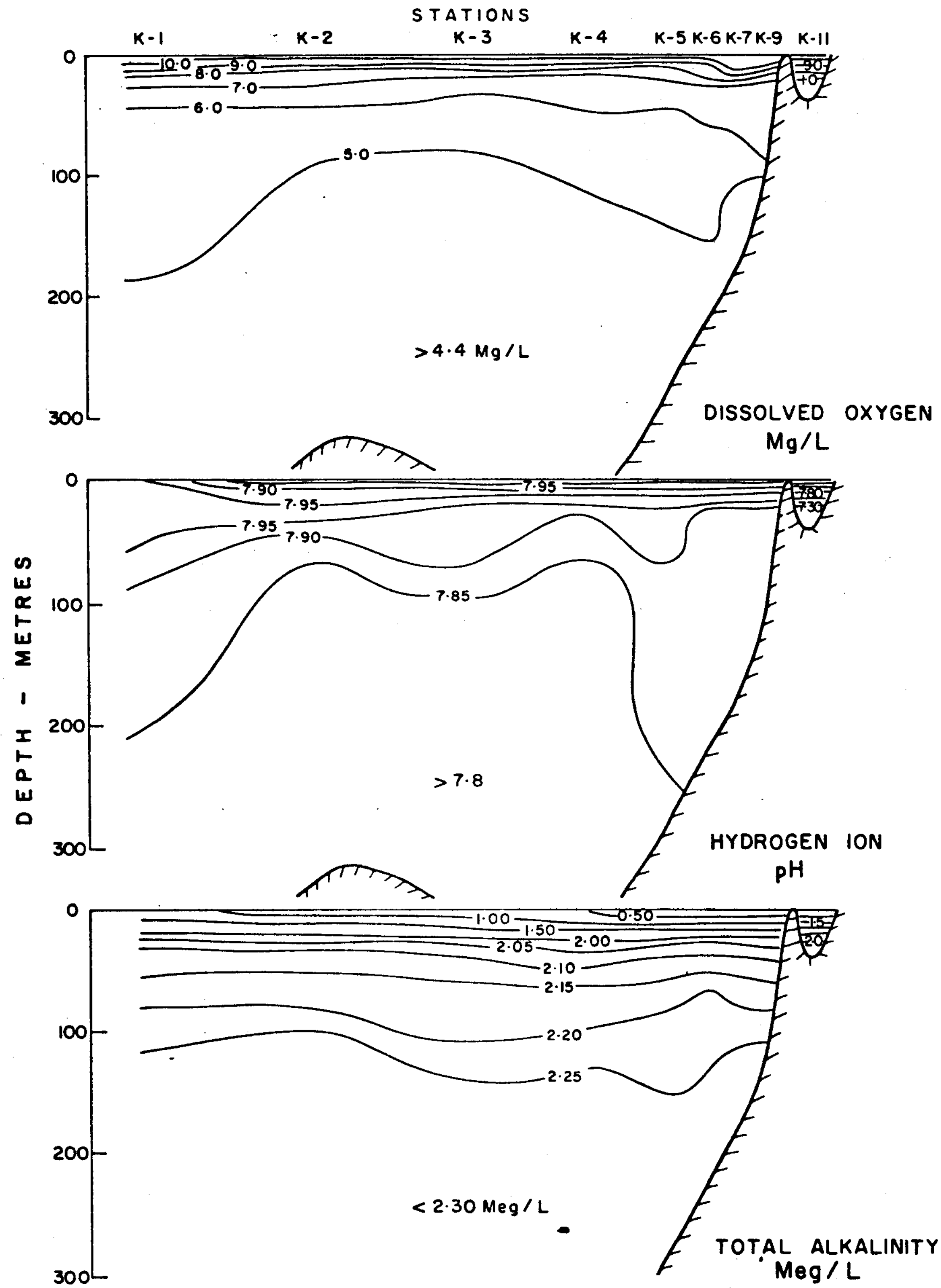


Fig. 5·7 Distributions of dissolved oxygen (DO), pH and total alkalinity (TA) in vertical sections through Douglas Channel - Kitimat Arm, 27- 28 Sept. 1967 for DO, and 16-19 Oct. 1964 for pH and TA (see Fig. 5·1 for station locations).

Some drift-pole observations have been made in Douglas Channel and at the approaches to Kitimat Arm for navigational purposes. However, the currents in the upper end of Kitimat Arm were never considered to be strong enough to merit observations, which would be useful for navigation purposes (W.S. Huggett, Canadian Hydrographic Service, personal communication). One set of surface drag and current meter observations has been taken from an anchored ship (Station K-9A; Position: 53°59.1'N; 128° 40.5'W) at the head of Kitimat Arm (see Station K-9 in Fig. 5.1) during the survey period 16-19 October 1964 (Waldichuk, et al., 1968). Drogue observations were also carried out for currents at 0.5, 2.5, 5.0 and 7.5m in the vicinity of Emsley Cove, about 15 km (8 n.mi.) southwest of the head of Kitimat Arm during 14-22 July, 1966, for the purpose of selecting the most suitable location for an outfall when this site was being considered for the Eurocan pulp mill (Schouwenburg and Jackson, MS, 1966). During the following year, when it was decided to consider a site closer to the town of Kitimat, drogue observations were made again at the same depths as in 1966 near Halfmoon Bay, a local name for the bay 0.3 km (0.15 n.mi.) south of wharf No. 2, as well as at points 1.4 km (0.75 n.mi.) to the south and 0.9 km (0.5 n.mi.) to the north (Canada Department of Fisheries, MS, 1967).

All available current information indicates that there is no jet stream through the inlet as a result of the freshwater flow from the Kitimat River. However, no observations were made at a time when the Kitimat River was in extreme flood. It appears generally that the flow from the Kitimat River produces a uniform current throughout the width of Kitimat Arm, but no marked currents were noted at any time. Current observations made at Station K-9A, in the middle of the north end of Kitimat Arm during a 26-hour period from 17 to 19 October 1964, only occasionally showed currents exceeding 25 cm/sec (>0.5 kn.). In most situations of stronger currents, the water was actually flowing up-inlet induced by the drag of a southerly wind.

Currents along the shoreline of Kitimat Arm are affected by the geographical configuration of the coast line, and eddies may form in the lee of a point extending into Kitimat Arm. For example, drogue observations made in the vicinity of Emsley Cove during July 1966, exhibited a remarkable effect of Emsley Point just north of Emsley Cove. Figure 5.8 shows drogues released at the beginning of a small ebb tide, at 2.5 m, drifting southwestward following release and then to the northeast on the latter stage of their excursions. All drogues at depths less than 5 m released just north of Emsley Point during an ebbing tide, eventually moved into Emsley Cove and were carried in a strong clockwise eddy within the Cove. There was also an indication of weaker and less consistent movements into Emsley Cove at depths of 5 and 7.5 m along the eastern shore of the cove.

Drogues released just south of Emsley Cove moved rather rapidly into the cove during the flooding tide. However, drogues released about 2.5 km (1.4 n.mi.) south of the mouth of Emsley Creek, which discharges into Emsley Cove, showed little evidence of movement into Emsley Cove on any of the tidal stages observed. For this reason, it was suggested at one point in planning of the Kitimat pulp mill that the outfall should be reasonably far removed from Emsley Cove, if effluent from the mill were not to be carried to the cove.

In another series of observations made with drogues in Kitimat Arm during July 1967, to determine the effect of discharge of effluent into Halfmoon Bay, approximately 3 km (1.6 n.mi.) seaward from the mouth of the Kitimat River, some information was gained on surface currents in the northwest corner of Kitimat Arm. At the most northerly release point, approximately 0.5 km (1 n.mi.) south of the Kitimat River, winds blew at 4 - 5 m/sec (8-12 mph) from the south for the duration of the float observations (4 hr. 10 mins.). Two of the 0.5 m drogues moved in a north-northeasterly direction for approximately 1.7 km (0.9 n.mi.) and were retrieved

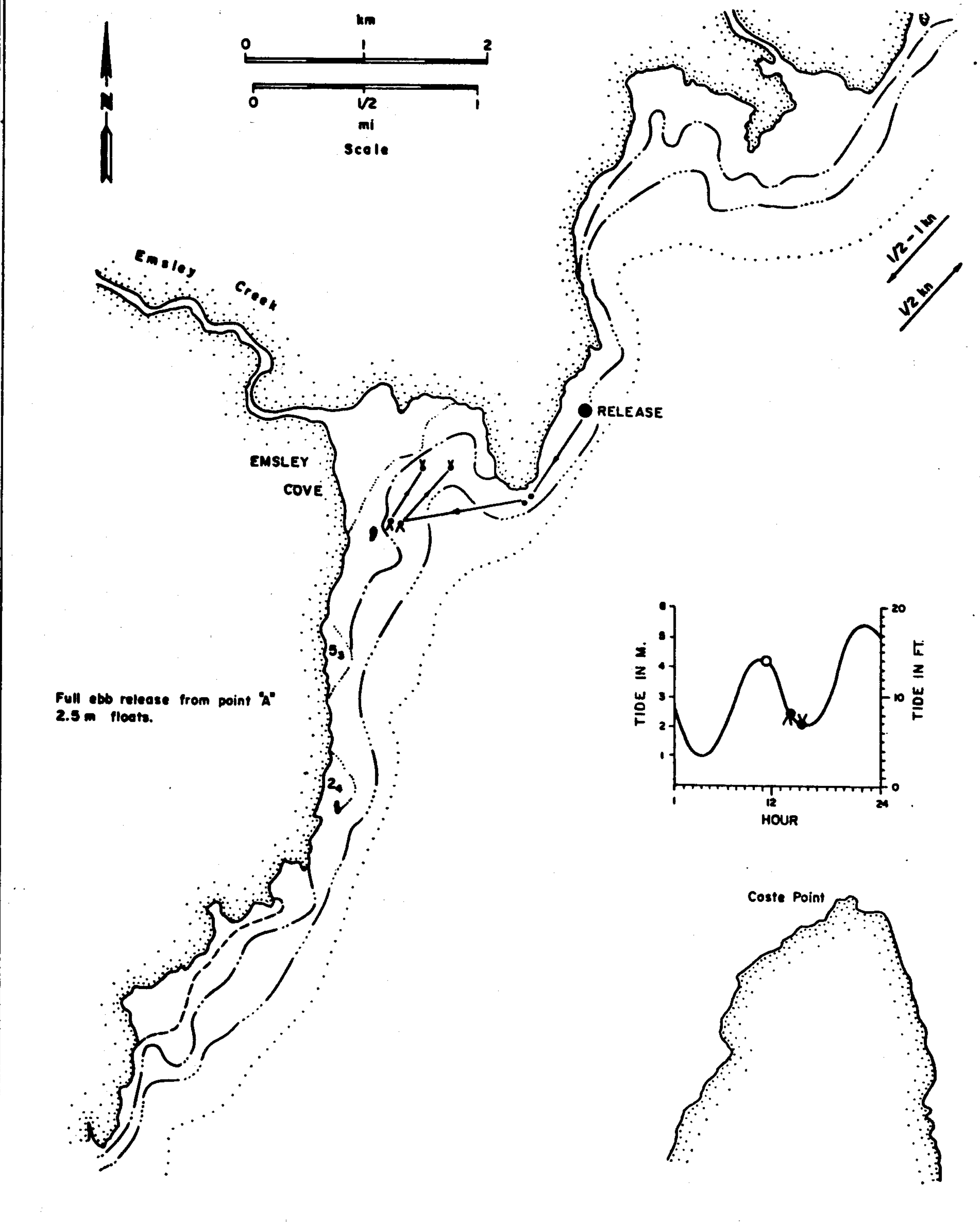


Figure 5.8 Movement of drogues at 2.5 m, released north of Emsley Cove on the west side of Kitimat Arm, during a small ebb 14 July 1966.
(From Canada Department of Fisheries, 1966)

in the Moore-Anderson Creek Channel. The third 0.5 m drogue drifted generally in the same direction for the first period of observation and then during the latter tidal stages, altered course to a more northeasterly direction across the mud flats toward the mouth of Minette Bay (Fig. 5.9.).

Drogues at all 4 depths (0.5, 2.5, 5.0 and 7.5 m), drifted northward. Although all these drogues were released at the beginning of a flood tide, which would normally move water northward, it is believed that the influence of the wind was dominant, inasmuch as it was blowing from the south during the full period of observations.

A series of observations was made with releases of drogues from the same point at the same depths at half-ebb tide. During this period the winds blew steadily from the north at 2.5 m/sec (6 mph) and the duration of the observation was 3 hours. All drogues drifted southward initially, although some reversed direction in the latter stage of their movement.

When drogues were released from the same point at the same depths at the beginning of a full ebb, with a light breeze from the north at 1.5 - 2 m/sec (3-4 mph), the two 0.5 m and 2.5m floats drifted rapidly to the south for about 2.4 km (1.3 n.mi.), but one of the 2.5 m drogues shifted direction during the latter part of its excursion and moved southwestward into Halfmoon Bay. The 5 m and 7.5 m drogues remained virtually stationary, and were picked up only a short distance south of the release point.

Similar types of observations were obtained at two other release points, about 0.9 km (0.5 n.mi.) and 2.8 km (1.5 n.mi.) south of the first release point. There was evidently a strong effect of winds, although the tide may have had a certain amount of influence. As in the area of Emsley Cove, there were eddies in the northwestern part of Kitimat Arm. There were also

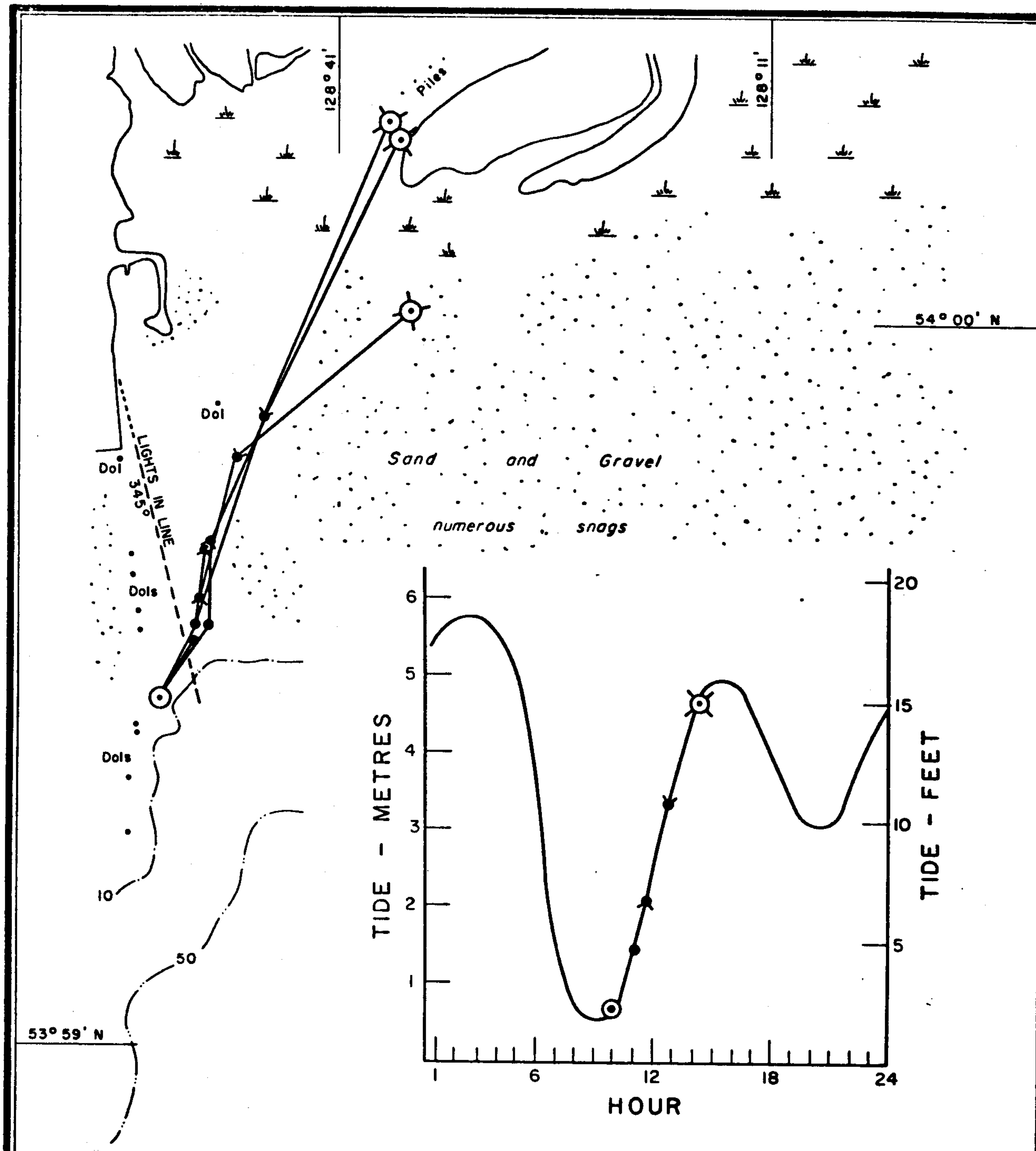


Fig. 5·9 Movement of drogues at 0·5m, released in the northwest corner of Kitimat Arm at the beginning of a flood tide with southerly winds of 4-6 m/sec (8-12 mph) on 8 July, 1967. (From Canada Department of Fisheries, 1967).

small localized onshore eddies in the vicinity of Halfmoon Bay and in the area between the Northland Navigation and Alcan docks. A larger, although less defined, surface eddy also was apparent in the waters at the head of the inlet. The strongest currents appeared to be always in the upper 2.5 m (approx. 25 cm/sec or 0.5 knots), while the deeper currents at 5 m and 7.5 m were evidently quite sluggish. Clearly, the tidal effect on currents is rather small at the head of Kitimat Arm. This is a consequence of the land boundary at the head of Kitimat Arm, with waters transported beyond only into the Kitimat River channel and Minette Bay. The shallow channel to Minette Bay certainly exhibits a moderate tidal current, because water must move in and out of this bay in order to equilibrate the sea level between it and Kitimat Arm.

In conclusion, one can say that there is a typical two-layered circulation in Kitimat Arm, with a net surface outflow seaward resulting from the input of fresh water from the Kitimat River and Anderson and Moore creeks. A net up-inlet flow must exist below the surface brackish layer to replace the sea water entrained into the brackish surface layer and transported seaward. However, the current systems at all depths are weak, and except during the freshet of the Kitimat River and during sustained periods of strong winds, currents seldom exceed 50 cm/sec (1 kn.). The coastal configuration, particularly where irregularities occur, can produce deviations from a straightforward up-inlet or down-inlet flow in the surface water, with nearshore eddies and other diversionary action caused by the topography.

5 (vi) WAVE ACTION

There is little information on waves in Kitimat Arm. The inlet is comparatively sheltered from three sides, and topography has a significant influence on wind direction so that only southerly winds can be considered as a major factor in creating significant wave action within Kitimat Arm. However, destructive waves have been noted as a result of the landslide in April 1975. Also, a tsunami, presumably from a seismic disturbance, was reported from Kitimat Arm on 24 October, 1974 (W.S. Huggett, personal communication).

The major fetch for winds is from the south and southwest, with approximately 37 km (20 n.mi.) as the maximum extent of unobstructed channels over which winds could blow relatively unimpeded. Strong winds from the southwest occur more commonly during the winter months, although it can be expected that up-inlet winds ("sea breezes") may also develop during the afternoons of clear, sunny summer days, if this inlet is typical of British Columbia inlets (see Climatology Section). There are no wave records, but it would be expected that the largest waves come from the south in winter with substantial wave action during afternoon up-inlet winds in summer. However, it is estimated that maximum heights would not exceed 1.5 m (5.0 ft.). This wave action can have some ecological effect on the tide flats at the head of Kitimat Arm. It was noted by Levings, et al. (1975) that during their observations in the Kitimat River estuary, 20-21 August, 1974, there were strong up-inlet winds, and the substrates in the intertidal zone of the delta at the head of Kitimat Arm were experiencing considerable abrasion from wave and current action, rendering them relatively unstable habitats.

The British Columbia Pilot (Canada Department of Energy, Mines and Resources, 1969, p.96) makes it quite clear that there is no satisfactory anchorage in mid channel at the head of Kitimat Arm, partly because of the southward exposure. Sudden gusty winds of brief duration may occasionally also occur in the winter months in the form of a "Squamish" or "Williwaw" when drainage of cold air from higher ground in the interior of the province takes place. Waves from these winds would only develop at some distance down-inlet from the head of Kitimat Arm.

Because of the general exposure of Douglas Channel to the open ocean through Camaaño Sound and Hecate Strait and Queen Charlotte Sound, any oceanic disturbances can have ready access to the network of channels leading to Kitimat Arm. Partly for this reason, a tsunami generated by a seismic disturbance somewhere in the Pacific can be felt as far as Kitimat, as apparently occurred on 24 October, 1974. There is also a possibility that the reason for the tsunami originating from a Chilean earthquake being observed at Kitimat (and Klemtu) is that the natural frequency of the basin was approximately the same as the frequency of the incoming waves.

The destructive wave that struck Kitimat on 27 April, 1975, was reported to be close to 25 ft. high when it caused an estimated $600,000 damage to waterfront facilities (PROVINCE, Vancouver, April 29, 1975). Kitamaat Village on the east side of Kitimat Arm also suffered damage, although the main destruction was done to the Northland Navigation Company Limited wharf on the northwest side. The Canadian Hydrographic Service of Ocean and Aquatic Sciences, Environment Canada, conducted a survey on 3-7 May, 1975, and pin-pointed the slide area at "Halfmoon Bay", centred at 53°59.1'N; 128° 41.8'W. From reports of long-time local residents, waves from submarine landslides have occurred before in the area. Apparently this is characteristic of unstable, unconsolidated, deltaic deposits in these inlets. While these waves are of short duration, they are catastrophic in that they can do a great deal of ecological disruption as well as damage to shore facilities.

6. INVERTEBRATES

6 (i) TERRESTRIAL INVERTEBRATES

Regular annual surveys of forest insects and disease in the Kitimat Valley are conducted by the Canadian Forest Service. The most damaging pests have been the saddle-backed looper (*Ectropis crepuscularia*) and spruce budworm (*Choristoneura orae*), having caused severe and widespread defoliation. Bark beetles (*Pseudohylesinus* sp.) have contributed to tree mortality by attacking weakened trees. In 1958 saddle-backed looper larvae became common in survey collections and the population build up continued in 1959 (see Figure 6.1). A heavy moth flight occurred in May, 1960 and by the end of July hemlock and balsam stands along the western side of the valley were severely defoliated. In an effort to protect the remaining foliage on trees around the Kitimat townsite, approximately 729 ha (1,800 acres) were sprayed on August 1 with .060 kg DDT/1 fuel oil (½ lb. DDT/US gal.) applied at a rate of 9.35 l/ha (1 US gal./acre) from a fixed wing aircraft (Silver, 1961a). This emergency operation was not succesful in terms of larval mortality as fall surveys showed a high surviving population. However, aerial observations in October indicated that trees in the sprayed area were in better condition than those in unsprayed areas.

Pupal surveys in the spring of 1961 revealed good survival of the overwintering population, hence tentative chemical control measures for treatment of areas already severely defoliated were finalized. Insecticide was applied over 3969 ha (9800 acres) between June 22 and July 12 by helicopter at a rate of 0.56 kg DDT/18.7 l fuel oil/ha (½ lb. DDT/2 US gal. fuel oil/ acre). Spray blocks were laid out such that low elevation stands were sprayed before those at higher elevations. An additional 284 ha (700 acres) of low elevation timber, where larvae were already approaching maturity, was sprayed near the end of the

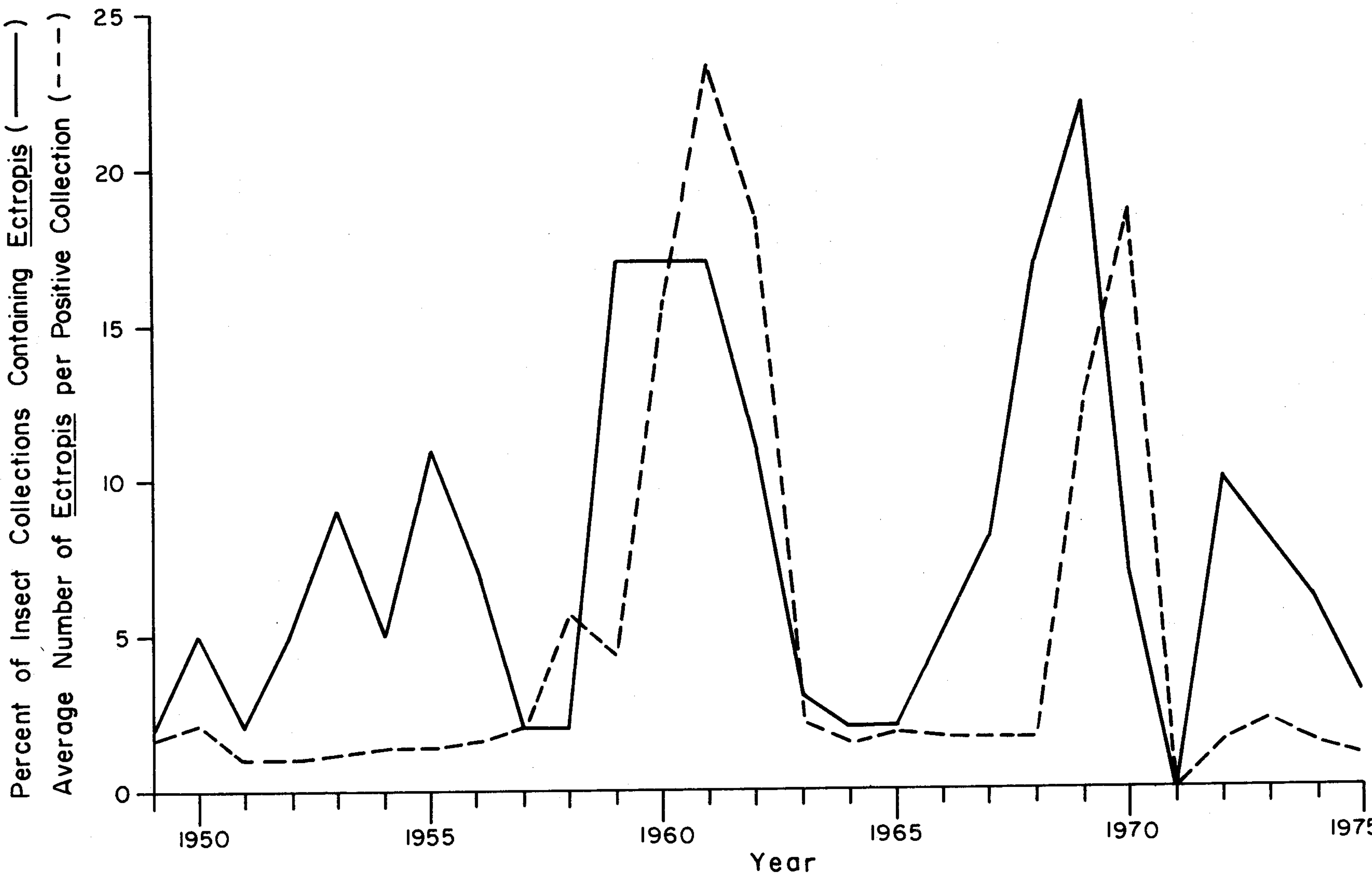


Figure 6·1 Summary of *Ectropis crepuscularia* populations in the Prince Rupert Forest District (condensed from Forest Insect Survey records, Canadian Forestry Service, Victoria, B.C.)

operation.

Liason with the Canada Department of Fisheries resulted in buffer swaths bordering the Kitimat River and estuary, as well as Goose, Moore and Anderson creeks being delineated to avoid possible fish and benthos mortality (Can. Dept. Fish., 1961). The estuary was considered particularly vulnerable owing to the substantial numbers of smolts thought to have been present during that time. Federal fisheries officers subsequently reported no fish mortality traceable to the 1961 spray project.

The principal object of the 1961 spray operation was to avert the almost certain death of most hemlock and true fir trees surviving the 1960 defoliation. As the larvae were killed while they were still small this objective was met. Tree mortality in the ensuing years was largely the direct result of the 1960 defoliation. Secondary factors include slowing of tree growth rates by fumes from the Alcan smelter and attack of weakened trees by bark beetles. There was 100% mortality of suppressed and intermediate crown class hemlock and alpine fir over large areas. Mortality of dominant and codominant trees was lighter except for local pockets. Losses reached 58.3 m^3/ha (10,000 bd. ft./acre) (Andrews and Erickson, 1974). The area of infestation and defoliation is illustrated in Figure 6.2.

Biological assessment of spray results was hampered by the almost total lack of small living trees from which larval samples could be collected. However, by respraying test plots with high dosages to ensure 100% larval mortality, the effect of the operational spray was estimated as being 90.0%. Somewhat less effective control was attained in the 284 ha (700 acres) section sprayed near the end of the operation. Autumn sampling showed that pupal populations were very low in the early treatment area of 1961 and variable in areas not sprayed having been further decimated by the hymenopterous parasite *Dusona pilosa* and a virus

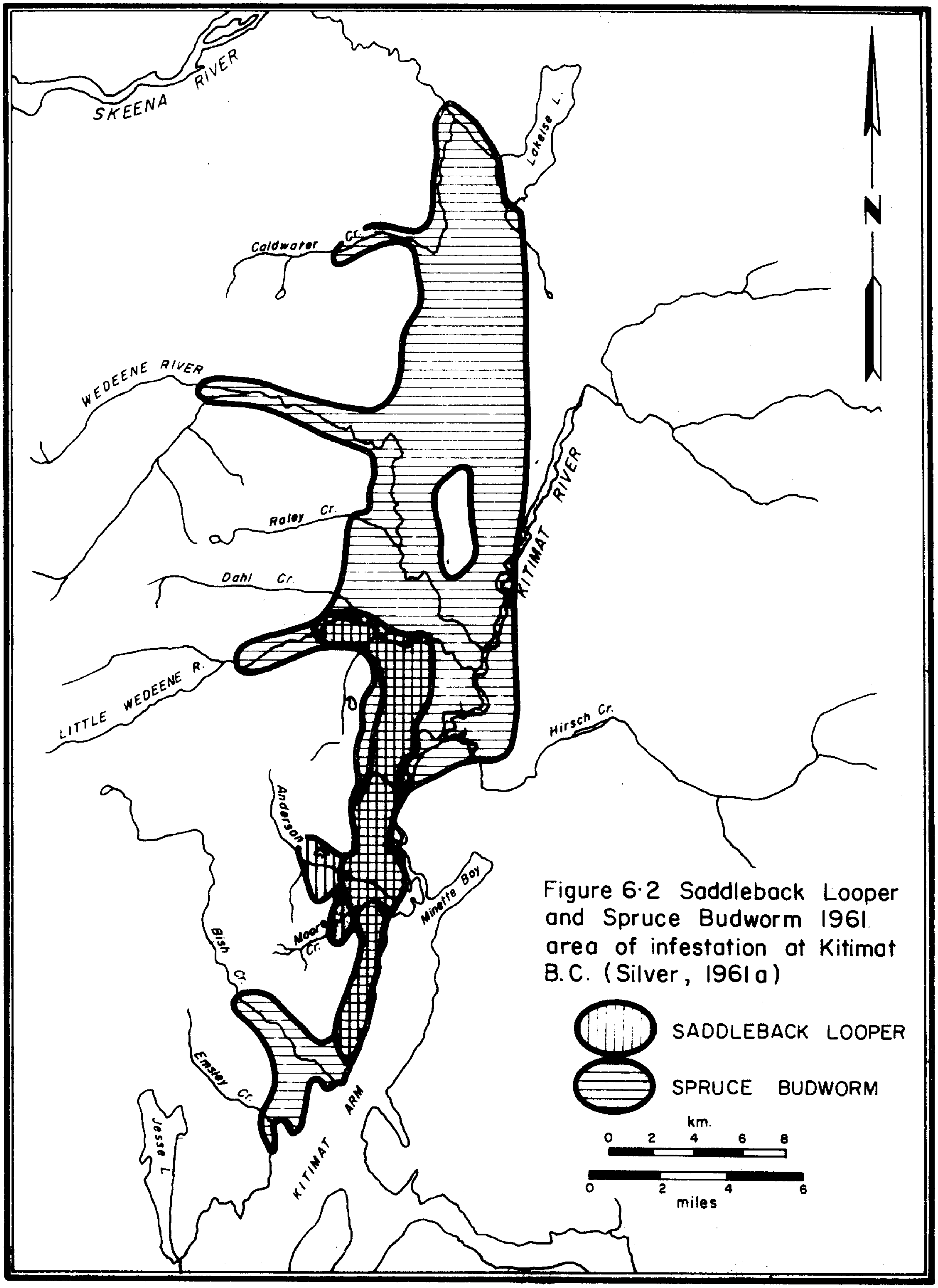


Figure 6·2 Saddleback Looper and Spruce Budworm 1961 area of infestation at Kitimat B.C. (Silver, 1961a) disease (Silver, 1961a).

Advantage was taken of the main control program, carried out in 1961, to compare the efficiency of the operational spray with a reduced DDT treatment, and three other materials, Dibrom, Phosphamidon and Thuricide. Experimental sprays were carried out on five contiguous 8-ha (20-acre) plots immediately west of the Kitimat Service Centre. The biological assessment of these experiments has been described by Kinghorn (1961). Results indicated that the operational spray of ½ lb. DDT in 2 U.S. gal/acre gave the best control, while the reduced DDT treatment (¼ lb. DDT/acre) ranked second. Control achieved by the three other materials was not considered satisfactory, as the mortality rate caused by any one of these three treatments was not greater than 40%.

The spruce budworm (*Choristoneura orae*) experienced a similar cycle of abundance from 1960 to 1963 and caused heavy defoliation of amabilis fir in the Kitimat Valley (Andrews and Erickson, 1974). Heavily defoliated areas (up to 75 and 98% of current year's foliage lost in 1963) extended from Bish Creek on Kitimat Arm to the Big Wedeene River (see Figure 6.2).

Both looper and budworm populations remained light until 1969 when they again caused moderate to severe defoliation from the Wedeene River south of Emsley Cove. Heaviest damage occurred south of Kitimat where 50% of overstory trees were defoliated, particularly hemlock and amabilis fir. Disease and parasitism reduced the surviving population to normal levels by the fall of 1969, and they have remained light since that time.

6 (ii) FRESHWATER INVERTEBRATES

The macroinvertebrate fauna of the lower Kitimat River has been sampled regularly as a result of environmental surveys commissioned by the Eurocan Pulp and Paper Company Limited and carried out to date by T.W. Beak Consultants Limited (1971, 1972, 1974). They reported a relatively high order of benthic productivity and diverse community composition at control sampling stations which although subject to large fluctuations, was indicative of clean water conditions. Benthic productivity, expressed as increased total numbers of organisms and increased animal diversity, increased downstream of the Kitimat city sewer outfall and the Eurocan pulp mill diffuser.

Greater numbers of invertebrates occurred directly below the city sewer and were mainly *Cladocera*, which are indicative of mild organic enrichment. The benthic community immediately downstream of the diffuser shifted to a predominance of oligochaetes, which are tolerant of organic pollution. Community composition further downriver returned to near control conditions as the number of pollution tolerant oligochaetes was reduced. Diversity index values supported the above findings, as they ranged from 0.72 to 3.20, with the lowest value found immediately below the diffuser. The number of benthic species was reduced immediately downstream of the diffuser. Species lists, compiled from the specific identification of some samples taken during these three surveys, are presented as Appendix 6.1.

6 (iii) MARINE INVERTEBRATES

The intertidal biota of Kitimat Arm, the shores of which are typically steep and rocky with a rapid drop-off, was described briefly by Kussat (1968). Mussels (*Mytilus* sp.), barnacles (*Balanus* sp.), and amphipods were abundant at all four stations. The isopods *Gnorimosphaeroma* sp., *Idothea* sp., and *Ligia* sp., the gastropods *Acmaea* sp. and *Littorina* sp., the shore crab *Hemigrapsus* sp., the mite *Hydracarina* sp., as well as oligochaetes, were also identified.

A benthic invertebrate survey of upper Kitimat Arm was conducted by the Environmental Protection Service in 1975 (Bradshaw, 1976). The study indicated that the mud bottom found was characteristic of most northern fjords. Benthos was sampled from the dredged area adjacent to the Alcan dock, and despite observations of alumina (aluminum oxide $AL_2 0_3$) being carried out over the area by strong winds and possible spillages during loading and unloading, there was still good representation of polychaetes (6 families), mollusca (*Macoma* sp., *Nuculana* sp., *Acteocina* sp.) and foraminifera (*Globigerina* sp.). Eleven taxa were represented in all with 391 organisms per square metre. Other sampling stations located off the delta front had good polychaete (more than 12 families), mollusc (primarily *Macoma* sp., with *Nucula* sp., *Nuculana* sp., and *Acteocina* sp.) and foraminifera representation. Amphipods were present at a few stations with a cumacean and *Brisaster* sp. (Echinodermata) present at one station each. The number of taxa represented at each station and the total number of organisms per square metre averaged 6 (range 0 - 11) and 238 (range 0 - 848), respectively (Bradshaw, MS, 1976). A "diverse biota" was recorded from benthic samples taken off the delta front in July, 1968 for the purpose of fibre analysis; however, no further biological data are available (Kussat, 1968).

Plankton tows were conducted along shore in shallow intertidal waters (<1.5 m deep) on the Kitimat delta by Howard Paish and Associates Limited in June and July of 1974. Isopods (4-12 mm in length), amphipods (particularly *Anisogammarus* sp. (2-16 mm in length), also *Corophium* sp. (9 mm) were captured at nearly all stations with acari (1 mm) and dipterans (4 mm). One tow captured a large number of mysids (11-21 mm).

Amphipods (*Anisogammarus* spp. in particular) were found in association with vegetation on the Kitimat estuary. *Fucus* sp. communities along the eastern shore of the delta from MK Bay into Minette Bay and along the outer margin of the central delta supported the largest concentrations of amphipods. The second largest observed concentrations were found in association with sedge communities on the delta. Filamentous green algae colonies were affixed to the wetted portions of floating logs. Also Minette Bay supported amphipod populations (Paish, 1974).

Stomach content analysis of juvenile salmon in the estuary (Paish, 1974) showed that estuarine benthic organisms such as *Anisogammarus* spp., *Corophium* sp., and *Gnorimosphaeroma oregonensis* were major food items. Cladocerans (*Podon* sp., *Evadne* sp.), mysids and insects (mainly chironomids) were also important food items. More extensive juvenile salmon diet analysis is in progress by personnel associated with the Habitat Protection Directorate of the Fisheries and Marine Service, Environment Canada (Higgins and Schouwenburg, in progr.).

Estuarine benthos has been sampled as part of environmental surveys conducted by Beak Consultants Limited (1971, 1972). Benthic surveys were conducted in the summers of 1969, 1970 and 1971 using sampling stations situated as a rough transect across the delta and into Minette Bay. In 1969 and 1970, data reflected fluctations typical of undisturbed invertebrate populations, although standing crop was generally greater in 1969. In 1971, the standing crop of benthic animals was much greater than in 1969 or 1970, particularly at stations off the mouth of the Kitimat River, where numbers of organisms per square metre exceeded those at all other stations. This increase was attributed to possible increased organic deposition as a result of city sewer and pulp mill discharges to the river. The low number of species recorded in all three surveys was attributed to the influence of fresh water. Benthos in all survey samples was identified to the lowest taxon possible, and these results are included in Appendix 6.2, which lists invertebrate species occurring in the Kitimat River estuary.

Results of 1971 survey furnished enough data for analysis using diversity indicies($d=-\Sigma(n_i/N)\log_2(n_i/N)$ where d=diversity per sample, n_i=number of individuals per taxon and N=total number of organisms) (Beak Consultants Ltd., 1972). Diversity of benthos ranged from 0.71 to 3.71 with the lowest diversity occurring at their station located in the dredged area off the Alcan dock facilities. The bristle worm *Nephthys cornuta* predominated at this station. The number of taxa and diversity index (d=1.52) in Minette Bay was also low relative to the other marine stations. The bristle worm *Nephthys ferruginea* appeared to predominate and overall polychaete diversity was low. Diversities for sample stations located on the central delta ranged from 1.92 to 3.71, which were probably representative of marine species composition in this area.

A preliminary survey of intertidal invertebrates of the Kitimat River estuary (Levings, 1976) was carried out in August 1974 as part of a comparative study of estuarine habitats for gammarid amphipods at a number of B.C. mainland estuaries (Levings, et al., 1975). The following is a summary of the biological findings of this survey.

A portion of the western sector of the Kitimat delta, between the dredged area adjacent to the Alcan dock and the log storage and handling area adjacent to the Eurocan dock remains intact and was characterized by sand containing the bivalve *Macoma inconspicua*.

The middle and eastern sectors of the delta, were disected by several channels. The rock and cobble substrate was dominated by gammarid amphipods, particularly *Paramoera columbiana*, *Gammarus setosus* and *Anisogammarus confervicolus*.

The eastern shore of the estuary (along Indian Reserve #2) was characterized by a cobble-mud substrate. A few mussels (*Mytilus edulis*) were observed and the tube building amphipod *Corophium spinicorne* was the most abundant organism at this site.

Other organisms identified during this survey included the isopod *Gnorimosphaeroma oregonensis*, the sipunculid *Golfingia* sp., oligochaetes, a tanaid (*Tanais stanfordi*) and chironomid larvae.

It was concluded that the low species diversity, supported by limited salinity data, indicated the predominance of fresh water on deltaic habitats. Species composition was different than those of southern B.C. "high runoff" inlets. The predominance of the larger growing *Gammarus setosus* over *A. confervicolus* may be of significance to the feeding behavior of juvenile salmon. Juvenile chum salmon (*Oncorhynchus keta*), for example, may be unable to ingest *G. setosus* because of its large size, whereas *A. confervicolus* is a preferred food item (Paish, 1974). Data on fish feeding habits is presently being analyzed (Higgins and Schouwenburg, in progr.).

6 (iv) THE INVERTEBRATE FISHERIES RESOURCE

Little commercial fishing for invertebrates occurs near the Kitimat River estuary; however, annual landed values for the commercial fisheries of Area 6 are presented in the following table.

Table 6.1. Annual reported landed values of the Invertebrate Fisheries of Area 6 from 1970 to 1975 (compiled from Area Worksheets, Economics Branch, Fisheries Operations, Fisheries and Marine Service, Vancouver,B.C.).

	Crab	Abalone	Clams (butter)
1975	$6,500	$40,000	$7,000
1974	*	9,000	5,000
1973	1,000	*	*
1972	2,000	*	*
1971	3,000	*	*
1970	2,000	*	*

* nil value

Commercial crab fishing by a local operator is conducted along Douglas Channel, particularly from Kiskosh, Kitkiata and Gilttoyees Inlets and off Crab River (see Fish Section Fig. 7.1 for place-names). Abalone are taken on the west coasts of Price and Aristazabal Islands with some coming from the Estevan Group. The high prices being paid for abalone (average $1.11 per pound in 1975) attracted several operators. Clams are taken under permit for canning from the Fin Island and Sainty Point areas (Macdonald, 1976).

Apart from salmon, the most popular tidal sport fishery is for crabs. They are readily available from many localities, the most popular being the Kitimat waterfront, bays and inlets along Douglas Channel (Bish Creek, Gilttoyees Inlet, Kitkiata Inlet, Kishkosh Inlet) and Danube Bay on Verney Passage (the site of a seasonal fishing resort). Although good numbers of crabs continue to be present off the Kitimat waterfront, the majority are under-sized, owing to heavy fishing pressure. Catch and effort has been estimated at 15,000 crabs and 5,000 fisherman days (Macdonald, 1976) and has remained relatively constant over the past several years.

Although good stocks of abalone exist in outside waters, exploitation by sports fishermen is limited by distance and harvesting opportunity. Outside areas are often closed to clam digging owing to incidence of paralytic shellfish poisoning. Minor quantities of shrimp and prawns are taken each year.

A recently published report (Boutillier and Cooke, 1976) deals with prawn trap exploration throughout Area 6 from September, 1975 to December, 1976. Laredo Sound, from Wilby Point to the entrance of Meyers Passage, was the most productive region found. Squally Channel, from Otter Channel to Union Passage and Gardner Canal, particularly from Icy Point to Entrance Bluff in Barrie Reach, also yielded fair catches of medium to jumbo sized shrimp. Fishing in these areas can be carried out by vessels with refrigerated holds or by troller and gillnet day boats from Hartley Bay, Kitimat and Klemtu.

7. FISH

7 (i) GENERAL DISCUSSION

The Kitimat River supports a large anadromous fish population (average annual escapement - 200,000) that is heavily exploited by commercial, recreational and Indian food fisheries.

Extensive logging within the watershed, industrial developments and a growing population are likely to have affected fish production in the Kitimat River. Any alleged effects are discussed in the Pollution and Effects of Development Sections.

Appended are salmon escapement data (Appendices 7.1 and 7.2), a list of Kitimat area fish species (7.3), Area 6 annual landed values (7.4), steelhead catch data (7.5), and Area 6 salmon tidal sportfishing catch data (7.6).

1. SALMON:

The Kitimat River system supports runs of all five Pacific salmon, though the sockeye run is not large. Limited sampling of juveniles on the estuary during the summer of 1974 resulted in the following conclusions (Paish, 1974):

1. Juvenile salmon were present on the estuary throughout the Paish sampling period (May, June, July) and also during August (sampled by Fisheries and Marine Service personnel). Peak numbers occurred in May.

2. The numbers of juveniles was significantly greater in samples taken from vegetated intertidal areas of the central and east delta than those taken from non-vegetated intertidal areas of the central and west delta.

3. Amphipods and other intertidal estuarine benthos, usually found in association with intertidal vegetation, were the major dietary components of juvenile salmon caught in the inner estuary. Alternate food sources were marine zooplankton and larval insects.

Large-scale downstream enumeration and tagging projects were undertaken by the Fisheries and Marine Service in the spring of 1974 and 1975, and data from these programs are presently being analyzed (Higgins and Schouwenburg, in prog.). The programs failed to capture the expected numbers of fish, and this was attributed to missing the bulk of the migration in 1974 (R.J. Higgins, pers. comm.) and to floods in January, 1973 and October, 1974, which decimated what would have been large downstream migrations in the spring of 1974 and 1975 (E.R. Christiansen, Federal Fisheries District Supervisor, pers. comm.). A severe flood in 1972 was also extremely destructive of incubating salmon eggs, which is reflected in the low 1975 escapements to the system.

Salmon escapements to the system have recently trended smaller, despite efforts to curtail the commercial, sport and Indian food fisheries. As a result of declining escapement, especially of the chinook salmon, some interest has been shown in establishing a salmon hatchery on the Kitimat River system near the 17-mile bridge on Highway #25 (Mitchell, 1974). A capture and tagging program on adult migrating salmon was carried out during the summer of 1975 to determine if sufficient adult stocks exist to supply hatchery needs (Schutz, in progr.). This program will also supply information on the local sport fishery as well as upriver migrating timing and enumeration. Results are not yet available.

(a) <u>Coho Salmon</u> (*Oncorhynchus kisutch*). Annual estimated escapements to the entire Kitimat River system have varied from a low of 1,550 in 1967 to over 100,000 in 1934 and have averaged approximately 11,450 between 1965 and 1974. (See Appendix 7.1).

A major portion of the escapement spawns in the Kitimat River, but Chist Creek, Hirsch Creek, Humphreys Creek, Nalbeela Creek, Big Wedeene River and Little Wedeene River are all important coho producers. The escapements for each of these watercourses from 1965 to 1975 is presented as Appendix 7.2. Generally speaking, all available gravel bars, side channels and streams are utilized.

Spawning generally begins in July and runs through until November with September and October being the heaviest months. Coho fry tend to remain in freshwater for up to a year after their springtime (April) emergence. Coho tagging programs carried out by the Fisheries Service in 1974 in the Squamish River system and on the west coast of Vancouver Island have illustrated the importance of small tributary streams and flooded areas to fry survival (Can. Dept. Env., 1976). Coho fry migrate from larger streams and rivers in late fall, into tributaries where low water velocities prevent them from being swept downstream and good stream cover offers protection from predators.

Some fry may be displaced into the estuary where they will rear near shore; however, most second-year coho enter the estuary in spring and remain until the end of August (Paish, 1974). Estuarine fish sampling conducted in May, June and July of 1974 resulted in peak catches during May (Paish, 1974). Coho smolts measured between 34 mm and 104 mm, with a mean fork length of 87.6 mm for specimens. Some coho smolts were analyzed for stomach contents. Estuarine benthic organisms such as *Anisogammarus* spp., *Corophium* sp., *Gnorimosphaeroma oregonensis*, and mysids, represented the major food source of coho smolts sampled at all beach seining stations. Cladocerans (*Podon* sp., *Evadne* sp.) and insects, mainly dipterans were important dietary components of coho sampled in Minette Bay on July 24, 1974 (Paish, 1974).

(b) Chum Salmon (*Oncorhynchus keta*). Annual escapements to the Kitimat River system have varied from 20,000 - 50,000 in 1974 to a low of 1,000 - 2,000 in 1965. From 1965 to 1974 the escapement has averaged 30,650 chum annually. Most chum spawn in the Kitimat River with lesser numbers spawning in the Big and Little Wedeene Rivers, Humphrey's Creek, Nalbeela Creek, Hirsch Creek, and Chist Creek (see Appendices 7.1 and 7.2). Spawning begins in this system in July, peaks sometime in August, and is over by the end of September.

Chum move downstream and enter the estuary shortly after their springtime emergence. The limited freshwater rearing was reflected in the relative uniformity in size of smolts (31 mm to 72 mm) sampled on the estuary from May to July, 1974 (Paish, 1974). Chum were generally smaller than other salmon caught in the same place and at the same time, but were also the most numerous salmon species sampled, the greatest numbers being caught in May of the above period. Those chums analyzed for stomach contents were observed to have been feeding on cladocerans (*Podon* sp., *Evadne* sp.) and insects (mainly chironomids) (Paish, 1974).

(c) Chinook Salmon (*Oncorhynchus tshawytscha*). Annual escapements to the Kitimat River system have varied from a low of 1,375 in 1976 to 50,000 - 100,000 in 1934 and have averaged approximately 8,000 between 1965 and 1975 (see Appendix 7.1). The Kitimat River absorbs most of the annual escapement, although the Big Wedeene River is also a major spawning area, followed by the Little Wedeene River, Chist Creek and Hirsch Creek. Escapements to each of these water-courses from 1965 to 1975 are presented as Appendix 7.2. Spawning occurs in the system from May through to September, though the heaviest spawning occurs in July and August.

Chinook smolts were sampled on the estuary from May to July, 1974, with the greatest numbers being caught in May, (Paish, 1974). The largest single catch of juvenile salmon, which consisted mainly of chinook smolts, occurred during May at MK Bay, where they were apparently feeding on newly hatched herring larvae. Fifty-eight chinook smolts retained for length analysis measured between 45 mm and 140 mm in fork length. Estuarine benthos such as *Anisogammarus* spp., *Corophium* sp., *Gnorimosphaeroma oregonensis* and mysids represented the major food sources of chinook smolts analyzed for stomach contents. Cladocerans and insects were also important food items.

A tagging program for migrating adult chinook salmon was carried out during July and August, 1975 on the estuary by the Fisheries and Marine Service. This program will yield information regarding the availability of adult chinooks for a possible salmon hatchery, time to spawning death, spawning distribution and sport fishing returns (Schutz, in progr.).

The 1975 chinook escapement to the system is the lowest on record. This occurred in spite of closures on commercial fisheries in Area 6, restrictions on the freshwater sport fishery (treble hook and salmon roe ban; closed river upstream of the 17-mile bridge on Hwy #25) and curtailment of the Indian food fishery.

(d) Pink Salmon (*Orcorhynchus gorbuscha*). As in other watercourses in northern British Columbia, the even-year run predominates in the Kitimat River system. Annual estimated escapements have varied from a low of 1,800 in 1971 (1,850 in 1973) to 246,500 in 1972 and have averaged approximately 97,000 between 1965 and 1974. The major portion of the escapement (75%) spawns in the Kitimat River with the remainder in the Big and Little Wedeene Rivers, and in Humphreys, Nalbeela, Hirsh and Chist Creeks (see Appendices 7.1 and 7.2).

Spawning begins in July, peaks in August and continues in September. Eggs hatch sometime in February and fry emerge from the gravel sometime in April or May after which they make an active downstream migration (Hart, 1973). After leaving fresh water, pink smolts tend to remain close inshore through their first summer and move into deeper water in September (Hart, 1973). Very few smolts were captured during the sampling program by Paish (1974), owing to the minimal escapement of the previous year. The 1975 downstream enumeration and tagging program by the Fisheries and Marine Service (Schouwenburg and Higgins, in progr.) did not obtain the expected numbers of fish, owing to the disastrous effect of the October 15, 1974 flood (16,296 cms, 582,000 cfs, Can. Dept. Env., 1975) on incubating pink salmon eggs (E.R. Christiansen, pers. comm.). As a result, no early life history information on pinks, specific to the Kitimat River system is available at present.

(e) Sockeye Salmon (*Oncorhynchus nerka*). Though sockeye were once abundant in the Kitimat River (max. escapement 10,000-20,000 in 1938) despite the lack of lakes in the system, there no longer is a run of any consequence. Fisheries Officers report incidental escapements of approximately 100 per year to the system (E.R. Christiansen, pers. comm.).

2. ANADROMOUS TROUT:

No direct estimates are available of the number of steelhead (*Salmo gairdneri*) and migratory coastal cutthroat trout (*Salmo clarki clarki*) spawners in the Kitimat River system. However, studies of steelhead catch to escapement ratios in other systems have estimated that annual catches represent less than one-third of the total steelhead run. The steelhead catch in the Kitimat River system (including Hirsch Creek and the Wedeene Rivers) has been estimated to be between 392 and 815 steelhead annually between 1966 and 1975. Steelhead catch statistics, compiled from the steelhead harvest analysis prepared by the B.C. Department of Recreation and Conservation, are presented as Appendix 7.5. Steelhead trout, cutthroat trout and Dolly Varden char (*Salvelinus malma*), between one and three years of age, were captured on the estuary by Paish (1974). Of these species the Dolly Varden char was the most numerous by far.

3. RESIDENT FRESHWATER SPECIES:

The resident fish fauna of the Kitimat River system is typical of intermediate sized northern coastal streams, as no species have been introduced by man. Cutthroat trout (*Salmo clarki clarki*), resident rainbow trout (*Salmo gairdneri*) and Dolly Varden char (*Salvelinus malma*) are distributed throughout the Kitimat River system and may also be found in the estuary. Threespine sticklebacks (*Gasterosteus aculeatus*), prickly and Aleutian sculpins (*Cottus asper, C. aleuticus*) are also found in the system.

4. MARINE SPECIES:

Fish sampling in nearshore estuarine environments was conducted on four days in early May, three days in late June and three days in late July, 1974 by Howard Paish and Associates Ltd. (1974). Beach seining and pole netting techniques were used. Juvenile salmon made up half of the total number of fish caught and threespine sticklebacks were the most numerous single species. The fish species caught in this sampling program are included in Appendix 7.3.

Herring (*Clupea harengus pallasi*) stocks in the upper Kitimat Arm are small. The fish are for the most part "homesteaders" and relatively slow growing (L.A. Webb, Fisheries and Marine Service, pers. comm.). Commercial exploitation is minimal owing to the small roes which these fish grow, making them less than top grade. Spawning occurs locally along the the foreshore between Kitamaat and Minette Bay. In 1975 spawning in this area occurred between March 26 and April 3 along 2,402 m (7,880 ft.) of foreshore covering 13,627 m^2 (15,760 sq. yds.) with very light to light spawn. In 1974 spawning occurred during March 18-20 along 853 m (2,800 ft.) of foreshore covering 11,806 m^2 (14,000 sq. yds.)

with light spawn (Macdonald, 1974, 1975).

Eulachon (*Thaleichthys pacificus*) spawn in the lower 16 km (10 miles) of the Kitimat River during March and April. The eulachons attract many avian, mammalian and piscine predators to the estuary during their spawning period. The eulachon runs were once heavily exploited by the native populace, as is evidenced by the old Indian village along the lower river course and the many eulachon-trade artifacts which remain preserved to date at the Kitimat Centennial Museum. However, with the start-up of the Eurocan pulp mill and the discharge of treated pulp mill effluent into the Kitimat River the eulachons allegedly became tainted and therefore unfit for human consumption. The Kitamaat Indian Band has not harvested Kitimat River eulachon, once a traditional fishery, since 1972 because of the alleged tainting. A proposal to study the problem has been drafted (Mahood, 1976).

Capelin (*Mallotus villosus*) spawn along Hospital Beach in early spring (March) during which time they may be harvested by amateurs (C.R. Fox, Alcan, pers. comm.). The numbers of spent capelin which can accumulate along shore during intense spawning have at times led to erroneous reports of fish kills by the local populace. Other smelts (Osmeridae) may occur in the area but large runs do not appear.

Groundfish such as ling cod (*Ophiodon elongatus*), grey cod (*Gadus macrocephalus*), rockfish (*Sebastes* spp.), sole and flounder (Bothidae, Pleuronectidae), and even halibut (*Hippoglossus stenolepis*) are also reasonably abundant in Kitimat Arm as evidenced by sport fishing catches (Macdonald, 1975).

7 (ii) THE FISHERIES RESOURCE

1. COMMERCIAL FISHING:

Except for a few local boats, no commercial fishing is conducted in Kitimat Arm which lies within the Fisheries and Marine Service Statistical Area 6, otherwise known as the Butedale Sub-district. Figure 7.1 illustrates the inside waterways and islands of Area 6 and Appendix 7.4 presents annual landed values.

Kitimat River salmon, along with those from the Kemano, Kitlope, and other smaller rivers contribute to commercial catches in the outside waters of Area 6. Inside waters of Area 6, including Douglas Channel, Gardner Canal and adjacent waterways are closed to commercial salmon fishing (see Figure 7.1). Fishing is concentrated in Whale Channel, Campania Sound, Squally Channel, Caamano Sound, Laredo Sound, Laredo Channel and Kitasu Bay. Trollers, gill netters and purse seiners (in order of fishing effort expended) operate in these areas. Estimated exploitation rates of Area 6 coho, chum, pink and sockeye stocks in 1974 were 45-50%, 30%, 60% and 40-45%, respectively (Macdonald, 1975). Commercial salmon fishing effort in these waters is regulated very carefully by limiting fishing time in order to ensure sufficient escapements to area rivers.

The commercial roe herring fishing of Area 6 is also conducted in outside waters, primarily in Kitasu Bay and Higgins Pass (Macdonald, 1976). Herring present in the Kitimat area do not contribute to these larger migratory stocks. Kitimat stocks are slower growing resident fish and do not grow roe large enough to be top grade (L.A. Webb, pers. comm.).

Halibut fishing is conducted in Douglas Channel, Gardner Canal, Sue Channel and Ursula Channel. This fishery is conducted largely by small one or two man boats with larger long-liners sometimes stopping to top up loads.

The catch of groundfish in the Butedale Sub-district is relatively minor. Chief species fished include the grey cod (*Gadus macrocephalus*), ling cod (*Ophiodon elongatus*) and black

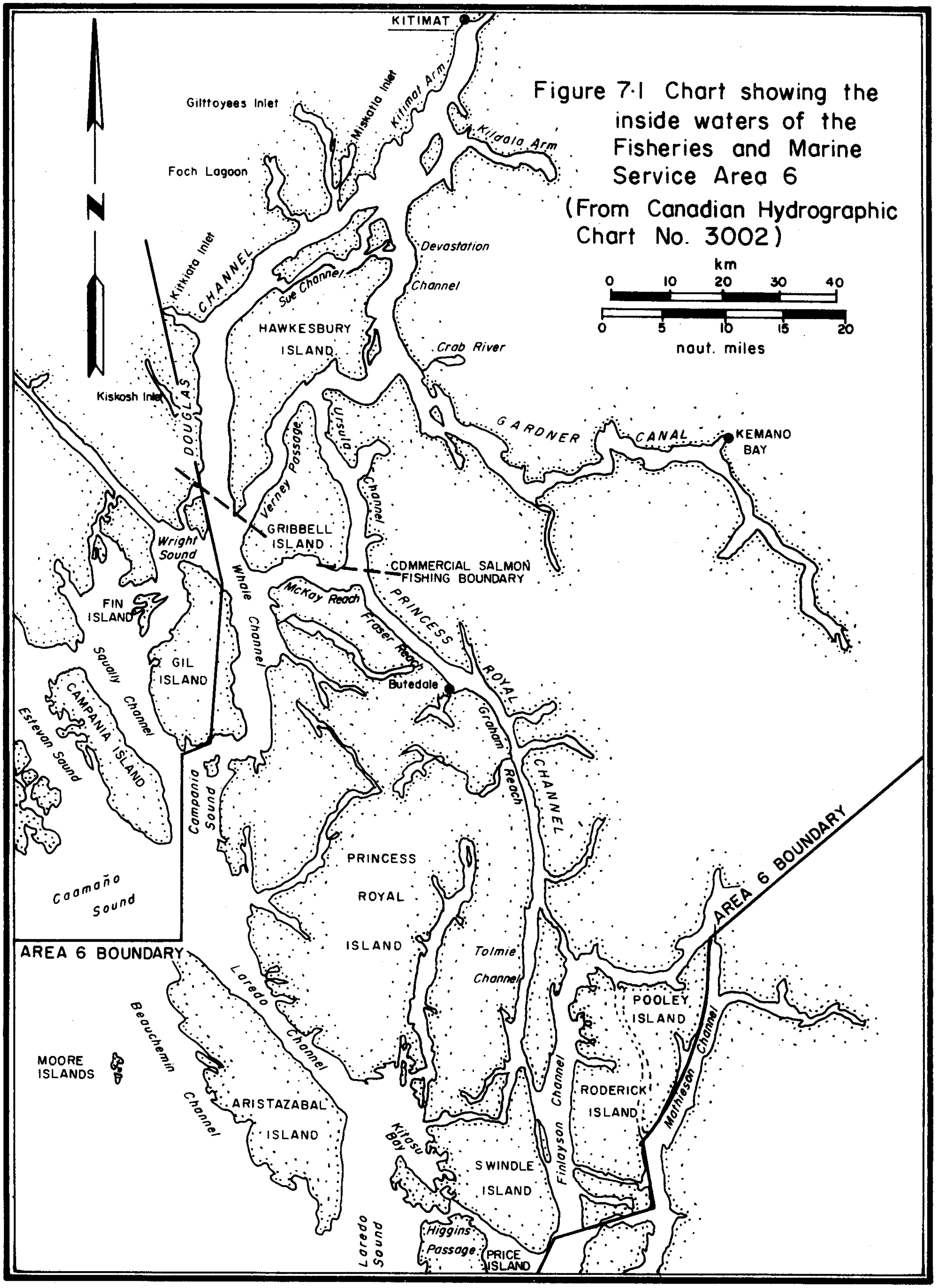


Figure 7·1 Chart showing the inside waters of the Fisheries and Marine Service Area 6
(From Canadian Hydrographic Chart No. 3002)
km
0 10 20 30 40
0 5 10 15 20
naut. miles
N
KITIMAT
Gilttoyees Inlet
Foch Lagoon
Miskatla Inlet
Kitimat Arm
Kildala Arm
Kitkiata Inlet
DOUGLAS CHANNEL
Sue Channel
Devastation Channel
HAWKESBURY ISLAND
Crab River
Kiskosh Inlet
Ursula Channel
Verney Passage
GARDNER CANAL
KEMANO BAY
GRIBBELL ISLAND
Wright Sound
COMMERCIAL SALMON FISHING BOUNDARY
McKay Reach
Fraser Reach
PRINCESS ROYAL CHANNEL
FIN ISLAND
GIL ISLAND
Whale Channel
Squally Channel
Butedale
CAMPANIA ISLAND
Estevan Sound
Graham Reach
Campania Sound
PRINCESS ROYAL ISLAND
Caamaño Sound
AREA 6 BOUNDARY
Laredo Channel
Tolmie Channel
POOLEY ISLAND
Beauchemin Channel
MOORE ISLANDS
RODERICK ISLAND
Mathieson Channel
ARISTAZABAL ISLAND
Kitasu Bay
Finlayson Channel
SWINDLE ISLAND
Laredo Sound
Higgins Passage
PRICE ISLAND

cod (*Anoplopoma fimbria*), though red and rock cod (*Sebastes* spp.), turbot (*Atheresthes stomias*), skate (*Raja* spp.) and sole (*Bothidae, Pleuronectidae*) are also landed.

Invertebrate fisheries are discussed in the Invertebrate Fisheries Resource subsection.

2. SPORT FISHING:

Sport fishing in Kitimat has assumed a degree of popularity seldom seen in other communities owing to the isolation of the area, and relative lack of other forms of recreation and the good fishing of various types available within a reasonable distance.

(a) Freshwater Sport Fishing. The Kitimat River, one of Canada's most heavily sport fished rivers, offers some of British Columbia's finest salmon, steelhead and trout fishing. The Kitimat was included as part of the lower Skeena valley region in a report documenting the importance of sport fishing in northern British Columbia (Reid, 1974). Shoreline river fishing for salmon was favourite among both resident and B.C. non-resident fishermen. The Kitimat River ranked third in total angler effort after the Skeena and Kispioux Rivers in terms of resident angler effort. In fact, almost all of the angler effort is expended by residents.

A recent report (Sinclair, 1975) documents the importance of the Kitimat River and the recreation opportunity it offers, to the social well-being of the Kitimat populace. More than half of the Kitimat residents used the river for sport fishing or some other form of outdoor leisure activity. The topography of the area and the lack of alternate leisure activities were taken to focus resident attention on the river.

The Kitimat is fished year-round. In summer and early fall, when the days are long and fish are running in the river, fishing goes on 24 hours a day. Many shift workers, travelling to and from work along a road paralleling the river, utilize these opportunities to fish for short periods of time. Kitimat fishermen are active and spend a considerable portion of their leisure time fishing (see Table 7). The Kitimat River (not including Douglas Channel) accounts for more than 60% of local annual sport fishing effort which amounted to 104,000 angler days in 1974 (Sinclair, 1975).

Table 7.1. Number of days fished per year by Kitimat resident sport fishermen surveyed on the Kitimat River in 1974 (Sinclair, 1975).

No. of Days	No. of Persons	Percentage
0 - 9	24	5.9
10 - 19	40	9.8
20 - 29	60	14.6
30 - 39	56	13.7
40 - 49	21	5.1
50 - 59	67	16.3
60 - 79	40	9.8
80 - 99	11	2.7
100 - 149	47	11.5
150 - 199	22	5.4
200 - 249	19	4.6
250 +	1	0.2

The Kitimat is a relatively low cost river to fish, which may account for it being the favourite fishing place of Kitimat residents surveyed in 1974. Average cost per day of fishing was estimated at $5.35 which is well within the reach of most of the Kitimat populace. An estimated $450,000 was spent by residents fishing the river in 1974 (Sinclair, 1975).

(b) Tidal Sport Fishing. Tidal water sport fishing in Area 6 is centered in the Kitimat Arm - Douglas Channel and Verney Passage - Ursula Channel waters. Angler effort is increasing steadily in the area as more people bring better boats into operation. Fisheries Officers estimate that in 1968 there were approximately 25 to 30 boats in the area whereas there are now (1976) approximately 200 to 300 boats (E.R. Christiansen, pers. comm.). Salmon are the principal fish species fished, and catch statistics are presented as Appendix 7.6. Crabs are the next most popular species; these and other invertebrate fisheries are discussed in the Invertebrates Fisheries Resource subsection.

During slack periods in salmon sport fishing, jigging for groundfish is both popular and productive. Various rockfish species and ling cod are widely available and the most sought after, although grey cod, sole and halibut are also taken. Catch estimates for 1975 for these fishes are 2,000 to 2,500 rockfish, 500 ling cod, and 75 to 100 halibut (Macdonald, 1976). Herring are also caught and used for both food and bait.

3. INDIAN FOOD FISHERY:

There are 6 Indian Reserves located in the present study area, the major one being Kitamaat, otherwise known as Kitimat Mission, which support a significant native population. The Kitamaat and Hartley Bay (located well down Douglas Channel) Indian bands fish actively in the Butedale Sub-district. Most of the food fishes are taken by the Kitamaat people from Kitimat Arm as far south as the Kitsaway Anchorage. Permits are issued for the taking of salmon which are usually taken by set net limited to 91.5 m (50 fathoms) in length. Fishing is limited to a maximum of four days per week when salmon are running. Special permits are issued for fishing in the Gardner Canal.

Table 7.2. Kitamaat Indian Salmon Food Fishery Statistics (Macdonald, 1975).

Year	Permits Issued (No.)	Catch (No.) Sockeye	Coho	Pink	Chum	Chinook	Steelhead
1975	132	200	400	300	800	100	-
1974	118	400	420	50	1400	800	-
1973	123	200	400	100	1500	200	-
1972	117	150	600	1000	2000	350	150
1971	149	150	700	150	2000	200	100
1970	114	100	800	1000	700	250	150

Permits are occasionally issued for the taking of herring, an estimated 1.8 tonnes (2 short tons) of which were taken from Kitimat Arm in 1975 (Macdonald, 1976). Herring roe is generally also gathered during the spring spawning period.

Eulachons spawning in the Kitimat River system, were once a major Indian food fishery. Eulachons are no longer taken (since 1972) from the Kitimat River in any quantity owing to alledged tainting by pulp mill effluent (see Water Pollution, Eurocan Pulp and Paper Mill Subsection). Kitamaat Indians now fish eulachon runs in other area rivers namely the Kitlope, Kemano, Kildala and Kowesas Rivers.

8. FLORA

The Kitimat delta and lower river valley (up to ca. 300 m asl) are located in the coastal western hemlock biogeoclimatic zone described by Krajina (1969). It is the wettest zone of British Columbia and is characterized by mild winters and cool summers. It is suitable for the highest production of several coniferous trees notably Douglas fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*) western white pine (*Pinus monticola*), grand fir (*Abies grandis*; in the drier subzones) and yellow cedar (*Chamaecyparis nootkatensis*; in the wetter subzone). Higher portions of the valley (ca. 300 m - 900 m) are included in the mountain hemlock zone (Krajina, 1969), which is characterized by heavy snow cover over unfrozen ground. The most common coniferous trees of this zone include mountain hemlock (*Tsuga mertensiana*), Pacific silver fir (*Abies amabilis*) and yellow cedar.

The vegetation of the Kitimat Valley has recently been studied by W. Hubbard of Biocon Research Ltd., Victoria and this work, reported by Hay (1976) forms the basis for much of this section of the report. Further botanical collections have been made in the area by Mrs. G. Mendel, curator of the Kitimat Centennial Museum. A species list of plants collected to date from the lower Kitimat Valley (not to be considered as a list of the total plant species possible in the area) is presented as Appendix 8.1.

8 (i) AQUATIC FLORA

Little work has been completed on the pelagic and benthic vegetation of Kitimat Arm to date. There are presently no estimates of the primary productivity of these waters. The physical factors affecting production are discussed, however, in the Oceanography section.

A short survey of Kitimat Arm intertidal sites was conducted in July 1968. Suitable sampling sites were difficult to find owing to the steep rocky shores and rapid drop-off. Those small bays surveyed had abundant brown and lesser amounts of red and green algae growing in the mid and lower mid intertidal zones, with kelp generally abundant in shallow water. Species identified included *Zostera* sp., *Bryopsis* sp., *Ulva* sp. and others of the Chlorophyta, *Fucus* sp., *Laminaria* sp. and others of the Phaeophyta and *Halosaccion* sp. of the Rhodophyta (Kussat, 1968).

Paish (1974) described rockweed (*Fucus* sp.) beds extending along the shore from MK Bay into Minette Bay (eastern shore of the delta). These beds are important to the spawning of herring, which occurs along this shore annually (see Fish section).

8 (ii) DELTAIC FLORA

The following discussion,as well as the accompanying Figure 8.1 are based upon a botanical survey conducted by W. Hubbard of Biocon Research Ltd., Victoria which was reported by Hay (1976). These community types are depicted as Land Unit No. 7 (Estuary Land) in Figure 8.2. An "aster-alder estuary grassland" forms a narrow fringe along the northern edge of the tidal flats. (See Figure 8.1.) This zone ends where the forest of alder becomes continuous and merges with the cottonwood alluvial flood plain forest described in the Terrestrial Flora subsection. Where land lies above the high tide level in the tidal flats, scattered patches of the aster-alder shrubland can be found. This vegetation zone is subject to marine influences, but only from salt mist and occasional flooding under high tide storm conditions. Red alder

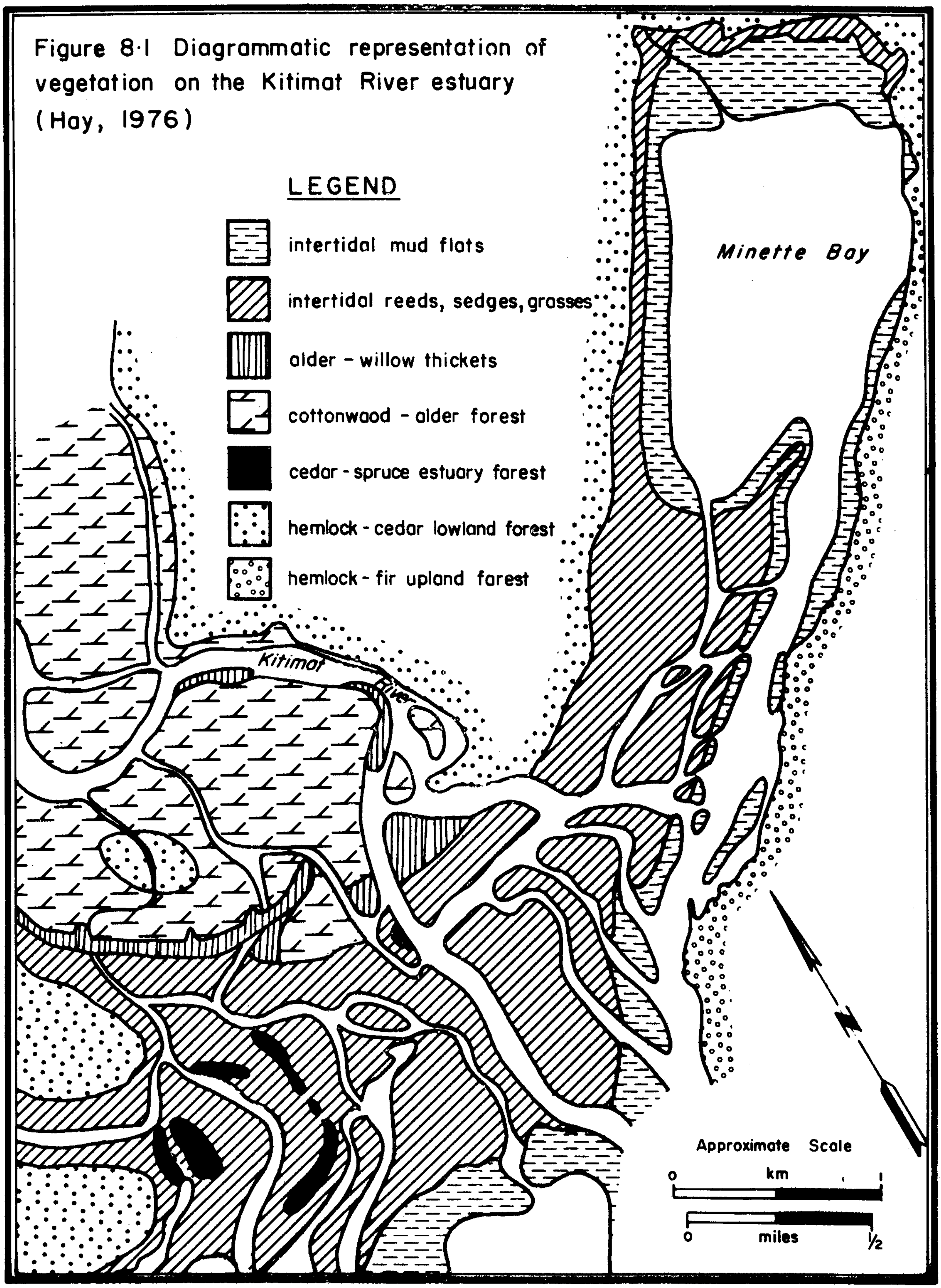


Figure 8·1 Diagrammatic representation of vegetation on the Kitimat River estuary (Hay, 1976)
LEGEND
intertidal mud flats
intertidal reeds, sedges, grasses
alder - willow thickets
cottonwood - alder forest
cedar - spruce estuary forest
hemlock - cedar lowland forest
hemlock - fir upland forest
Minette Bay
Kitimat River
N
Approximate Scale
0
km
1
0
miles
½

(*Alnus rubra*) and sitka alder (*A. sinuata*) are common in the low overstory, with a dense undergrowth formed by black twinberry (*Lonicera involucrata*), thimbleberry (*Rubus parviflorus*), salmonberry (*R. spectabilis*), and elderberry (*Sambucus racemosa*). The ground surface is dominated by grasses, including bentgrass (*Agrostis* sp.), reedgrass (*Calamagrostis* sp.), little hairgrass (*Deschampsia caespitosa*), red fescue (*Festuca rubra*), alkaligrass (*Puccinellia* sp.), and at higher levels, beach rye (*Elymus mollis*). Other species present are yarrow (*Achillea millefolium*), common burdock (*Arctium minus*), thistle (*Cirsium* spp.), fireweed (*Epilobium angustifolium*), lupine (*Lupinus* sp.), purple aster (*Aster subspicatus*), Indian paintbrush (*Castilleja* sp.), hemlock-parsley (*Conioselinum pacificum*), chocolate lily (*Fritillaria kamchatchensis*), bedstraw (*Galium* sp.), plantain (*Plantago lanceolata*), sourgrass (*Rumex acetosella*), curl dock (*Rumex crispus*), and clover (*Trifolium* sp.), with Baltic rush (*Juncus balticus*), creeping buttercup (*Ranunculus repens*) and silverweed (*Potentilla pacifica*) in moist depressions near the ocean. Mosses are common above the high tide line, with one species (*Polytrichum* sp.) found often.

There are some groves of mature coniferous forest in this sub-unit, totally surrounded by the salt marshes. They are found near the western edge of the area and are dominated by western red cedar (*Thuja plicata*) and Sitka spruce (*Picea sitchensis*), with western hemlock (*Tsuga heterophylla*) in somewhat lesser abundance.

Arrowgrass salt marshes occur over most of the delta where the river channels merge with salt water. The marsh is usually submerged only at high tide. In the upper portion of this zone, large clumps of glasswort (*Salicornia pacifica*) and dodder (*Cuscuta maritima*) are dominant. These are interspersed with tufts of arrowgrass (*Triglochin maritimum*) and, on the mud, sea blite (*Suaedia marina*) and sand spurry (*Spergularia marina*). Below this are the sedges (*Carex eurycarpa, C. lyngbyei*

Carex obnupta), bulrushes (*Scirpus cyperinus, S. microcarpus, S. validus*), and sometimes spike-rush (*Eleocharis* sp.) and cattail (*Typha latifolia*).

The lowest portions of the tidal flats, which are for the most part bare mud, are only exposed at low tide. This area is dominated by eelgrass (*Zostera marina*) and benthic algae. Paish (1974) and Levings (1976) noted rockweek (*Fucus* sp.) as being the dominant vegetation cover on the lower delta, as it grew on scattered sunken wood debris (Minette Bay and Channel), on gravel substrates near river channels (central delta) and on gravel bars (west delta). The red algae *Ahnfeltia* sp. and green algae *Rhizoclonium* sp. were also identified from the east and central deltas respectively (Paish, 1974). Paish also noted a close association between amphipods (*Anisogammarus* sp.), the isopod (*Gnorimosphaeroma oregonensis*) and green algae growing in tidal sloughs on the central delta. Although beds of eelgrass are present along the outermost delta east of the Eurocan dock facilities and in Minette Bay, the most extensive beds occur in the Minette Bay Channel (C.D. Levings, pers. comm.). Eelgrass is an important form of intertidal vegetation, as it supplies food for waterfowl, spawning substrate for herring and habitat for crabs, other invertebrates and fish. It contributes large amounts of detritus to the food web (Harrison and Mann, 1975), recycles nutrient elements from the substrate into the water column (McRoy, et al., 1972), and its roots stabilize and prevent erosion of sediments.

The Kitamaat (Kitimat Mission) foreshore was dominated by glasswort with some sedges and rushes present; however, no eelgrass was observed in September, 1975. The back beach area was vegetated with patches of beach rye (*Elymus mollis*), beach pea (*Lathyrus japonicus*), and small amounts of sea rocket (*Cakile edulenta*) and sea purslane (*Honkenya peploides*).

Estuarine vegetation may also be found on the deltas of Bish Creek and Emsley Creek where they flow into Kitimat Arm.

8 (iii) TERRESTRIAL FLORA

A recent study of the wildlife of the Kitimat Valley (Hay, 1976) includes, botanical work done by W. Hubbard during September, 1975 and this report forms the basis of the following discussion. In this work ten land units were described and these are depicted in Figure 8.2.

The alluvial flood plain forest (Land Unit No. 1) includes the terraces of the lower Kitimat River and its major tributaries including the Wedeene River, Little Wedeene River, Hirsch Creek, Nalbeelah Creek and Humphreys Creek. Dominant in the overstory of the flood plain are large stands of northern black cottonwood (*Populus trichocarpa*) which occupy the river banks, especially along the lower Kitimat River. Red alder (*Alnus rubra*) is abundant in the lower story and on the sandbars of the river. Willow (*Salix* spp.), Sitka spruce (*Picea sitchensis*), western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) are present in small quantities with vine maple (*Acer circinatum*), paper birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*) and Pacific crab-apple (*Pyrus fusca*) being rarely encountered. The understory is very thick, except in mature stands of cottonwoods. Characteristic of this shrub layer are goat's beard (*Aruncus sylvester*), red osier dogwood (*Cornus stolonifera*), black twinberry (*Lonicera involucrata*), Devil's club (*Oplopanax horridum*), wild currant (*Ribes* sp.), Nootka rose (*Rosa nutkana*), thimbleberry (*Rubus parviflorus*), salmonberry (*Rubus spectabilis*), elderberry (*Sambucus racemosa*), waxberry (*Symphoricarpos* sp.), and highbush cranberry (*Viburnum edule*). The herb layer is less dense, though it is still plentiful. Dominant in areas saturated by water are skunk cabbage (*Lysichitum americanum*), common horsetail (*Equisetum arvense*),

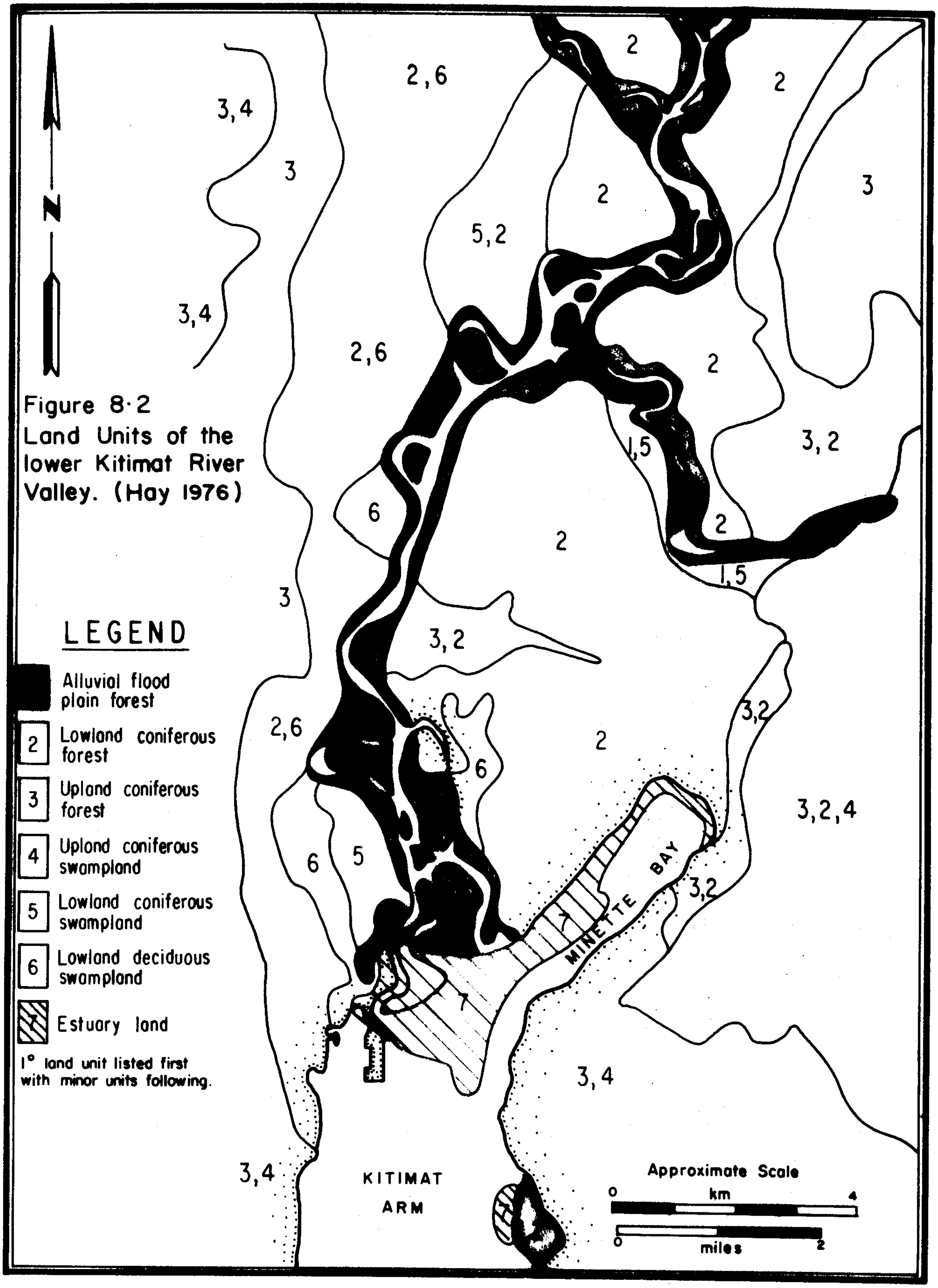


Figure 8·2
Land Units of the lower Kitimat River Valley. (Hay 1976)
N
LEGEND
Alluvial flood plain forest
2 Lowland coniferous forest
3 Upland coniferous forest
4 Upland coniferous swampland
5 Lowland coniferous swampland
6 Lowland deciduous swampland
7 Estuary land
1° land unit listed first with minor units following.
MINETTE BAY
KITIMAT ARM
Approximate Scale
0 km 4
0 miles 2
2
2,6
3,4
3
3,4
5,2
2
2
3
2,6
2
1,5
3,2
6
2
2
1,5
3
3,2
2,6
2
6
3,2
3,2,4
6
5
3,2
7
3,4
3,4

and some sedges (*Carex* spp.). In other areas, species include baneberry (*Actea rubra*), pearly everlasting (*Anaphalis margaritaceae*), fireweed (*Epilobium angustifolium*), wild lily-of-the-valley (*Maianthemum dilatatum*), sweet cicely (*Osmorhiza chilensis*), creeping buttercup (*Ranunculus repens*), star-flowered Solomon's seal (*Smilacina stellata*), cow parsnip (*Heracleum lanatum*), and stinging nettle (*Urtica* sp.) Mosses and ferns are fairly abundant. Ferns include wood fern (*Dryopteris austriaca*) and lady fern (*Athyrium filix-femina*), with some mosses being common (*Antitrichum* sp., *Hypnum circinale, Mnium glabrescens, Mnium insigne*).

Also part of this land unit is alder regeneration forest, groves of which are found near the Kitimat River north and south of the Old Indian Village (1.6 km south of the Kildala Neighborhood - refer to Figure 1.1), along the northern edge of the estuary tidal flats north of the Eurocan dock facilities, adjacent to the oxbows of the Kitimat River north of the Service Centre, and along both sides of the Wedeene and Little Wedeene Rivers two miles upstream from their junction with the Kitimat River. Although red alder is presently dominant, the western hemlock forest will take over in a matter of decades. Sitka alder (*Alnus sinuata*) is more prevalent near the tidal flats than red alder. The willows are quite common in the lower story of the alder regeneration forest, with a few scattered examples of paper birch and Pacific crab-apple present. The relatively scarce conifers in this vegetation zone are Sitka spruce, western red cedar, and western hemlock. The shrub layer is very localized, depending upon conditons of soil mositure and texture. Common species are thimbleberry, salmonberry, and elderberry, with many young alders and willows. In moist depressions, herbs and flowers are evident, but uncommon. These include pearly everlasting, fireweed, and cat's ear (*Hypochaeris radicata*). The mosses remain the same as those occurring in the stand prior to clearing.

The lowland coniferous forest (Land Unit no. 2) consists of three zones, namely, the lowland cedar-hemlock bogs, skunk cabbage bottomlands, and Devil's club lower slopes. The lowland cedar-hemlock bogs occur north of the townsite near the Kitimat River and east of the Alcan smeltersite. Drainage is very poor and there is a high water table with deep organic soils. This zone is not subject to flooding by the Kitimat River or its tributaries. The overstory consists of western hemlock, with occasional Sitka spruce and western cedar. Near the edges of the bog are a few specimens of swamp birch, paper birch, and willow. Lodgepole pine (*Pinus contorta*) becomes increasingly common north of Kitimat and at high elevations. The shrub layer, dominated by bog laurel (*Kalmia polifolia*) and labrador tea, is restricted to areas of good drainage within the swamps. Underneath these shrubs is a deep mat of sphagnum moss, dotted with skunk cabbage. Herbs and flowers are almost non-existent, although several species of sedges and rushes are present.

The skunk cabbage bottomlands are common near the Kitimat River, south of Kildala Neighborhood, and along the northern shore of Minette Bay. Drainage is also poor in this zone and there are often large amounts of standing water. The overstory is very dense, dominated by western hemlock and western red cedar, with some Sitka spruce and the occasional vine maple (in the lower story). The shrub layer is quite thick, containing Devil's club, salmonberry, elderberry, red huckleberry, Alaska blueberry (*Vaccinium alaskaense*), and some goat's beard.(*Aruncus sylvester*). In the depressions saturated by water, skunk cabbage is dominant. Herbs and flowers are uncommon on slightly higher ground, with baneberry, bunchberry, wild lily-of-the-valley, mitrewort (*Mitella nuda*), and foam flower (*Tiarella trifoliata*) present. Mosses and ferns cover the ground. Included are lady fern, wood fern, and several mosses (*Antitrichum* sp., *Drepanocladus* sp., *Dicranum* sp., *Eurhynchium stokesii*, *Hylocomium splendens*, *Hypnum circinale*, *Mnium glabrescens*, *Polytrichum* sp., and *Sphagnum* spp.).

The Devil's club lower slopes zone contains the remaining lowland coniferous forest. The forest cover is very dense in this well-drained wet area. Western hemlock is dominant, with varying amounts of western red cedar, Pacific silver fir and Sitka spruce. The understory is almost impassable because of dense growths of Devil's club. Shrub species found in the skunk cabbage bottomlands are also common, with additional false azalea (*Menziesia ferruginea*) and highbush cranberry. In the herb layer, only bunchberry and Queen's cup (*Clintonia uniflora*) are plentiful. Other species are spotted coral root (*Corallorhiza maculata*), rattlesnake orchid (*Goodyera oblongifolia*), heart-leafed twayblade (*Listera cordata*), Indian pipe (*Monotropa uniflora*), wintergreen (*Pyrola* sp.), and twinflower (*Linnaea borealis*). Mosses and ferns are abundant, including lady fern, deer fern, wood fern and many mosses (*Antitrichum* sp., *Dicranum fuscecens, Eurhynchium stokesii, Hylocomium splendens, Mnium glabrescens,* and *Pleurozium* sp.).

The upland coniferous forest (Land Unit No. 3) consists of the hemlock-balsam mid-slopes zone and the blueberry upper slopes zone which occur along the lower and mid sides of the Kitimat Valley respectively. In the hemlock-balsam mid-slopes zone, hemlock is again dominant in the overstory, with some Pacific silver fir and small amounts of western red cedar present. The same common shrubs cover the ground, except that oval leaf huckleberry (*Vaccinium ovalifolium*) replaces red huckleberry, and goat's beard is absent. The herbs and flowers are sparse, with only a few in this zone: Queen's cup, bunchberry, twisted stalk (*Streptopus asplexifolius*), foam flower, and mitrewort. Among the ferns, wood fern, lady fern, and deer fern are found in this zone. The moss layer is not very thick, represented by a few species (*Dicranum fuscecens, Hylocomium splendens, Lycopodium clavatum, Plagiothecium undulatum,* and *Rhytidiadelphus loreus*).

The blueberry upper slopes zone forms fairly large continuous belts mid-way up the sides of the Kitimat Valley.

Drainage is very good and conditions quite dry. The overstory consists of western hemlock, with some Pacific silver fir and western red cedar. Sometimes present at higher elevations are yellow cedar and, at lower elevations near rock outcrops, lodgepole pine and the occasional Douglas fir. Both the overstory and understory are open, the shrub layer having only Alaska blueberry and some salal (*Gaultheria shallon*). Herbs and flowers are seldom evident, the ground being covered entirely by mosses (*Eurhynchium oreganum, Hylocomium splendens, Plagiothecium undulatum, Rhytidiadelphus loreus,* and *Rhytidiopsis robusta*).

The upland coniferous swampland (Land Unit No. 4) or upland pine muskeg zone is found commonly above 500 m (1500') elevation along the sides of Kitimat Arm, while it becomes patchy inland. This zone is open, discontinuous, and characteristic of rocky depressions in the mountains. Lodgepole pine is dominant, and is sometimes interspersed with yellow cedar, western red cedar, and western hemlock. Common shrubs are crowberry (*Empetrum nigrum*), bog cranberry (*Vaccinium oxycoccus*), cloudberry (*Rubus chamaemorus*), and bog blueberry (*Vaccinium uliginosum*). Herbs and flowers are plentiful, including several species of sedges and rushes, cotton grass, sundew (*Drosera rotundifolia*), white rein orchid, skunk cabbage, marsh cinquefoil, beaked rush (*Rhynchospora alba*), ladies tresses (*Spiranthes romanzoffiana*) and false asphodel (*Tofieldia glutinosa*). The ground is usually covered with sphagnum moss, with another moss (*Polytrichum juniperinum*) sometimes present on well-drained hummocks.

The lowland coniferous swampland (Land Unit No. 5) depicted in Figure 8.2 consists of cedar-hemlock bogs which were previously described as part of the lowland coniferous forest (Land Unit No. 2). The lowland deciduous swampland (Land Unit No. 6) consists of hardhack-willow bogs which are located in the basins of the river systems and are sometimes subjected to flooding. The overstory is almost absent, with infrequent remnants of the former coniferous forest. Common trees of the low overstory are paper birch, bitter cherry (*Prunus emarginata*), Pacific crab-apple, Hooker willow (*Salix sitchensis*), with occasional swamp birch (*Betula glandulosa*), red alder, trembling aspen, northern black cottonwood, and other willows. The poor drainage and high water table of the bog results in a dense shrub layer, which is dominated by hardhack (*Spiraea douglasii*). Other shrubs characteristic of this section are red osier dogwood, black twinberry, thimbleberry, salmonberry, and elderberry. The understory of herbs and flowers is sparse, dominated by skunk cabbage, common horsetail, and the sedges *Carex eurycarpa* and *Carex obnupta*. Small amounts of mint (*Mentha arvensis*), stinging nettle, water hemlock, baltic rush (*Juncus balticus*), marsh cinquefoil (*Potentilla palustris*), wapato (*Sagittaria latifolia*), and bulrush (*Scirpus microcarpus*) are also found in this swamp. Mosses and ferns are uncommon, represented by wood fern and few mosses (*Aulacomnium* sp. and *Mnium* spp.). Within the wettest portions of the bog are cat-tail (*Typha latifolia*), creeping buttercup, bulrush (*Scirpus cyperinus* and *Scirpus validus*), burr reed (*Sparganium* sp.), spike-rush (*Eleocharis* sp.), buckbean (*Menyanthes triphylla*), yellow pond lily (*Nymphaea polysepalum*), and pondweed (*Potamogeton* spp.). Bogs of this type are found just east of the Alcan smeltersite, near the west bank of the Kitimat River north of the Service Centre, near the Wedeene River two miles upstream from its junction with the Kitimat River, and along Humphrys Creek near its junction with the Kitimat River. Other hardhack-willow bogs occur in the extensive cutover areas of the Kitimat Valley, but are generally small and scattered with a low growth of shrubs.

Logging in the Kitimat Valley is discussed under Land Use. The effects of logging, slash burning as well as smelter emissions upon the environment are discussed under the Pollution Section.

9. WILDLIFE

The Kitimat area is only moderately important in terms of overall numbers of birds, as Kitimat Arm forms a relatively minor portion of the Pacific flyway. However, the estuary and lower river course are the most important habitats of the area, particularly during winter when heavy snowfalls blanket terrestrial food sources. The avifauna of the Kitimat Valley is concentrated in the lowland deciduous bogs and the arrowgrass salt marshes with aster-alder estuary grasslands and lowland coniferous forests also supporting varied and abundant avian populations (see Flora Section).

A recently completed survey (Hay, 1976) of bird distribution and abundance on the estuary and in the surrounding area forms the basis of the following discussion. The survey, done under contract to the Canadian Wildlife Service, reviewed all previous wildlife information and was based on 50 continuous weeks of field observations from September, 1974 to August, 1975. A list of birds, mammals, and amphibians known to occur in the Kitimat area is presented as Appendix 9.1.

9 (i) WATERFOWL

The British Columbia Land Inventory rates the Kitimat estuary as being an important migration and/or wintering area for waterfowl, but not important for waterfowl production (Class 3M) (B.C. Waterfowl Capability Manuscript Map 103½ East Half). Waterfowl are present on the estuary year-round; but numbers increase over the winter and peak during the spring migratory period when many birds move through the area. The estuary is a particularly important food source during the winter when freshwater feeding habitats are frozen and/or snow covered. The tides of the area (mean tide amplitude 4.2 m (13.8 ft.)) ensure that food resources remain available.

Dabbling ducks were most commonly observed over the tidal flats of the central delta and in Minette Bay. The connecting Minette Bay Channel area was utilized extensively only during the spring migration. Approximately 300 birds overwintered in the area in 1974-75 and the monthly mean number of birds observed peaked in April, when 570 were observed. The dabblers observed included the mallard (*Anas platyrhynchos*), pintail (*A. acuta*), American widgeon (*A. americana*), shoveler (*A. clypeata*), blue-winged teal (*A. discors*) and green-winged teal (*A. crecca*). Dabbling duck numbers comprised 8% of all bird sightings.

Canada geese (*Branta canadensis*) were seen in large flocks from January to April, grazing above the high tide line and occasionally joining the flocks of dabblers on the tidal flats. Black brant (*Branta bernicla nigricans*), white fronted geese (*Anser albifrons*), snow geese (*Chen caerulescens*) trumpeter swans (*Olor buccinator*) and whistling swans (*O. columbianus*) were infrequently observed on the estuary to the east of the Eurocan terminals. Geese comprised 2% of the total sightings made by Hay (1976).

Diving ducks used the Minette Bay Channel most extensively but were also abundant over the central delta and in Minette Bay. They were only occasionally observed on the small bay between the Alcan and Eurocan docking facilities. The most abundant overwintering divers included the common goldeneye (*Bucephala clangula*) (also found in flocks, up to 150 birds in size, feeding at the municipal sewage treatment plant from December to March), Barrow's goldeneye (*B. islandica*) and bufflehead (*B. albeola*). Greater scaup (*Athya marila*) and harlequin ducks (*Histrionicus histrionicus*) were also found in the area in late spring and early summer. Large flocks of surf scoters (*Melanitta perspicillata*) (maximum of 260 on May 24, 1975), and the occasional Barrow's goldeneye and white-winged scoter (*M. deglandi*) occurred along the Kitimat foreshore during the spring. From November to May, the bufflehead, common goldeneye and harlequin duck were recorded regularly in small numbers in this area. Rafts of surf scoters and white-winged scoters occurred at the north end of Kitimat Arm and at Coste Island Rock from May to July (maximum 840 on July 4, 1975). Other divers, including the greater scaup, harlequin duck and black scoter (*M. nigra*) were also observed in these open waters. Diving ducks made up 10% of all area bird sightings in 1974-75 (Hay, 1976).

9 (ii) MARSHBIRDS AND SHOREBIRDS

Marshbirds and shorebirds are abundant on the estuary only during the spring and fall migrations as the dunlin (*Calidris alpina*) was the only shorebird species observed regularly over the entire winter. This bird group made up 1% of total bird sightings made by Hay over 1974-75, but difficulties in censusing this bird group may have resulted in low reported numbers.

The aster-alder grasslands and arrowgrass saltmarshes of the central delta supported the most diverse and abundant shorebird populations. Species observed included the spotted sandpiper (*Actitis macularia*), Bairds sandpiper (*Calidris bairdii*), dunlin, western sandpiper (*C.* mauri), least sandpiper (*C. minutilla*), sanderling (*C. alba*), the semipalmated plover (*Charadrius semipalmatus*), killdeer (*C. vociferous*), American golden plover (*Pluvialis dominica*), black-bellied plover (*P. squatorola*), lesser yellowlegs (*Tringa flavipes*), long-billed dowitcher (*Limnodromus griseus*) and common snipe (*Cappella gallinago*). Spotted sandpipers and common snipes were observed along the Kitimat foreshore and back beach areas. The great blue heron (*Ardea herodias*) was sighted infrequently feeding along the estuary shoreline from September to December.

9 (iii) GULLS

Gulls were the most numerous bird group observed in the Kitimat area in 1974-75 as they made up over 50% of the total number of birds sighted (Hay, 1976). Numbers were relatively constant through much of the year (approx. 400) except in December when 1030 were sighted and in June and July when numbers were reduced to 111 and 136 respectively. Numbers peaked in March and April (1,030 and 2,000) which coincides with the spring eulachon spawning period.

Gulls were observed congregated into large feeding and resting flocks on the estuary tidal flats (60% of all sightings), at the municipal dump, and sewage treatment plant, particularly during the winter months. Gulls were most abundant along the Kitimat River and on the estuary during the fall salmon, and particularly the spring eulachon, spawning periods (maximum of 2,840 gulls on April 24, 1975).

The glaucous-winged gull (*Larus glaucescens*) was by far the most abundant gull species and is suspected to nest on Coste Rocks, some small islets just outside the Kitimat Harbour Limit (Figure 1.1). Herring gulls (*L. argentatus*) and mew gulls (*L. canus*) were also abundant at times, with Thayer's gull (*L. thayeri*) Bonaparte's gull (*L. philadelphia*) and a single ring-billed gull (*L. delawarensis*) also being identified.

9 (iv) OTHER WATERBIRDS

Groups of diving birds other than the diving ducks also utilized the estuary extensively. The alcid species identified were limited to the common murre (*Uria aalge*), pigeon gillemot (*Cepphus columba*), and marbled murrelet (*Brachyramphus marmoratus*), and these species were seen only sporadically in the deeper waters of the estuary and along Kitimat Arm. Nesting by the pigeon guillemot as well as the pelagic cormorant (*Phalacrocorax pelagicus*) is suspected to occur on Coste Rocks, located south of Coste Island in Kitimat Arm. Pelagic and double-crested cormorants (*Phalacrocorax auritus*) were sighted on the water-covered portions of the estuary from December to July. The number of cormorants in the area increased dramatically during April (15 during March, 85 in April) which coincided with the eulachon spawning period.

Grebes were observed on the water-covered portions of the estuary and along Kitimat Arm in all months except June. Numbers were relatively constant (approximately 20) except in November when 60 were sighted and in the spring months of March, April and May when 166,179 and 102 birds were sighted, respectively. Red-necked grebes (*Podiceps grisegena*), horned grebes (*P. auritus*), western grebes (*Aechmorphorus occidentalis*) and pied-billed grebes (*Podilymbus podiceps*) were identified. Small numbers (year average 5) of loons were also observed in all months except October. Numbers were greatest in November and December when 14 and 11 were sighted respectively. The common loon (*Gavia immer*), Arctic loon (*G. arctica*) and red-throated loon (*G. stellata*) were identified.

9 (v) RAPTORIAL BIRDS

Of the eleven bird of prey species identified in the Kitimat area (listed in Appendix 9.1) the bald eagle (*Haliaeetus leucocephalus*) was the most numerous. Eagles were often present along the estuary foreshore in particular, though sighted throughout the Kitimat area. Other raptor species sighted from May until August, and therefore suspected of nesting in the area, include the goshawk (*Accipiter gentilis*), sharp-shinned hawk (*A. striatus*), red-tailed hawk (*Buteo jamaicensis*), bald eagle, marsh hawk (*Circus cyaneus*) and American kestrel (*Falco sparverius*). Raptor sightings were common around the Kitimat townsite and throughout the Kitimat Valley. The pygmy owl (*Glaucidium gnoma*) was the only owl species observed in the area.

9 (vi) OTHER BIRD SPECIES

Five species of upland game birds are reported to occur in the Kitimat area. They include the blue grouse (*Dendragapus obscurus*), ruffed grouse (*Bonasa umbellus*), band-tailed pigeon (*Columba fasciata*), rock dove (*C. livia*) and mourning dove (*Zenaida macroura*).

The common raven (*Corvus corax*) and northwestern crow (*C. caurinus*) were common throughout the year throughout the Kitimat area. Flocks of these birds migrated along with gulls between the tide flats and the Kitimat dumpsite where they fed over the winter. The northwestern crows often used the tide flats as a rallying point prior to roosting, the largest flock being 175 on March 21, 1975. Gray jays (*Perisoreus canadensis*) and Steller's jays (*Cyanocitta stelleri*) were also common on the estuary and in the woodlands of the Kitimat Valley. Ravens, crows and jays made up 6% of all bird sightings by Hay (1976).

The swallows, swifts and nighthawks were absent from the Kitimat area from November to March inclusive, but were otherwise commonly observed. The rufous hummingbird (*Selasphorus rufus*) was observed from April to August, most frequently in July. A few belted kingfishers (*Megaceryle alcyon*) were observed year-round on the estuary and along the lower river course. Many other passerine species, listed in Appendix 9.1, were observed in the Kitimat area over 1974-75. A majority of these species was associated with habitats found along the river course, in the lowland deciduous bogs (see Flora Section) and Kitimat townsite.

9 (vii) MAMMALS

There are few data relating to the distribution and abundance of mammals in the study area. A list of mammals (Hay, 1976), as well as of amphibians (Mendel, pers. comm.), occurring in the Kitimat area is presented as part of Appendix 9.1. Mammalian nomenclature is based on Banfield (1974).

Sea lions (*Eumetopias jubata*) are present off the mouth of the Kitimat River annually during the spring eulachon run. These large mammals have been shot on occasion (one in 1974, 3 in 1971) and the carcasses butchered and used for food by the Kitamaat Indian Band (Macdonald, 1975; Christiansen, 1972).

Harbour seals (*Phoca vitulina richardi*) are present off the mouth of the Kitimat River during salmon migration. They enter the river and may be seen as far upstream as the Haisla Boulevard bridge during this time. The permanent or semi-permanent population of Area 6 was estimated at between 50 and 100 in 1974 (Macdonald, 1975); however, a control program has been recommended owing to excessive salmon predation.

Pods of killer whales (*Orcinus orca*) are sighted most frequently in the inlets leading to Kitimat during the spring and summer months. They have followed migrating salmon as far as the mouth of the Kitimat River and are often seen each year during this period (E.R. Christiansen, Federal Fisheries District Supervisor, pers. comm.).

Small mammals which are common throughout the Kitimat Valley include the vagrant shrew (*Sorex vagrans*), red squirrel (*Tamiasciurrus hudsonicus*), white-footed mouse (*Peromyscus maniculatus*), red fox (*Vulpes vulpes*), marten (*Martes americana*), American mink (*Mustela vison*) and river otter (*Lontra canadensis*) (the latter two are common only near watercourses) (Hay, 1976).

American beaver (*Castor canadensis*) and muskrat (*Ondatra zibethicus*) are common around Lakelse Lake and are occasionally sighted along the lower Kitimat River. The American black bear (*Ursus americanus*) is common throughout the Kitimat Valley and regularly causes complaints to the local Conservation Officer because of its proximity to the townsite. Grizzly bears (*Ursus arctos*) are common at high elevations, but removal of forest cover has resulted in a decrease in numbers in the Kitimat area. The mountain lion (*Felis concolor*) and Canada lynx (*Lynx lynx*) have been sighted in the valley, which is west of their normal range. The striped skunk (*Mephitis mephitis*), ermine (*Mustela erminea*), wolf (*Canis lupus*) and American porcupine (*Erithizon dorsatum*) are uncommon in the valley, and tracks of the racoon have been noted on the estuary.

Sitka deer (*Odocoileus hemionus sitkensis*) are common near Terrace and are occasionally sighted in the Kitimat Valley, though the heavy winter snowfalls limit their distribution. The moose (*Alces alces*) may be sighted in the lower Kitimat Valley and is common north of Lakelse Lake. Mountain goats (*Oreamnos americanus*) are present on the alpine peaks surrounding the Kitimat Valley.

9 (viii) WILDLIFE AND HUMAN INTERACTIONS

The Kitimat River estuary and watershed, offer considerable wildlife-oriented recreation much of which has not yet been realized. Major outdoor recreational activities near Kitimat are fishing, hiking, boating and, to a lesser extent, hunting (I. Brown, CFS Ranger, pers. comm.).

Hiking trails are established in Hirsch Creek Provincial Park, Radley Municipal Park, and to the summit of Claque Mountain, with the remainder of the Kitimat Valley accessible via the extensive system of logging roads. An abundant and varied wildlife contribute to the enjoyment of this activity.

The Kitimat Valley does not offer the renowned hunting found in valleys to the north and east of Terrace where moose, blacktail deer, mountain goat, black bear, grizzly bear and wolf abound. These species may occasionally be observed near Kitimat but only the black bear remains numerous.

Waterfowl and upland game bird hunting occurs throughout the area though limited by the relative scarcity of these species. Grouse are common only when the local population experiences a peak year and ducks are abundant only near the tidewater. Geese are, in addition, very wary during the fall hunting season and avoid any contact with man at that time. Coots, snipe, doves and mergansers are not hunted at Kitimat. Present hunting pressures do not threaten to lead to a general decline of any local bird species (Hay, 1976). Resident hunters (and fishermen) have organized to form the Kitimat Rod and Gun Club, whose clubhouse is located beside the Kitimat River at the Harsla Boulevard bridge.

The Kitimat River and estuary is studied sparingly by secondary school students at the present time (N. Worboys, Mt. Elizabeth Sec. School, pers. comm.). Studies are ecological in nature with concentration on pollution and pollution control. Some identification of local flora and fauna is included.

10. LAND AND WATER USE

10 (i) GENERAL

Early in 1951 the Aluminum Company of Canada commenced construction of the first stage of the Nechako-Kemano-Kitimat project, regarded as a major international engineering achievement. The choice of Kitimat as the site for an aluminum smelter (initial annual capacity 90,000 tons) and its accompanying townsite, was based largely on the availability of the enormous hydro-electric power potential of the Nechako-Kemano River system.

The reduction of alumina (processed bauxite), imported from Jamaica and Australia, requires large amounts of power, about 8.5 KW Hr. per pound of aluminum, and economical transportation for the vast quantities of ore and other raw materials used in the reduction process. About 4 lb. of bauxite are required per lb. of aluminum. The site at the head of Kitimat Arm for the aluminum smelter and harbour facilities, plus the hydro power available at Kemano, satisfied both of these criteria.

For a full description of the history and development of the Nechako-Kemano-Kitimat Project, the reader is referred to the Engineering Journal (1954), which devoted the entire technical content of the November issue to specially written papers on the Alcan Project. The planning and development of the Kitimat Townsite has been summarized and compiled into two volumes of reports and drawings, the Kitimat Townsite Report (1951-1942) and subsequent reports and drawings (1953-1958). These reports were prepared for the Aluminum Company of Canada and for the development of the town of Kitimat (Corporation of the District of Kitimat, 1960). An evaluation of the physical planning and development of Kitimat was subsequently compiled as a Master's Thesis by Endersby (1965).

A major study of the economic development of the Regional District of Kitimat-Stikine was compiled for the District Regional Board by AVG Management Science Ltd. (1971). This was followed by a series of studies by the District of Kitimat Planning Department, which examined the residential recreational and industrial uses of the land and water areas within the District of Kitimat (Corp. of the Dist. of Kitimat, 1976a, 1976b, 1976c). These studies are discussed in more detail under the appropriate headings of the succeeding sub-sections.

In June 1976, the first phase of the industrial, utility and transportation corridor (IUTC) study was completed (Corporation of the District of Kitimat, 1976d). This study was prepared jointly by the District of Kitimat and the Aluminum Company of Canada, with participation by the Department of Highways, Canadian National Railway, the British Columbia Environment and Land Use Committee Secretariat. British Columbia Harbours Board Eurocan Pulp and Paper Co. Ltd., and the Regional District of Kitimat-Stikine. Further details of this study are discussed later under sub-section 10(iv) Industrial land and water use.

10 (ii) RESIDENTIAL

The Kitimat District Municipality, incorporated in 1953, is situated within the Kitimat-Stikine Regional District. It encompasses an area of 25,960 ha (100.23 sq. mi.) and in 1972 had a population of 11,803 (Statistics Canada, 1972). Kitimat and Terrace are the dominant communities of the area, and together their population represents 72 percent of the total population of the Regional District (AVG Management Science Ltd., 1971).

The development of the Kitimat Townsite has been based on a planning study and report prepared for the Aluminum Company of Canada by Stein (1952). This plan, formulated in 1951, called for the progressive development of ten residential neighbourhoods, with alphabetical coding indicating the approximate order in which they would be developed. To date, Kitimat has three residential neighbourhoods (A,B and C), which are almost fully developed, and plans are being developed for expansion in the D/G neighbourhood area (Corp. of the District of Kitimat, 1976a).

The D/G neighbourhood area is composed of 405 ha (1,000 ac.) of relatively flat land, of which 182 ha (450 ac.) would be net residential land. Planning for this new neighbourhood has taken into account the option of being phased for development in sections, or all at once, should major development occur. Over 16 ha (40 ac.) of this new neighbourhood area have been planned for expansion of the existing City Centre, which now occupies an area of 14 ha (35 ac.). It is estimated that this central administrative and commercial core will be surrounded by a population of some 30,000. A smaller Upper City Centre, located approximately 8 km (5 mi.) east of the present City Centre will service the future residential areas "E", "F", "H", "I" and "J" (Fig. 10.1). These areas are expected to have a population of 20,000 (Corp. of the District of Kitimat, 1976a).

Within the District of Kitimat, four Indian Reserves occupy a total of 253 ha (633 ac.) (Philpot, 1974). The largest of these is the Indian Reserve No. 1, located on the east bank of the Kitimat River, just north of the estuary. In 1971 it had a population of 681 (Statistics Canada, 1972). The three other Reserves are located at the head of Minette Bay (IR No. 5), and on the west side of Kitimat Arm at Bish Creek (IR No.6) and Emsley Cove (IR No.7).

Three additional reserves are situated on the east side of Kitimat Arm, outside the boundary of the Kitimat District Municipality. The largest of these is the Indian Reserve No. 2 at the mouth of the Wathl River. This settlement referred to as Kitimat Mission on the Kitimat Arm topographic map (Can. Dept.

Figure 10·1
Kitimat district land use.
(District of Kitimat
Planning Dept. 1975)

Energy Mines and Resources, 1974) has been named locally as Kitamaat Village (Corp. of the Dist. of Kitimat, 1976a). The other two, smaller reserves, No. 3 (Waweith) and No. 8 (Kuaste) are located at the mouth of Wathlsto Creek and Gobeil Bay.

10 (iii) RECREATIONAL

The recreation potential of the District of Kitimat originally discussed in the Kitimat Townsite Report (Corp. of the Dist. of Kitimat, 1960), is currently being studied in detail by the Kitimat Planning Department (Corp. of the Dist. of Kitimat, 1975, 1976b). One of the best known recreational areas in the Kitimat Valley is at Lakelse Lake, where in addition to fishing and hunting, there is a series of hot springs. In 1958 the Lakelse Hot Springs were developed into bathing facilities at a resort hotel, and have since become a major tourist attraction. There are nine springs with an average temperature of 86^{o}C (186^{o}F) (Souther and Halstead, 1969).

In April, 1973, representatives of the Fisheries and Marine Service and the Regional District of Kitimat-Stikine met to discuss the existing and foreseeable resource and land use conflict problems on Lakelse Lake and within the Lakelse Lake watershed. Much of Lakelse Lake's shoreline is owned privately, and extensive sub-divisions were being planned. The use of the lake itself had grown to a point where water-skiers, boaters, sport fishermen, canoeists and swimmers were interfering with one another and with the lake's resident salmon spawning areas, and waterfowl populations.

The forementioned meeting resulted in the preparation of a report on the socio-economic importance of maintaining the quality of the Lakelse Lake recreational resources (Sinclair, 1974). The report concludes that "Lakelse Lake is a very valuable common property resource..... Even though Lakelse Lake's importance is tied inextricably to recreationally related activities it is also of commercial importance..... The planning and development of Lakelse Lake must be based on the concept that it has a limited, and identifiable, capacity to accommodate shoreline and water-oriented activities".

A brief submitted to the British Columbia Provincial Parks Branch by the Regional District of Kitimat-Stikine (1975), examined the recreational opportunities throughout the Kitimat Valley with a view to reducing the public pressure on the limited resources at Lakelse Lake, and the preservation of areas with high recreational capability recently altered by timber harvesting practices. As of 1975, recreation facilities in the District of Kitimat included 5 parks and 1 nine-hole golf course.

In 1972, a study was undertaken for the District of Kitimat (Swan Wooster Engineering Co. Ltd.) to investigate alternate sites for public marina capable of accommodating up to 200 boats. Seven locations were investigated as potential marina sites, namely, Kitamaat Indian Village, MK Bay, Minette Bay, Northeast of the Eurocan Terminal, the existing Yacht Club Basin, Hospital Beach and Mickey's Cove. The advantages and disadvantages of these sites were discussed in the study, and the Hospital Beach location recommended as the most suitable site. In 1975, a study was completed by the Advisory Marina Commission for the Regional District of Kitimat-Stikine (A. Jones, Kitimat Municipality, pers. comm.), and after a thorough evaluation of the current situation of past reports, MK Bay was chosen as the location for the new Regional District Marina. A 200 boat marina was constructed in 1975-1976. While MK Bay is also currently used for log booming, the marina facilities could be expanded to accommodate 1,000 boats (A. Jones, pers. comm.).

A recent study of the Kitimat recreation areas (District of Kitimat, 1976b), has been prepared with input from the Advisory

Planning Commission in conjunction with the Advisory Recreation Commission and the Recreation Department, School District #80, and the Kitimat Hiking Club. The study was based on the Land Reserves Plan submitted by the Kitimat Council to the Regional District and the B.C. Lands Commission in 1974.

Eight recreation areas were noted, comprising a green-belt and park system (Figure 10.2). These were (1) Hirsch Creek Park and Canyon, (2) Hirsch Creek West/Kitimat River, (3) Sentinel Hill, (4) Radley Park, (5) Minette Bay, (6) Robinson Lake Area, (7) Clague and Squirrel Mountains, and (8) the Douglas Channel. A description of these areas and their present status is contained in the study mentioned above.

"The Minette Bay area which offers a diversity of plant and animal life, warm, sheltered water and significant historical areas, has excellent potential for park, recreational and educational uses" (Corp. of the Dist. of Kitimat Planning Dept., 1975). Following a field trip and meeting of the Advisory Planning Commission Recreation Commission and Kitimat and Terrace School District Outdoor Education Committees, the Kitimat Planning Division produced a plan for recreational development of the Minette Bay area, stressing the "natural environment" usage of the area.

The study group recommended that development be considered as follows (Figure 10.3):

1. the northeast corner of the Bay be developed as a waterfront park;
2. other recreational areas be restricted to the north and east sides of the Bay;
3. access to the Bay be restricted to the east side;
4. an historical area be restored to give a sense of history to Kitimat;

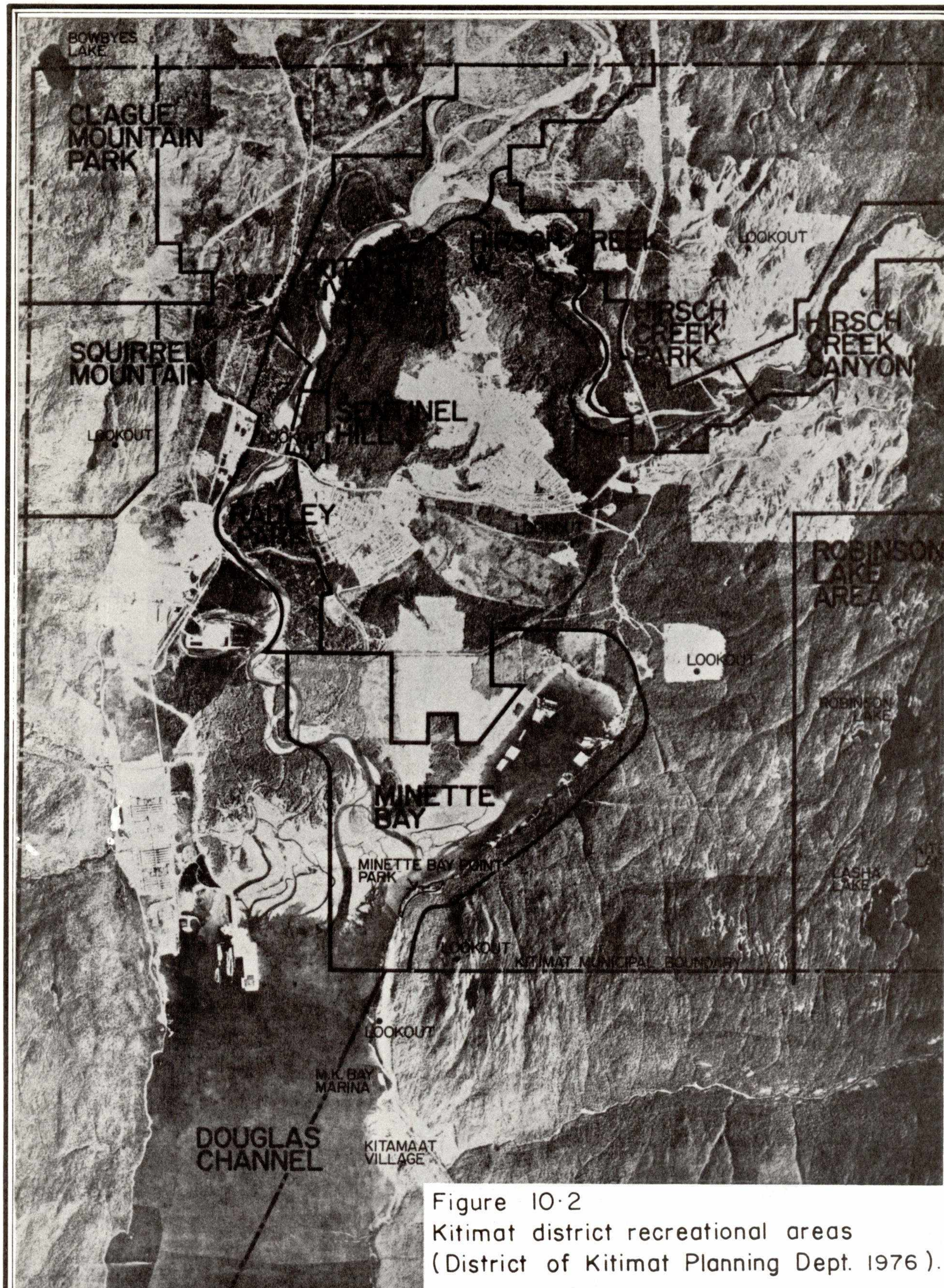


Figure 10·2
Kitimat district recreational areas
(District of Kitimat Planning Dept. 1976).

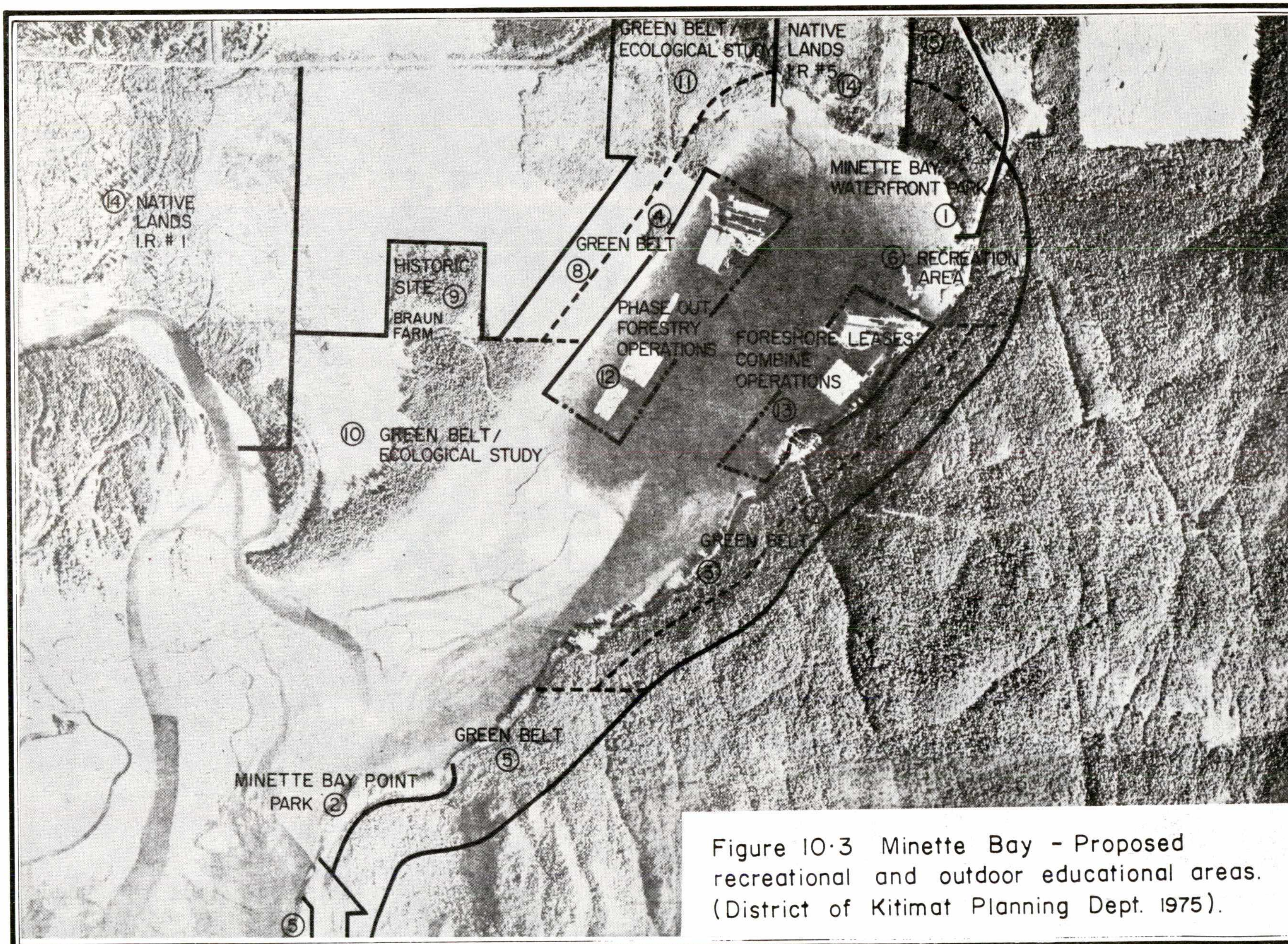


Figure 10·3 Minette Bay - Proposed recreational and outdoor educational areas. (District of Kitimat Planning Dept. 1975).

5. the west side of the Bay be used for the development of an outdoor education program.

Educational study areas have been proposed to study the following subjects:

Stream study - stream dynamics and the erosion feature of stream beds.

Intertidal study - an area for the study of biological life that lives in association with the salt and fresh water mixing area.

Animal habitat study - an area for the study of the animals of the woodlot, woodlot-field transition and field.

Comparative marine study - areas for comparative examinations of sites at or adjacent to existing or former booming grounds.

Arboretum - an area of field and woodland for the purpose of a forestry course in conservation.

10 (iv) INDUSTRIAL

The IUTC study, prepared jointly by the District of Kitimat and the Aluminum Company of Canada (Corp. of the Dist. of Kitimat, 1976d), points out that Kitimat has ample land for industrial development. Approximately 1600 ha (4,000 ac.) have been classed as industrial land within the Municipality of the District of Kitimat, with an additional 800 ha (2,000 ac.) in the Emsley Cove-Jesse Lake area and 1000 ha (2,500 ac.) north of the District, having potential for industrial development.

Industrial sites in the District of Kitimat are mainly located in the Industrial Corridor (Figure 10.1), a narrow belt of land on the western side of the Kitimat Valley, 1.6 km (1 mi.) wide on the average and extending 13 km (8 mi.) north from Kitimat Arm. The Alcan smelter site occupies 140 ha (350 ac.) adjacent to the estuary, while the Eurocan pulp mill and the Kitimat Service Centre are located on 280 ha (700 ac.) and 40 ha (100 ac.), respectively, to the north.

1. MANUFACTURING:

The major industry in the Kitimat area is the Alcan smelter, an aluminum reduction plant built partly on alluvial fans on the western side of the Kitimat River delta (Aluminum Company of Canada Limited, 1954). To raise the smelter site to a working level for foundation construction, it was necessary to fill an area 366 m (1200 ft.) by 488 m (1600 ft.) with fill varying in depth to a maximum of 9 m (30 ft.). The finished grade of the smelter area was chosen to prevent flooding by tides and the mountain freshets.

The Alcan Kitimat smelter commenced operation in August 1954, with a production capacity of 90,000 tons of aluminum per year. Today the plant has an installed capacity of 300,000 tons per year, and employs about 2,500 people. Bauxite ore mined in Jamaica by Alumina Jamaica Ltd., a fully-owned subsidiary of Alcan Aluminum Limited, is treated to remove clay and other extraneous materials before shipping to Kitimat for reducing to aluminum ingots.

In 1959, Canadian Liquid Air Ltd. was Kitimat's second largest manufacturing industry. Their plant in Kitimat manufactures acetylene, bottles oxygen and distributes welding supplies, as well as other bottled gases such as argon, nitrogen, nitrous oxide and carbon dioxide.

When the Eurocan Pulp and Paper Co. Ltd. commenced operations in 1970,it became the second largest manufacturer in the area, and provided jobs for approximately 1,200 people. The mill located in the Kitimat industrial corridor is subject to stringent environmental controls which are discussed under the Pollution Section of this report. The mill produces unbleached kraft pulp, kraft paper and lumber. Production details have been described in the preceding sub-section relating to the forest industry. A large sawmill also forms part of the Eurocan complex at Kitimat.

2. PORT FACILITIES:

The Port of Kitimat located at the head of Douglas Channel (Figure 10.4) was originally constructed as part of the Alcan Project. The design and construction of the Kitimat harbour facilities for handling ore ships from Jamaica has been documented by Pugh (1954). Since then a deepsea dock, with special lumber handling facilities, has been constructed for the Eurocan Pulp and Paper Company Ltd. This terminal has also been designed to accommodate a future ferry slip and its access, via the extension of highway 25 (A. Jones, District of Kitimat, pers. comm.). A wharf to handle the coastal passenger-freight ships of the Northland Navigation Company Ltd. is located on the west side of Kitimat Arm, just south of the Alcan terminal.

The present Kitimat harbour facilities are all located on the western side of Kitimat Arm, where deep water off the delta front (30 to 150 m) facilitates handling of deep draught ocean going ships. Minette Bay and the eastern shore of Kitimat Arm are included in long-term development plans to provide recreational facilities, including environmental and ecological study areas for the residents of the region (Corp. of the District of Kitimat, 1975).

All major oil Companies run their tankers into the port and have unloading facilities at the Coastal and Aluminum Company

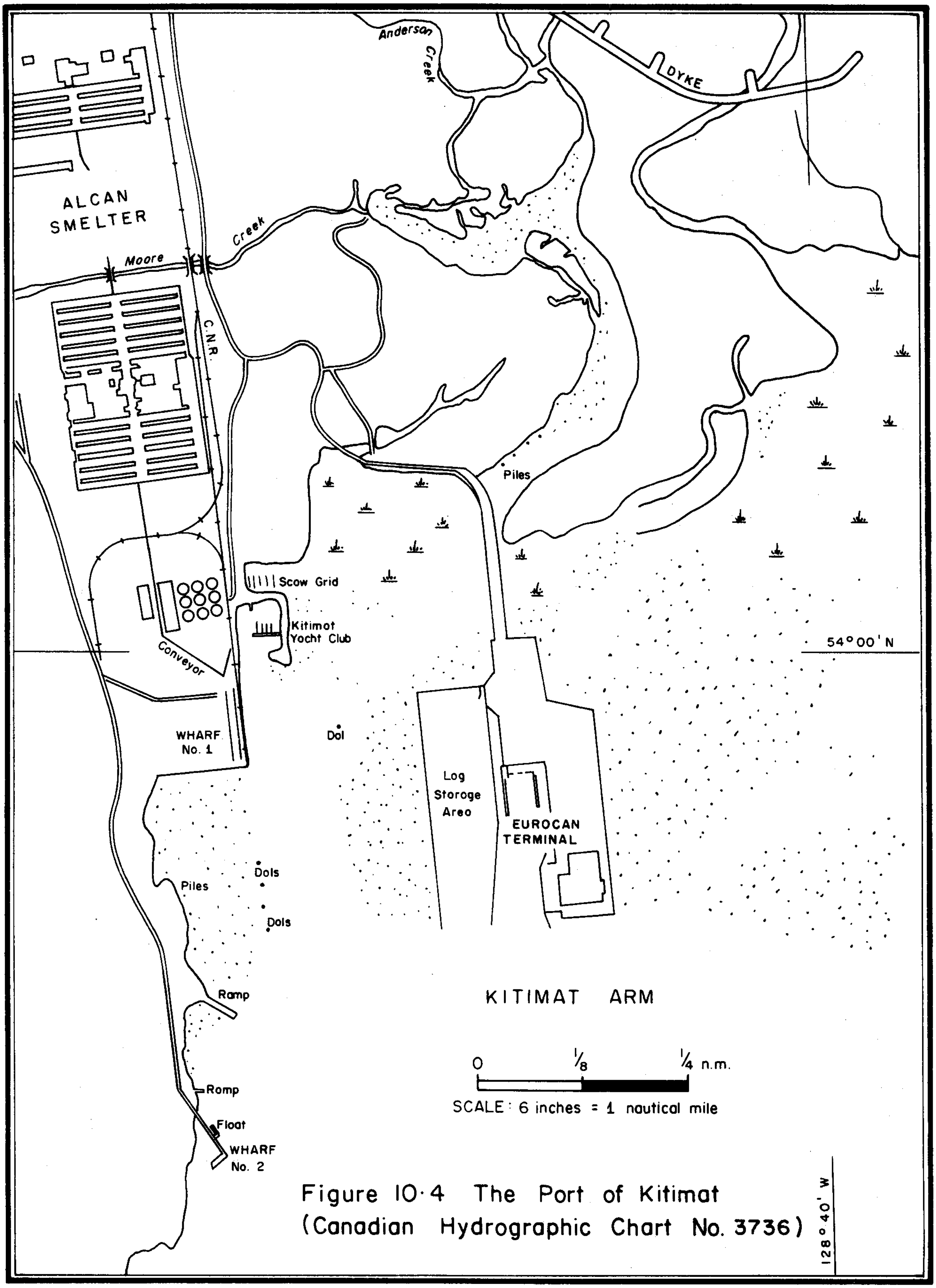


Figure 10·4 The Port of Kitimat (Canadian Hydrographic Chart No. 3736)

Terminals. A feasibility study is presently being undertaken by Trans-Mountain Pipe Line Co. Ltd. to ascertain Kitimat's potential for the construction of a crude oil dock and receiving terminal for oil from both southern and northern latitudes (Vancouver Province, 1976).

The Port of Kitimat has a Canada Customs House and handles approximately 100 deep-water ships a year, and about 165 coastal vessels (Outwest Magazine, 1975). Aluminum, paperboard, newsprint, pulp and paper products make up the bulk of commodities exported to foreign countries from the Port of Kitimat, with alumina, coal, coke and chemicals accounting for the major imports. In 1973 and 1974 the Port handled over one million tonnes of cargo. A summary of the tonnages handled for the years 1972, 1973 and 1974 is shown below (Table 10.1).

Table 10.1. Total metric tonnes of cargoes handled at the Port of Kitimat for years 1972, 1973 and 1974 (Statistics Canada, 1974b, 1975b, 1975c).

	Tonnes loaded			Tonnes unloaded		
Commodity	1972	1973	1974	1972	1973	1974
Alumina (bauxite ore)	-	-	-	432,057	548,534	542,107
Pulp and Paper products	95,857	213,803	175,029	-	-	-
Aluminum	135,316	127,907	121,234	-	-	-
Miscellaneous	1,575	44,666	9,134	46,915	72,710	61,705
Totals	232,748	386,376	305,397	478,972	621,244	603,812

A report examining the potential Kitimat Port traffic to 1991 was prepared for the Aluminum Company of Canada Ltd., to "permit orderly planning of future site allotments, provision of services, etc" (British Columbia Research Council, 1967). The report includes an estimate of tonnages of exports and imports (excluding Alcan's own raw materials and finished products) for the years 1971, 1976, 1981 and 1991. In addition, it examines: (a) prospective industrial development; (b) Kitimat's prospects as a transit port, especially for export of bulk commodities; (c) berthing and other requirements implied by trade forecasts; and (d) expected population in Kitimat. The report concludes that "Kitimat's natural advantages of deep water, availability of land and its ocean distance advantage over Vancouver, combined with equalized freight rates from bulk producing areas of western Canada appear to provide conditions that would enable it to be developed as a bulk port serving the Far East". The concept of Kitimat as a port area for handling resources from northern areas has also been discussed in a report prepared for the Northern Development Council concerning the development of northern British Columbia (Reed, F.L.C. and Associates Ltd., 1972).

3. FORESTRY:

An estimated 13,000 ha (32,500 ac.) of the total area of the District of Kitimat is productive forest land (Philpot, 1974), and is held under five separate tenures, vacant crown land, crown granted lands, S.P. 75 land (land owned by the Aluminum Company of Canada), timber licenses and Indian Reserves. For a description of these property holdings and the forest resources of the Kitimat area, the reader is referred to the feasibility study for a municipal tree farm license for the District of Kitimat, prepared for the Municipal Council (Philpot, 1974).

While some logging of the Kitimat Valley was carried out in the early 1900's (see Introduction - Historical Perspective), major logging operations have only been underway since 1950

(Holland, et al., 1972). Most of the land in the Kitimat Valley has reverted to the Crown. Forest cover maps are available from the British Columbia Forest Service (Appendix 10.1), and the British Columbia Lands Service provides Departmental Reference maps showing land leased to companies and individuals engaged in forestry operations. In the Kitimat Valley in 1971, there were about 40,460 ha (100,000 ac.) of old timber licenses that did not come under allowable cut or sustained yield controls. This land will revert to the Crown when the timber has been logged (AVG Management Science Ltd., 1971).

Special timber licenses issued to Crown Zellerbach Ltd. and MacMillan Bloedel Ltd., cover the bulk of the lower valley, with the Eurocan Tree Farm License (#41) covering the remainder. A progress map of logging in the Kitimat area (Eurocan, 1969) is updated annually and documents the extent of logging in the valley. Forest regeneration maps, illustrating areas planted and naturally regenerating after having been logged are produced by the individual logging concerns, and copies are kept on file at the B.C. Forest Service Ranger Station located in Kitimat. A resource management folio (Eurocan, 1975) has been prepared for the area covered by cutting permit #10 of Tree Farm License #41, by the Kitimat logging Division of the Eurocan Pulp and Paper Co. Ltd. Maps in this folio include descriptions of soils, fish habitat and spawning areas, wildlife and recreation potential, harvesting, development and site treatment (i.e. planted or natural regeneration).

The major logging operations in the area are carried out by MacMillan Bloedel Ltd., Crown Zellerbach Ltd., and Eurocan Pulp and Paper Co. Ltd. Construction for the Eurocan Pulp and Paper mill, located southwest of Kitimat Townsite was completed in 1969, and the mill commenced operation in the summer of 1970. The Company employs approximately 1,200 people in the mill, woods and other operations, and produces lumber, pulp, liner board and kraft papers. At full capacity the mill is capable of producing 1,000 tonnes of pulp a day. To produce a high quality pulp, the coastal wood fibre is blended with an interior wood fibre obtained from the Burns Lake area, which after transportation to Kemano is water-towed to Eurocan Terminal on the Kitimat River estuary (Figure 10.4). The primary source of supply for the coastal timber is Tree Farm Licence #41 which runs from Lakelse Lake to the headwaters of the Kitlope River on Gardner Canal.

MacMillan-Bloedel and Crown Zellerbach both have logging operations in the Kitimat Valley and haul their logs to Minette Bay for log-booming and storage. Foreshore leases have been granted to Eurocan (10 ha or 25.5 ac.) and Crown Zellerbach (17 ha or 43 ac.) on the east side of Minette Bay. Full details of property ownership and foreshore leases in the vicinity of Minette Bay may be obtained from the Municipality of the District of Kitimat, and the British Columbia Department of the Environment, Lands Branch.

A summary of yearly logging activities in the area is contained in the District Fishery Officer's report for the Butedale Sub-District (Macdonald, 1974, 1975) and for Kitimat District #7(Christiansen, 1971, 1972, 1973). In 1975 the centre of the logging activity in the Butedale Sub-District was in the Kitimat Watershed. Eurocan Pulp and Paper Co. Ltd., cutting on their Tree Farm License #41, removed the most timber. MacMillan Bloedel and Crown Zellerbach Ltd., were reported to be nearing the end of their operations on their Special Timber Licenses (Macdonald, 1975).

4. AGRICULTURE:

Agriculture is not a major activity of the area. The amount of useful agricultural land is limited by the narrowness of the river valleys, by lack of access, and by high costs of clearing. Terrace is the preferred area for farming having good soils and a longer frost-free season than most areas in the Kitimat-Stikine Regional District. Vegetables are the main produce grown. Most of the milk for the area comes from Bulkley Valley and is processed at Kitimat (AVG Management Science, 1971). An increase in population and improved transportation facilities, resulting from industrial development, has made the importation of packaged and frozen foods, fruits and vegetables a more viable proposition. This, however, has reduced the incentive for local farming, and in some instances has turned small farms in the area into uneconomic units.

Agricultural Land Reserves in the Kitimat-Stikine Regional District are designated on plans available from the British Columbia Lands Service (Appendix 10.1). However, Agricultural Land Reserve boundaries are subject to revision quarterly, and therefore it is important to ensure that the copies of Land Reserve Plans used are current.

5. MUNICIPAL SERVICES:

The Kitimat Service Centre presently occupies about 40 ha (100 ac.) at the northern end of the "industrial corridor". Details of the Centre,as it was originally conceived,are contained in the Kitimat Townsite Report (Mayer and Whittlesey, 1953). Designed to facilitate the light industrial section of the Kitimat Townsite, the Centre is located adjacent to the Canadian National Railway Line from Terrace. The railway continues south to the Alcan holding yard,at which point the exchange of cars between the C.N.R. and Alcan is made. From this point, the Alcan Terminal Railway extends south, for a distance of approximately 4 km. (2.5 mi.), to the Kitimat Terminal Wharf No.1, with sidings into the smelter plant.

More recently, June 1976, a study was released by the Kitimat Planning Department,outlining the existing and projected function of the Service Centre (Corp. of the Dist. of Kitimat, 1976c). This study delineates an area of approximately 100 ha (250 ac.), bounded by Radley Park to the east, Squirrel Mountain to the west, Goose Creek to the north and Sandhill to the south, as the extent of the area available for development of the Service Centre.

Details of the townsite water supply system, storm drainage and sewage disposal systems have been described in the Kitimat Townsite Report (Eberlin, 1952). A well-field, adjacent to the Kitimat River just south of the Haisla Bridge, supplies water to the Municipal system. A water supply study (Swan Wooster Engineering Co.Ltd., 1969) was carried out to examine the existing water supply and distribution system in Kitimat, and to evaluate methods by which the system could be modified to handle future water demands.

Industrial water supply for the Eurocan pulp and paper mill is supplied from a water intake on the Kitimat River. The mill uses approximately 1.3 cms (48 cfs), with a diversion of up to 2 cms (70 cfs) allowed under a conditional water license (The Province of British Columbia - Water Act, Appendix 10.2). Water quality is monitored to determine the amount of water treatment required.

The Aluminum Company of Canada retains three water licenses for water supply but only uses two. Licenses are held to use 1.4 cms (50 cfs) from the Kitimat River and 0.6 cms (20 cfs) from Anderson Creek for industrial purposes (C. Fox, Alcan Kitimat, pers. comm.). However, in 1974 only a maximum of 0.7 cms (24.4 cfs) was used between both licenses. An additional license for 0.05 cms (1.86 cfs) from Moore Creek, originally issued for water supply to the Alcan construction camp, is renewed annually and held in reserve.

The average water consumption for the smelter is 0.5 cms

(18.6 cfs), with a peak consumption of 0.75 cms (26.7 cfs), based on the 1974 water consumption figures for an annual production of 300,000 tons of aluminum (C.R. Fox, Alcan, pers. comm.). Water from the Kitimat River is pumped through an 18-inch diameter line to a settling basin in the plant and pre-treated with chlorine only before using. Water from Anderson Creek flows by gravity.

Sewage disposal for the Kitimat Townsite has been designed initially for primary treatment with consideration for further treatment as the need arises. Effluent from the Eurocan mill also receives primary treatment in a specially designed system before being discharged into the Kitimat River (see Pollution Section). Industrial waste from the Alcan complex, after retention in settling tanks, is discharged into the Kitimat Estuary during receding tides.

11. POLLUTION AND WATER QUALITY

11 (i) WATER POLLUTION

Water pollution control is administered largely under Section 33 of the Fisheries Act federally and under the B.C. Pollution Control Act provincially. Pollution from ships, particularly oil pollution, is controlled through the federal Canada Shipping Act. The Ocean Dumping Control Act regulates the dumping of all materials for the purpose of disposal, including dredge spoils, into the sea. Various other pieces of federal and provincial legislation, as well as municpal bylaws control specific aspects of environmental pollution (Shaw and Reuben, 1974). For a review of legistation affecting the environment of British Columbia,the reader is referred to Ince (1976).

The Environmental Emergency Branch (EEB) of the Environmental Protection Service has recently completed resource maps of Kitimat Arm, Douglas Channel and contiguous waters, as part of the oil and chemical spill countermeasures series (Can. Dept. Env., 1976a,b). These maps inventory some of the existing resource information and are compiled to aid in initial decision making and contingency planning in the event of an environmental emergency.

Monitoring of effluent water quality and quantity is often stipulated when B.C. Pollution Control Branch (PCB) effluent permits are issued. Computerized results of testing by both the permittee and PCB personnel, as well as permit listings, are available upon request from the PCB head office in Victoria. Permit listings are summarized in Appendix 11 and monitor programs are summarized briefly under the appropriate subsections.

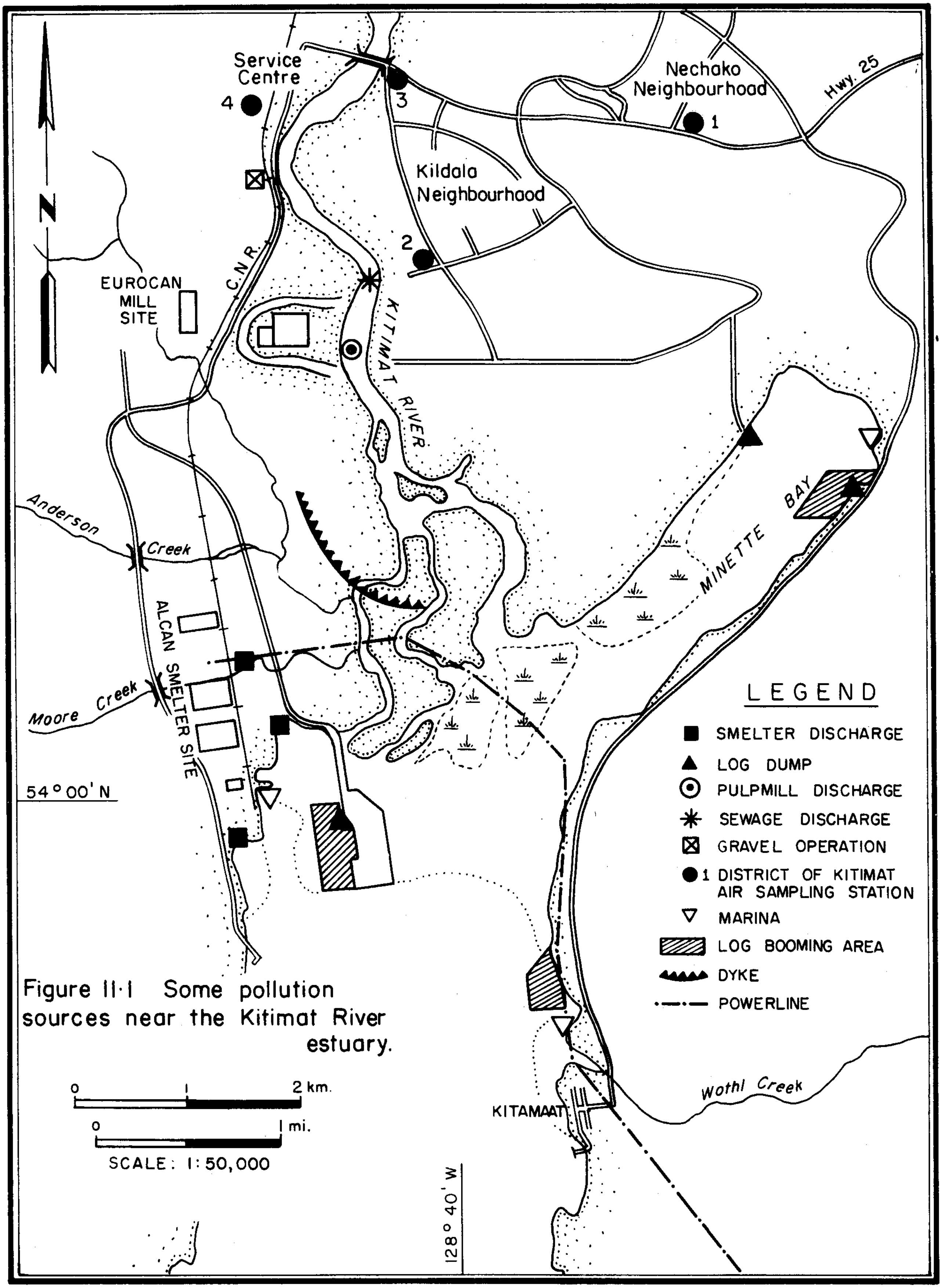


Figure 11·1 Some pollution sources near the Kitimat River estuary.

1. WATER QUALITY DATA:

Data collected by the Inland Waters Directorate (IWD) of Environment Canada on the Kitimat River includes a single day of detailed analysis on the 23rd of August, 1966 (Station No. 00BC-08FF0001) at the Highway No. 25 bridge (Can. Dept. Env., 1974). Sampling stations have since been established at two sites upstream of municipal and industrial outfalls on the Kitimat River and on Hirsch Creek and the Wedeene River. Data from samples collected during October, 1975, June, 1976 and September, 1976 are available upon request from the IWD; however, it should be noted that no high fluoride values have been found (W.L. Kreuder, IWD, pers. comm.).

With the start-up of the Eurocan pulp mill (April, 1971), weekly, then monthly, analyses of intake water quality were conducted until May of 1972 (Pottle, unpublished data). Incoming water is still monitored to determine whether water treatment is necessary prior to the water being used in the pulping process (Pottle, pers. comm.). The physical, chemical and biochemical quality of the Kitimat River, Kitimat Arm and Minette Bay were documented in surveys commissioned by Eurocan and conducted by T.W. Beak and Associates Ltd. in 1969, 1970 and 1971.

Initial surveys were conducted in July and August of 1969 with detailed weekly surveys from February through September 1970 (Beak, 1970). Further surveys were conducted in November and December of 1970 and in July, August and October of 1971 (Beak, 1972). Kitimat River water was found to be very soft and low in dissolved solids. Suspended solids were also generally low except during high runoff periods. Water temperatures were generally low (average 7.0^{o}C; range 2-12^{o}C); dissolved oxygen was near saturation; and colour was very slight, increasing during runoff periods.

Biochemically the river was low in organic matter, with small increases in biochemical oxygen demand (BOD_5) due to the discharge of the city of Kitimat municipal waste and the Eurocan pulp mill waste. The number of coliform bacteria in the river water was also increased by the municipal outfall (Beak, 1972).

The Eurocan effluent was transported along the west side of the river by currents, causing a slight increase in suspended, dissolved solids and temperature and a slight decrease in dissolved oxygen concentration immediately downstream of the outfall. Effluent dilution 100 m downstream of the diffuser was estimated at 30 to 1 (Beak, 1972).

The waters of Kitimat Arm were found to be stratified (discussed in greater detail under Oceanography) as demonstrated by hardness, chloride and magnesium results. Surface waters generally possessed the same characteristics as Kitimat River water, and waters at depths greater than 25 m were characteristic of normal sea water. Minette Bay waters were similarly stratified, with deeper sea water samples showing higher than average BOD_5 concentrations, lower dissolved oxygen levels and higher colour values than those samples at comparable depth from Kitimat Arm (Beak, 1970).

Water quality was included as part of an EPS environmental surveillance report (Bradshaw, MS, 1976). Temperature, salinity, dissolved oxygen, as well as copper, lead, iron, cadmium and mercury concentrations were determined in water column samples. No unusually high heavy metal concentrations were noted. Sediment sub-samples taken off the delta front in Kitimat Arm were analyzed for cobalt, copper, iron, manganese, nickel, lead, zinc, silver and cadmium. Again no unusual values were reported. A sediment sample from the Alcan outfall ditch differed substantially from those of the estuarine bottom, as expected, and consisted largely of inactive carbon particles, left over from the electrolytic processing of alumina.

Aluminum was not measured, inasmuch as a suitable analytical procedure to give meaningful data has not been developed. It occurs naturally as a major element and is considered to be relatively non-toxic although flocs of aluminum hydroxide may affect rooted aquatics and invertebrate benthos (NAS, 1973). Only a portion of aluminum present in water is considered biologically functional (Bradshaw, MS, 1976). Aluminum concentrations in sediments were reported in a previous EPS survey (Goyette, MS, 1971); however, the values obtained (74,000 μg/g) are only approximate at best. Included in this survey were temperature, salinity, dissolved oxygen as well as sediment copper, zinc, cadmium, and iron determinations.

Werner (1968) completed chemical analyses of suspended sediments sampled off the Kitimat delta front (3 samples) and off Jesse Lake falls (1 sample) during 1965 and 1966, while the Alcan smelter was in operation but before the Eurocan pulp mill was constructed. Sediments were largely mineral (rock) in composition, and no carbonate gas was evolved from the samples, suggesting little organic material.

Polychlorinated biphenyl (PCB) residues have been recorded from invertebrates collected from British Columbia waters (Garret, MS, 1976). Dungeness crabs (*Cancer magister*) have been sampled from Kitimat Arm and were found to contain an average of 0.25 ± 0.09 ppm dry weight (range 0.1430-0.3950) (Albright, et al., 1975). These values were lower than those recorded from both the Fraser River delta and Cowichan Bay, B.C.

2. DOMESTIC SEWAGE:

Disposal of municipal wastes until October, 1970, when the sewage treatment plant went into effect, was by direct discharge of untreated sewage into the Kitimat River. Estimates based on a minimum river flow of 17 cms (600 cfs) as well as BOD and coliform content of the sewage, suggested that a population of

7,000 could be serviced by this means (Eberlin, 1952). However, it was alleged by some of the local citizens from time to time that fish were being affected by the municipal sewage.

Primary treatment of sewage consists now of comminution and retention in an aeration lagoon prior to discharge into the Kitimat River. Effluent is monitored according to PCB permit stipulations and a summary of monthly monitoring data is presented as Table 11.1. Removal efficiency for total, suspended and volatile suspended solids as well as for BOD have averaged 97%, 93%, 93% and >85% respectively (C. Brewer, Dist. of Kitimat, pers. comm.). Surveys of Kitimat River water quality (Beak, 1970, 1971) disclosed some enrichment (increased BOD_5 concentrations, increased benthic standing crop) downstream of the effluent outfall.

Table 11.1. Municipal Sewage Treatment Plant Effluent Characteristics (condensed from PCB permit monitoring data from February, 1972 to April, 1976, Victoria, B.C.)

	pH	Total Solids	Suspended Solids	Volatile Sus. Solids	Specific Conductivity
Average	7.0	154 mg/1	13.4 mg/1	5.6 mg/1	260 umho/cm
Range	6.6-7.2	146-160	0-36	<1.0-19.0	220-288

	Temperature	Dissolved Oxygen	Settleable Solids	$B.O.D._5$	Total Coliforms
Average	9.3°C	3.5 mg/1	0.12 mg/1	14.1 mg/1	450,000 M.P.N.
Range	1-20	0.7-6.7	0.02-.50	0-195	<20,000-1,600,000

Domestic sewage from both the Alcan smelter and Eurocan pulp mill is pumped into the municipal sewer system. Sewage from the smelter was treated and discharged via 10 septic tanks prior to 1975 and sewage from the pulp mill was treated along with mill wastes during the first week of startup operation.

3. ALCAN SMELTER:

The Alcan smelter is an integral part of the Kitimat-Kemano hydro-electric and smelter operations, having a total installed annual capacity of 299,720 tonnes (295,000 tons). Raw materials, brought in by deep-sea vessels, include alumina, green and calcined petroleum coke and coal-tar pitch (from which carbon paste is manufactured). Aluminum fluoride, cryolite, soda ash and lithium carbonate, which make up the cell electrolyte, are also imported.

The heart of the process is the electrolytic cell, of which there are about 900, where alumina is reduced to aluminum metal. The cell consists of a large carbon-lined steel box. The cell cavity contains a melt of fluoride compounds at close to 1,000°C, which acts as the electrolyte in which alumina is dissolved. A block of carbon dips into the electrolyte, serving as the anode. Direct-current electricity is passed continuously through the electrolyte from the carbon anode to the carbon-lined steel box which serves as the cathode. Under these conditions, the alumina reacts with the carbon anode to produce aluminum metal and carbon oxides (Kraft, 1971).

The carbon oxides off-gas from the cells consists mainly of carbon dioxide and carbon monoxide and contains volatile fluorine compounds, hydrocarbon fumes plus carbon and aluminum particles. Cell off-gases are collected and passed through scrubbers. The wet scrubbers used previously are gradually being replaced with dry scrubbers. The changeover has been delayed by strikes and construction slowdowns but is scheduled for completion by January, 1977. The wet scrubbers will remain in place as backup systems to the dry scrubbers. Fluoride concentrations in mill effluent (measured at the settling lagoon weir) are expected to drop from the present 50 mg/l (with one wet scrubber in operation) to 15 mg/l as specified in Alcan's PCB permit (C.R. Fox, Alcan pers. comm.). Effluent from the wet scrubbers is conveyed through a system of canals and settling lagoons, where it is mixed and diluted by cooling water and other process waters.

Molten aluminum is solidified in the casting department by water cooling using various techniques. Other water uses include cooling of electrical transformers and rectifiers, indirect cooling of coke calciner products, cooling of carbon paste for anodes and sanitary sewers (the latter discussed under Domestic Sewage).

Mill wastes are discharged at three points around the millsite. Discharge points are illustrated in Figure 11.2 and PCB effluent stipulations for each are listed in Appendix 11.1. The major discharge, that of the settling pond system, flows through an open drainage ditch onto the delta immediately east of the smeltersite. A sediment sample analyzed from this ditch had an ionic composition different from that of estuarine sediments, as expected, and was mostly composed of inactive carbon particles (Bradshaw, MS, 1976). These carbon deposits, which remain readily noticeable in the immediate discharge area, were products of the wet scrubbing system. A fisheries officer report (Engelson, 1961) remarked on the deposits, but related no undesirable effects, as the particles settled rapidly.

Cooling water and surface runoff from the coke calciner area of the millsite is discharged at the southwestern mill foreshore, near Hospital Beach. Surface runoff from the potlining disposal and storage area contributed to effluent high in fluorides being discharged at this point. However, the storage area has since been perimeter-dyked so that runoff is channelled to the settling lagoons. The amount of potlining stored on the site has also been reduced. Some of the leachates may still enter the estuary through groundwater; and a sampling program is in progress

Table 11.2 Alcan Effluent Sampling and Monitoring Program (as specified by PCB permit PE-1494)

Parameter Tested	Sampling Point Identification					
	A	B	D	F	G	H
Suspended Solids mg/l	W	W	W	W	Q	Q
Dissolved Solids mg/l	Q	M	M	M	Q	Q
pH	W	W	W	W	W	W
Temperature (^{o}F)	W	W	W	W	W	W
Oils mg/l	Q	M	M	M	Q	Q
Dissolved Fluoride mg/l	Q	W	W	W	Q	Q
Dissolved Aluminum mg/l	Q	M	M	M	Q	Q
Dissolved Calcium mg/l	Q	M	M	M	Q	Q
Dissolved Iron mg/l	Q	M	Y	Y	Q	Q
Dissolved Chromium mg/l	Y	Y	Y	Y	Q	Q
Dissolved Copper mg/l	Y	Y	M	M	Q	Q
Dissolved Mercury mg/l	Y	Y	Y	Y	Q	Q
Dissolved Manganese mg/l	Y	Y	Y	Y	Q	Q
Dissolved Nickel mg/l	Y	Y	Y	Y	Q	Q
Dissolved Lead mg/l	Y	Y	Y	Y	Q	Q
Dissolved Titanium mg/l	Y	Y	Y	Y	Q	Q
Dissolved Vanadium mg/l	Y	Y	Y	Y	Q	Q
Dissolved Zinc mg/l	Y	Y	Y	Y	Q	Q
Total Cyanide mg/l	-	M	M	M	-	-
Coliform Bacteria (mpn per 100 ml)	Y	Y	Y	Y	Q	Q
Assessing Toxicity (PCB Mining Objectives, Table V)	-	SY	SY	SY	-	-

Sampling abbreviations:

A = Supply water, Anderson Creek and/or Kitimat River
B = Effluent discharged at weir from settling lagoon
D = Effluent discharged to Douglas Channel
F = Effluent discharged to Moore Creek
G = Moore Creek upstream of discharge point
H = Moore Creek downstream of discharge point
W = Weekly grab
M = Monthly Composite of weekly grab samples
Q = Quarterly (each three months) grab
Y = Yearly grab
SY = Semi-yearly grab

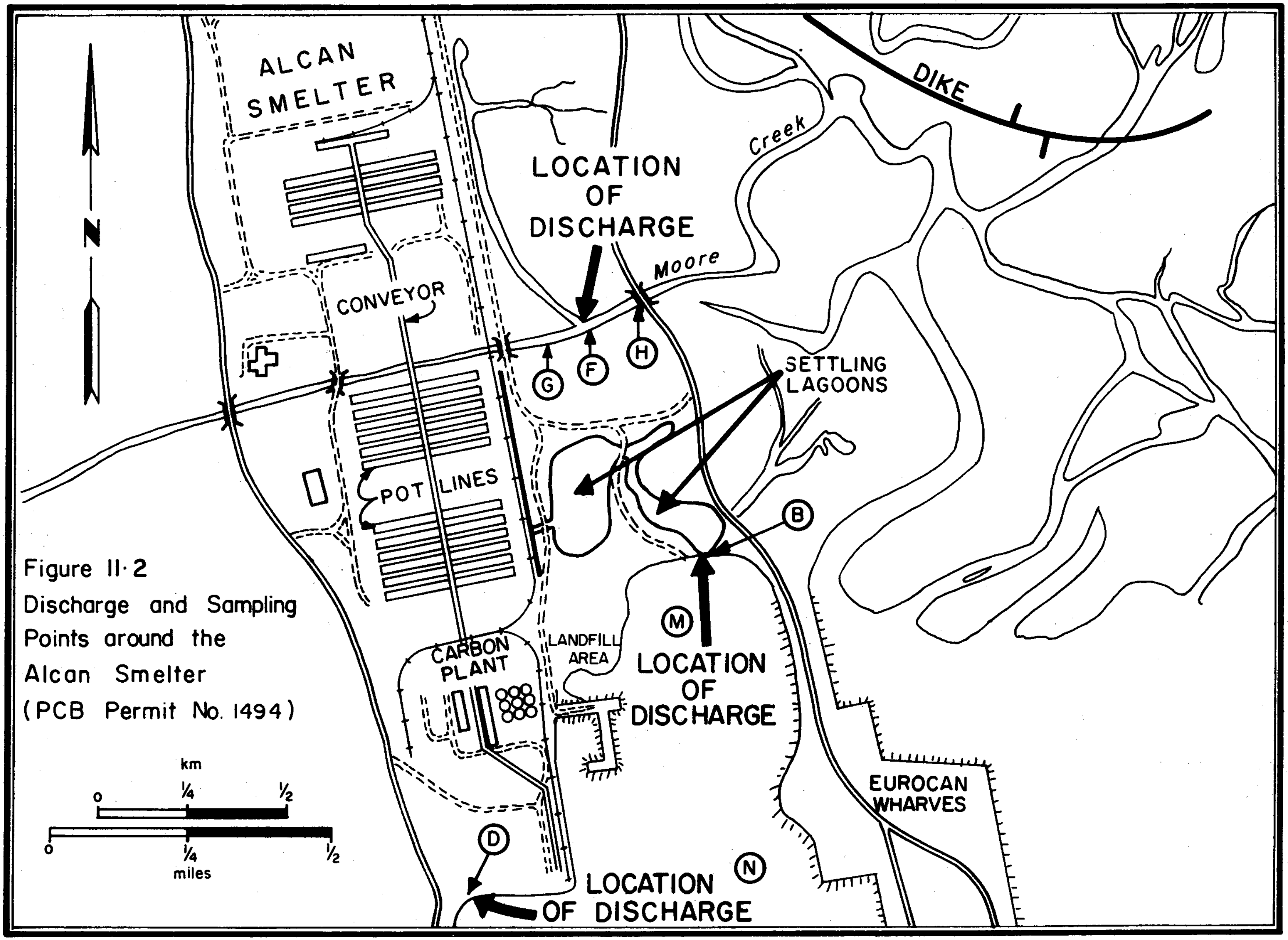


Figure II·2
Discharge and Sampling Points around the Alcan Smelter (PCB Permit No. 1494)

Table 11.3. Summary of pertinent Alcan effluent data reported up until July, 1976 (PCB permit monitoring data, Victoria, B.C.)

Sampling Site	Flow l/min	Temp °C	pH	Oil & Grease mg/l	Suspended Solids mg/l	Dissolved Solids mg/l	Fluoride mg/l	Cyanide mg/l	Dissolved Aluminum mg/l	Calcium Total mg/l	Copper mg/l
Main Discharge East of Smeltersite PE 149401 (B on Fig. 11.2)	1,470 (890-3,120)	5.3 (0-10.8)	3.1 (2.3-5.6)	2.42 (<1.0-5.6)	8.17 (0.8-62.0)	205.4 (103-307)	128.8 91.5-256)	0.15 (<0.1-0.3)	10.2 (0.8-18.2)	4.90 (0.6-8.0)	0.008 (0.006-0.010)
Discharge from coke calciner area PE 149402 (D on Fig.11.2)		13.7 (4-23.5)	6.9 (6.0-9.1)	26.4 (<1.0-385)	205.5 (1-5680)	361.3 (52-3326)	12.26 (<0.1-31.0)	0.52 (<0.1-1.3)	1.66 (<0.1-13.9)	10.85 (3.3-42.4)	.023 (<0.01-0.14)
Discharge into Moore Creek PE 149403 (F on Fig. 11.2)	334 (137-910)	16 (6.5-23)	6.5 (3.4-7.4)	1.99 (0.6-6.0)	8.40 (0.7-77)	67.67 (39-162)	2.99 mg/l (0.4-42)	0.10	0.95 (<0.1-3.3)	4.9 (2.7-7.6)	0.03 (<.01-0.19)

Note - Given values are cumulative averages of sampling to date; ranges are quoted in brackets.

to assess this possibility (W.G. Wallace, Alcan, pers. comm.).

Uncontaminated cooling water and surface runoff are discharged into Moore Creek which runs through the millsite. The effluent is retained in a cooling pond prior to discharge, in order that the temperature of Moore Creek does not increase more than 3°C. Moore Creek has received a number of minor fuel spills, one of which has resulted in a conviction under the Fisheries Act. A heavy equipment storage area nearby is now dyked, such that runoff carrying oil and grease is diverted away from the creek. Fuel storage tanks have also been relocated and protected by gravel dykes (C.R. Fox, pers. comm.).

Extensive monitoring of mill effluents is stipulated by the PCB permit, and the plant's program is summarized in Table 11.2. Results, submitted quarterly, are available from the PCB head office in Victoria and summarized in Table 11.3. Measurements of effluent quantities at all three discharge points are included in the monitor program, as are data on biweekly sampling of contiguous waters. These are summarized in Table 11.4.

Table 11.4. Fluoride Concentrations (mg/1) in Waters Contiguous to the Alcan Smeltersite (PCB Permit Monitoring Data, February, 1975 to March, 1976, Victoria, B.C.).

Depth	100m south of lagoon outfall	Mid-channel between Alcan and Eurocan wharves
surface	<0.20* - 50.6 (7.02)	<0.20 - 4.0 (1.68)
mid-depth	0.30 - 8.60 (2.18)	<0.20 - 1.70 (0.81)
bottom	0.30 - 5.90 (1.53)	<0.20 - 1.20 (0.82)

* 0.20 is the limit of detection
cumulated mean quoted in brackets

A survey of fluoride ion concentrations in waters of Howe Sound and Kitimat Arm/Douglas Channel (Harbo, McComas and Thompson, 1974) indicated that fluoride levels were measurably higher in the latter area. Values averaged 1.17 mg/1 (0.10 - 11.0) and 1.17 mg/1 (0.94 - 1.32) for Kitimat Harbour surface and subsurface waters, respectively, as compared to 0.23 mg/1 (0.14 - 0.96) and 1.02 mg/1 (0.34 - 1.12) for Howe Sound. Subsurface waters in Kitimat Arm/Douglas Channel averaged 1.20 mg/1 (1.10 - 1.30). Levels were not "dangerously high", except in surface waters near the smelter outfalls, owing to considerable tidal flushing, but results indicated smelter influence several kilometres distant from the site. Sediment analysis indicated no enrichment of fluoride above that normally encountered in marine sediments.

It should be noted that the fluoride concentrations in contiguous marine waters quoted above may no longer be representative, as a result of the dry-scrubbing system now in operation and the improvements to the potlining storage area.

Some indication of the toxic effects of fluorides on estuarine organisms are given in experiments conducted in South Africa (Hemens and Warwick, 1972). Fluoride was not found to be acutely toxic to fish or invertebrates (96h at 100 mg F/1) but all species did accumulate fluoride in their tissues. Sublethal effects were noted during long-term exposures (72 days) of fish (mullet) and decapod crustaceans to 52 mg F/1. Fluoride did not accumulate in plants or algae.

4. EUROCAN PULP AND PAPER MILL

The Eurocan mill is a fully integrated operation developed with minimized pollution output, in co-operation with Environment Canada and the British Columbia Pollution Control Branch. Extensive meetings were held to determine suitable effluent disposal and water intake methods. An outfall through a submarine diffuser, situated well down Kitimat Arm taking into account oceanographic conditions (Kussat, 1967; Schouwenburg and Jackson, 1967; Waldichuk, 1967) was considered, but owing to the difficult terrain and prohibitive costs for such disposal, complete biological treatment was accepted as a more viable alternative. Thus, advanced equipment and facilities were installed and are used for the treatment and monitoring of effluent. In addition, the water intake located in the Kitimat River was designed so that juvenile salmon would be deflected away from the intake.

Three separate sewer systems, the fibre sewer, general sewer and toxic sewer, collect liquid mill wastes. The fibre sewer collects wastes with high fibre and low chemical content, an example being woodmill wastes, and directs them to the clarifier where solids are settled out. Clarifier supernatant flows into the general sewer, which is mixed with the toxic sewer at the valve house. The toxic sewer collects wastes with high chemical content and low fibre content and bypasses the effluent clarifier. In the event of an upset in the mill, including chemical spill or deliberate release of a "cook" from the digesters, the toxic sewer effluent is automatically (when effluent conductivity >2500 μmhos) diverted into a 18,925 m^3 (5 million US gal.) toxic spill basin (volume equivalent of effluent from 24 hours production during normal operating time). Thus diverted, the effluent may then be pumped back gradually into the combined effluent, so that the pH does not increase above 9.5. The pH of the effluent is regulated using a metering pump and concentrated sulfuric acid or lime (Pottle, 1974, pers. comm.).

The combined effluent leaves the valve house and passes to the nutrient feed house where nitrogen and phosphorus in the form of anhydrous ammonia and mono-ammonium phosphate are added to the effluent at a rate of 100:1.3:0.3.

After nutrient addition, the effluent is pumped to one of two 22,710 m^3 (6 million US gal.) settling ponds. One of these basins is dredged while the other is being used; the fibre removed is used as landfill. The settling pond overflows into the 250,650 m^3 (90 million US gal.) aeration lagoon which has a retention time of five days. Nine 100 hp. floating aerators mix and aerate the effluent. A wooden dyke creates a quiescent, foam-free zone before the outlet, where biomass and precipitated lignin settle. The treated effluent then flows by gravity through a buried pipe to a single point discharge in the middle of the Kitimat River (Pottle, 1974, pers. comm.).

Some problems were experienced by Eurocan with respect to siltation of the original ten-port diffuser resulting in back-up of the system and possible overflow of the settling ponds. In an effort to repair the faulty diffusers in October, 1973, effluent was diverted through an emergency outlet into the oxbow surrounding the treatment site. The ensuing fish kill resulted in a conviction under the Fisheries Act (Northern Sentinel, Jan. 3, 1974). The present single port discharge in the middle of the river and rock groin extending out from the opposite shore of the river (slightly upstream) was subsequently constructed to provide adequate dilution and dispersion of effluent without danger of further siltation.

In addition to the monitor program listed in Table 11.5 and summarized in Table 11.6, monitoring of neighbouring creeks, monitoring and control of mill site runoff water (waste dump leachates), as well as biological river surveys are specified in Eurocan's PCB permit. This is necessary because solid wastes, from both the settling ponds and the clarifier are dumped in a millyard through which flows Beaver Creek, a tributary of Anderson Creek. Both these creeks once supported small coho salmon runs, but no fish have been reported in them since 1972 (Macdonald, 1975).

Environmental surveys of receiving waters (the lower

Figure II·3 Plan of effluent disposal on the Eurocan millsite.

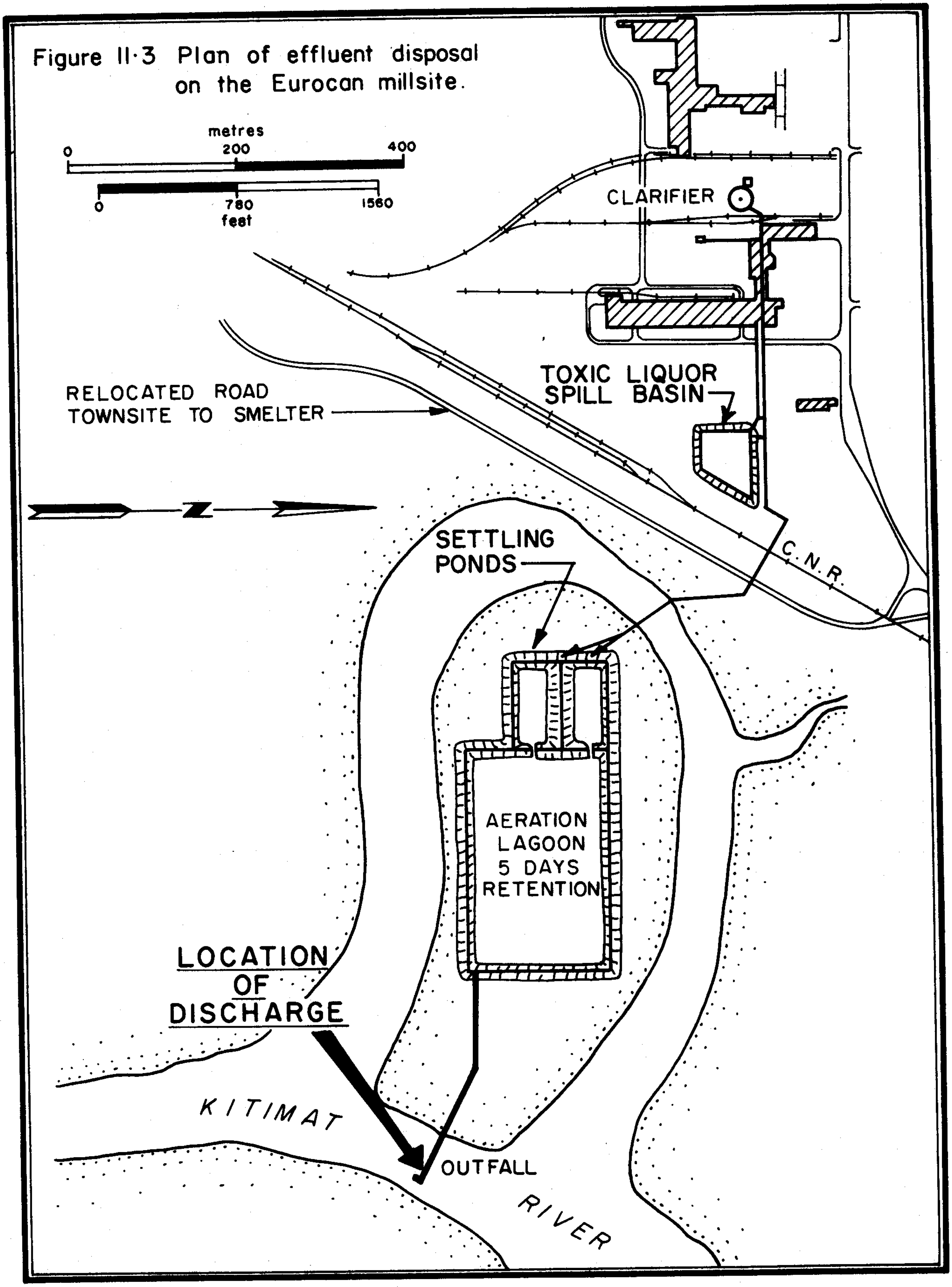


Table 11.5 Eurocan Effluent Sampling and Monitoring Program (as specified by PCB Permit PE 292).

Parameter Tested	Frequency/Type of Sampling: Clarifier In	Clarifier Out	Settling Ponds In	Settling Ponds Out	Final Effluent
Volume					D
Production					D
pH					Cont.
Temperature					W/G
Total solids					W/DC
Total Suspended solids	W/DC	W/DC	W/DC	W/DC	W/DC
Volatile suspended solids					W/DC
Floatable solids					D/I
Settleable solids	W/DC	W/DC	W/DC	W/DC	W/DC
BOD_5			W/DC	W/DC	W/DC
Colour					W/DC
Toxicity					Q*
Mercaptans					W/G
Total sulfides					W/G
Resin acids					W/G
Dissolved oxygen					D/G
Conductivity					D/G
Total dissolved phosphorus					M/DC
Nitrate and nitrite					M/DC
Total phosphorus					M/DC
Kjeldahl nitrogen					M/DC
Kitimat River flow					D

Sampling abbreviations:

Frequency

Cont. - continuously
D - daily
W - weekly
M - monthly
Q - quarterly
* - if failure, repeat weekly until objectives met.

Type

DC - composite taken over 24 hour period
G - grab
I - visual inspection

Data generated by the above sampling program is available from either the PCB head office in Victoria or the Pollution Abatement Branch of the Environmental Protection Service.

Table 11.6. Summary of Eurocan effluent data reported up until July, 1976 (PCB permit monitoring data, Victoria, B.C.)

Colour	pH	Total Solids	Suspended Solids	Dissolved Solids	Settleable Solids	Floatable Solids
528 rel. units	7.7	737.2 mg/1	875 mg/1	87.9 mg/1	0.23 ml/1	0 ml/1
(85-2000)	(5.8-9.8)	(498-1492)	(875)	(38-190)	(0.-2.5)	(0)

Volatile Suspended Solids	Specific Conductivity	Temperature	Dissolved Oxygen	Flow	Total Alkalinity
39.3 mg/1	693.5 μmho/cm	22.1°C	5.1 mg/1	28,008 m^3/day	120 mg/1
(38-41)	(190-1500)	(5.6-32.8)	(0.2-11.9)	(0-85,275)	(109-1B1)

NO_2/NO_3	Total NO_3	Total Nitrogen	$B.O.D._5$	Phenol	Dissolved Phosphorus	Total Phosphorus	Tannin & Lignin
0.045 mg/1	0.67 mg/1	0.99 mg/1	74.3 mg/1	0.29 mg/1	0.018 mg/1	1.24 mg/1	48.2 mg/1
(0.02-0.07	(0-1.5)	(0-2.3)	(17-250)	(0.025-056)	(0.011-0.025)	(0-5.6)	(20-176)

Sulfide	Resin Acids	Mercaptans	Sodium	Total Coliforms	Production
0.34 mg/1	3.5 mg/1	0.096 mg/1	100 mg/1	2380 MPN	598 tonnes
(<0.1-2.5)	(0.6-8.8)	(<0.05-0.20)	(82-118)	(200-4900)	(0-990)

Kitimat River and the Kitimat estuary) have been conducted by T.W. Beak Consultants Limited (1970, 1971, 1972), who also designed the $5,000,000 effluent treatment facilities. Results of ambient air quality, water quality and biological investigations are summarized under Air Pollution, Water Quality and Invertebrates, respectively. From the results of chemical and biological testing to date, it appears that pulp mill effluent alters water quality immediately downstream of the diffuser, but that river water trends back toward natural conditions further downstream. Another biological river survey is presently being conducted for Eurocan by International Environmental Consultants (I.E.C., in progr.).

No measurable deterioration in water quality of Kitimat Arm has been reported since the Eurocan pulp mill went into operation. However, with the startup of the Eurocan pulp mill in 1970 the annual spring run of eulachon (*Thaleichthys pacificus*) to the Kitimat River allegedly became tainted and therefore unfit for human consumption. The alleged tainting severely affected the local Indian food fishery based on the eulachon (Northern Sentinel, June 20, 1973; Needham, 1975).

Concern that tainting of salmon and steelhead, returning to the Kitimat River, would also occur (Schouwenburg, 1973) resulted in an investigation of tainting of sockeye salmon through exposure to pulp mill effluent (Geiger, 1972). This experiment was unfortunately rendered inconclusive because control fish were judged tainted. No complaints have been received by either the mill management or the area Fisheries Officers with regard to the edibility of resident trout or migratory salmon taken anywhere from the Kitimat River (Mahood, 1976; E.R. Christiansen, Federal Fisheries District Supervisor, pers. comm.).

5. LOGGING AND LOG HANDLING:

The Kitimat River Valley has seen logging activity since the late 1800's, but has been most actively logged over in the past decade. As a result, much of the lower valley has been logged over and is in the early stages of regeneration. Annual narrative reports by area Fisheries Officers (Can. Dept. Env., unpublished data) consistently report that the deposition of mud and silt in the river and its tributaries, as the result of logging and road building operations, constitutes the most serious threat to the aquatic environment within the Kitimat watershed. The extent and location of logging activity in the area is documented in these reports. No major incidents such as slides or man-made depositions have occurred in recent years, but continual erosion of disturbed areas has kept the silt load of the Kitimat River at a high level (Macdonald, 1976). Problems which do arise are generally settled at the field level, and logging practices are improving as attitudes change towards multiple resource use (P. Kwataschin, Eurocan, Kitimat Logging Division, pers. comm.). The rate of timber removal within the watershed is slowing down, thus reducing the number of resource-use conflicts that arise.

Erosion and siltation will also be reduced, especially as forests regenerate and soils stabilize over the many large logged-off areas.

Portions of Minette Bay, because of quiet waters and easy road access, are presently being used by Crown Zellerbach and MacMillan Bloedel as a log dumping and storage area. The MacMillan Bloedel log dump and storage area and the Crown Zellerbach storage area on the west shore of the bay are to be phased out and concentrated into one dumping facility on the east shore (presently Crown Zellerbach's) within five years (Corp. Dist. Kitimat, 1975). Some water quality impairment has been reported for Minette Bay owing to salinity stratification, poor flushing (see Oceanography Section) and the settling of wood wastes generated by log handling and storage. Beak Consultants Ltd.(1970, 1971) reported increased BOD_5 and colour values and decreased dissolved oxygen concentrations in subsurface waters. Paish (1974) also reported low dissolved oxygen values in subsurface waters and qualitatively described the epibenthos in the bay as being scarce. All of these findings have been attributed to log handling and storage in this highly stratified bay with little or no deepwater exchange for most of the year.

A portion of the Kitimat delta west of and adjacent to the Eurocan wharf is used as a log storage and handling area to supply the Eurocan sawmill and pulp mill. MK Bay is also used as a booming ground.

The deleterious effects of log handling and storage have been discussed in previous reports in this series, but briefly stated are as folows:

(1) Log booms shade the water column and substrate, thereby inhibiting primary production, but on the other hand, provide suitable attachment substrate for macrophytic algae if left immersed long enough.

(2) Grounding of log booms compacts and/or churns up sediments, destroying benthic plant and animal life. Propellor wash from log handling boats can also severely scour sediments.

(3) Debris (bark, wood chips, etc.) settling onto the substrate alter its structure, resulting in a loss of, or change in (usually detrimental), the benthic community.

(4) Leachates from logs and debris can become toxic without adequate dilution; they also colour the water, thereby reducing primary productivity.

(5) Biological degradation of dissolved organic substances (leachates) and deposited debris increases BOD (uptake of oxygen) of waters and sediments, which can lead to lowered dissolved oxygen concentrations detrimental to animal life.

Eelgrass beds (*Zostera* sp.) have been noted in previous reports in this series as being highly productive habitat and sensitive to the detrimental effects of log booming and handling.

6. SHIPPING:

Deep-sea shipping to Kitimat Harbour poses both sewage and oil pollution threats. In the event of an oil spill occurring, manpower and physical resources (boats, booms, gear, etc.) required for containment and cleanup would be available from a variety of sources. Oil cleanup equipment is on standby in Prince Rupert, Vancouver and Victoria. Pollution by oil from ships is controlled under the Canada Shipping Act and fines levied against offending ships can range to $100,000.

The increase in shipping associated with the possible location of a pipeline terminus and/or steel mill in the Kitimat area would greatly increase the possibility of an accident occurring in the constricted approach waterways and hence increase the threat of a major oil spill. This would necessitate stand-by equipment and materials closer at hand for emergency needs in the event of an oil spill in the area.

7. STREAM CHANNELIZATION:

It is a natural process for streams to meander and create new channels; however, this does cause problems when man-made structures impinge on stream beds. While extensive flood and river bank protection works have been constructed in the Kitimat area, no major channelization has been carried out (see Hydrology Section).

Channelization increases stream gradients, thereby increasing flow rates and erosion upstream and sedimentation rates downstream (Funk and Ruhr, 1973). Channel realignments which cut off natural meanders, side channels and sloughs, remove habitat essential to fish production (Bayless and Smith, 1967; Bustard, 1973).

(ii) AIR POLLUTION

1. REGULATION:

Polluting emissions are regulated by the Pollution Control Branch under the B.C. Pollution Control Act. Permits, stipulating emission quality and accompanying monitoring programs, are issued based upon Pollution Control Objectives. Emissions permits and applications for the Kitimat area are presented as Appendix 11.2. However, under the Municipal Act, the District of Kitimat is delegated statutory powers, which include the ability to regulate industry or even prohibit the establishment of industry within zones of the municipality, the ability to specify the tolerable levels of airborne emissions from any home or industry and the ability to prescribe, through bylaw, the manner of industrial waste disposal (Fletcher, 1970).

Air pollution control in Kitimat was initially established through careful town planning and industrial design. The industrial area was placed to one side of the valley and is separated from the commercial and residential areas by the Kitimat River flood plain. This design has kept the townsite relatively free of direct airborne industrial discharges carried by prevailing up-and-down valley winds. With the advent of the Eurocan Pulp and Paper complex, with its 840 tonnes (930 tons) per day kraft mill and 306,800 m^3/year (130 million fbm/year) sawmill, Kitimat's natural ability to assimilate airborne wastes was reassessed. Subsequent studies and discussion with the major industry groups led to the preparation of a municipal bylaw regulating the emission of wastes.

The Works Waste Regulation Bylaw No. 1 adopted on December 11, 1968 (not enforced until December, 1970) requires that each industry monitor specified emissions and that these emissions do not exceed certain maximum practical levels. Presumed practical levels are included in the bylaw and were established on the basis of operating experience and of regulatory enactments elsewhere, together with special discussions with each industry group.

2. AMBIENT AIR MONITORING PROGRAM:

An ambient air quality monitoring program was initiated by the District of Kitimat in November, 1967, with the two-fold objective of establishing the background level of selected substances in the lower atmosphere and of assessing the degree to which industrial wastes were being dispersed and assimilated in the community. The monitoring program, which began during November 1967, measured only fluorides and sulfides until April 1968 when particulates (non-volatile, aluminum, sodium and total) were also monitored. Early results (up to February 1969 from the three monitoring stations, located in the Service Centre, Nechako and Kildala Neighbourhoods were summarized by Fletcher (1970). They indicated that the townsite and residential areas were not free from smeltersite discharges, although they were spared direct contact with the emissions plume. Particulate levels in the Service Centre area have fluctuated considerably, and at times, caused relatively high dustfall levels.

The number of sample stations was increased to 4 in 1970. They are located in the Public Safety Building (1), the municipal sewage treatment plant (2), the municipal pump house (3), and the public works yard (4) (see Figure 11.1). Monitored parameters include relative fluorides, sulfation rate and dustfall which are based upon monthly sampling periods, and gaseous fluorides (sampling began in 1972) and suspended particulates, which are based on 24-hour sampling periods. Summarized results of the sampling program from 1971 to 1975 are presented in Table 11.7. Apart from the long-term mean calculation, no trend analysis has been performed. The expected trend of higher readings at station 3 (public works yard), as opposed to stations on the east side of the Kitimat River, is apparent. Sulfur dioxide has also been monitored on a 24-hour, once-a-week basis at stations 1 and 2.

Table 11.7 Summary of Ambient Air Quality Monitoring Program - Kitimat, B.C.
(District of Kitimat, unpublished data)

Year	Stn**	Suspended Particulates $\mu g/m^3$	Relative Fluorides $\mu g/cm^2 day$	Dustfall Total Solids $tonnes/km^2/mnth$ (tons/sq.mi/mnth)	Dustfall Non-volatile Solids $tonnes/km^2/mnth$ (tons/sq.mi/mnth)	Sulfation Rate $SO_3/dm^2/day$	Gaseous Fluorides $\mu g/m^3$
1971	1	22.33	0.02	1.69 (4.84)	1.46 (4.18)	38.23	-
	2	22.59	0.02	1.68 (4.79)	0.89 (2.55)	29.54	-
	3	-	0.04	4.90 (14.00)	3.69 (10.54)	65.85	-
	4	-	0.02	4.22 (7.34)	1.63 (4.65)	39.36	-
1972	1	24.23	0.14	1.75 (5.00)	1.23 (3.50)	69.84	-
	2	23.10	0.00	2.03 (5.80)	1.23 (3.50)	38.27	1.38
	3	-	0.00	5.84 (16.68)	4.05 (11.57)	71.90	-
	4	-	0.00	3.19 (9.13)	1.99 (5.68)	36.60	-
1973	1	15.57	0.01	0.98 (2.81)	0.57 (1.63)	25.98	-
	2	19.89	0.01	1.27 (3.62)	0.81 (2.33)	37.25	1.02
	3	-	0.05	5.98 (17.07)	4.32 (12.34)	73.32	-
	4	-	0.01	2.10 (6.00)	1.63 (4.65)	25.90	-
1974	1	20.07	0.02	1.44 (4.11)	0.43 (1.22)	16.99	-
	2	20.86	0.01	1.33 (3.81)	0.95 (2.70)	20.69	0.00
	3	-	0.04	4.56 (13.02)	3.44 (9.84)	34.48	-
	4	-	0.03	1.80 (5.13)	1.19 (3.41)	20.49	-
1975	1	16.94	0.39*	2.03 (5.79)	1.208 (3.45)	9.06	-
	2	17.70	0.38*	1.64 (4.70)	0.853 (2.44)	19.02	0.85
	3	-	1.19*	5.30 (15.13)	3.387 (9.62)	24.47	-
	4	-	1.20*	4.22 (12.04)	2.523 (7.28)	8.16	-
Cumulated Ave.	1	18.04	0.11	1.60 (4.58)	0.98 (2.81)	21.78	-
	2	19.92	0.11	1.55 (4.44)	0.94 (2.68)	29.73	1.00
	3	-	0.37	5.46 (15.59)	3.72 (10.62)	49.35	-
	4	-	0.31	3.21 (9.18)	2.12 (6.04)	20.55	-

- no value recorded
* distorted by July and September results
** see Figure 11.1 for station locations

However, values from this test have been negligible.

Ambient air quality stations have recently (September 1975) been established in the Kitimat area by the B.C. Pollution Control Branch. Stations are located south of the smeltersite (1) north of the smeltersite, south and north of Anderson Creek (2,3) at the municipal sewage treatment plant, and at mile 6 of the Eurocan logging road. Data collected thus far are limited to monthly relative fluoride readings starting March, 1976, and are available through the PCB head office in Victoria. Pre-and post-operational ambient air quality surveys have also been conducted for the Eurocan Pulp and Paper Co. Ltd. (Beak, 1971, 1972). These studies are summarized under the Eurocan Pulp Mill subsection of Air Pollution.

3. ALCAN SMELTER:

Electrolytic smelting of alumina results in gases, largely carbon dioxide and carbon monoxide, containing volatile fluorine, sulfur and hydrocarbon compounds as well as particulates containing fluorine, carbon and aluminum, being given off. These gases are collected from the vertical-stud, Söderberg (VSS)-type pots by gas collection skirts, which surround the anode and collect the major portion of the gases evolved in a relatively concentrated form. Most of the hydrocarbons and carbon monoxide in these hot gases are burned with air by a simple burner connected to the skirt. These gases are then conveyed via headpipe to the scrubbing towers of which there are eight, each one located between two potline buildings (C.R. Fox, Alcan, pers. comm.).

The fraction of fluorine compounds not collected by the pot exhaust system mixes with the potroom atmosphere. Ventilation air of the potline buildings is exhausted unscrubbed (no secondary cleaning) via roof vents to the atmosphere, making gas collection efficiency of crucial importance to the total emissions from the plant. Alcan is midway through a staged improvement program (to be completed by 1977) to increase collection efficiency from 70 to 90%.

Exhaust gases are passed through a scrubbing system to remove gaseous fluorides. The dry scrubbing process being implemented (nearing completion) relies on hydrogen fluoride being absorbed onto alumina powder, which is injected into the airstream and subsequently filtered out using fabric bag filters. This alumina is then used in the normal smelter process. Dry scrubbing results in a cleaning efficiency of over 98% (with respect to gaseous fluorides) and little scrubber downtime (3%) (C.R. Fox, Alcan, pers. comm.).

In the event of the dry scrubbers being shut down, the wet scrubbers (hydrogen fluoride is highly soluble in aqueous media) are implemented. This system has a similar gas-cleaning efficiency, but results in a fluoride-rich effluent (see Water Pollution, Alcan Smelter subsection).

An ambient air quality assessment report (Choquette, 1974) concluded that, under certain adverse meteorological conditions, local episodes of high ground-level concentrations of gaseous fluoride and suspended particulate matter could be experienced downwind of the smelter. Results based on emission data taken from PCB permit application No. AA2552, forecasted for 1977 when major improvement programs will be completed, indicated that maximum ground-level concentrations could exceed B.C.'s "Level A" objectives, under adverse conditions, by 3 times for gaseous fluoride (HF) and by 16 times for particulate matter. Particulate concentrations would exceed the federal government's maximum acceptable level by close to 21 times under the same adverse conditions. Sulfur dioxide ground-level concentrations would not seem to present a major problem.

Tables 11.8 and 11.9 present emission data which suggest that cleaning of potroom ventilating air (secondary cleaning) would be necessary to meet B.C.'s longer-term "Level A" objective for particulate and fluoride emissions. Technology for ventilation control exists at present, but implementation is involved with plant economics. The 800 ppm sulfur dioxide emission essentially results from the coke calciner rotary kiln stack, and would require a reduction of at least 76% in the sulfur content of coke used to achieve the "Level A" objective (Heskin, 1974).

Table 11.8. Estimated 1977 Overall Emissions Data for the Alcan Smelter at Kitimat, B.C. (Heskin, 1974).

Source	Particulates (excl. solid fluorides) kg/tonne Al (lb/ton Al)	Fluorides (solid & gaseous) kg/tonne Al (lb./ton Al)	Sulfur Dioxide ppm
Pot offgas scrubbing system	0.06 (0.12)	1.08 (2.15)	250
Potroom ventilators	9.92 [2.98] (19.8 [5.94*])	2.53 [0.31*] (5.05 [0.61*])	1.2
Ancillary operations	0.4 (0.8)	.0005 (.001)	800
TOTAL	10.38 [3.49*] (20.72 [6.96*])	3.61 [1.38*] (7.20 [2.76*])	1,051

* values in square brackets refer to estimated emissions, if scrubbing of roof vent emissions were practised at an overall efficiency of removal of 88% for fluorides and 70% for particulates.

Table 11.9. Pollution Control Objectives for Mining, Mine Milling and Smelting Industries of B.C.

Level	Particulate (excl. solid fluorides) kg/tonne Al (lb./ton Al)	Fluorides (solid & gaseous) kg/tonne Al (lb./ton Al)	Sulfur Dioxide ppm
A	5.0 (10)	1.5 (3)	250
B	7.5 (15)	2.5 (5)	1,000
C	16.5 (33)	5.0 (10)	2,500

Smelter emissions, particularly gaseous fluoride compounds, have had deleterious effects on the local environment. Fluoride has affected neighbouring vegetation visibly, by causing "tip-burn" or browning of the edges of broad leaves or tips of conifer needles (Macdonald, 1976). Airborne fluoride enters the trees through the stomata and is carried to the edges or tip of the leaf. Upon reaching a critical concentration, specific by species, necrosis occurs in that part of the tissue. If the fluoride concentration reaches a certain level within the remainder of the leaf tissue, the stomatae may fail to close, permitting continued access of fluoride and advancing the rate of necrosis (Parker, Bunce and Smith, 1974).

Those plants which scavenge the largest amount of fluoride are the tallest and most elevated species. Highest fluoride concentrations and the most severe leaf damage are found on the outermost and uppermost foliage of exposed trees and plants (Gordon, 1976).

The effects of smelter emissions on forest growth in the Kitimat area are being studied quantitatively by Reid, Collins and Associates (Bunce, in progr.). A report detailing effects on total volume and productive capacity of the forest is nearing completion and will offer quantitative conclusions based on X-ray densitometry techniques. Preliminary results, reported in a paper outlining the use of X-ray densitometry in assessing air pollution effects (Parker, Bunce and Smith, 1974) indicated that growth of forests may be reduced through fluoride exposure. Preliminary results indicated reduced annual ring width and maximum density in western hemlock (*Tsuga heterophylla*), sampled from fluoride-affected study plots for periods after 1954, when compared with pre-1954 periods or control site trees. The report recommended further research to investigate the possibility of an interaction between fluoride effects and the area's insect infestations (see Terrestrial Invertebrates sub-section). Assessment of air pollution effects using the above technique is on-going (1976-77) at the Western Forest Products Laboratory in Vancouver (Parker, in progr.).

Fluoride content in vegetation and soil samples has been assessed by a number of researchers (Palmer, 1973; Gordon, 1976; Hocking and Hocking, in progr.) and has generally been found to be "exceptionally high" for the area surveyed (Palmer, 1973) (see Table 11.10 for values). The area affected by fluoride emissions was described as being 1.6 km (1 mi.) wide and 32 km (20 mi.) long by Gordon (1976), as being 78 km^2 (30 sq. mi.) in area by Reid, Collins and Associates Ltd. (Bunce, pers. comm.) and 389 km^2 (150 sq. mi.) in area by Carlson, et al. (1972) and Palmer (1973).

A surveillance committee to investigate the quality of emissions from the smelter and their effect on the environment in the Kitimat area has recently been established by the Pollution Control Branch (Vancouver Sun, Nov. 12, 1976). The committee was formed in response to recent publicity about the fluoride levels in foliage reported by Gordon (1976) (Vancouver Province, Oct. 21, 22, 1976; Vancouver Sun, Oct. 23, 1976) and the PCB's own review of permits. Representatives from the PCB (chairman), B.C. Department of Health, District of Kitimat, Alcan and the Canadian Association of Smelter and Allied Workers (CASAW) make up the committee which will make recommendations to the director of the PCB based on their findings (H.J. Howie, PCB, pers. comm.).

4. EUROCAN PULP MILL:

Two locations were considered as suitable sites for the mill, namely Jessie Lake-Emsley Cove and the present mill site. Among the many advantages which the present mill site offered, provided the mill was built with the latest technology and operated with control of its waste discharge, was the relatively innocuous dispersion of the emission plume. At the Kitimat millsite, the plume, with proper stack discharge, generally rises

Table 11.10 Fluoride Content (ppm) of Soils and Selected Plant Species Found in the Vicinity of the Alcan Smelter, Kitimat, B.C. (Palmer, 1973)

SPECIES	TISSUE	LOCATION RELATIVE TO SMELTERSITE				
		1.9 km N	6.4 km N	12.8 km N	19.2 km N	2.4 km S
Grass	washed leaves	401.0				
Dryopteris austriaca (Wood Fern)	fronds		240.0		446.0	
Picea sitchensis (Sitka Spruce)	new needles	474.0	51.1		47.3	25.8
Picea sitchensis (Sitka Spruce)	old needles	1486.0	171.0		181.0	160.0
Populus trichocarpa (Northern Black Cottonwood)	leaves	1272.0	284.4			
Salix sitchensis (Sitka Willow)	leaves		446.0			57.5
Thuja plicata (Western Red Cedar)	scales	1004.0			259.0	
Tsuga heterophylla (Western Hemlock)	new needles	415.0	194.0	231.0	185.0	26.8
Tsuga heterophylla (Western Hemlock)	old needles	1377.0	279.0	498.0	371.0	182.0
Vaccinium parvifolium (Red Huckleberry)	leaves				460.0	
Soil		334.0	314.0	60.5	23.0	

Sampling time - July 11, 12, 1973.
Values reported as ppm on a dry weight basis.
Control Values (Bowen, 1966) Soil - 200 ppm; Land Plants - 0.5-40 ppm

above the town and is carried by prevailing winds over uninhabited land before cooling and falling to the ground (Fletcher, 1970).

In addition, plans for the proposed mill were appraised to indicate the nature, sources and extent of air pollution which would result from the mill (Rossano and Gardner, 1967). Specific recommendations regarding the practical control of waste emissions were made. The municipal pollution control bylaw subsequently adopted was based upon the use of recommended sampling and analysis equipment and assumed levels of emissions.

Eurocan controls particulates from the kiln and power boiler stacks, the particulates and hydrogen sulfide (H_2S) from the recovery stack, and the sulfur-containing gases from the smelt dissolving plant, evaporators, oxidation plant and digester gases. Stacks and vents are monitored for certain parameters as specified in the PCB emission permit (summarized in Appendix 11.2).

Pre- and post-operational ambient air quality surveys were conducted from April to September, 1970 and from October, 1970 to September, 1971 respectively by T.W. Beak Consultants Limited for Eurocan (Beak, 1971, 1972). Five sample stations were chosen, based on existing wind information to give complete coverage of the area likely to be affected by the mill emission plumes. Meteorological parameters measured were wind speed and direction, ambient temperature and precipitation. Physical contaminants measured were dustfall and suspended particulates; chemical contaminants measured were sulfur dioxide, hydrogen sulfide, calcium, sodium fluoride and sulfate. Monitoring of ambient air quality at these five stations was continued by mill personnel for several years until manpower cutbacks forced their closure (Pottle, Eurocan, pers. comm.). Only the stacks continue to be monitored.

In general, the level of particulate fallout was the same in pre- and post-operational surveys except at stations located in the direct path of both mill and smelter discharges (stations were also affected by nearby earthen logging roads). Dustfall levels (except for the previous two stations) were well below the maximum dustfall limits (5.25 tonnes/km^2/month [15 tons/sq.mi./month] in residential areas; 10.5 tonnes/km^2/month [30 tons/sq.mi./month] in industrial areas) specified in the Health Act. Ambient suspended particulate concentrations showed a general decrease from the pre-operational survey and were within provincial pollution control requirements.

Sulfur dioxide (SO_2) was present in the atmosphere of the northern end of the millsite over 90% of the time (peak concentration 1.1 ppm by volume) as opposed to 85% (peak concentration 1.8 ppm) in the pre-operational survey. All of the sulfation rates were considerably less than the accepted standards of other Canadian provinces (B.C. has no sulfation limits). There was an overall improvement in SO_2 levels in the atmosphere of the Kitimat Valley during 1971.

The level of hydrogen sulfide (H_2S) increased slightly at all of the sampling stations, but concentrations were significant only at stations near the pulp mill and smelter. Measureable concentrations of H_2S were present consistently only at the station adjacent to the pulp mill.

5. POST-LOGGING TREATMENT:

Fire researchers from the Canadian Forestry Service conducted informal slash burning and smoke management investigations in the Kitimat area a few years ago (Macdonald, 1976). At that time they concluded that slash burning was an undesirable post-logging treatment because:

(1) forests in the area regenerate naturally if unburned but must be planted if burned.

(2) though slash burning reduces fire hazard it appears unnecessary with proper logging patterns and excellent fire protection (i.e. good road access, plentiful labour, an aware public and a good firefighting organization, etc.) in the area.

(3) seasonal patterns are such that the only burning period occurs at the height of the outdoor recreational season.

(4) frequent atmospheric inversions in the area cause excessive smoke problems.

However, they also concluded that there may be justification for the use of fire for stand sanitation purposes after careful assessment of needs. A disease organism, hemlock dwarf mistletoe (*Arceuthobium tsugense*), is prevalent and damaging in western hemlock stands. One method of control is broadcast slash burning after clearcut logging (Baranyay and Smith, 1972).

6. PROPOSED STEEL MILL:

An environmental quality assessment of the potential impact of a proposed integrated steel mill involving the Nippon Kokan Kaisha Steel Company of Japan (NKK) has been completed for the District of Kitimat (Rossano, 1975). The report consists of deductions regarding the nature and extent of potential environmental pollution, primarily air pollution, at the proposed B.C. mill. The report is based principally on information and performance data (collected in Fukuyama, Japan) pertinent to the prototype mill.

A preliminary feasibility and siting study for the proposed steel mill has been completed by B.R. Hinton and Associates Limited for the provincial Department of Economic Development (Hinton, 1976). However, this report has not yet been released to the public.

12. EFFECTS OF DEVELOPMENT

While the planning, design and construction of the Alcan smelter, Eurocan pulp mill, harbour facilities and townsite have been carried out so as to minimize environmental impact, some changes to the physical and biological features of the region have inevitably occurred.

The effects of effluent disposal on the Kitimat River and estuary have been disucssed in detail in the Water Pollution sub-section. Briefly stated they are as follows:

1. Discharge of smelter effluents into Moore Creek and onto the western delta has resulted in the deposition of inert carbon particles on the western delta as well as elevated fluoride concentrations in contiguous waters. Directly related biological effects are limited to habitat degradation in the immediate vicinity of Alcan's main discharge point.

2. Discharge of treated pulp mill effluents into the Kitimat River has resulted in significant enrichment of Kitimat River waters. Benthic community composition immediately downstream of the diffuser has been altered, but trends back toward normal downstream. No effects have been noted on the Kitimat River estuary. The annual eulachon spawning run to the Kitimat River has allegedly become tainted by pulp mill effluent affecting the Indian food fishery for eulachon. No tainting of resident or migratory trout or salmon has ever been reported.

3. Discharge of primary treated municipal sewage into the Kitimat River has resulted in minor enrichment of Kitimat River waters. Benthic community composition was altered slightly immediately downstream of the discharge point.

Atmospheric emissions have affected air quality and vegetation in the Kitimat area. Details are discussed in the Air Pollution subsection and briefly stated are as follows:

1. Emissions from the Alcan smelter under adverse weather conditions cause increased ground-level concentrations of gaseous fluorides and particulate matter, particularly west of the river corridor. Fluoride emissions have caused visible vegetation damage and reduced forest growth rates in the direct path of smelter fumes and were possibly a factor in local insect infestations.

2. Emissions from the Eurocan pulp mill are generally carried by the prevailing north-south winds out over uninhabited lands of the Kitimat Valley or out over Kitimat Arm before they cool and settle to ground level. Some sulfur containing compounds may be detected in the immediate vicinity of the millsite.

Construction of harbour facilities for the Alcan smelter and Eurocan pulp mill has resulted in filling and dredging of portions of the western sector of the delta. Any effects on the productivity of the estuary have, not been fully evaluated at the present time.

The eastern sector of the delta has remained relatively unchanged. Apart from the construction of a 300 kv. transmission line across the delta, south of the river mouth, no other development has taken place. Plans are currently underway to phase out log storage in Minette Bay and develop this section of the estuary for recreational uses, with a minimal impact on the quality of the environment. Details are discussed in the Land Use Section.

Active logging in the Kitimat Valley over the past decade has resulted in extensive cutover areas in varying stages of regrowth. While post-logging slash burning has resulted in some air pollution problems, road construction has allowed access to much of the valley for recreationalists.

The feasibility of constructing a major oil terminus on the southwestern shore of Kitimat Arm is presently being studied. Studies by environmental consultants will assess the impact of proposed developments on the natural resources of the area.

Plans for future industrial development in the Kitimat area have included the construction of a steel mill by the NKK Company of Japan. A preliminary feasibility study for site selection (Hinton, 1976) and an impact assessment on air quality (Rossano, 1975) have been completed (see Pollution Bibliography for references).

13. CONCLUSIONS

Prior to the planning, design and construction of the Alcan aluminum reduction plant at Kitimat, little was known about the natural characteristics of the area. There was a paucity of knowledge relating to the renewable natural resources of the Kitimat River and its estuary. Since 1950, however, this situation has changed rapidly with the participation of both industry and government agencies in detailed environmental studies and environmental quality monitoring programs. The status of environmental knowledge as compiled in this report, is based largely on the work carried out over the past 25 years, and forms the basis for the following conclusions:

1. Discharge of effluents from the Alcan smelter, Eurocan pulp mill and municipal sewage treatment plant have not had, apart from isolated incidents, severe effects on water quality and aquatic life of the Kitimat River and estuary.

2. Climatic conditions in the area do not favour dilution and dispersion of industrial air emissions. Smelter emissions have caused visible vegetation damage in the path of the emissions plume; however, improved control measures are being implemented, as a result of regulatory legislation.

3. Dredging and filling for harbour facilities has resulted in the loss of areas of benthic habitat on the western sector of the delta. Though the extent of these losses has not been fully evaluated, rehabilitation of these areas as habitat for benthic invertebrates and juvenile salmon is unlikely in view of shipping activities and accelerating development.

4. The lower reaches of the river and the estuary are the most important habitats for avian wildlife.

5. Salmon escapements to the Kitimat River have fluctuated greatly despite close management of the fisheries. Improved attitudes toward environmental degradation plus application of salmonid enhancement technology could upgrade and stabilize fish production.

6. Ample and varied recreation opportunities are of prime importance to the residents of Kitimat, owing to its remote location from other major communities. The Kitimat District Planning Department has given high priority to land use planning for recreational facilities.

7. Kitimat has limited natural resources, good transportation facilities, ample source of power, and an established, growing community. However, additional industrial and commercial development in the area must be planned with environmental and living resource considerations in mind.

14. APPENDICES

Appendix 1.1. Sources of Information

The references and data used in this summary of environmental information on the Kitimat River estuary were gathered from many sources, particularly the members of the Estuary Working Group. The following is a list of agencies, whose personnel and libraries provides much information and advice, and aided in the compilation of literature.

1. Canada, Department of the Environment

Environmental Protection Service, Pacific Region
- Pollution Abatement Branch
- Ecological Protection Branch
- Environmental Emergency Branch

Fisheries and Marine Service
- Fisheries Management
  - Economics and Special Assistance Programs Directorate
  - Field Services Directorate (Kitimat Office)
  - Habitat Protection Directorate
  - Resource Services Directorate
  - Pacific Biological Station
  - Pacific Environment Institute
- Ocean and Aquatic Sciences

Environmental Management Service
- Atmospheric Environment Service
- Canadian Forestry Service
  - Pacific Forest Research Centre
  - Western Forest Products Laboratory
- Canadian Wildlife Service
- Inland Waters Directorate
- Lands Directorate

2. Canada, Department of Energy, Mines and Resources

Geological Survey of Canada (Coastal and Terrain Sciences)
Surveys and Mapping Branch

3. Statistics Canada

User Advisory Service

Appendix 1.1. (cont'd).

4. Province of British Columbia

    Department of Recreation and Travel Industry
      Fish and Wildlife Branch
      Marine Resources Branch
      Provincial Museum
      Provincial Parks Branch
      Surveys and Mapping Branch

    Department of Environment
      British Columbia Forest Service - Research Division
      Environment and Land Use Committee Secretariat
      Pollution Control Branch
      Water Investigations Branch

    Department of Municipal Affairs

    Department of Economic Development

    Department of Agriculture

    Department of Mines and Petroleum Resources

5. District of Kitimat

    District Planning Department
    Office of Municipal Manager
    Kitimat Centennial Museum

6. Regional District of Kitimat-Stikine

7. Alcan Smelters and Chemicals Ltd., Kitimat, B.C.

8. Eurocan Pulp and Paper Co. Ltd., Kitimat, B.C.

9. Canadian Association of Smelter and Allied Workers, Local 1, Kitimat, B.C.

10. Environmental and Engineering Consultants

    Acres, H.G. and Company Ltd.,
    Associated Engineering Services Ltd.
    AVG Management Science Ltd.
    Beak, T.W. Consultants Ltd.
    Biocon Research Ltd.

Appendix 1.1. (cont'd).

10. Environmental and Engineering Consultants (cont'd)

British Columbia Research Council
Crippen, G.E. and Associates Ltd.
Dolmage, Mason and Stewart Ltd.
Golder, Brawner and Associates Ltd.
Hinton, B.R. and Associates Ltd.
Howe, C.D. Western Ltd.
International Environmental Consultants Ltd.
Klohn, Leonoff Consultants Ltd.
Paish, Howard and Associates Ltd.
Philpot Forestry Services Ltd.
Reed, F.L.C. and Associates Ltd.
Reid, Collins and Associates Ltd.
Ripley, Klohn and Leonoff Ltd.
Simons, H.A. (International) Ltd.
Slaney, F.F. and Co. Ltd.
Swan Wooster Engineering Company Ltd.

11. University of British Columbia

Departments of Biology, Botany, Geography, Geological Sciences, Soil Science and Zoology
Faculty of Forestry
Institute of Animal Resource Ecology
Institute of Oceanography

12. University of Victoria

Departments of Biology and Chemistry

13. Libraries

City of Vancouver and Municipal Public Libraries
Federal and Provincial Government Department Libraries
University Libraries and Reading Rooms

Appendix 1.2. On-going research in the Kitimat River estuary and area.

Bunce, H.: Fluoride emissions and forest growth (a program using 64 forest test plots sampled at 5 year intervals and analyzed using x-ray densitometry to determine annual ring width and density). Reid, Collins and Associates Limited, Consulting Foresters, Vancouver, B.C.

Carnow, B.W.: Health study of Kitimat smelter workers. Prepared for the Canadian Association of Smelter and Allied Workers, Local #1, Kitimat, B.C. Illinois School of Public Health, University of Illinois, U.S.A.

Clague, J.J. (GSC): Sand and gravel resources of Kitimat, Terrace and Prince Rupert, British Columbia (detailed mapping of sand and gravel deposits in the Terrace-Kitimat Valley). Terrain Sciences Division, Geological Survey of Canada, Vancouver, B.C.

District of Kitimat: Study by British Columbia Harbours Board and Swan Wooster Engineering Company Ltd., to determine the terms of reference for a study to formulate a comprehensive plan to make the best use of the potential of the Kitimat Harbour area. Kitimat Planning Department, Kitimat, B.C.

Higgins, R.J. and W.J. Schouwenburg (FMS): Downstream salmon enumeration (a program to capture and mark downstream migrants conducted in the spring of 1975 and 1976, data are presently being analyzed). Habitat Protection Directorate, Fisheries Management, Fisheries and Marine Service, Vancouver, B.C.

Hocking, M.B. and D. Hocking (U.Vic): An investigation of fluoride and gallium levels in foliage and surficial soil samples in the Kitimat area. Chemistry Department, University of Victoria, Victoria, B.C.

Holman, N. and G.A. Packman (EPS): Visual observations of the Kitimat River delta front and bottom photography of Kitimat Arm, from two dives on October 21, 1976 aboard the submersible, Pisces IV. Pollution Abatement Branch, Environmental Protection Service, Vancouver, B.C.

International Environmental Consultants Limited: 1976 environmental survey of the Eurocan pulp mill receiving area (a biological river survey). Prepared for the Eurocan Pulp and Paper Company Limited, Vancouver, B.C.

Appendix 1.2 (cont'd).

Parker, M.L. (FS): An assessment of the effect of air pollution on annual ring width and density of forest trees. Western Forest Products Laboratory, Canadian Forestry Service, Vancouver, B.C.

Pollution Control Branch: Surveillance committee formed to review the Alcan PCB permits. Members include the PCB, B.C. Department of Health, District of Kitimat, Alcan and CASAW.

Regional District of Kitimat - Stikine: Lakelse Lake zoning study (a study of existing and future land use), Terrace, B.C.

Schutz, D.C. (FMS): Upstream-migrant chinook salmon enumeration and tagging (a program to determine the availability of brood stock for the proposed Kitimat River salmon hatchery). Habitat Protection Directorate, Fisheries and Marine Service, Vancouver, B.C.

Slaney, F.F. and Company Limited: Environmental impact assessment of the proposed Kitimat tanker route. Prepared for the Hecate Straits Engineering Company Limited, Vancouver, B.C.

Wallace, W.G. (Alcan): Groundwater sampling program around the Kitimat smeltersite (a program to determine the presence of any contaminated groundwater discharges). Aluminum Company of Canada Limited, Kitimat, B.C.

Appendix 1.3. Metric Conversion Factors

EXISTING UNIT x	CONVERSION FACTOR =	SI UNIT
acre	0.405	hectare
acre foot (1 acre-foot = 1 acre x 1 foot)	1,233.5	cubic metre
cubic foot per second	0.0283	cubic metre per second
cubic yard	0.7646	cubic metre
cunit (100 cubic feet)	2.831	cubic metre (solid timber)
degrees Fahrenheit	5/9 (F-32)	degrees Celsius
fathom (6 feet)	1.8288*	metre
foot	0.3048*	metre
foot per second	30.480*	centimetre per second
gallon (Imp.)	0.004546	cubic metre
gallon (U.S.)	0.003785	cubic metre
grain per standard cubic foot (68°F, 1 ATM)	55.044	milligram per mole
inch	2.54*	centimetre
inch of mercury	3.386	kilopascal (kPa)
knot (nautical miles per hour)	51.444	centimetre per second
mile	1.609	kilometre
nautical mile (Int.)	1.852*	kilometre
parts per million	1.0	milligrams per litre
pound	0.4536	kilograms
pounds per cunit	0.1602	kilograms per cubic metre (solid wood)
pounds per short ton	0.500*	kilograms per tonne
square miles	259	hectares
standard cubic foot per minute (air pollution)	0.0196	moles per second
cubic foot per minute	0.0005	cubic metre per second
ton (2,000 lbs)	0.9718	tonne (1,000 kg)

*exact conversion factor

Appendix 1.3. Metric Conversion Factors (cont'd)

Note: Metric equivalents of measurements for use in hydraulic computations are taken from list on page v in, Environment Canada, Surface Water Data, B.C. 1974, Water Survey of Canada, Ottawa. The common usage of metric units, by the Water Survey of Canada and the United States Water Resources Division is currently under discussion.

References:

British Columbia Department of Environment. 1976. The international system of units (SI), metric practice guide. Water Resources Service, Victoria, B.C. 9 p.

Canadian Standards Association. 1973. Metric practice guide. National Standard of Canada. CAN-3-001-01-73 CSA 7234.1-1973. 43 p.

Gaboury, J.A.M. 1968. Conversion factors and tables. PO Box 24, Station "B", Montreal 110, Que., Canada. 71 p.

Rennie, P.J. 1967. Measure for measure. Canada Department of Forestry and Rural Development, Forestry Branch, Dept. Publ. No. 1195. 31 p.

Appendix 2.1 Geologic Time Scale

ERA	PERIOD	APPROXIMATE NUMBER OF YEARS AGO*
Cenozoic	Quaternary Recent Pleistocene (Ice Age)	 Last 10,000 10,000 to 1,000,000
	Tertiary Pliocene Miocene Oligocene Eocene Paleocene	(Millions) 1 to 13 13 to 25 25 to 36 36 to 58 58 to 63
Mesozoic	Cretaceous Jurassic Triassic	63 to 135 135 to 181 181 to 230
Palaeozoic	Permian Pennsylvanian and Mississippian Devonian Silurian Ordovician Cambrian	230 to 280 280 to 345 345 to 405 405 to 425 425 to 500 500 to 600
Proterozoic	Keweenawan Huronian	600 to 2,000
Archaean	Temiskaming Keewatin	2,000 to 4,800

* *Science, April 14, 1961, p.1111.*

Appendix 2.2 Events associated with the occurrence of marine clays in the Kitimat Valley - Kitimat Arm area (Golder, Brawner and Associates Ltd. 1975).

Emsley Cove

Circa. 1964, a subsoil investigation was carried out at Emsley Cove, on the west side of Kitimat Arm, approximately 15 miles south of the present Kitimat River Delta. Very soft marine clays were encountered beneath the surficial gravels that mantle the flatbottomed Emsley Creek valley. Also, marine clays outcrop on the beach in contact with bedrock at Emsley Cove. The presence of the marine clay and attendant risk of mass sliding and destruction of proposed near-shore structures and installations was a factor in rejection of this site for development of a proposed industrial complex.

Nechako Dock

Circa. 1971. Alcan placed a very small volume of fill on shore as part of the development of the Nechako dock, to accommodate docking of the service boat to Kemano. This fill caused a small slide which dislocated pilings that had been driven for support of the walkway and dock. The failure occurred in the marine clay. It was necessary to remove part of the fill and to flatten the slope in order to stabilize this localized failure.

Alcan Plant Site

The marine clay underlies a thick deposit of deltaic sand and gravel on which Alcan's Kitimat plant site has been developed. Consolidation of the marine clay under the plant site loads has resulted in large settlements at the Alcan plant site.

Town Site

During initial residential development in the upper townsite area a minor amount of debris was disposed of at the edge of a ravine. Placement of this small amount of fill at the edge of the ravine initiated a flow slide in the marine clay. The slide travelled several hundred feet into the ravine. Because of the presence of the marine clay and the demonstrated low factor of safety on the banks of the ravine, residential buildings were kept well back from the edge of the ravine.

Kitimat River Bridge

The Kitimat River Bridge on the highway between Terrace and Kitimat is supported on timber foundation piles. These piles encountered the marine clay at relatively shallow depths below the surficial, alluvial gravels. The remoulding that resulted from penetration of the piles into the clay reduced the clay to such soft consistency that when the pile driving hammer was removed from the head of driven piles, the piles were buoyed vertically upward.

To overcome this problem, the piles were held down by cables for a short period after they had been driven. Thixotrophic hardening of the remoulded clay surrounding the pile shafts took place so that the piles then became capable of sustaining their design loads.

Lakelse Slide

Circa. 1962, a large landslide occurred on the eastern side of Lakelse Lake. This slide cut the Kitimat-Terrace Highway, and destroyed a Provincial Government campsite. The slide was seated in marine clay, and moved on a very flat slope. Trees and slide debris, including the campsite were carried hundreds of feet out into the lake.

Appendix 4.1. Kitimat River Estuary Streamflow Data
(Can. Dept. Env., 1976)

STATION NO.	NAME	GAUGE LOCATION	DRAINAGE AREA	DISCHARGE RECORDS
08 FF 001	Kitimat River below Hirsch Creek	54° 03' 10" 128° 41' 21"	768 sq. mi. (198,912 ha)	1964 - cont.
08 FF 002	Hirsch Creek near the mouth	54° 03' 48" 128° 36' 00"	141 sq. mi. (36,519 ha)	1966 - cont.
08 FF 003	Little Wedeene River below Bowbyes Creek	54° 07' 48" 128° 39' 12"	71.5 sq. mi. (185,185 ha)	1966 - cont.

Appendix 6.1.

List of Freshwater Invertebrates recorded from the lower Kitimat River (T.W. Beak Ltd., 1971, 1972, 1974).

PHYLUM NEMATODA
- unidentified species

PHYLUM ANNELIDA
- Class Oligochaeta
  - *Aulodrilus* sp.
  - *Limnodrilus* sp.
  - Family Echytraeidae
    - *Echytraeus* sp.
  - Family Lumbriculidae
    - unidentified species
  - Family Naididae
    - *Nais* spp.
    - *Paranais litoralis*
    - *Specaria josinae*
    - *Uncinais uncinata*
  - Family Tubificidae
    - unidentfied species

PHYLUM MOLLUSCA
- Class Gastropoda
  - unidentified species
- Class Bivalvia
  - Sphaeridae sp.
  - *Sphaltium* sp.

PHYLUM ARTHROPODA
- Class Arachnida
  - Order Acarina
    - *Hydracarina* sp.
    - *Lebertia* sp.
    - *Megapus* sp.

Appendix 6.1 (cont'd).

Class Insecta
  Order Ephemeroptera
    Family Baetidae
      Ameletus sp.
      Amertropus sp.
      Baetis cincaudatus
      B. tricaudatus
      B. sp.
      Centroptilum sp.
      Ephemerella doddsi
      E. inermis
      E. invaria
      E. micheneri
      E. proserpina
      E. serrata
      E. simplex
      E. walkeri (fuscata)
      E. sp.
      Iron sp.
      Neocloeon sp.
      Pseudocloeon sp.
      Siphlonisca sp.
    Family Heptageniidae
      Rhithrogena sp.
  Order Plecoptera
    Allopla sp.
    Isogenus sp.
    Family Chloroperlidae
      Chloroperla sp.
      Hastaperla brevis
      H. sp.
    Family Nemouridae

Appendix 6.1 (cont'd).

Nemoura zapada columbiana
N. sp.
Family Perlidae
Acroneuria sp.
Family Perlodidae
Arcynopteryx parallela
Isoperla sp.
unidentified species
Order Hemiptera
Family Ochteridae
Order Coleoptera
Family Dytiscidae
Hydrovatus sp.
Family Staphylimidae
unidentified species
Order Trichoptera
Agapetus sp.
Micrasema sp.
Family Hydropsychidae
Arctopsyche sp.
Family Phychomyiidae
unidentified species
Family Rhyacophilidae
Glossoma sp.
Rhyacophila sp.
Order Diptera
Eriocera gultonensis
E. sp.
Family Chironomidae
Sub-Family Chironominae
Colopsectra sp.
Chironomus (Dicrotendipes) nervosus
C. sp.

Appendix 6.1 (cont'd).

- *Cryptochironomus* sp.
- *Endochironomus* sp.
- *Glyptotendipes* sp.
- *Micropsectra* sp.
- *Polypedilum fallax*
- *P. sordens*
- *P.* sp.
- *Pseudochironomus* sp.
- *Tanytarsus confusa*
- *T.* sp.
- unidentified species

Sub-Family Diamesinae

- *Diamesa* sp.
- *Prodiamesa* sp.
- *Syndiamesa nivosa*
- *S.* sp.

Sub-Family Orthocladiinae

- *Brillia par*
- *B.* sp.
- *Cardiocladius* sp.
- *Corynoneura* sp.
- *Cricotopus bicinotus*
- *C. fugax*
- *C.* spp.
- *Diplocladius* sp.
- *Metriocnemus* sp.
- *Nanocladius brevinervis*
- *N.* sp.
- *Orthocladius nivoriundus*
- *Psectrocladius* sp.
- *Smitta* sp.
- *Trichocladius* sp.
- unidentified species

Appendix 6.1 (cont'd).

Sub-Family Tanypodinae
Ablabesmyia sp.
Pentaneura carnea
P. sp.
Procladius sp.
Family Ceratopogonidae
Culicoides unicolor
Family Dolichopodidae
unidentified species
Family Empididae
Chelifera sp.
Hemorodromia sp.
Roederella sp.
unidentified species
Family Rhagionidae
Atherix sp.
Family Simulidae
Prosimulium sp.
Simulium sp.
Family Tipulidae
unidentified species
Class Crustacea
Subclass Branchiopoda
Daphnia pulex
Subclass Malacostraca
Order Amphipoda
Family Talitridae
Pontoporeia affinis
unidentified species
Order Mysidacea
Mysis sp.

Appendix 6.2.

List of Invertebrate Species Recorded from the Kitimat River Estuary as Compiled from the Available Literature.

PHYLUM PROTOZOA

- Foraminifera
- *Globigerina* sp.
- unidentified species

PHYLUM NEMERTEA

- *Cerebratulus* sp.
- *Tetrastemma* sp.

PHYLUM NEMATODA

- unidentified species

PHYLUM ANNELIDA

- Class Polychaeta
  - Subclass Errantia
    - *Cheilonereis* sp.
    - *Eteone spitsbergensis* var *pacifica*
    - *Glycera nana*
    - Glyceridae sp.
    - *Glycinde armigera*
    - *G. picta*
    - *Harmothoe* sp.
    - *Hemispodus borealis*
    - *Lepidonotus caelorus*
    - *L.* sp.
    - *Lumbrinereis latreilli*
    - Lumbrineridae spp.
    - *Nephthys ferruginea*
    - *N. cornuta*
    - Nephthyidae spp.

Appendix 6.2. (cont'd.)

Nereidae spp.
Orbiniidae spp.
Pholoe sp.
Phyllodoce citrana
P. maculata
P. madeirensis
Polynoidae spp.
Sphaerodorum minutum

Subclass Sedentaria

Ammotrypane aulogaster
Ampharetidae sp.
Arenicola pusilla
Aricia sp.
Maldane glebifex
Maldanidae spp.
Notomastus sp.
Opheliidae spp.
Orbiniidae spp.
Oweniidae spp.
Paraonidae spp.
Pectinaria belgica
Peisidice aspera
Scalibregma inflatum
Scoloplos armiger
Sternapsis fossor
Stenaspidae spp.
Terebellidae spp.

PHYLUM MOLLUSCA

Class Gastropoda

Acmaea sp.
Acteocina sp.
Colus sp.

Appendix 6.2. (cont'd.)

Lacuna sp.
Littorina sp.
Odostomia sp.
Viviparidae sp.
Class Bivalvia
Kellia sp.
Leda hamata
Lucinidae sp.
Macoma inconspicua
Mytilus edulis
Nucula sp.
Nuculana sp.
Psephidia lordi

PHYLUM ARTHROPODA
Class Arachnida
Hydracarina sp.
Class Insecta
Order Plecoptera
Baetis sp.
Order Diptera
Clunio sp.
Class Crustacea
Subclass Cirripedia
Balanus sp.
Subclass Branchiopoda
unidentified species
Subclass Copepoda
Gaidius pungens
Subclass Malacostraca
Order Cumacea
Leucon sp.
unidentified species

Appendix 6.2. (cont'd.)

Order Isopoda

Gnorimosphaeroma oregonensis

Idothea sp.

Ligia sp.

Order Tanaidacea

Tanais stanfordi

Order Amphipoda

Anisogammarus confervicolus

Anonyx sp.

Atylus sp. (*Nototropis* sp.)

Corophium spinicorne

C. sp.

Gammarus setosus

Oradarea sp.

Paramoera columbiana

Parapleustes sp.

Planoplea sp.

Polycheria sp.

Synchelidium sp.

Order Decapoda

Cancer magister

Hemigrapsus sp.

PHYLUM SIPUNCULIDA

Golfingia sp.

PHYLUM ECHINODERMATA

Class Echinoidea

Brisaster sp.

Appendix 7.1 Kitimat River System (includes tributaries) Anadromous Fish Escapement Data Summary (Fisheries and Marine Service, Pacific Region, Vancouver, B.C.).

Species	Years of Enumeration	Average Annual Escapement 1965-1975	Date and Size of Max. Escapement*	Date and Size of Min. Escapement*	Period of Spawning (Peak Underlined)
SOCKEYE	1927, 1929-1956 1966, 1969 1971-1975	Transient	(1938) 10,000-20,000	(1970) 0	Sept.
CHINOOK	1927-1947 1949-1951 1953-1975	7,498	(1934) 50,000-100,000	(1975) 1,375	May-July-Aug.-Sept.
COHO	1927-1947 1949-1951 1953-1975	10,634	(1934) 100,000+	(1967) 1,500	July-Sept.-Oct.-Nov.
PINK	1927, 1929-1947 1949-1951 1953-1975	88,416	(1972) 246,500	(1971) 1,800	July-Aug.-Sept.
STEELHEAD	1927-1928 1933-1944 1947, 1949 1951, 1954-1958, 1969-1971	Transient	(1935) 10,000-20,000	(1962-1968) 0	Feb.-April-May
CHUM	1927-1947 1949-1951 1953-1975	28,050	(1972) 68,750	(1965) 1,500	July-Aug.-Sept.

*most recent max. and min. figures stated in cases of a tie.

Appendix 7.2 Kitimat River and Tributaries Salmon Escapements from 1965 to 1975. (Fisheries and Marine Service, Pacific Region, Vancouver, B.C.)

Pink salmon (*Oncorhynchus gorbuscha*)

Year	Chist Creek	Hirsch Creek	Humphreys Creek	Kitimat River	Nalbeela Creek	Big Wedeene	Little Wedeene	Total
1975	-	50	25	2,000	-	100	200	2,375
1974	250	2,500	5,000	80,000	4,000	8,000	6,000	105,750
1973	-	200	100	1,000	50	300	200	1,850
1972	1,500	15,000	7,500	200,000	7,500	-	7,500	246,500
1971	-	200	200	1,000	-	-	200	1,800
1970	400	15,000	7,500	180,000	3,500	-	15,000	236,400
1969	-	200	100	3,500	-	-	750	5,300
1968	-	15,000	3,500	150,000	7,500	-	15,000	206,000
1967	-	-	-	7,500	-	-	100	7,600
1966	-	5,000	5,000	100,000	3,000	-	12,000	137,000
1965	-	-	-	15,000	-	-	3,500	22,000

Chum salmon (*Oncorhynchus keta*)

Year	Chist Creek	Hirsch Creek	Humphreys Creek	Kitimat River	Nalbeela Creek	Big Wedeene	Little Wedeene	Total
1975	50	200	400	1,000	100	150	100	2,000
1974	200	4,000	1,500	40,000	1,000	4,000	3,500	54,200
1973	1,000	3,000	1,500	25,000	700	6,000	5,000	42,200
1972	-	1,500	1,500	60,000	750	3,500	1,500	68,750
1971	-	750	750	25,000	200	750	750	28,200
1970	-	750	750	15,000	400	3,500	1,500	21,900
1969	-	750	400	15,000	100	1,500	750	18,500
1968	-	200	1,500	15,000	400	750	400	18,250
1967	-	200	100	7,500	-	1,500	750	10,050
1966	-	500	300	20,000	200	10,000	12,000	43,000
1965	-	-	-	1,500	-	-	-	1,500

Appendix 7.2 (con't)

Chinook salmon (*Oncorhynchus tshawytscha*)

Year	Chist Creek	Hirsch Creek	Humphreys Creek	Kitimat River	Nalbeela Creek	Big Wedeene	Little Wedeene	Total
1975	200	100	-	1-000	-	50	25	1,375
1974	300	300	-	2,000	-	1,000	600	4,200
1973	750	300	-	3,500	-	3,500	200	8,250
1972	750	200	-	3,500	-	1,500	400	6,350
1971	750	400	-	5,500	-	3,500	750	10,900
1970	400	400	-	3,500	-	1,500	400	6,200
1969	400	250	-	3,500	-	1,500	750	6,400
1968	-	250	-	3,500	-	1,500	750	6,000
1967	-	50	-	3,500	-	1,500	750	5,800
1966	-	-	-	20,000	-	3,500	-	23,500
1965	-	-	-	3,500	-	-	-	3,500

Coho salmon (*Oncorhynchus kisutch*)

Year	Chist Creek	Hirsch Creek	Humphreys Creek	Kitimat River	Nalbeela Creek	Big Wedeene	Little Wedeene	Total
1975	50	200	75	1,500	150	400	100	2,475
1974	1,000	500	800	3,000	300	1,500	1,000	8,100
1973	400	300	-	2,000	100	400	400	3,600
1972	3,500	750	750	3,500	750	1,500	1,500	12,250
1971	1,500	400	750	3,500	750	3,500	750	11,150
1970	1,500	400	400	7,500	200	3,500	3,500	17,000
1969	750	200	400	3,500	400	1,500	750	7,500
1968	-	3,500	100	7,500	100	750	750	12,700
1967	-	100	50	750	50	400	200	1,550
1966	-	500	-	30,000	-	-	-	30,500
1965	-	1,500	200	7,500	200	-	750	10,150

Appendix 7.3

List of Fish Species Recorded from the Kitimat Study Area (includes the Kitimat River System and Kitimat Arm), as Compiled from the Available Literature.

1. *Anoplopoma fimbria* (sablefish or black cod)
2. *Artedius fenestralis*
3. *Clupea harengus pallasi* (Pacific herring)
4. *Cottidae* (sculpins)
5. *Cottus asper* (prickly sculpin)
6. *Cottus aleuticus* (Aleutian sculpin)
7. *Cymatogaster aggregata* (shiner sea perch)
8. *Gadus macrocephalus* (Pacific or grey cod)
9. *Gasterosteus stenolepis* (threespine stickleback)
10. *Hippoglossus stenolepis* (Pacific halibut)
11. *Hypomesus pretiosus* (surf smelt)
12. *Icelinus filamentosus* (threadfin sculpin)
13. *I. tenuis* (spotfin sculpin)
14. *Lampetra* sp. (lamprey)
15. *Leptocottus armatus* (staghorn sculpin)
16. Lyparidae (liparids)
17. *Malacocottus kincaidi* (blackfin sculpin)
18. *Mallotus villosus* (capelin)
19. *Nautichthys oculofasciatus* (sailfin sculpin)
20. *Oncorhynchus gorbuscha* (pink salmon)
21. *O. keta* (chum salmon)
22. *O. kisutch* (coho salmon)
23. *O. nerka* (sockeye salmon)
24. *O. tshawytscha* (chinook salmon)
25. *Ophiodon elongatus* (lingcod)
26. *Platichthys stellatus* (starry flounder)
27. Pleuronectidae (flounders)
28. Rajidae (skates)
29. *Salmo clarki clarki* (coastal cutthroat trout)
30. *S. gairdneri* (rainbow trout)
31. *Salvelinus malma* (Dolly Varden char)

Appendix 7.3 (cont'd.)

32. *Sebastes* sp. (rockfish)
33. *Sebastes elongatus* (green striped rockfish)
34. *Squalus acanthias* (dogfish shark)
35. Stichaeidae (pricklebacks)
36. *Thaleichthys pacificus* (eulachon)
37. *Xiphister* sp. (prickleback)

APPENDIX 7.4.

Annual reported landed values in $000's for Area 6 (compiled from Area Worksheets, Economics Branch, Fisheries Operations, Pacific Region, Vancouver).

Year	Salmon	Herring	Halibut	Sole & Turbot	Red and Rock Cod	Ling Cod	Grey Cod	Black Cod	Tuna	Area Total**
1975	523	600	119	520	1	6	4	10		1,317
1974	2,182	527	28		3	7		4		2,765
1973	1,788		125		1	2		2		1,926
1972	4,655		66		1	3	*	23	6	4,756
1971	619	78	18		1	5		2	1	727
1970	3,265	17	69		2	5		1		3,361
1969	489		99	*	*	1		3		592
1968	2,622	1	25		*	1				2,649
1967	581	53	28		*	1		*		663

* value less than $1000

** all species including shellfish

Appendix 7.5 Steelhead Catch Data for the Kitimat River including the Wedeene Rivers and Hirsch Creek (compiled from Steelhead Harvest Analysis, B.C. Department of Recreation and Conservation, Fish and Wildlife Branch, Victoria, B.C.)

Year	Days Fished Rept.	Days Fished Est.	No. Anglers Rept.	No. Anglers Est.	Catch Rept.	Catch Est.	Released Rept.	Released Est.	Kill/ Day	Catch/ Day
1974-75	2,380	6,172	223	590	529	1367	232	603	0.124	0.221
1973-74	1,413	6,029	158	657	202	864	101	430	0.072	0.143
1972-73	1,250	5,050	156	594	150	604	64	258	0.069	0.120
1971-72	1,373	4,598	157	502	150	491	86	284	0.045	0.107
1970-71	859	4,207	119	552	43	239	25	132	0.003	0.057
1969-70	1,019	6,616	137	831	97	650				0.098
1968-69	1,232	4,834	172	657	172	686				0.142
1967-68	798	3,356	122	495	82	348				0.104
1966-67	203	781	106	407	75	288				0.369

Rept. - reported
Est. - estimated

Appendix 7.6 Salmon sport catch, fishing effort and success for tidal waters in statistical area 6, Kitimat-Butedale (condensed from Salmon Sport Fishing Catch Statistics for B.C. Tidal Waters, annual reports 1967-1975, Can. Dept. Env., Fish, Oper., Vancouver, B.C.)

Period	Springs No.	Jacks No.	Coho No.	Spring Grilse No.	Coho Grilse No.	Pinks & Others No.	Total No.	Effort Boat days	Average catch per boat day No.
1975	1,032	1,305		115	305	110	3,466	5,810	0.6
1974	1,103	480	1,020			101	2,704	2,540	1.1
1973	1,935	170	520	3			2,628	4,010	0.7
1972	1,005	282	418	30		400	2,135	6,400	0.3
1971	897	81	45	2	15		1,040	930	1.1
1970	550	375	25			250	1,200	1,150	1.0
1969	625	125	100				850	1,125	0.8
1968	450	60	300	50		60	920	530	1.7
1967	1,025	225	225	few		50	1,525	1,000	1.5
1966	1,650	250	400	150		50	2,500	950	2.6
1965	175	125	75			100	475	675	0.7

Appendix 8.1.

List of Floral Species Identified from the Lower Kitimat Valley (species identified by G. Mendel, Kitimat Centennial Museum marked *; species identfied by W. Hubbard, Biocon Research Ltd., Victoria, marked ').

Aceracae (maple family)
Acer circinatum (vine maple)'
A. glabrum (maple)*
Alismataceae (water plantain family)
Alisma plantago-aquatica var. *americanum* (water plantain)*
Sagittaria cuneata (arrow-head or wapato)*
Amblystegiaceae (moss family)
Drepanocladus sp. '
Apocynaceae (dogbane family)
Apocynum androsaemifolium (spreading dogbane)*
Araceae (arum family)
Lysichitum americanum (skunk cabbage)*
Araliaceae (ginseng family)
Aralia nudicaulis (sarsparilla)*
Oplopanax horridum (devils club)*
Aristolochiaceae (birthwort family)
Asarum caudatum (wild ginger)*
Aulacomniaceae (moss family)
Aulacomnium sp.'
Betulaceae (birch family)
Alnus rubra (red alder)*'
A. crispa sinuata (sitka alder)*'
Betula papyrifera (paper birch)*'
B. pumila var. *glanduligera* (swamp birch)'
Boraginaceae (borage family)
Myosotis laxa (forget-me-not)*
Brachytheciaceae (moss family)
Euryhynchium austriaca'
E. oreganum'

Euryhynchium stokesii'

Campanulaceae (campanula family)

Campanula rotundifolia (harebell)*

Caprifoliaceae (honeysuckle family)

Linnaea borealis var. *americana* (twinflower)*'

Lonicera involucrata (black twinberry)*'

Sambuccus racemosa (red elderberry)*'

Symphoricarpos albus (snowberry)*'

Viburnum edule (squashberry)*'

Caryophyllaceae (pink family)

Arenaria sp. (sandwort)*

Cerastium vulgatum (large mouse-ear chickweed)*

Honkenya peploides (sea purslane)*

Sagina sp. (pearlwort)*

Spergularia arvensis (corn spurry)*

S. marina (salt marsh sand spurry)*'

Stellaria crispa (crisped starwort)*

Chenopodiaceae (goosefoot family)

Atriplex patula var. *zosteraefolia* (common orache)*

Chenopodium album (lamb's quarters)*

Salicornia virginica (glasswort)'

Suaeda maritima (sea blite)'

Compositae (composite family)

Achillea millefolium (yarrow)*'

Anaphalis margaritaceae (pearly everlasting)*'

Antennaria rosea (rosy pussytoes)'

Arctium minus (common burdock)'

*Aster junciformis**

*A. modestus**

A. subspicatus (Douglas' aster)'

Chrysanthemum leucanthemum (oxeye daisy)*

Cirsium spp. (thistle)

Cotula coronopifolia (mud disc)*

*Gnaphalium sylvaticum**

G. uliginosum (low cudweed)*

G. sp. (cudweed)'

Hieracium albiflorum (white flowered hawkweed)*'
H. praelatum var. *decipiens**
Hypochaeris radicata (hairy cat's ears)*'
Matricaria matricarioides (pineapple-weed)*
*Prenanthes alata**
*Senecio sylvaticus**
*S. triangularis**
*S. vulgaris**
Tanacetum vulgare (tansy)*
Taraxacum officinale (dandelion)

Coniferae (conifer family)
Abies amabilis (Pacific silver fir)*'
A. lasiocarpa (subalpine fir)'
Chamaecyparis nootkatensis (yellow cedar)*'
Picea sitchensis (Sitka spruce)*
Pinus contorta (shore pine)*'
Pseudotsuga menziesii (Douglas-fir)*'
Thuja plicata (western red cedar)
Tsuga heterophylla (western hemlock)*'

Cornaceae (dogwood family)
Cornus canadensis (bunchberry)*'
C. stolonifera (red osier dogwood)*'

Cruciferae (mustard family)
*Arabis lyrata**
*Barbarea orthoceras**'
Cakile edentula (sea rocket)'
Capsella bursa-pastoris (shepherd's purse)*
Cardamine pensylvanica (bitter cress)*
Cochlearia anglica (scurvey grass)*
*Dentaria tenella**
Rorippa islandica (borbas)*
R. nasturtium-aquaticum (water-cress)*

Cyperaceae (sedge family)
*Carex canescens**
C. eurycarpa'
C. flava (yellow-fruited sedge)*

*Carex lenticularis**
C. lyngbyei (Lyngbye's sedge)'
*C. microglochin**
C. obnutata (slough sedge)*'
*C. paupercula**
C. rostrata (beaked sedge)*
*C. stipata**
Eleocharis sp. (spike rush)*'
Eriophorum chamissonis (russet cotton-grass)'
*Eriophorum sp.**
Rhynchospora alba (white beaked-rush)'
Scirpus cyperinus'
S. microcarpus (small fruited bulrush)'
S. validus'

Cuscutaceae (dodder family)
Cuscuta maritima (dodder)'

Dicranaceae (moss family)
Dicranum fuscescens'

Droseraceae (sundew family)
*Drosera anglica**
D. rotundifolia (round-leaved sundew)*'

Empetraceae
Empetrum nigrum (crowberry)*

Entrodontaceae (moss family)
Pleurozium sp.'

Equisetaceae (horsetail and scouring rush family)
Equisetum arvense (horsetail)*'
*E. fluviatile**
*E. pratense**
*E. sylvaticum**
*E. variegatum**

Ericaceae (heather family)
Andromeda polifolia (rosemary)*
Arctostaphylos uva-ursi (kinnikinnick)*
Chimaphila mensiesii (little prince's pine)*
C. umbellata (western prince's pine)*'

Gaultheria shallon (salal)*'
*Hemitomes congestum**
*Hypopitys monotropa**
Kalmia polifolia (swamp laural)*'
Ledum groenlandicum (Labrador tea)*'
*Menziesia ferruginea**
*Moneses uniflora**
Monotropa uniflora (Indian pipe)'
Oxycoccos quadripetalus (bog cranberry)*
Pyrola asarifolia (large wintergreen)*
P. secunda (one-sided wintergreen)*
P. sp.'
Vaccinium alaskaense (blueberry)*'
V. caespitosum (dwarf blueberry)*
*V. membranaceum**
V. ovalifolium (oval-leaved huckleberry)*'
V. oxycoccus (bog cranberry)*'
V. parvifolium (red huckleberry)*'
V. uliginosum (bog blueberry)'

Fumariaceae (bleeding heart family)
*Corydalis sempervirens**

Gramineae (grass family)
Agrostis sp. (bent grass)'
Alopecurus aequalis (short-awn foxtail)*
Calamagrostis sp. (reedgrass)'
Deschampsia caespitosa (tufted hairgrass)'
Elymus mollis (American dunegrass)*'
Festuca rubra (red fescue)'
*Hierochloe odorata**
Hordeum jubatum (foxtail barley)*
Phragmites sp. (common reed)'
Puccinellia sp.'

Grimmiaceae (moss family)
Rhacomitrium sp.'

Grossulariaceae (gooseberry family)
Ribes bracteosum (stink currant)*

*Ribes laxiflorum**
R. sp. (wild currant)'
Hydrophyllaceae (waterleaf family)
Romanzoffia sitchensis (sitka romanzoffia)
Hylochomiacea (moss family)
Hylocomium splendens'
Hypericaceae (St. John's wort family)
Hypericum perforatum (common St. John's wort)
Hyponiaceae (moss family)
Hypnum circinale'
Juncaceae (rush family)
Juncus balticus (Baltic rush)'
*J. covillei**
J. effusus (common rush)*
J. ensifolius (dagger-leaved rush)*
J. falcatus (sickle-leaved rush)*
J. tenuis (slender rush)*
Luzula sp. (woodrush)*
Juncaginaceae (arrowgrass family)
*Scheuchzeria palustris**
Triglochin maritimum (seaside arrowgrass)*'
*T. palustris**
Labiatae (mint family)
Lycopus uniflorus (bugle-weed)*
Mentha arvense (Canada mint)*'
Prunella vulgaris (heal-all)*
Stachys ciliata var. *pubens**
Leguminosae (pea family)
Lathyrus japonicus (beach pea)*'
L. palustris (marsh pea)*
Lupinus littoralis (seashore lupine)*
Lupinus sp.'
Melilotus officinalis (yellow sweet clover)*
Trifolium dubium (least hop clover)*
T. hybridum (Alsike clover)*
T. pratense (red clover)*

Trifolium repens (white clover)*
T. sp.'
Vicia americana (American vetch)*
V. gigantea (giant vetch)*

Liliaceae (lily family)

Clintonia uniflora (Queen's cup)*
Disporum oreganum (fairy bells)'
Fritillaria camschatcensis (rice root)
Maianthemum dilatatum (wild lily-of-the-valley)*
Smilacina racemosa (false spikenard)*
S. stellata (star-flowered Solomon's seal)*'
Streptopus amplexifolius (twisted stalk)*
*S. roseus**
*Tofieldia glutinosa**
Veratrum viride var. *escholtzii* (green false hellebore)*

Lobeliaceae

*Lobelis kalmii**

Lycopodiaceae (club-moss family)

Lycopodium annotinum (stiff club-moss)*
*L. clavatum**'
*L. selago**

Mniaceae (moss family)

Mnium glabrescens'
M. insigne'

Menyanthaceae (buck bean family)

Menyanthes trifoliata (buckbean)*'

Myricaceae (sweet gale family)

Myrica gale (sweet gale)*'

Nymphaeceae (water lily family)

Nuphar polysepalum (yellow water lily)*'

Ophiglossaceae (adder's-tongue family)

Botrychium multifidum (leathery grape-fern)*

Onagraceae (evening primrose family)

Circaea alpina (enchanters nightshade)*
Epilobium angustifolium (fireweed)*'
E. latifolium (willow herb)*

Epilobium watsonii (common western willow-herb)*

Orchidaceae (orchid family)

Calypso bulbosa (calypso)*

Corallorhiza maculata (spotted coral root)*'

C. trifida (northern coral root)*

Goodyera oblongifolia (green-leaved rattlesnake orchid)*'

Habenaria dilatata (tall white bog orchid)*'

H. orbiculata (large round-leaved orchid)*

H. saccata (slender bog-orchid)*

Listera caurina (twayblade)*

*L. convallarioides**

L. cordata (heart-leaved twayblade)*

Malaxis monophyllos var. *brachipoda**

*M. paludosa**

*Spiranthes romanzoffiana**

Plagiotheciaceae (moss family)

Plagiothecium undulatum'

Plantaginaceae (plantain family)

Plantago lanceolata (English plantain)'

P. major (common plantain)*

P. maritima (seaside plantain)*

Polygonaceae (knotweed family)

Polygonum aviculare (common knotweed)*

P. convolvulus (black bindweed)*

P. lapathifolium (dock-leaved persicaria)*

P. persicaria (spotted knotweed)*

Rumex acetosella (red sorrell)*'

R. crispus (curly-leaved dock)'

R. salicifolius (coastal willow-leaved dock)*

Polypodiaceae (polypody fern family)

Adiantum pedatum (northern maidenhair)*'

Asplenium trichomanes (spleenwort)*

Athyrium filix-femina (lady fern)*'

Blechnum spicant (deer-fern)*'

Cryptogramma crispa (parsley fern)*

Dryopteris austriaca (spiny wood-fern)*'

Gymnocarpium dryopteris (oak fern)*'
*Matteucia struthiopteris**
*Polystichum braunii ssp. andersonii**
P. munitum (western sword-fern)*
*P. vulgare**
Pteridium aquilinum (bracken fern)*'
*Thelypteris phegopteris**

Polyprichaceae (moss family)
Atrichum sp.'
Polytrichum juniperinum'

Primulaceae (primrose family)
Dodecatheon pauciflorum (few-flowered shooting star)*
Glaux maritima (sea milkwort)

Portulacaceae (purslane family)
Montia parviflora (stream-bank spring beauty)*
M. sibirica (western spring beauty)*
M. sp.'

Potamogetonaceae (pondweed family)
*Potamogeton berchtoldii**
*P. filiformis**
*P. nodosus**
P. sp.'

Ranunculaceae (buttercup family)
Actea rubra (baneberry)*'
Aquilegia formosa (western columbine)*
*Coptis asplenifolia**
*C. trifoliata**
Ranunculus acris (tall buttercup)*
R. cymbalaria (seaside buttercup)*
R. flammula (smaller creeping buttercup)*
R. macounii (Macoun's buttercup)*
R. occidentalis (western buttercup)*
R. repens (creeping buttercup)'
Trautvetteria caroliniensis var. *occidentalis* (false bugbane)*

Rhytidiaceae (moss family)
Rhytidiadelphus loreus'

Rhytidiadelphus triquetrus'
Rhytidiopsis robusta
Rosaceae (rose family)
Amelanchier alnifolia (june or service berry)*
Aruncus sylvester (goats-beard)*'
Geum macrophyllum (large-leaved ravens)*
Potentilla pacifica (Pacific silver cinquefoil)*'
P. palustris (marsh cinquefoil)*'
*P. villosa**
Prunus emarginata (bitter cherry)*'
Pyrus fusca (Pacific crabapple)*'
Rosa nutkana (Nootka rose)'
*R. sp.**
Rubus arcticus
R. chamaemorus (cloudberry)*'
R. idaeus (raspberry)*
R. leucodermis (blackcap raspberry)*
R. parviflorus (thimbleberry)*'
*R. pedatus**
R. spectabilis (salmonberry)*'
R. ursinus (Pacific blackberry)'
Sorbus sitchensis (mountain ash)*'
Spirea douglasii (western spirea)*'
S. pyramidata (hardhack)*'
Rubiaceae (madder family)
Galium cymosum (bedstraw)*
G. sp.'
Salicaceae (willow family)
Populus tremuloides (trembling aspen)*'
P. trichocarpa (black cottonwood)*'
Salix hookeriana (Hooker willow)'
S. lasiandra (red willow)*
S. sitchensis (Sitka willow)*
Santalaceae (sandalwood family)
*Comandra livida**

Saxifragaceae (saxifraga family)
Mitella nuda (mitrewort)'
*Parnassia fimbriata**
*Saxifraga ferruginea**
*S. punctata**
Tellima grandiflora (large fringecup)*
Tiarella trifoliata (three-leaved coolwort)*'
T. unifoliata (western coolwort)*
*Tolmiea menziesii**
Scrophulariaceae (figwort family)
Castilleja sp. (paintbrush)*
Collinsia parviflora (small-flowered collinsia)*
*Euphrasis arctica**
*Melampyrum lineare**
Mimulus guttatus (common monkey flower)*'
M. lewisii (red monkey flower)*
*Pedicularis capitata**
Penstemon davidsonii var. *manziesii**
Veronica americana (American speedwell)*
Sparganiaceae (bur-reed family)
Sparganium sp. (bur-reed)'
Sphagnaceae (moss family)
Sphagnum sp.'
Typhaceae (cat-tail family)
Typha latifolia (broad-leaved cat-tail)
Umbelliferae (parsley family)
Angelica genuflexa (kneeling angelica)*
A. lucida (angelica)'
Circuta douglasii (western water hemlock)*'
*Coelopleurum longipes**
*Conioselinum chinense**
C. pacificum'
Heracleum lanatum (cow parsnip)*'
Ligusticum grayi
Oenanthe sarmentosa (water parsely)*
Osmorhiza chilensis (western sweet cicely)*

Urticaceae (nettle family)

*Urtica lyallii**

U. sp.'

Violaceae

Viola glabella (yellow woodland violet)*'

V. langsdorfii (bog violet)*

Viscaceae

Arceuthobium tsugense (hemlock dwarf mistletoe)

Zosteraceae (eelgrass family)

Zostera marina (eelgrass)

Appendix 9.1.

Species Lists of Birds, Mammals, Amphibians and Reptiles from the Kitimat River Estuary and Area.

(i) BIRDS[1]

1. *Gavia immer* (common loon)'*
2. *G. arctica* (Arctic loon)*
3. *G. stellata* (red-throated loon)*
4. *Podiceps grisegena* (red-necked grebe)'*
5. *P. auritus* (horned grebe)'*
6. *Aechmophorus occidentalis* (western grebe)'*
7. *Podilymbus podiceps* (pied-billed grebe)'*
8. *Phalacrocorax auritus* (double-crested cormorant)*
9. *P. pelagicus* (pelagic cormorant)'*
10. *Ardea herodias* (great blue heron)'*
11. *Olor columbianus* (whistling swan)*
12. *O. buccinator* (trumpeter swan)'*
13. *Branta canadensis* (Canada goose)'*
14. *B. bernicla nigricans* (black brant)*
15. *Anser albifrons* (white-fronted goose)*
16. *Chen caerulescens* (snow goose)*
17. *Anas platyrhynchos* (mallard)'*
18. *A. acuta* (pintail)*
19. *A. strepera* (gadwall)*
20. *A. crecca* (green-winged teal)'*
21. *A. discors* (blue-winged teal)'*
22. *Anas americana* (American wigeon)*
23. *A. clypeata* (northern shoveler)*
24. *A. collaris* (ring-necked duck)'
25. *A. valisineria* (canvasback)'*

[1]order and nomenclature based on Godfrey (1966) and American Ornithologists Union (1973).
'reported by Brooks (unpublished data)
*reported by Hay (1976)

Appendix 9.1 (cont'd).

26. *A. marila* (greater scaup)'*
27. *A. affinis* (lesser scaup)'*
28. *Bucephala clangula* (common goldeneye)'*
29. *B. islandica* (Barrow's goldeneye)'*
30. *B. albeola* (bufflehead)'*
31. *Clangula hyemalis* (oldsquaw)*
32. *Histrionicus histrionicus* (harlequin duck)'*
33. *Melanitta deglandi* (white-winged scoter)*
34. *M. perspicillata* (surf scoter)'*
35. *M. nigra* (black scoter)*
36. *Lophodytes cucullatus* (hooded merganser)'*
37. *Mergus merganser* (common merganser)'*
38. *M. serrator* (red-breasted merganser)*
39. *Accipiter gentilis* (goshawk)*
40. *A striatus* (sharp-shinned hawk)*
41. *Buteo jamaicensis* (red-tailed hawk)'*
42. *Haliaeetus leucocephalus* (bald eagle)'*
43. *Circus cyaneus* (marsh hawk)'*
44. *Pandion haliaetus* (osprey)*
45. *Falco rusticolus* (gyrfalcon)*
46. *F. peregrinus* (peregrine falcon)*
47. *F. columbarius* (merlin)*
48. *F. sparverius* (sparrow hawk or American kestrel)'*
49. *Dendragapus obscurus* (blue grouse)*
50. *Bonasa umbellus* (ruffed grouse)'*
51. *Fulica americana* (American coot)*
52. *Charadrius semipalmatus* (semipalmated plover)'*
53. *C. vociferus* (killdeer)'*
54. *Pluvialis dominica* (American golden plover)*
55. *P. squatarola* (black-bellied plover)*
56. *Capella gallinago* (common snipe)'*
57. *Numenius phaeopus* (whimbrel)*
58. *Actitis macularia* (spotted sandpiper)'*
59. *Tringa solitaria* (solitary sandpiper)'*

Appendix 9.1 (cont'd).

60. *Tringa melanoleuca* (greater yellowlegs)*
61. *T. flavipes* (lesser yellowlegs)*
62. *Calidris melanotos* (pectoral sandpiper)*
63. *C. bairdii* (Baird's sandpiper)*
64. *C. minutilla* (least sandpiper)*
65. *C. alpina* (dunlin)*
66. *C. pusillus* (semipalmated sandpiper)*
67. *C. mauri* (western sandpiper)*
68. *C. alba* (sanderling)*
69. *Limnodromus griseus* (short-billed dowitcher)*
70. *L. scolopanceus* (long-billed dowitcher)*
71. *Lobipes lobatus* (northern phalarope)'*
72. *Stercorarius parasiticus* (parasitic jaeger)*
73. *Larus glaucescens* (glaucous-winged gull)*
74. *L. argentatus* (herring gull)'*
75. *L. thayeri* (Thayer's gull)*
76. *L. delawarensis* (ring-billed gull)*
77. *L. canus* (mew gull)*
78. *L. philadelphia* (Bonaparte's gull)'*
79. *Uria aalge* (common murre)*
80. *Cepphus columba* (pigeon guillemot)*
81. *Brachyramphus marmoratus* (marbled murrelet)*
82. *Columba fasciata* (band-tailed pigeon)'*
83. *C. livia* (rock dove)'*
84. *Zenaida macroura* (mourning dove)*
85. *Glaucidium gnoma* (pygmy owl)*
86. *Chordeiles minor* (common nighthawk)*
87. *Cypseloides niger* (black swift)'*
88. *Chaetura vauxi* (Vaux's swift)'*
89. *Selasphorus rufus* (rufous hummingbird)'*
90. *Megaceryle alcyon* (belted kingfisher)'*
91. *Colaptes auratus* (common flicker)'*
92. *Dryocopus pileatus* (pileated woodpecker)*
93. *Sphyrapicus varius* (yellow-bellied sapsucker)'*

Appendix 9.1 (cont'd).

94. *Dendrocopos villisus* (hairy woodpecker)*
95. *D. pubescens* (downy woodpecker)'*
96. *Picoides tridactylus* (northern three-toed woodpecker)*
97. *Empidonax Traillii* (Traill's flycatcher)'*
98. *E. minimus* (least flycatcher)'
99. *E. oberholseri* (dusky flycatcher)*
100. *Contopus sordidulus* (western wood peewee)'*
101. *Nuttallornis borealis* (olive-sided flycatcher)'*
102. *Eremophila alpestris* (horned lark)*
103. *Tachycineta thalassina* (violet-green swallow)'*
104. *Iridoprocne bicolor* (tree swallow)'*
105. *Riparia riparia* (bank swallow)'*
106. *Stelgidopteryx ruficollis* (rough-winged swallow)'*
107. *Hirundo rustica* (barn swallow)'*
108. *Petrochelidon pyrrhonota* (cliff swallow)'*
109. *Perisoreus canadensis* (gray jay)*
110. *Cyanocitta stelleri* (Steller's Jay)'*
111. *Corvus corax* (common raven)'*
112. *C. caurinus* (northwestern crow)'*
113. *Parus atricapillus* (black capped chickadee)'*
114. *P. gambeli* (mountain chickadee)*
115. *P. rufescens* (chestnut-backed chickadee)'*
116. *Sitta canadensis* (red-breasted nuthatch)'
117. *Certhia familiaris* (brown creeper)'*
118. *Cinclus mexicanus* (American dipper)'*
119. *Troglodytes troglodytes* (winter wren)'*
120. *Turdus migratorius* (American robin)'*
121. *Ixoreus naevius* (varied thrush)'*
122. *Catharus guttata* (hermit thrush)'*
123. *C. ustulata* (Swainson's thrush)'*
124. *Sialia currucoides* (mountain bluebird)'
125. *Myadestes townsendi* (Townsend's solitaire)'
126. *Regulus satrapa* (golden-crowned kinglet)'*
127. *R. calendula* (ruby-crowned kinglet)'*

Appendix 9.1 (cont'd).

128. *Anthus spinoletta* (water pipit)*
129. *Bombycilla garrulus* (bohemian waxwing)*
130. *B. cedrorum* (cedar waxwing)'*
131. *Lanius excubitor* (northern shrike)*
132. *Sturnus vulgaris* (common starling)'*
133. *Vireo solitarius* (solitary vireo)*
134. *V. olivaceus* (red-eyed vireo)*
135. *V. gilvus* (warbling vireo)*
136. *Vermivora peregrina* (Tennessee warbler)*
137. *V. celata* (orange-crowned warbler)*
138. *Dendroica petechia* (yellow warbler)'*
139. *D. magnolia* (magnolia warbler)*
140. *D. tigrima* (Cape May warbler)'
141. *D. coronata* (yellow-rumped warbler)'*
142. *D. nigrescens* (black-throated gray warbler)*
143. *D. townsendi* (Townsends warbler)'*
144. *D. striata* (blackpoll warbler)*
145. *Seiurus aurocapillus* (ovenbird)*
146. *S. noveboracensis* (northern waterthrush)'*
147. *Oporornis tolmiei* (MacGillivrays warbler)'*
148. *Geothlypis trichas* (common yellowthroat)'*
149. *Wilsonia pusilla* (Wilson's warbler)'*
150. *Setophaga ruticilla* (American redstort)'*
151. *Passer domesticus* (house sparrow)*
152. *Xanthocephalus xanthocephalus* (yellow-headed blackbird)'
153. *Agelaius pheoniceus* (red-winged blackbird)'*
154. *Euphagus carolinus* (rusty blackbird)'
155. *E. cyanocephalus* (Brewer's blackbird)*
156. *Molothrus ater* (brown-headed cowbird)'*
157. *Piranga ludoviciana* (western tanager)'*
158. *Pheucticus melanocephalus* (black-headed grosbeak)*
159. *Hesperiphona vespertina* (evening grosbeak)'*
160. *Pinicola enucleator* (pine grosbeak)*
161. *Leucosticte tephrocotis* (gray-crowned rosy finch)*

Appendix 9.1 (cont'd).

162. *Acanthis flammea* (common redpoll)'
163. *Spinus pinus* (pine siskin)'*
164. *S. Tristis* (American goldfinch)*
165. *Loxia curvirostra* (red crossbill)'*
166. *Passerculus sandwichensis* (Savannah sparrow)'*
167. *Junco hyemalis* (dark-eyed junco)'*
168. *Spizella arborea* (tree sparrow)*
169. *S. passerina* (chipping sparrow)'*
170. *Zonotrichia leucophrys* (white-crowned sparrow)'*
171. *Z. atricapilla* (golden-crowned sparrow)'*
172. *Passerella iliaca* (fox sparrow)'*
173. *Melospiza lincolnii* (Lincoln's sparrow)'*
174. *M. melodia* (song sparrow)'*
175. *Calcarius lapponicus* (lapland longspur)*
176. *Plectrophenax nivalis* (snow bunting)*

(ii) MAMMALS[2]

Order Insectivora (shrews)
Family Soricidae
Sorex vagrams (vagrant shrew)
Order Chiroptera (bats)
Family Vespertilionidae
Myotis lucifugus (little brown bat)
Order Rodentia
Family Sciuridae (squirrels, chipmunks, marmots)
Tamiasciurrus hudsonicus (American red squirrel)
Family Castoridae (beavers)
Castor canadensis (American beaver)
Family Muridae (rats, mice and voles)
Ondatra zibethicus (muskrat)
Peromyscus maniculatus (deer mouse or white-footed mouse)

[2]reported by Hay (1976), order and nomenclature after Banfield (1974).

Appendix 9.1 (cont'd).

Family Erethizontidae (new world porcupines)
Erithizon dorsatum (American porcupine)
Order Cetacea (whales and dolphins)
Family Delphinidae (dolphins and porpoises)
Orcinus orca (killer whale)
Phocoena phocoena (harbour porpoise)
Phocoenoides dalli (Dall's porpoise)
Order Carnivora (carnivores)
Family Canidae (dogs)
Canis lupus (wolf)
Vulpes vulpes (red fox)
Family Ursidae (bears)
Ursus americanus (American black bear)
Ursus arctos (grizzly bear)
Family Procyonidae (racoons)
Procyon lotor (racoon)
Family Mustelidae (weasels and allies)
Martes americana (American marten)
Mustela erminea (ermine or stoat)
M. vison (American mink)
Mephitis mephitis (striped skunk)
Lontra canadensis (river otter)
Family Felidae
Felis concolor (mountain lion)
Lynx lynx (lynx)
Order Pinnipedia (seals, sea-lions and walrus)
Family Otaridae (eared seals)
Eumetopias jubata (northern sea-lion)
Family Phocidae (true seals)
Phoca vitulina richardi (harbour seal)
Order Artiodactyla (cloven-hoofed mammals)
Family Cervidae (deer)
Odocoileus hemionus sitkensis (Sitka deer)
Alces alces (moose)

Appendix 9.1 (cont'd).

(iii) AMPHIBIANS AND REPTILES[3]

Ambystoma gracile gracile (northwestern salamander)
A. gracile gracile (northwestern salamander, neoteny form)
A. macrodactylum (long-toed salamander)
Bufo boreas boreas (northwestern toad)
Rana aurora aurora (red-legged frog)
Taricha granulosa granulosa (Pacific coast newt)

[3]G. Mendel (pers. comm.), Kitimat Centennial Museum

Appendix 10.1. Maps, charts and aerial photographs of the Kitimat Region.

TOPOGRAPHIC MAPS:

	Sheet No.	Scale
Kitimat, British Columbia	103 1/2 east half	1:50,000
Kitimat Arm, British Columbia	103 H/15	1:50,000
Lakelse, British Columbia	103 1/7 east half	1:50,000
Mount Davies, British Columbia	103 1/1	1:50,000
Chist Creek, British Columbia	103 1/8	1:50,000

GEOLOGICAL AND SOILS MAPS

Terrace map-area	(GSC Map: 1136-A)	Scale:	1 in = 4 mi.
British Columbia Physiographic Subdivisions (Dept. of Mines and Petroleum Resources Bulletin No. 48)		Scale:	1 in = 30 mi.
Soils of the Bulkley-Terrace Area (B.C. Soil Survey Report No. 4 1954)		Scale:	1 in = 1 mi.

MISCELLANEOUS MAPS:

	Map Nos.	Scale
British Columbia Lands Service Departmental Reference Maps (Foreshore leases, timber leases, survey lots and sections.)	R103 H /NE R103 1 /SE	1 in = 1 mi.

Canada Land Inventory
Land Capability Maps

	Sheet No.	Scale
Agriculture	103 I/2,4	1:50,000
Recreation, Waterfowl	103 I/2,4	1:50,000
Present land use	103 I/SE,SW	1 in = 2 mi.
Ungulates	103 I/SE	1 in = 2 mi.

District of Kitimat
Planning Department

Proposed Land Reserves	Dwg No. 7401-1	1 in = ½ mi.

Appendix 10.1 (cont'd).

		Scale
Recreational Survey Kitimat Valley and Channel	Plan No. 6112-1 (May, 1961)	1 in = 4 mi.

British Columbia Forestry Service

District of Kitimat Forest Cover Map (compiled from aerial photographs and 1949 inventory maps).

Eurocan Pulp and Paper Co. Ltd.
(Kitimat Logging Division)

Progress map, Kitimat Area. Updated to December 16, 1975.
Scale: 1 inch = 40 chains

HYDROGRAPHIC CHARTS:

	Chart No.	Scale
Kitimat and Kemano Bay	3736	1:12,165
Douglas Channel	3743	1:73,032

AERIAL PHOTOGRAPHS:

B.C. Government	Flight Line	Photo No.	Scale
Kitimat Arm to Lakelse Lake and surrounding areas.	BC 5303 (August 2, 1968)	58-71; 99-111	1 in = ½ mi.
	BC 5608 (August 14, 1974)	25-34; 50-62 65-76; 91-99	1 in = ¼ mi.
	BC 5612 (August 18, 1974)	82,147	1 in = ¼ mi.
Kitimat River headwaters.	BC 7327 (July 17, 1971)	116-244	1 in = ¼ mi.
Kitimat River Special Report (June 19, 1975)	BC 5664 (Project No. OP-302/75)	1-215	approx. 1:10,000

Alcan Smelters and Chemicals Ltd.

Aerial mosaic of the Kitimat Valley and estuary.	Flown 12 August 1974 McElhanney Surveying and Engineering Ltd., Photo No. 06112-0.	approx. 1 in = 1320 ft.

Appendix 10.1. (cont'd).

Kitimat District Municipality

Planning Department - aerial mosaics

			Scale
Kitimat District	- land use	(April 1975)	1 in = 2,500 ft
	- land ownership	(April 1975)	1 in = 2,500 ft
	- recreation areas	(January 1976)	1 in = 2,500 ft
	- recreation status	(February 1976)	1 in = 2,500 ft
	- roadways	(February 1976)	1 in = 2,500 ft
	- service centre area	(June 1976)	1 in = 400 ft
	- D/G neighbourhood concept	(June 1976)	1 in = 2,500 ft
	- industial corridor	(June 1976)	1 in = 2,500 ft
Minette Bay area	- existing land use and ownership	(July 1975)	1 in = 800 ft
	- environmental conditions	(July 1975)	1 in = 800 ft
	- parks open space and recreation	(July 1975)	1 in = 800 ft
	- proposals for action	(July 1975)	1 in = 800 ft

Further information on the availability of aerial photographs and aerial mosaics may be obtained from;-

Map and Air Photo Sales, B.C. Lands Service, 553 Superior St., Victoria, B.C.

National Air Photo Library, Department of Energy, Mines and Resources, Ottawa, Ontario.

Kitimat District Municipality Planning Department, Kitimat, B.C.

Aluminum Smelters and Chemicals Ltd. Property Department, Box 1800, Kitimat, B.C.

Appendix 10.2. Environmental legislation - a partial list of acts relating to water and air pollution. (Reference: Ince, J.G. 1976. Environmental Law - A study of legislation affecting the environment of British Columbia)

WATER POLLUTION - FEDERAL STATUTES

The Canada Shipping Act R.S.C. 1970c. 3-9 as amended.

The Act's environmental provisions are of two kinds. The first deals with prohibiting pollutant discharges and the second concerns civil consequences which arise because of the discharge.

The Ocean Dumping Control Act S.C. 1974-75c. 55.

The Act defines "dumping" as the deliberate disposal of substances from ships, aircraft or platforms (S.2.). It therefore does not apply to accidental discharges. The Act does not apply to any lakes, rivers and other fresh water areas in Canada.

Canada Water Act R.S.C. 1970c. 5 (1st Supp.) as amended.

The Act has two major parts. The first part is aimed at controlling pollution of specified water bodies. The second part of the Act deals with nutrients.

Fisheries Act R.S.C. 1970c. F-14 as amended.

The Fisheries Act applies to all waters in Canada frequented by fish (it thus includes all lakes, streams, and rivers and Canada's coastal waters).

Navigable Waters Protection Act R.S.C. 1970c. N-19.

This Act does not directly concern itself with water pollution, but does contain sections relevant to most water pollution problems, especially if they affect navigation.

Migratory Birds Convention Act R.S.C. 1970c. M-12 as amended.

Regulations passed pursuant to this Act afford protection of waters frequented by migratory birds.

WATER POLLUTION - PROVINCIAL STATUTES

The Pollution Control Act, 1967 S.B.C. 1967c.34 as amended.

Section 5(1) of the Act prohibits the direct or indirect discharge of sewage or other waste material into any water without a permit or approval from the Director of the Pollution Control Branch.

Water Act R.S.B.C. 1960c.405 as amended.

The B.C. Water Act is the main provincial statute regarding the use and development of water resources in rivers and streams in the province. The Act is mainly concerned with the consumption of water by industry and public water suppliers.

Health Act R.S.B.C. 1960c.170 as amended.

The Health Act gives the Cabinet wide powers to pass Regulations concerning public health, and by section 6(h) of the Act can deal with stream pollution.

Fisheries Act R.S.B.C. 1960c. 150 as amended.

While the federal government has constitutional authority to regulate fishing, the provinces have limited powers with regard to fisheries due to their proprietary ownership of the fishery, which stems from their ownership of the beds of the fishery. The most environmentally relevant sections in this Act concern obstructions in streams and rivers.

AIR POLLUTION - FEDERAL STATUTES

Clean Air Act S.C. 1970-71-72c. 47.

The Act gives the Cabinet power to establish maximum legal limits of air emissions.

AIR POLLUTION - PROVINCIAL STATUTES

Pollution Control Act, 1967 S.B.C. 1967c. 34 as amended.

Section 5A(1) of the Act provides that after January 1, 1971, no person either directly or indirectly shall cause or permit the discharge into the air of any contaminant without a permit or approval from the Director of the Pollution Control Branch.

Municipal Act R.S.B.C. 1960c. 225 as amended.

This statute gives municipal councils power to pass by-laws to:
"Require the owners of real property to eliminate or reduce the fouling or contamination of the atmosphere through the emission of smoke, dust, gas or sparks, or other effluvia; and for prescribing measures and cautions to be taken for such purposes, and for fixing limits not to be exceeded in respect of such emissions." (s.870(i)).

Appendix 11.1 Water Pollution Sources near Kitimat, B.C.
(from PCB permit listings, Victoria, B.C.)

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	VOLUME m^3/day (IGD)	EFFLUENT PARAMETERS	COMMENTS
PE 00256 Jan.8/1969	District of Kitimat	Kitimat River 4 km upstream of the mouth	13,650 (3,000,000)	SS-100mg/l BOD_5-35mg/l Coliform-$10x10^6$MPN pH-7.0-9.0 Temp.-1.7-18.3^oC	Comminuted domestic sewage (no toxic chemicals) retained in aerated lagoon before discharge into Kitimat River.
PE 01900 July 31/1973	Parker Investments Limited	Lakelse Lake	45.5 (10,000)	TSS-60mg/l BOD_5- 45mg/l Cl^- - 0.5-1.0mg/l	Domestic sewage treated via activated sludge, extended aeration with 1 hr chlorine contact
PE 02287 Aug.9/1973	Scott,L.G. and Sons Construction Ltd.	Service Centre Kitimat	182 (40,000)		Asphalt plant wash waters treated via settling pond prior to groundwater discharge.
PE 0229901 Dec.6/1973	Canadian Liquid Air Ltd. - Air Liquide Canada Ltée.	Service Centre Kitimat	7.96 (1,750)		Treatment via exfiltration, groundwater discharge.

Appendix 11.1 (cont'd.)

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	VOLUME m^3/day (IGD)	EFFLUENT PARAMETERS	COMMENTS
PE 0149401 Sept.16/1974	Aluminum Company of Canada Ltd.	Kitimat Estuary via ditch onto western portion of delta	35,015 (7,300,000)	TSS-50mg/l pH-6.0-8.5 Temp.-max 38°C Oil & grease - 15mg/l F - 15mg/l Al - 10mg/l Fe - 1.0mg/l	Wastes collected via canal system, treated in settling pond and discharged via open ditch. Acute bioassays conducted quarterly along with an extensive monitoring program.
02		Kitimat Estuary southwest corner of mill foreshore	1,365 (300,000)	TSS-50mg/l pH-6.0-8.5 Temp.-max 38°C Oil & grease - 15mg/l F - 15mg/l Al - 10mg/l Fe - 10mg/l	Cooling waters and runoff from coke calciner area of mill. Acute bioassays conducted quarterly.
03		Moore Creek	17,845 (3,900,000)	TSS-50mg/l pH-6.0-8.5 Oil & grease - 15mg/l F - 5.0mg/l Al - 1.0mg/l Fe - 1.0mg/l Temp - such that temp.rise of Moore Creek <3°C.	Cooling waters and surface runoff. Treatment via cooling pond, pipe discharge

Appendix 11.1 (cont'd.)

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	VOLUME m^3/day (IGD)	EFFLUENT PARAMETERS	COMMENTS
PE 0250301 Oct.23/1974	Ocean Construction Supplies Northern Limited	Between service centre and Eurocan millsite, Kitimat	2,184 (480,000)	TSS-150mg/1	Treatment via settling pond, discharge via pipe
PE 0029201 Dec.5/1975	Eurocan Pulp and Paper Co. Limited	Kitimat River 3.2 km upstream of the mouth	56,775 (15,000,000)	pH-6.5-8.0 Temp-<35°C TSS-6,865kg/day SS-0.5ml/1 BOD_5-6,865kg/day Mercaptans - <0.5mg/1 Sulfides - <0.5mg/1 Resin acids - <5.0mg/1 D.O. - >2.0 mg/1 Toxicity (TLm96) - 50% survival @ 100% effluent concentration over a 96-hour exposure period	In-plant chemical and fibre recovery facilities, a mechanical clarifier, a toxic spill basin, two settling ponds, an aeration lagoon, related appurtenances and a submerged outfall. Effluent generally meets level A objectives.

Appendix 11.2 Air Pollution Sources in the Kitimat Area
(from PCB permit listings, Victoria, B.C.)

PCB I.D.#	DISCHARGER & TYPE OF OPERATION	LOCATION OF EMISSION	TOTAL FLOW RATE moles/sec (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
PA 02288 01 Aug.21/1973	L.G.Scott & Sons Construction Ltd. Asphalt Plant		490 (25,000) max. daily ave.	Total Particulates: 0.022 g/m³ (0.10 gr/scf) max. daily ave.	Treatment via mechanical cyclones and wet collectors discharge via stack, 8 hrs daily
PA 02552 01 02 Oct.10/1975	Aluminum Company of Canada Ltd. Aluminum Smelter	Roof ventilators Potlines 1A, 1B, 1C and 2A, 2B, 2C	141,120 (7,200,000) (for each sub-permit)	24 hrs/day	Control and report on fluoride emissions as specified
-03 -04 -05		Roof ventilators Potlines 3A, 3B; 4A, 4B; and 5A, 5B	137,200 (7,000,000) (for each sub-permit)	24 hrs/day	Control and report on fluoride emissions as specified.
-06		Roof ventilator Potline 7B	70,560 (3,600,000)	24 hrs/day	Control and report on fluoride emissions as specified
-07		Roof ventilator Potline 8A, 8B	141,120 (7,200,000)	24 hrs/day	Control and report on fluoride emissions as specified

Appendix 11.2 (cont'd.)

PCB I.D.#	DISCHARGER & TYPE OF OPERATION	LOCATION OF EMISSION	TOTAL FLOW RATE moles/sec (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
-08 -09 -10		Potroom scrubber 1 2 3	862 (44,000) (for each subpermit)	Total Particulates: 0.55 mg/mol (0.010gr/scf) control and report on fluoride emissions as specified	Treatment via mechanical venturi scrubber, fabric filters and after-burner, discharge via stack, 24 hrs/day.
-11 -12 -13		Potroom scrubber 4 5 6	882 (45,000) (for each subpermit)	Total Particulates: 0.55 mg/mol (0.010gr/scf) control and report on fluoride emissions as specified	Treatment via mechanical venturi scrubber, fabric filters and after-burner, discharge via stack, 24 hrs/day.
-14		Potroom scrubber 8	686 (35,000) (for each subpermit)	Total Particulates: 0.55 mg/mol (0.010gr/scf) control and report on fluoride emissions as specified	Treatment via mechanical venturi scrubber, fabric filters and after-burners, discharge via stack 24/hrs/day.

Appendix 11.2 (cont'd.)

PCB I.D.#	DISCHARGER & TYPE OF OPERATION	LOCATION OF EMISSION	TOTAL FLOW RATE moles/sec (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
-15		Potroom scrubber 9	1,372 (70,000)	Total Particulates: 0.55 mg/mol (0.010gr/scf) control and report on fluoride emissions as specified	Treatment via mechanical venturi scrubbers, fabric filters and after-burner, discharge via stack 24 hrs/day.
-16		Coke calciner rotary kiln	1,058 (54,000)	Total Particulates: 5.5 mg/mol (0.10 gr/scf) SO_2-800 mg/l	Treatment via pyro scrubber. Discharge via stack 24 hrs/day
-17		Coke calciner cooler	196 (10,000)	Total Particulates: 0.150 mg/l(2hrs/day) 0.125 mg/l (24 hrs/day)	Treatment via multicyclones discharge via stack (24 hrs/day)
-18		Casting furnaces	2,156 (110,000)	Total Particulates: 2.75 mg/mol (.050 gr/scf) Cl-10.0mg/l max. 3.0mg/l max.da.av. HCl-30.0mg/l max. 10.0mg/l max. da.av.	Discharge via stack 6 hrs/day

Appendix 11.2 (cont'd.)

PCB I.D.#	DISCHARGER & TYPE OF OPERATION	LOCATION OF EMISSION	TOTAL FLOW RATE moles/sec (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
-19		Casting furnaces	784 (40,000)		Discharge via stack 3 hrs/day
-20		Rectifier repair shop	123 (6,300)		2 hrs/day 3 days/week
-21		Marinite shop	69 (3,500)	Total Particulates: 0.55 mg/mol (0.010 gr/scf)	Treatment via fabric filter 8 hrs/day
-22		Pot repair and lining shop	5,645 (288,000)		Discharge via stack 8 hrs/day
-23		Vacuum ship unloader	470 (24,000)		Treatment via fabric filter 24 hrs/day
-24		Welding, forging and paint shops	125 (6,400)		Discharge via stack 12 hrs/day
-25		Welding, painting and carpentry shops	862 (44,000)		Treatment via mechanical cyclones, discharge via stack

Appendix 11.2 (cont'd.)

PCB I.D.#	DISCHARGER & TYPE OF OPERATION	LOCATION OF EMISSION	TOTAL FLOW RATE moles/sec (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
-26		Laboratories and acid tip tank	423 (21,600) 4 hrs/day 349 (17,800) max.da.av.		Discharge via stack
-27		Soderberg paste plant and stud casting	1,274 (65,000) 16 hrs/day 1,137 (58,000) max.da.av.	Total Particulates: 27.5 mg/mol (0.50 gr/scf)	Treatment via fabric filters, discharge via stack 24 hrs/day
-28		Potlining and potroom service operations	1,078 (55,000)	Total Particulates: 0.55 mg/mol (0.010 gr/scf)	Treatment via fabric filter, discharge via stack 4 hrs/day
-29		Raw material conveying and storage system	490 (25,000)		Treatment via fabric filter, discharge via stack 16 hrs/day
-30		Steam plant	23,520 (1,200,000)		Discharge via stack 24 hrs/day

Appendix 11.2 (cont'd.)

PCB I.D.#	DISCHARGER & TYPE OF OPERATION	LOCATION OF EMISSION	TOTAL FLOW RATE moles/sec (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
-31		Hydrator and potlining incinerator	5.88 (300)		Treatment via afterburners, discharge via stack
AA0439201	Aluminum Company of Canada Ltd. Aluminum smelter	Lot 93			Discharge via stack, applied for September 13, 1973
PA0308301 Aug. 18, 1976	Eurocan Pulp & Paper Co. Ltd. Kraft pulpmill and sawmill.	Recovery boiler stack.	6,630 (337,902) 24 hrs/day	Total Particulates: 5 kg/ADUt (10 lb/ ADUT) SO_2-max. 250 ppm H_2S-max. 20 ppm	Treatment via electrostatic precipitator.
-02		Power boiler stack.	2,352 (119,902) 24 hrs/day	Total Particulates: max. 8.3 mg/mol (0.150 gr/SCF at 12% CO_2)	Treatment via multicyclone collectors.
-03		"Other" sources as specified.	22,100 (1,126,860) 24 hrs/day	Total Particulates: 1.0 kg/ADUt (2.0 lb/ADUT) Sulfur- 0.35 kg/ADUt (0.7 lb/ADUT)	As Specified.
-04		Seventeen paper machine vents.	10,700 (545,615) 24 hrs/day		

Appendix 11.2 (cont'd.)

PCB I.D.#	DISCHARGER & TYPE OF OPERATION	LOCATION OF EMISSION	TOTAL FLOW RATE moles/sec (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
-05		Four lumber dry kilns.	1,280 (65,000) 24 hrs/day		
-06		Chip screening sawdust blowline.	5.8 (15,000) 24 hrs/day		
-07		Eight batch digester cyclones and one sawdust digester cyclone.	863 (44,000) 24 hrs/day	Total particulates: 5.5 mg/mol. (0.100 gr/SCF) per cyclone	
-08		Woodmill cyclone.	294 (15,000) 15 hrs/day	Total particulates: 5.5 mg/mol (0.100 gr/SCF)	
-09		Eight chip and sawdust blowlines.	1,785 (91,000)		

Appendix 11.3 Landfill Operation in the Kitimat Area
(from PCB permit listings, Victoria, B.C.)

PCB I.D.#	DISCHARGER	LOCATION OF LANDFILL	VOLUME m^3/day (cu.yd./day)	WASTE CHARACTERISTICS	COMMENTS
PR0165001 Nov.26/1974	Eurocan Pulp & Paper Co. Ltd.	rear of mill-site	87.2 (114)	settling pond solids, green liquor dregs, slaker dregs, power boiler ash & wood mill wastes	Sanitary landfill disposal. Monitoring of Beaver Creek specified.
PR03608 Nov.21/1975	District of Kitimat	near Hirsch Creek	191 (250)	misc. metal and typical municipal refuse	Landfill compacted and covered as specified.
PR03772 Nov.21/1975	Bay Forest Products Ltd.	near Weewanie Creek	.77 (1)	domestic and commercial refuse	Landfill compacted and covered as specified.
PR0252701	Aluminum Company of Canada Ltd.	estuary foreshore east of millsite	(5.3)	inert industrial wastes	Cyanide and fluoride assayed annually.
-02		(near yacht basin)	(1.2)	inert industrial wastes	
-03			(14.7)	inert industrial wastes	Landfill compacted and covered as specified.

15. GLOSSARY

GLOSSARY OF SELECTED TERMS

advection: refers to the horizontal or vertical flow of sea water as a current.

algae: a group of mainly aquatic plants, variously one celled, colonial, or filamentous, containing chlorophyll and/or other pigments (especially reds and browns), and having no vascular system.

alluvial: pertaining to alluvium, a general term for all detrital deposits resulting from the operations of modern rivers, thus including the sediments laid down in river beds, flood plains, lakes, fans at the foot of mountain slopes, and estuaries.

alumina: an aluminum oxide (Al_2O_3) refined from bauxite ore (natural hydrated aluminum oxide) used for electrolytic production of aluminum.

amphipod: one of an order of crustacea, mostly marine, characterized by having the first and, perhaps, the second thoracic segment fused with the head; the abdomen is not well differentiated from the thorax, and the legs are modified for various functions; the body is laterally compressed.

anadromous: a form of fish life cycle in which maturity is attained in salt water, and the adults enter fresh water to spawn.

anemometer: an instrument by which the velocity and often also the direction of the wind is measured.

angler-day: a day on which a fisherman participates in a sport fishery for any reasonable length of time.

anoxic: anaerobic, without oxygen.

aquatic: growing or living in, or frequenting, water; occurring, or situated in, or on, water. Analogous to "terrestrial" for the case of land.

aquifer: a layer of rock which holds water and allows water to percolate through it.

artesian well: a type of well which normally gives a continuous flow, the water being forced upwards by hydrostatic pressure.

atmospheric pressure: the pressure exerted by the atmosphere as a consequence of gravitational attraction exerted upon the column of air lying directly above the point in question. The metric unit of atmospheric pressure adopted by Canada is the kilopascal (1 kPa equals 3 3.386 in. of mercury).

avian: of, relating to, or derived from birds.

bacteria: microscopic organisms living, either singly or in colonies, in soil, water or the bodies of plants and animals (including man).

batholith: a large body of intrusive rock.

bathymetry: the science of measurement of the depths of oceans, seas, or lakes.

bauxite: the principal ore of aluminum.

benthic algae: a group of mainly aquatic plants, variously one-celled, colonial, or filamentous, containing chlorophyll and/or other pigments (especially reds and browns), and having no vascular system, which live in or on the bottom sediments of a water body.

benthos: organisms living in or on the bottom sediment of a body of water; can be broken into three size groups - macro (greater than 1.0 mm), meio (1.0 mm to 0.5 mm), and micro (less than 0.5 mm).

bioassay: a determination of the concentration, or dose, of a given material necessary to affect a test organism under stated conditions; or, the use of living organisms as an index to determine environmental conditions.

biochemical oxygen demand (B.O.D.): a measure of the amount of oxygen used by micro-organisms to consume biodegradable organics in waste water. The 5 day BOD test is widely used to measure the organic strength of waste water in terms of dissolved oxygen that would be consumed if the waste water were discharged into a natural body of water.

biochronology: geologic time scale based on fossils.

biogeoclimate zone: a regional ecosystem characterized by a zonal or mesic (moist) vegetation and soil which are a product of the macroclimate in which they occur.

biomass: the total weight of living organisms per unit volume of water or per unit area.

biota: the living organisms of an ecosystem as distinct from the abiotic or non-living component of an ecosystem.

bivalve: one of a class of molluscs, soft unsegmented animals most of which are protected by a shell containing calcium in some form. They are either permanently attached to a material (e.g., sediment or wood) or burrow into it. The class includes clams, mussels and oysters.

brackish: describe water having a salinity less than about $17^o/_{oo}$ and more than $0.5^o/_{oo}$ (parts per thousand).

chernozem: very black soil rich in humus and carbonates that forms under cool to temperate, semi-arid conditions.

chironomid: any of a family of tiny flies that are two-winged and lack piercing mouthparts.

cirque: a deep, steep-walled recess in a mountain, caused by glacial erosion.

cladocera: an order of Crustacea commonly known as "water-fleas".

climax community: a final, self-pertetuating community of plants and animals that develops in a particular climate and soil; it will persist as long as the same conditions prevail.

cloud cover: the percentage or fraction of sky covered by cloud, e.g., 2/10 scattered cloud, 10/10 overcast.

coliform: designating of, or like the aerobic bacillus normally found in the colon; a coliform count, is designated by the most probable number (MPN) of bacteria derived statistically from a series of cultures of different dilution. It is often used as an indicator of fecal contamination of water supplies.

comminute: to reduce to small, fine particles.

community: a naturally occurring group of different organisms inhabiting a common environment, interacting with each other, and relatively independent of other groups; or, an assemblage of closely tied niches.

conifer: any of an order (Coniferales) of cone-bearing trees and shrubs, mostly evergreens, as the pine, spruce, fir, cedar, yew, etc.

copepod: any of a large class of usually small marine and freshwater crustaceans. Most species range between about 0.5 to 10 millimetres in length. They often form an important source of food for fish in temperate and subpolar waters.

cordillera: a group of mountain ranges including valleys, plains, rivers and lakes. Specifically the mountains of western North America between the Central Lowland and the Pacific Ocean.

crustacean: any of a large class of mostly aquatic creatures having an outer skelton ("exoskelton") composed of calcium carbonate chitin, or of a form of carbohydrate; it includes shrimps, crabs, wood lice, water fleas, and barnacles.

dabbling ducks: ducks that obtain their food by submerging only the head, while the body remains floating on the water surface.

decapod: crustaceans having ten legs such as lobsters, crabs and shrimps or any cephalopod having ten arms, as a squid.

delta: an alluvial deposit at the mouth of a river emptying into a lake or sea.

detritus: dead organic matter, both plant and animal in origin. Fragments of matter that have been removed - by disintegration, weathering or other processes - from the surface of rocks; a deposit of any of all forms of detritus (adjective: detrital).

diatom: One of a class of microscopic phytoplankton organisms, characterized by thin shells of silica. Diatoms are one of the most abundant groups of organisms in the sea, and are a primary food source for marine animals.

diffusion: the spreading, scattering or transfer of matter under the influence of a change in its concentration with distance; the movement is from the stronger to the weaker concentration.

dipteran: any of a large order (Diptera) of insects, including the housefly, mosquito, gnat, etc.,having one pair of functional membranous wings and usually a vestigial second pair.

diurnal: daily; recurring once a day, having a period or cycle of approximately one tidal day.

diving ducks: ducks which obtain their food by diving below the water surface.

drainage area: the region that drains all the rainwater and snow that falls on it apart from that removed by evaporation, into a river or a stream, which then carries the water to a sea or a lake; its boundary is defined by the ridge beyond which water flows in the opposite direction - away from the basin.

driftpole observations: observations of water currents made by following the movements of a weighted pole suspended vertically in the water.

drogue: a current-measuring assembly consisting of a weighted cross-piece, parachute, or similar device and an attached surface buoy. The drogue can be placed at any desired depth and current speed and direction determined by tracking and timing of the surface buoy.

ebb tide: outgoing or falling tide.

ecology: the branch of science dealing with the interrelationships of organisms and their environments; the totality or pattern of relations between organisms and their environments.

ecosystem: the complex of a community (biotic) and its environment (abiotic), functioning as an ecological unit in nature.

eddy: circular movement of water usually formed where currents pass obstructions, between two adjacent counter-flowing currents, or along the edge of a permanent current.

eelgrass: a submerged marine plant that has long narrow leaves, produces seeds and generally grows on a sand or mud substrate, in the lower intertidal and upper subtidal zones.

effluent: waste material (such as sewage or liquid industrial refuse) discharged into the environment, especially when considered as a pollutant.

electrolyte: a compound which, in solution or molten state, conducts an electric current and is simultaneously decomposed by it. Current is conducted by ions and eletrolytes which may be acids, bases or salts.

emission: in pollution work, usually refers to gaseous or vaporized wastes, as opposed to liquid wastes which are called effluents.

entrainment: the transfer of fluid from one water mass to another; occurs if the masses are in motion relative to one another, and results from mixing due to frictional effects at the interface between the masses.

environment: the totality of climatic, soil and biotic factors that act upon an organism or an ecological community and ultimately determine its form and survival.

escapement: the number of fish that escape, or are permitted to pass unharmed; often used in the sense of being left free to proceed to spawning grounds.

estuary: a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage.

eulachon: marine food fish of the north Pacific coast, related to the smelt (Osmeridae), rendered by coast Indians for its oil which remains solid at ordinary temperatures.

eustatic: pertaining to simultaneous, world-wide changes in sea-level.

fauna: animal life of a specific region or time (microfauna - organisms that pass through a 100 micron mesh; meiofauna - organisms that pass through a 500 micron mesh but are retained by a 100 micron mesh; macrofauna - organisms retained by a 500 micron mesh).

fetch: in wave forecasting, the continuous area of water over which the wind blows in essentially a constant direction.

fingerling: a small finger sized fish or a young fish up to the end of the first year.

fjord (fiord): a long narrow inlet into the seacoast with more or less steep sides.

floc: a very fine fluffy mass formed by the aggregation of fine suspended particles, as in a precipitate.

flood plain: the area of land, adjacent to a river channel, subjected to flooding, when floodwater levels reach a predetermined height.

flood tide: rising or incoming tide.

flora: plant life of a specific region or time.

fluoride: a compound of fluorine and one or more elements or radicals (fluorine is the most reactive nonmetallic element known and forms fluorides with almost all the known elements).

fluvial: of or pertaining to, rivers; produced by river action, as a fluvial plain.

food chain: a series of organisms in a community in which each uses the next lower member in the sequence as a food source and is in turn consumed by animals on the next level above.

food web: the totality of, and interrelationships between, all the food chains characterizing a community.

foraminifera: a group of protozoa, mostly marine, which form shells, usually of lime.

freshet: a sudden increase or rise in river flow or level because of melting snow and/or heavy rain.

front: the line of separation at the earth's surface between cold and warm air masses.

fry: the young fish of a year.

game birds: wild birds hunted for sport or food; usually refers to members of the grouse family, and to ducks and geese.

gauging station: a location where systematic records of stage (water level) or stage and discharge are obtained.

glacio: a combining form frequently used with other words to denote formation by or relationship to glaciers.

grilse: immature sea-going chinook or coho salmon.

groundwater: water found underground in porous rock strata and soils, as in a spring.

habitat: the place where an organism, or a population, lives.

harmonic constants: the amplitude and epoch of a constant recurring motion such as tides; used in prediction of local tide height and timing relative to reference datum.

headwaters: the streams and creeks that are the sources of a river or other water body.

hinterland: the land or district behind that bordering on a coast or river.

humidity: a measure of the water vapour present in the air; may be given in terms of relative humidity, or the absolute humidity.

hydrograph: a graph showing changes in water flow over a period of time.

hydrography: the study, description, and mapping of oceans, lakes, and rivers, especially with reference to their navigational and commercial uses.

intertidal zone: the area of shore bounded by the levels of high and low tide.

invertebrate: an animal not having a backbone.

isopod: any of an order of crustaceans, mostly aquatic, with a flat, oval body and seven pairs of walking legs of similar size and form, each pair attached to a segment of the thorax.

isostatic: subject to equal pressure from every side, being in hydrostatic equilibrium.

jacks: male chinook salmon returing to spawn in their second or third year.

juvenile: not having attained maturity in all respects.

Kitamaat: Haisla Indian word meaning "people of the ever snowing valley".

larva: the early, free-living, immature form of any animal that changes structurally when it becomes an adult, usually by a complex metamorphosis.

leach: to subject to the action of percolating liquid (such as water) in order to separate the soluble components; to dissolve out by the action of a percolating liquid.

lithosols: one of a group of a zonal soils; thin surface soils over bedrock commonly found on steep slopes.

macrophyte: a large plant; used to describe algal species large enough to be readily apparent to the naked eye.

maritime climate: a regional climate that is under the predominant influence of the sea, and that is characterized by small diurnal and annual ranges of temperature.

marsh: a tract of soft, wet land, characterized by growth of plants such as sedges and grasses; a saltmarsh is subject to overflow by salt water, as by tidal action.

mercaptan: a substance containing the monovalent radical SH.

migratory: to pass, usually periodically, from one region or climate to another for purposes of feeding, breeding, etc.

mixed tide: type of tide in which a mixture of semi-diurnal and diurnal waves produces large inequalities in heights and/or durations of successive high and/or low waters.

modified maritime climate: a maritime climate that has attained a degree of continentality owing, for example, to occasional intrusions of cold arctic air.

morphology: the observation of the form of lands; or the study of the form and structure of organisms.

mysid: any of an order (Mysidacea) of small shrimp-like crustaceans with a carapace over most of the thorax, which has two branched appendages.

necrosis: the death or decay of tissue in a particular part of the body and/or plant.

nutrient: a substance necessary to maintain life and promote growth.

oceanography: the science that deals with the oceans, and includes the delimitation of their extent and depth, the physics, chemistry and biology of their waters and the exploitation of their resources; can be divided into branches according to basic interest, e.g., chemical oceanography (chemistry).

oligochaete: any of a class of segmented worms, such as earthworms, which lack a definite head and have relatively few body setae (bristles); found mainly in soil and fresh water.

paleontology: the science that deals with the life of the past geological ages. It is based on the study of the fossil remains of organisms.

pan: a natural basin or depression, especially one containing standing water or mud.

permeability: the ease with which gases and liquids penetrate or pass through a rock or soil.

pH: a symbol for the degree of acidity or alkalinity of a solution; originally expressed as the logarithm of the reciprocal of the hydrogen ion concentration in gram equivalents per litre of solution but may have other operational definitions.

phytoplankton: plant life, mostly microscopic, found floating or drifting in the oceans or large bodies of fresh water; forms the base of most aquatic food chains as the main primary producers.

plankton: plant and animal life, mostly microscopic, drifting or floating freely in the water column of oceans and bodies of fresh water.

podzols: highly bleached soils low in iron and lime, formed under moist and cool climatic conditions.

polychaete: any of a class of mostly marine, segmented worms; usually having a pair of fleshy leg-like appendages covered with setae, on most segments, and usually having a well developed, distinct head.

primary productivity: the rate at which energy from light is absorbed and utilized with carbon dioxide in the production of organic matter in photosynthesis.

raptorial bird: a bird of prey, usually having a strong hooked beak and sharp talons (e.g., eagles, hawks, owls, vultures).

regosols: one of a group of azonal soils; largely confined to areas of steeply sloping glacial drift.

roe: fish eggs, especially when still massed in the ovarian membrane.

run-off: the portion of rainfall which ultimately reaches the streams; it consists of the water which flows off the surface, instead of sinking into the ground, together with some of the water which originally sank into the ground and joins it later in the streams.

salinity: a measure of the quantity of dissolved salts in seawater. It is formally defined as the total amount of dissolved solids in seawater - in parts per thousand ($^{o}/_{oo}$) by weight - when all the carbonate has been converted to oxide, the bromide and iodide replaced by chloride, and all organic matter is completely oxidized.

salmonid: any fish of the family Salmonidae (e.g., salmon or trout).

salt marsh: grassland over which salt water flows at intervals.

sedge: any of a family of grasslike plants often found on wet ground or in water, usually having triangular solid stems, three rows of narrow, pointed leaves, and minute flowers borne on spikelets.

sedimentary rock: rock formed by the accumulation of sediment in water or from air usually having a characteristic layered structure known as bedding or stratification.

shorebird: any of a number of birds that feed (usually by wading)or nest on the shores of oceans, rivers, etc; examples are sandpipers, snipes, etc.).

silt: fine-grained (0.063 mm to 0.004 mm), unconsolidated sediment with particles intermediate in size between very fine sand and clay, carried or laid down as sediment by moving water.

slough: a swamp, bog or marsh, especially one that is part of an inlet or backwater.

smolt: life stage of a salmonid older than a fry, that is leaving fresh water and entering salt water.

spawn (verb): to produce or deposit eggs - usually used in reference to aquatic animals such as fish, or crustaceans. (noun): eggs of the above.

specific gravity: ratio of the weight or mass of a given substance to that of an equal volume of another substance (water for liquids and solids, air or hydrogen for gases) used as a standard.

stage: in hydrology, a water level.

stage gauge: the water level measured from any chosen reference line.

Stevenson screen: the standard shelter for thermometers on meteorological and climatological stations, to enable the true temperature of the air to be taken by protecting the thermometers from solar and terrestial radiation.

stoma: a microscopic opening in the epidermis of plants, surrounded by guard cells and serving for gaseous exchange (plur.: stomata).

stratification: the state of a fluid that consists of two or more horizontal layers arranged according to their density, the lightest layer being on top, and the heaviest on the bottom.

subtidal: below the lowest low tide.

sulfide: a compound of sulfur with another element or radical.

supernatant: designating or of a liquid standing over a precipitate

surficial geology: characteristic of, pertaining to, formed on, situated at, or occurring on the earth's surface; especially, consisting of unconsolidated residual, alluvial, or glacial deposits lying on the bedrock.

suspended solids: substances, the particles of which are dispersed through a fluid but not dissolved in it, and which will separate out on standing.

temperature inversion: an increase of temperature with height above the earth's surface, being the reverse of the normal situation in which the temperature falls with height.

thermocline: a vertical temperature gradient in some layer of a body of water, that is appreciably greater than the gradients above and below it.

tidal flat: a gently sloping marshy, muddy, sandy or sometimes pebbly area which is covered and uncovered by the rise and fall of the tide.

tidal flushing: replacement of some or all of the water mass of a semi-enclosed water body, such as an estuary bay or inlet, by outside water caused by the action of the tides.

topography: the surface features of an area including its relief, usually represented by means of contours and physical features such as forests, rivers and lakes.

toxic: of, relating to, or caused by a toxin or poison - which through chemical action, kills, injures, or impairs an organism.

trawl: to fish by dragging a large bag-like net along the bottom of a fishing bank.

troll: to fish with a moving line, especially one with a revolving lure, trailed behind a moving boat.

turbidity: the measure of the content of suspended and/or dissolved material in a body of water that inhibits light penetration, indicates the corresponding decrease in clarity.

vapour pressure: the pressure exerted in the atmosphere by a substance through its vapourization, and usually measured in millimetres of mercury; in meteorology this term is used almost exclusively to denote the partial pressure of the molecules of water vapour in the atmosphere.

vernal: relating to, or appearing, or occurring in, the spring.

visibility: the distance of visual perception, usually through the atmosphere, measured in kilometres; in meteorology, defined as the horizontal distance at which a prominent dark object can be seen and identified against the sky at horizon (daytime) or at which a known light source of moderate intensity can be seen and identified (nighttime).

volcanic rocks: the class of igneous rocks that have been poured out or ejected at or near the earth's surface.

waterfowl: birds that live on, or near, water, especially swimming game birds like geese and ducks.

watershed: the elevated boundary line separating the headstreams which are tributary to different river systems or basins.

water quality: the totality of physical, biological, chemical and aesthetic characteristics of water; the applicability - based on these characteristcs - of water for various uses.

wind rose: a diagram illustrating the proportion of winds which blow from each of the main points of the compass at a certain place, taken over a considerable period.

X-ray densitometry: a technique developed to measure annual ring width and annual ring specific gravity of trees.

zooplankton: animal life, usually microscopic, found floating or drifting in the water column of oceans or bodies of fresh water; form the bulk of the primary consumer link in aquatic food chains.

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