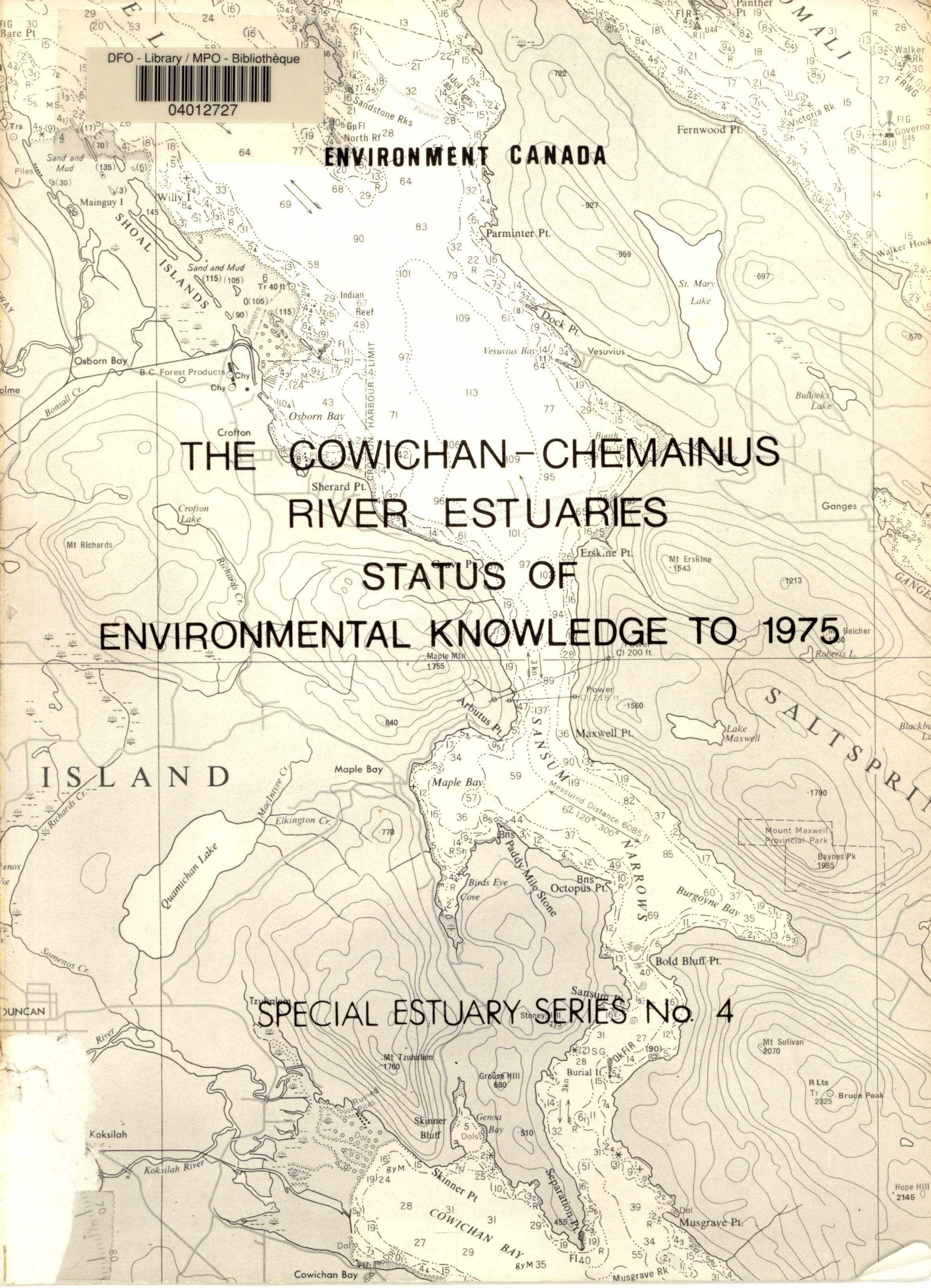
ENVIRONMENT CANADA

THE COWICHAN-CHEMAINUS RIVER ESTUARIES
STATUS OF ENVIRONMENTAL KNOWLEDGE TO 1975

SPECIAL ESTUARY SERIES No. 4



ENVIRONMENT CANADA

THE COWICHAN-CHEMAINUS RIVER ESTUARIES STATUS OF ENVIRONMENTAL KNOWLEDGE TO 1975

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

By
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SPECIAL ESTUARY SERIES No. 4

JANUARY 31, 1976

Aerial photograph of the Cowichan River delta (July 1972), showing Westcan Terminals log handling facilities on the right, and the construction site for the Doman sawmill (centre).

Aerial photograph of the Chemainus River delta (September 1974), showing the Crofton Kraft pulp mill on the right, Chemainus Harbour (centre), and the entrance to Ladysmith Harbour on the left.

Aerial photograph of the Cowichan River estuary (September 1974), showing Satellite Channel (centre) and the entrance to Saanich Inlet on the right.

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ABBREVIATIONS AND SYMBOLS

asl	above sea level
A.L.R.	Agricultural Land Reserve
A.R.D.A.	Agricultural Research and Development Act
ADT	air dry ton
et al.	and others
Atmos. Environ. Serv. (AES)	Atmospheric Environment Service
B.A.	Bachelor of Arts
B.A.Sc.	Bachelor of Applied Science
B.Sc.	Bachelor of Science
BP	before present (geologic time scale).
BOD	biochemical oxygen demand
B.C.	British Columbia
BCFP	British Columbia Forests Products
C.L.I.	Canada Land Inventory
CO_2	carbon dioxide
C	Celsius (or centigrade)
cm	centimetres
cm/sec	centimetres/sec.
Cl	chlorine
cont'd.	continued
Cu	copper
cfs	cubic feet per second
cu.m (m^3)	cubic metres
cms	cubic metres per second
^{o}	degrees
δ_{τ}	density anomaly (sigma t)
Dept. of Agric.	Department of Agriculture
Dept. of Fish.	Department of Fisheries
D.I.N.A.	Department of Indian and Northern Affairs
D.I.A.N.D.	Department of Indian Affairs and Northern Development (earlier name of foregoing department)
D.O.E.	Department of the Environment
Ph.D.	Doctor of Philosophy

ABBREVIATIONS AND SYMBOLS (cont'd).

E	east
Econ. Br. Pac. Reg.	Economics Branch Pacific Region
Ed.	Editor or edition
Environ. Can.	Environment Canada
EEB	Environmental Emergency Board
ELUC	Environment and Land Use Committee
ELUCS	Environment and Land Use Committee Secretariat
EPS	Environmental Protection Service
pH	expression for acidity or alkalinity of a solution
F	fahrenheit
fm	fathoms
ft	feet
F.& W.Br.	Fish and Wildlife Branch
e.g.	for example
g	gram
g/sq.m	grams per square metre
g wet wt/sq.m	grams wet weight per square metre
G.S.C.	Geological Survey of Canada
>	greater than
H_2S	hydrogen sulphide
IGD	Imperial gallons per day
in	inch
Ibid.	in the same place
IOUBC	Institute of Oceanography, University of British Columbia
Fe	iron
km	kilometre
km/hr	kilometre per hour
KME	Kraft mill effluent
Pb	lead
<	less than
l	litre
MS	manuscript

ABBREVIATIONS AND SYMBOLS (cont'd).

M.A.	Master of Arts
M.A.Sc.	Master of Applied Science
M.Sc.	Master of Science
m	metre
mi.	mile
m.p.h.	miles per hour
meq/1	milliequivalents per litre
mg/1	milligrams per litre
MMbm	million board feet
′	minute
min.	minute
misc.	miscellaneous
meas.	measure
MPN	most probable number
n.mi.	nautical miles
N	nitrogen or north
NO_2	nitrogen dioxide
n.d.	no date
#	number
oz.	ounce
P.B.S.	Pacific Biological Station
P.E.I.	Pacific Environment Institute
Pac. Reg.	Pacific Region
pp.	pages
ppm	parts per million
$^{o}/_{oo}$	parts per thousand
%	percent
P	phosphorus
PCB	Pollution Control Branch
lb	pound
Reg. Bd.	Regional Board
rept.	report
NaCl	sodium chloride or common salt
ser.	series
S	south

ABBREVIATIONS AND SYMBOLS (cont'd).

spec.	special
sp.	species (singular)
spp.	species (plural)
sq.ft	square feet
sq.m	square metres
sq.mi	square miles
STD.(std.)	standard
SCF	standard cubic foot (air pollution)
SCFM	Standard cubic foot per minute (air pollution)
SO_2	sulphur dioxide
SS	suspended solids
temp.	temperature
i.e.	that is
Mbm	thousand board feet
Mcf	thousand cubic feet
TDS	total dissolved solids
TIC	total inorganic carbon
TOC	total organic carbon
P Tot.	total phosphorus
TS	total solids
U.B.C.	University of British Columbia
U. of Vic.	University of Victoria
Var.	variation (navigation), variance (statistics), variety (Biology)
W	west
yr.	year

PREFACE

This is the fourth volume in the Estuary Series of Environment Canada Pacific Region. It covers the important and highly valuable estuarine area on the southeast coast of Vancouver Island between Dodd Narrows and Satellite Channel, protected by the chain of islands commonly known as the "GULF ISLANDS". To the east of these islands is the important inland sea of the Strait of Georgia, and to the southeast are the American islands of the San Juan Archipelago and the vertically mixed waters of its channels.

The coastal waters considered here have a great diversity of geographical configurations and offer a wealth of opportunities for commerce and recreation. Coal mining has left its mark in slag piles deposited in Ladysmith Harbour, and Crofton still exhibits the remnants from a copper concentrator located there after the turn of the century. The forest industry has provided a basis for employment in logging since the late 19th century in nearby Vancouver Island forests, and in pulp mills at Harmac, just north of Dodd Narrows, since 1950, and at Crofton since 1958. One need only to visit the Forest Museum near Duncan to obtain a flavour of early logging activities in Vancouver Island. Then one must not neglect to recall that agriculture has been practised since the white man arrived in the low-lying Duncan-Chemainus area, one of the few suitable farming areas on Vancouver Island. One cannot help but be impressed by the typical "English-countryside" pastoral scene that one still encounters (although it is rapidly vanishing with increasing urbanization) along the Island Highway, and particularly along the side roads from Ladysmith to Chemainus and from Duncan to Cowichan Bay.

Recreational values are perhaps the greatest assets and potentials of this coastal area, however. Cowichan Bay is famous for its chinooks and cohoes. Oysters are found virtually along the whole coastline, including the islands, both on commercial leases and in the wild state. Unfortunately, many of these are contaminated by sewage and industrial effluents. Marinas dot the coastline offering boaters havens for tying up overnight or for longer periods. The protected waters offer unparalleled scenery (except for being marred by the industrial emissions from pulp and paper mills), and opportunities for comparatively safe sailing. The waters are relatively clear and are rich in diverse flora and fauna, attracting SCUBA divers from the mainland and Vancouver Island points. Because the waters are generally stratified, unlike the waters of the San Juan channels, they tend to warm up at the surface in summer and can be actually quite pleasant for bathing and water skiing.

Because of the unique ecological characteristics of the Gulf Islands and of at least one of the estuaries, i.e. the Chemainus, there have been proposals to develop them as ecological preserves or marine parks. Clearly, some thought has to be given to preserve certain parts of this valuable coast, which is so vulnerable to degradation by development, for the enjoyment by future generations.

Development has already marred industrialized areas such as Crofton. Log storage in booms covers valuable sections of estuary and delta from Ladysmith to Cowichan Bay, in order to feed local sawmills and pulp mills. Sections of the Cowichan River estuary have been already developed for industry, e.g. Slegg Forest Products with about 65 acres. Conflicts arise in flood control. Recognizing some of the problems in estuarine use and developments, the provincial government, through its Environment and Land Use Committee Secretariat, initiated the formation of the Cowichan Estuary Task Force, a federal/ provincial/regional body which issued a report in October 1974, "Development Alternatives for the Cowichan and Koksilah Estuaries". The threats to wildlife, fisheries and recreational attributes by various development alternatives were identified, and suggestions were made for further study. It was clear from this task force's examination that we have not yet reached a state of knowledge that would allow us to estimate the impact of estuarine development on salmonid production, for example.

The present report summarizes available information and some of the gaps in environmental knowledge for the Cowichan River - Chemainus River estuaries and contiguous waters. We hope that it provides a useful starting point for government, university and private consultant investigations on estuarine problems. Some of the information provided in appendices has been compiled from various sources, and in that respect, we hope that this volume can serve as a useful reference for data to government workers, academics, students and consultants. In the interests of metrication, an effort is made in this report to provide data in the metric system, although the equivalent data in traditional units are retained in parenthesis.

These reports are the products of contractors working on behalf of the Estuary Working Group [Preface Table (i)] of the Regional Board Pacific Region. Each member of the Working Group, or a colleague, reviews each report for accuracy of contents before it is printed. I wish to thank the members once again, for continued participation in this project by reviewing draft reports and by discussions at our bimonthly meetings, and the regional DOE directors-general and directors for both moral and financial support.

M. Waldichuk

Preface Table (i).

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Acknowledgements

The authors would like to thank all agencies and individuals that supplied reports and data, particularly unpublished material.

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We are grateful to Dr. M. Waldichuk for writing the Oceanography Section, and for his guidance and continuing interest in this series of reports.

Finally, we wish to thank Mrs. Rose Dawson for typing the manuscripts.

SUMMARY

The Cowichan, Koksilah and Chemainus River systems drain an area of 158,000 hectares (610 sq.mi.) of generally hilly and mountainous topography reaching elevations of up to 1,500 metres (5,000 ft.). The river discharges exhibit the unique characteristics of Vancouver Island and coastal river systems. Maximum flows occur during the winter months instead of during the spring freshet, typical of rivers such as the Fraser and Skeena, which drain the interior mainland basins.

The Cowichan River originates in Cowichan Lake at an elevation of 159 metres (530 ft.), flows eastward for about 47 kilometres (29 mi.) and discharges into Cowichan Bay near Duncan. The mean annual discharge measured at Cowichan Lake is 44.5 cubic metres per second (1,590 cfs). The Koksilah River, rises on the slopes of Waterloo Mountain and also discharges into Cowichan Bay. The major portion of the Cowichan-Koksilah River lowlands, below the Esquimalt and Nanaimo Railway bridges, is subject to flooding during peak winter flows, and some areas are subject to tidal flooding.

The Chemainus River originates in the Vancouver Island Ranges at elevations of more than 1,500 metres (5,000 ft.) and follows a fault-controlled course for 53 kilometres to its estuary, 4.5 kilometres south of the town of Chemainus. The mean annual discharge, measured near Westholme, is 20.0 cubic metres per second (670 cfs). The lower reaches of the river are characterized by extensive gravel areas highly suited to salmonid spawning.

The Cowichan and Chemainus River estuaries experience a modified maritime climate, also referred to as a cool summer mediterranean climate. Located in the rain shadow from the mountains of Vancouver Island and the Olympics, and well protected by the Saanich Peninsula and Gulf Islands, they have a

drier and generally more pleasant climate than most mainland estuaries.

Both estuaries exhibit the dry summer-wet winter pattern of the British Columbia coast. Mean annual precipitation is less than 1,270 millimetres (50 in.), bright sunshine averages more than 1,800 hours annually, and the frost-free period averages about 200 days a year. Prevailing winds are from the east to southeast, although of somewhat lower strength than over the open Strait of Georgia, due to protection offered by the Gulf Islands.

Although the Cowichan-Chemainus River systems occupy contiguous drainage basins, their estuaries are separated by approximately 40 kilometres of rugged rocky coastline adjacent to Sansum Narrows. The drainage basins of these rivers include rock types ranging from resistant volcanics to clastic detrital rocks, including conglomerates, shales, and sandstones, which are covered in places by drift deposits left by the melting of glaciers, that occupied the area during the last glacial period known as the Pleistocene.

Little is known about the sediment types maintaining the Cowichan-Chemainus deltas, or their distribution. The Chemainus delta is characterized by four major morphological units. The most extensive unit is the tidal flats, incised by numerous tidal channels. Algal mats found on both the salt marshes and tidal flats, play a major role in the vertical accretion of sediments.

The soils of this region are those classified under the Lower Nanaimo Lowlands zone. The most prominent arable soils are the Fairbridge silt loams, which predominate on the west side of Cowichan Bay and the area to the north and west of Duncan, and the Chemainus silt loam, which is visible in the deltaic

environment of the Cowichan and Chemainus rivers. The Fairbridge soils are rated as the most desirable for agriculture on Vancouver Island.

Freshwater invertebrate studies have been conducted in relation to fish-rearing capability in the Cowichan River. Dominant macroinvertebrates of the upper Cowichan River include bivalves, amphipods and mayfly, caddisfly and chironomid nymphs. Except for the deepwater chironomids, the insect population of Cowichan Lake was found to be scanty. The zooplankton of Cowichan Lake was diverse but not abundant.

The invertebrate biology of these estuaries has not been investigated or documented to any great extent. The benthos of Satellite and Stuart channels and Cowichan Bay displays a clam-polychaete association typical of a soft substrate with bivalves, polychaetes, echinoderms, amphipods and copepods all being abundant. The intertidal fauna of Stuart Channel is characterized by the Pacific oyster, an introduced species, which forms the basis of the oyster industry. Intertidal oyster leases, many of which are closed owing to fecal contamination, are located on the Chemainus River delta and in Ladysmith Harbour. The commercial oyster industry is hampered by a number of problems, one being pollution. Oysters also contribute to the recreational value of the study area. A small but productive shrimp and prawn fishery operates in Stuart Channel and Sansum Narrows.

The Cowichan is a highly important river on Vancouver Island because of the variety and abundance of salmonid species inhabiting it, and the degree of utilization of its fish stocks by commercial, recreational and Indian fisheries. The Koksilah and Chemainus rivers support sizeable, but smaller fish populations than does the Cowichan River. The continued existence of all these fish stocks is dependent upon maintaining a stable and viable estuarine ecosystem. The value of the

Cowichan-Koksilah fish stocks to the commercial and recreational fisheries has been estimated at $2.2 million and $2.4 million, respectively, based on 1973 prices. Many marine fish species are recorded from Cowichan Bay, and the food sources of these estuaries contribute to the large Gulf Island herring stocks. The waters immediate to the estuaries are closed to commercial fishing. However, they are among the most heavily sport-fished waters of British Columbia.

The Cowichan-Chemainus estuaries lie within the coastal Douglas-fir zone which occurs on the southeast (leeward) coast of Vancouver Island. The forests of the area are characterized by Douglas-fir, salal and Oregon grape. Garry oak and arbutus (madrona) are common in drier areas. Deltaic flora on the Chemainus, and to a lesser extent on the Cowichan, exhibits typical estuarine zonation. However, dyking, landfilling and grazing of foreshore areas have altered floral community structures to the detriment of fish and wildlife. The productivity of the intertidal zone on the Cowichan River estuary, which is thought to be considerable in view of the large fish and waterfowl stocks it supports, is presently being assessed.

The Cowichan and Chemainus estuaries are highly important migrant waterfowl resting and/or overwintering areas. Avian wildlife is particularly diverse and abundant on and around these estuaries, and it attracts considerable consumptive and non-consumptive recreational activity. The Cowichan River estuary supports intensive waterfowl hunting, as it is highly accessible and close to urban centres. The mammalian fauna is less diverse than that of the birds, and is sensitive to development in the area. Both the Cowichan and Chemainus watersheds support considerable deer and upland game bird hunting. The wildlife of the study area is a valuable recreational resource and is dependent upon the preservation of natural habitats for its continued existence.

xxiii. Summary

The estuarine system, from Dodd Narrows in the north to Satellite Channel in the south is the innermost waterway of the Gulf Islands archipelago and consists mainly of Stuart Channel and Sansum Narrows. It is connected to the Strait of Georgia through Dodd Narrows to the north and to Boundary Pass through Satellite Channel to the south. The system is quite stratified vertically in salinity distribution, except near Dodd Narrows and in Sansum Narrows, where there is considerable vertical mixing due to tidal turbulence. Currents are predominantly tidal, directed along the axes of Stuart Channel and Sansum Narrows, with the flood setting to the northwest and the ebb to the southeast. Tides are a blend of mixed tides, having a large time difference between low and high water in the Strait of Georgia, and a small time difference in Juan de Fuca Strait. The flooding tide may enter into the north end of Stuart Channel from the Strait of Georgia, before it has reached there through the inside passages, because of the configuration of the channels and the constrictions of the narrows.

Tidal currents in Stuart Channel can attain a maximum of 50 cm/sec (1.0 knot), with an average speed of about 15 cm/sec (0.3 knot) at the surface and 5-10 cm/sec (0.1 - 0.2 knot) at 18 metres (60 ft) in depth. Tidal currents near Dodd Narrows, in Sansum Narrows and in Satellite Channel may reach 150 cm/sec (3 knots). Wind-driven surface currents in Stuart Channel may approach the speed of tidal currents there during intensive, prolonged winds, especially in winter. However, winds in the protected inside passages are usually considerably lighter and of shorter duration than those in the Strait of Georgia. Hence, wind-driven currents and waves are small to moderate in magnitude and usually short-lived in Stuart Channel, and even less severe in the Cowichan and Chemainus River estuaries. Protection from the Shoal Islands renders inshore effects of wind waves and currents at the Chemainus River estuary rather minimal.

xxiv. Summary

Flushing of the Stuart Channel-Sansum Narrows-Satellite Channel system is important from the point of view of pollution prevention in these waters. River flushing of the estuaries is particularly active during the autumn-winter-spring seasons of heavy runoff. However, areas such as Ladysmith and Chemainus harbours have virtually no flushing by runoff in summer. Tidal flushing of Stuart Channel is somewhat restricted by the connecting passages to the north and south, and there is rather minimal exchange through inter-island passes.

Sewage pollution has forced the closure of most of the productive shellfish grounds in the study area. The waters of Cowichan Bay, Ladysmith Harbour and much of the Chemainus River estuary are closed owing to coliform contamination.

Forest industries create and/or threaten to create major pollution problems in the study area. Logging within the watersheds has created less stable flow regimes. The Crofton pulp mill has had wide-ranging effects on contiguous water quality despite measures taken to minimize environmental damage. The Chemainus sawmill and associated log booming activity has caused the deterioration of Chemainus Bay as a natural habitat. The former Slegg Brothers' sawmill, now being replaced by a much larger operation by Doman Industries Limited, is situated in prime estuarine fish and waterfowl habitat on the Cowichan River estuary. Water quality in the surrounding area is being affected by toxic leachates from hog-fuel and mill wastes previously used as fill material. Finally, the substantial amount of log handling and booming activity within the study area has caused habitat degradation in specific locations.

Prior to 1800, the east coast of Vancouver Island was populated by the Coast Salish Indians. In 1862, HMS *Hecate* dropped anchor in the sheltered waters of Cowichan Bay with one hundred white settlers on board. This group represented the nucleus of pioneer settlement in the Cowichan-Chemainus district.

 Summary

In the early years, agriculture was the only successfully established economy in the valley. The advent of the Esquimalt and Nanaimo Railway in 1886 opened up the area for the lumber industry, and influenced the creation of new settlements such as Ladysmith, Saltair, Chemainus, Westholme and Duncan.

By 1906, the Cowichan Leader newspaper rated mining as the primary industry of the region, with agriculture, still the mainstay of the valley, though rated second in importance, Sawmilling was rated by the Paper as the third industry. In 1919, lumber mills at Chemainus and in the vicinity of Duncan were producting at a rate greater than any other mills in the province. Following the economic slump of the 1930's, the forest industry started expanding, becoming the main economic activity of the region, a position it retains today.

The municipality of North Cowichan is the largest municipal area on Vancouver Island, covering 20,500 hectares (50,489 acres) between Duncan and Chemainus. Included within its boundaries are the communities of Westholme, Crofton, Maple Bay and Somenos. Crofton is supported by the pulp and paper industry. The British Columbia Forest Products Ltd. pulp and paper mill, in operation since 1958, has a capacity of 925 tons per day of full bleach kraft and 750 tons per day of 30 lb. newsprint. In 1973, the port of Crofton handled 883,129 tons of wood products and pulp and paper for newsprint for destinations in foreign countries, as compared to 332,510 tons of lumber and timber exported through the port of Chemainus.

Practically all of the agricultural industry in the Cowichan-Chemainus area is concentrated in the more fertile regions between Duncan and Cowichan Bay, and in the lower Chemainus and Koksilah valleys. Dairying is the principal enterprise, accounting for more than 50% of the farms having annual sales of $2,500 or more.

The City of Duncan is the largest settlement in the study area, and is a service centre for the Cowichan-Chemainus district. In 1971, it had a population of 4,388, with approximately 7,000 more inhabitants in a large suburban area extending into the neighbouring North Cowichan Municipality.

Canadian Census figures for the years 1951 and 1971 show that the Cowichan Valley census subdivision (Ladysmith to Mill Bay) has experienced a population growth of 2.95% a year, slightly below the provincial average of 3.26%. However, an extraordinarily high rate of growth in the area adjacent to the Cowichan River estuary (8.8% a year between 1966 and 1971) prompted the Cowichan Valley Regional District to prepare a community plan for this area. The plan recommends the deferment of all industrial development until such time as the resource potential is fully evaluated in regard to the impact of development on the environmental and ecological qualities of the region.

1. INTRODUCTION

1 (i) GENERAL

The Cowichan and Chemainus River estuaries are located on the southeast coast of Vancouver Island below the 49th parallel of latitude. For the purpose of this report, the northern and southern limits of the combined estuaries are defined as follows.

The northern limit is marked by Ladysmith Harbour, latitude 49° 00' north and longitude 123° 50' west. The southern extremity is delineated by the Chemainus Harbour limit in Satellite Channel, between Hatch Point on Vancouver Island and Cape Keppel on Saltspring Island, at latitude 48° 43' north and longitude 123° 30' west (Figure 1.1).

The Cowichan and Chemainus River estuaries and Ladysmith Harbour are unique environments in that they do not readily fit the standard estuarine classification system, examples of which are the Fraser River estuary, a highly stratified submerged river valley, and the stratified fjord type estuaries such as the Skeena and the Squamish.

Ladysmith Harbour has been described by geologists as a drowned postglacial river mouth, inundated by a eustatic rise in sea level 5,000 to 8,000 years ago. Freshwater inflow to the harbour is provided by four small streams, namely - Bush Creek, Rocky Creek, Holland Creek, and Stocking Creek. During the dry season, usually the summer months, the freshwater flow is very low or even non-existent, resulting in 'negative' estuary conditions, that is, evaporation exceeds precipitation and runoff, and surface salinities are higher there than in the adjacent sea. A 'positive' estuary is defined as one having a salinity lower than the adjacent sea with a net seaward flow.

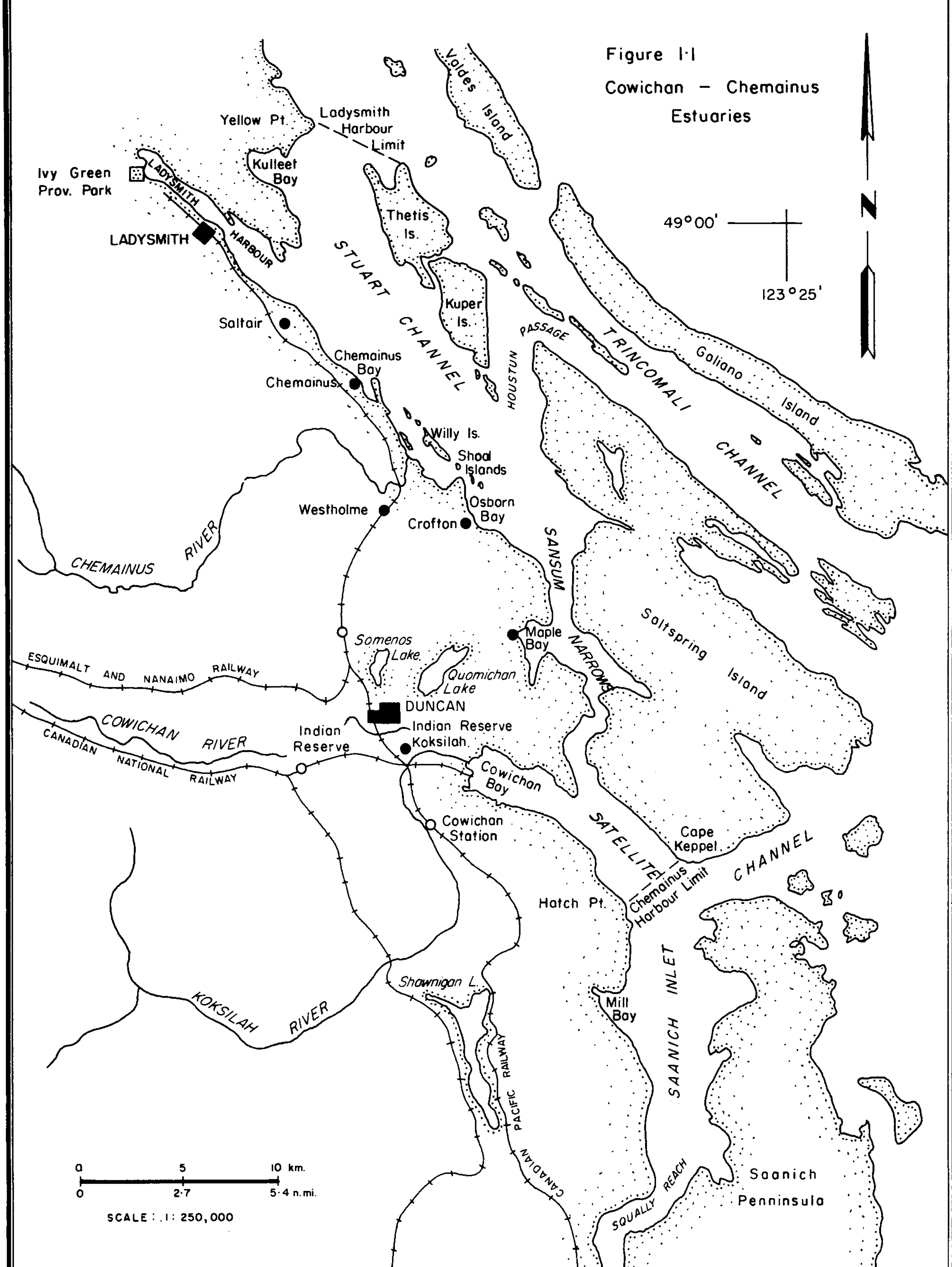


Figure 1·1
Cowichan – Chemainus
Estuaries
49°00'
123°25'
Valdes Island
Yellow Pt.
Ladysmith Harbour Limit
Kulleet Bay
Ivy Green Prov. Park
LADYSMITH HARBOUR
LADYSMITH
Thetis Is.
Kuper Is.
STUART CHANNEL
HOUSTUN PASSAGE
TRINCOMALI CHANNEL
Galiano Island
Saltair
Chemainus Bay
Chemainus
Willy Is.
Shoal Islands
Osborn Bay
Westholme
Crofton
CHEMAINUS RIVER
SANSUM NARROWS
Saltspring Island
Somenos Lake
Maple Bay
Quomichan Lake
ESQUIMALT AND NANAIMO RAILWAY
DUNCAN
Indian Reserve
Koksilah
COWICHAN RIVER
CANADIAN NATIONAL RAILWAY
Cowichan Bay
Cowichan Station
SATELLITE CHANNEL
Cape Keppel
Chemainus Harbour Limit
Hatch Pt.
Shawnigan L.
KOKSILAH RIVER
CANADIAN PACIFIC RAILWAY
Mill Bay
SAANICH INLET
SQUALLY REACH
Saanich Penninsula
0 5 10 km.
0 2·7 5·4 n.mi.
SCALE : 1 : 250,000

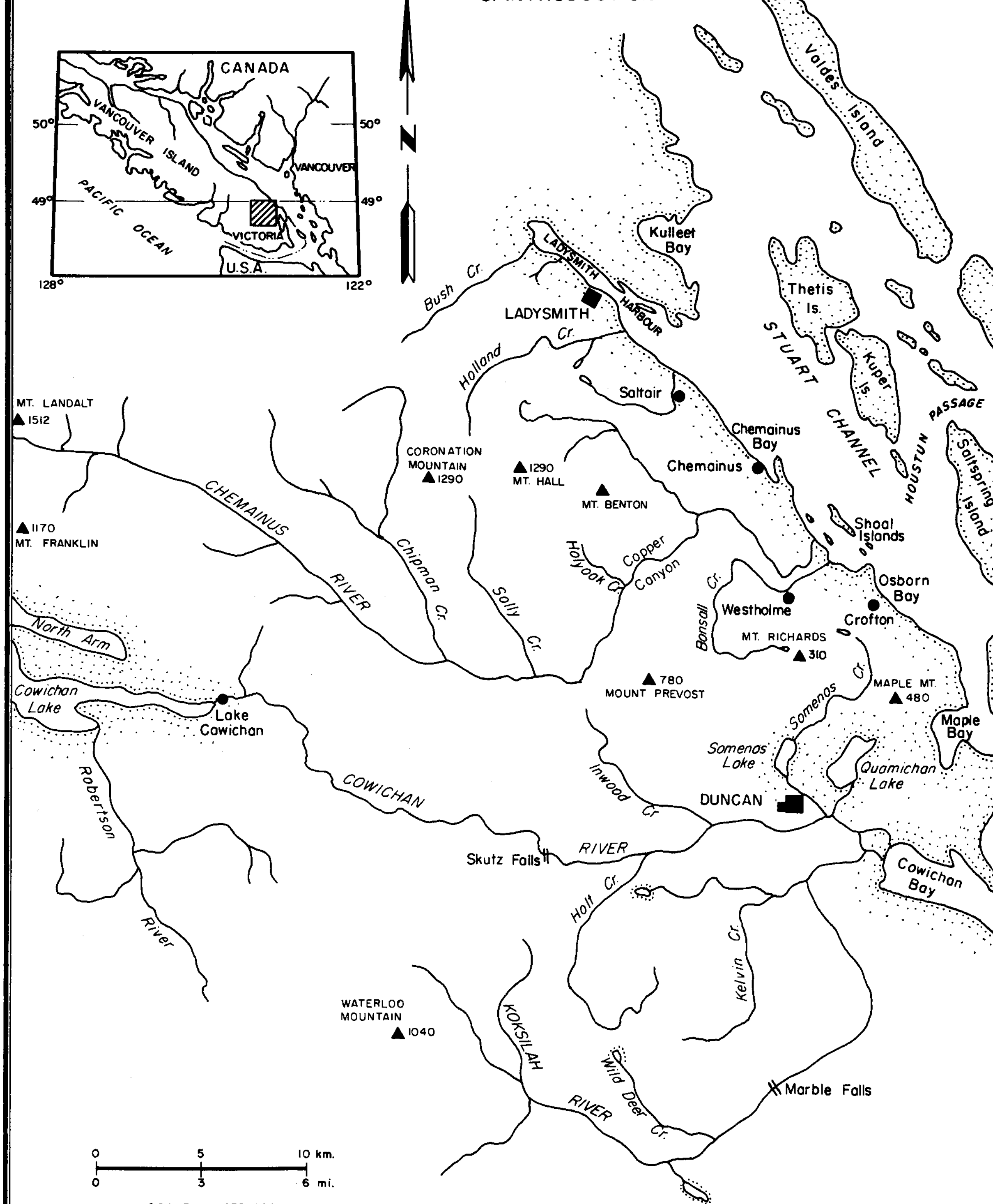


Figure 1·2 Chemainus River, Cowichan River and Koksilah River Drainage Basins. (Dept. Mines and Technical Surveys, 1964).

4. Introduction

The Chemainus River estuary, a submerged river valley, is unique in that the growth of the river delta is influenced by the protective barrier of the Shoal Islands, approximately one kilometre offshore, and the tidal currents of Stuart Channel and Houstoun Passage.

The Chemainus delta, with a diversified ecology, supports a wide variety of fish, flora and wildlife. It is relatively unaffected by man-made structures. The Crofton pulp and paper mill is the only major development in the area and it is located at the southern end of the delta on Osborn Bay.

The delta is currently being considered by the Provincial Government as one of a number of terrestrial and coastal ecological reserves in British Columbia. The preservation of the major portion of this environment in its natural condition would enable scientists to carry out field-oriented research, and establish base-line data vital for future assessments of the environmental and ecological impact of industrial and commercial development in the coastal zone. Pollution studies of the effect on the Crofton mill complex and ancillary structures, such as water intakes, sewage outfalls, and ship-loading facilities, have been and are currently being carried out as a joint undertaking of industry, government and academia.

The Cowichan River, originating in Cowichan Lake approximately 47 kilometres (29 mi.) east of Cowichan Bay, drains the mountainous slopes of the Cowichan Valley. It is separated from the Chemainus River Valley by Mount Prevost (780 m), Mount Richards (310 m), and Maple Mountain (480 m), and along with the Koksilah River, provides the freshwater inflow to Cowichan Bay (Figure 1.2).

Industrial development in the intertidal zone of the Cowichan estuary, as a result of the rapid expansion of the forest industry since 1960, has been responsible for the reclamation of 91 hectares (224 acres) of prime estuary wetland. The lack of adequate inventories of the natural resources of the estuary and scientific data relating to its biological productivity make it difficult to assess the full impact of such development.

Periodic flooding of the lowlands between the city of Duncan and the estuary, combined with a rapid population growth in the region, have highlighted the need for additional resource and planning studies. These should determine the future course of industrial, residential and recreational growth of the Cowichan estuary and its hinterland.

It is hoped that this report will, in some measure, help to plot the course, by reviewing for its readers the status of environmental knowledge of scientific research, past, present and in progress, for the area just described.

1 (ii) HISTORICAL PERSPECTIVE

Prior to 1800 the east coast of Vancouver Island was populated by the Coast Salish Indians, whose territories extended from Campbell River in the north to Victoria in the south. The languages of the Indians of British Columbia were many and varied and have been used by anthropologists to provide a broad classification of the major ethnic groups (Duff, 1964).

Two of the Coast Salish dialects, Chemainus and Cowichan, were adopted as the names of the major regional groups of Indians inhabiting the area from Ladysmith Harbour to Cowichan Bay. In native dialect, Cowichan means "land warmed by the sun". Regional groups of Indians were divided into tribes and bands, tribes originally being the coastal equivalent of the "bands" of the plateau. Today the word "band" has a fixed legal meaning for purposes of Indian administration. A summary of the Cowichan and Chemainus tribes and bands from 1850 to 1963, appears in Table 1.1.

Initially, Vancouver Island and mainland British Columbia were British colonies politically separate from Canada. In 1849, the Imperial Government, seeing the necessity for colonizing Vancouver Island in order to confirm British sovreignty in the area, entrusted the task to the Hudson's Bay Company of London. The company was empowered to sell lands to settlers, retaining ten percent of the proceeds as a profit factor and using the balance for the betterment of the colony. The first recorded visit of the white man to the Cowichan Valley took place in 1850. Between 1858 and 1859 a total of 9,880 acres was sold to 19 purchasers most of whom bought for speculative purposes.

In 1858, Vancouver Island became a Crown Colony and the Cowichan region had one white settler. A government survey of the Cowichan region was completed in 1860, and it was estimated that there were "45,000 acres of superior agricultural lands waiting to be occupied" (Wells, 1860). Two years later, in 1862, H.M.S. *Hecate* dropped anchor in the sheltered waters of Cowichan Bay with one hundred settlers on board. This group represented the nucleus of pioneer settlement in the Cowichan-Chemainus district.

Olsen (1963) in his book "Water over the Wheel" provides the reader with a narrative of the pioneer history and industrial development of the Chemainus district from 1791 to 1961. The history of development of the Cowichan Valley and Cowichan Lake areas has been documented by Norcross (1959) and Saywell (1967). A summary of the early history of the City of Duncan and a detailed account of events during the depression years (1929 to 1933) is contained in a M.A. Thesis (UBC, Department of History) by Arthur J. Wright (1967).

Table 1.1. Coast Salish Indian Tribes and Bands, 1850-1963 (Duff, 1964)

Dialect and Regional Groups	Tribes and Bands (1850)	Names Given by Reserve Commission (1916)	Band Name and Population (1963)	
Chemainus	Chemainus (Kulleet Bay)	Chemainus Tribe: (Chemainus Band	Chemainus	366
	Sicameen (Ladysmith Harbour)	Siccameen Band (included Kumalockasun Band)		
	Halalt (Willy Island	Halalt Band	Halalt (Westholme)	95
	Lyacksun (Shingle Point)	Lyacksun Band	Lyacksun (Westholme)	77
	Penelakuts (Kuper Island)	Penelakut Band (included Tsussie)	Penelakut	326
	Yekoloas (Telegraph Harbour)	(joined Penelakuts)		
	Lilmalche (Lamalchi Bay)	(joined Penelakuts)		
Cowichan	Cowichan Lake	Cowichan Lake Tribe	Cowichan Lake	4
	Somenos (Cowichan River)	Cowichan Tribe (amalgamation in 1888 of: Somenos	Cowichan	1,228
	Quamichan (Lower Cowichan River)	Quamichan		
	Comiaken (Lower Cowichan River)	Comiaken		
	Clemclemaluts (Lower Cowichan River)	Clemclemaluts		
	Koksilah (Koksilah River)	Koksilah		
	Kenipsen (Cowichan Bay)	Kenipsen		
	Kilpaulus (Cowichan Bay)	Kilpaulus)		

Introduction

The following summary of the history of the region from the middle of the 19th century, is based primarily on these four works.

Industrial development of the area started as early as 1866. "The Mill Bay and Chemainus sawmills shipped lumber regularly, but the Cowichan Valley had little success in establishing any industry other than this and agriculture. In August, 1868, Thomas Askew of Chemainus wrote the "Colonial Secretary" about the discovery of a seam of coal where the Ladysmith mines were later developed, but nothing was done about it (Norcross, 1959).

By 1871, the population of Cowichan had grown to 486. However, from 1871 to 1886, there was no growth in the Cowichan Valley as the Esquimalt and Nanaimo Railway Company had put a reserve on all unsettled lands for twenty miles on either side of their proposed line. In 1886 construction of the line was completed and villages started springing up around railway stations, including Cobble Hill, Koksilah, Duncan, Somenos and Chemainus. The original Chemainus settlement became known as Hall's Crossing, and later was named Westholme, the name it has retained to the present day. New communities also developed in the north. Wilson's Crossing, now known as Saltair, Blainey, and Ladysmith founded in 1900. About the same time (1895), Chemainus Bay became Kulleet Bay and Horse Shoe Bay was renamed Chemainus Bay following a survey by the British Hydrographic Office.

Prior to 1886 agriculture had been the only successfully established industry in the valley. The advent of the railway, however, made possible the rail shipment of lumber from the sawmills and influenced the development of the new settlements just described.

"The railway enabled the Cowichan farmers to exploit more fully the Victoria market and they began at once to ship milk. The increase in dairy herds which this led to, led also to the formation in 1896 of the Cowichan Creamery Association" (Norcross, 1959).

The Tyee Copper Company commenced operations in 1900, and supported by coal mining and the Tyee smelter, the village of Ladysmith expanded rapidly. In 1902, two Americans from Montana built a smelter on Osborn Bay in the name of the North-west Smelting and Refining Company (Norcross, 1959). South of Ladysmith a commercial centre, known as Duncan's Station, was developing in the Cowichan district. This centre was later to become the City of Duncan, providing then, as it does today, services to the surrounding districts. "The community at Duncan's Station seceded from the Municipality of North Cowichan after five years of discussion on the matter, and received its charter as the City of Duncan in March, 1912" (Olsen, 1963).

By 1906, the pioneer age of logging was nearing an end. Newer logging methods had greatly increased production of timber for the mills. Lumbering, however, had not yet become the prime industry of the area. The Cowichan Leader (1906) rated mining first, with agriculture, rated as of secondary importance, still the mainstay of the valley. Sheep raising had become important and the production of fruit was doing well. Sawmilling was rated as the third industry.

During the early 1900's, Duncan started to grow as a city. Water was "laid on" in 1906 by the Cowichan Waterworks Company. A year later (1907), the Duncan Power and Development Company was incorporated. The telephone had already made its appearance in Chemainus, where in 1908, there were fifteen subscribers. In 1910, a sewerage system was proposed for the city, but its completion was not achieved until some forty years later (Norcross, 1959). In the same year a fish hatchery was established at Lake Cowichan. By 1912, the population of Duncan had grown to 1,500, while the number of Indian inhabiting the Cowichan Valley had been reduced to 500.

The Esquimalt and Nanaimo railway commenced construction of spur lines from Westholme to Crofton and to Cowichan Lake in 1912, and by the end of 1913 a "road-bed" was in as far as Youbou, on Cowichan Lake, opening up a whole new area for the lumber industry. For a detailed description of the history of logging in the Cowichan Valley prior to the First World War, the reader is referred to Saywell (1967).

In 1919, the Genoa Bay mill was turning out lumber at the rate of 100,000 linear feet a day and was one of the most active mills on Vancouver Island. It had orders from eastern Canada, Britain and South Africa. "At Chemainus the huge Victoria Lumber and Manufacturing Company's mill was setting a pace no mill in the province could match" (Wright, 1967). The Chemainus mill output for 1922 was 42,000,000 linear feet, while the Genoa mill produced 25,000,000 linear feet (The Cowichan Leader, December 28, 1922). Mayo Lumber Company's mill, eight miles west of Duncan, employed 175 men in 1924, and was one of the largest producers in the valley. In the same year, the Hillcrest Lumber Company, located five miles outside of Duncan, was renovated and set up to produce 100,000 linear feet of lumber a day.

Wright (1967) ably sums up the situation in Duncan and the Cowichan Valley at the end of the decade. "By the end of the twenties, Duncan was a multi-industry community. It was a city which, though containing important agricultural and forestry operations, had developed a widely diversified economic base through the growth of other industrial and service functions". By 1929, the forest industry was the Cowichan Valley's greatest producer of wealth, and had replaced mining as the community's primary industry.

Chemainus, the site of the huge Victoria Lumber and Manufacturing Company, producing 300,000 linear feet a day, was also the shipping port for finished lumber from the Cowichan area throughout the 1920's and 1930's. In 1929, the Port of Chemainus handled approximately 60 million linear feet of finished lumber, while the Cowichan Bay Booming Association had handled over 125 million linear feet of logs during the season, establishing an all-time record (The Cowichan Leader, January 9, 1930).

The same year (1929) was also the most profitable year for the merchants of Duncan (Wright, 1967), but late in the year the stock market collapsed, heralding the start of the depression years of 1929 to 1934. By December 1929, booming grounds at Crofton and Cowichan Bay were crowded with an accumulation of logs for which there was little demand. An account of the depression years in the Cowichan Valley is contained in a thesis by Wright (1967). By the spring of 1931 only the Chemainus and Youbou mills were working steadily, and by 1932, lumber production had fallen to its lowest point since the start of the industry.

A year later the situation had changed considerably, and in 1933 lumber shipments from the Cowichan area were higher than they had been for many years. Shipments totalled 100 million linear feet, a little more than one-seventh of all the lumber exported from the Province (The Cowichan Leader, February 8, 1934). From April to December, 1933, 151 deep-sea vessels had loaded at Chemainus, where docking facilities had been enlarged to allow for the loading of two ships at once.

After the economic slump of the 1930's, agriculture, once the most important source of income in the Cowichan area, had slumped to an all-time low. The lumber industry, however, was once again expanding. In 1942, Western Forests Products Limited, built a new mill with a capacity of 115 million linear feet per year at Honeymoon Bay on Cowichan Lake. British

12. Introduction

Columbia Forest Products Limited was incorporated in 1946, and was granted a tree farm licence for the management of 159,500 hectares (391,000 acres). In 1955, the Company announced its decision to build a 500 ton per day full-bleach kraft mill at Crofton (A.C. Wallace - pers. comm.). By 1965, the mill capacity had been expanded to produce 950 tons per day of full bleach kraft and 250 tons per day of newsprint. In 1968 a second 350 ton-per-day newsprint machine was started up, and between then and 1975, additional equipment was added to establish the present mill capacity of 925 tons per day of full-bleach kraft and 750 tons per day of 30 lb. newsprint.

In 1959, B.C. Hydro's Georgia Generating Station, located at Bare Point on the east side of Chemainus Bay, commenced operations, adding another 75,500 kilowatts to the power system. Distribution of power is presently handled by the Vancouver Island Terminal Station, which, located 4 kilometres (2.5 mi.) north of Duncan, and built in the early 60's, is the Island's largest transformer station. The station is designed to both receive power from or feed power to the Arnett Terminal Station on the British Columbia mainland. A submarine cable links the mainland station with the Gulf Islands, from which the final link in the system (between Saltspring Island and Vancouver Island) is made by aerial transmission lines spanning Sansum Narrows, just north of Maple Bay.

Please note:- References made in the Introduction are found in the Land Use Bibliography.

2. GEOLOGY AND SOILS

The Chemainus River estuary and the Cowichan-Koksilah estuary both lie on the east coast of Vancouver Island. Although these river systems occupy contiguous drainage basins, their estuaries are separated by approximately 40 kilometres of rugged rocky coastline bordering Sansum Narrows, which separates in this area, Vancouver Island from Saltspring Island.

The Chemainus River rises in the Vancouver Island Ranges at elevations of more than 1,500 metres and flows eastward, following a fault-controlled course for 53 kilometres, to discharge at a point 4.5 kilometres south of the town of Chemainus.

The Cowichan River flows from Cowichan Lake, which occupies a fault-controlled valley at the southern end of the Vancouver Island Ranges. The Cowichan River flows 47 kilometres eastward, past the city of Duncan, to discharge into Cowichan Bay. Cowichan Bay accommodates both the estuaries of the Koksilah and Cowichan rivers.

The drainage basins of these rivers include rock types ranging from resistant volcanics which form bold peaks, to clastic detrital rocks including conglomerates, shales and sandstones. In places, the latter are covered by drift deposits left by the melting of glaciers that occupied the area during the last geological epoch known as the Pleistocene (Appendix 2.1).

2 (i) PREVIOUS GEOLOGICAL WORK

Prior to 1908, little geological work of a general and correlative nature had been done in the southeastern part of Vancouver Island. Dr. A.C. Selwyn and Mr. James Richardson explored the eastern coast of the island in 1871 (Selwyn, 1872).

Richardson subsequently continued to work on the coal areas of the island, including the Nanaimo and Cowichan fields, for another four years. Dawson (1887, 1890) reported on the Upper Cretaceous rocks of the northern "Suquash" area and first proposed the name Nanaimo Group for the entire Upper Cretaceous succession.

In 1912, Clapp published a preliminary report on the geology of southern Vancouver Island, in which he describes the distribution and composition of the rocks. From 1912 to 1917 he carried out geological mapping of about 1040 hectares (4000 sq. mi.) of southern Vancouver Island and established and named the succession of formations in the Nanaimo-Cowichan area (Table 2.1, 2.2).

A major work on the geology of the Sooke and Duncan map areas was published in 1917 by Clapp and Cooke. Following this, little work was done until 1955, when Fyles published a report on the geology of the Cowichan Lake area. A good general description of the Georgia Depression and the adjacent Nanaimo Lowland can be found in a discussion on British Columbia land-forms by Holland (1964). A short section on glaciation was also included in this report.

A more detailed study of glaciation of the Cowichan Valley was done by Halstead (1968). He suggested the existence of an ice tongue that occupied Cowichan Valley, and extended east-ward to Saanich Peninsula, prior to the merging with and being overridden by the Cordilleran ice of the last major glaciation.

In 1965, Halstead mapped the surficial geology of the Duncan area at a scale of 1 inch to 1 mile (Map 14-1965, Duncan, British Columbia 92B/13 east half). He found that surficial de-posits are commonly below an elevation of 150 metres (500 feet), and include laminated silts and clays, gravels, and stony till.

The most recent and definitive work on the geology of

Table 2.1. Formations of the Vancouver Group (Clapp, 1912).

Formation	Age	Rock Types
Metchosin volcanics	Jurassic	Ophitic basalt flows, tuffs, and agglomerates with intrusive diabase dykes. Less metamorphosed than rest of Vancouver group.
Sicker series	Jurassic or Triassic, gabbro-diorite porphyrites, may be lower Cretaceous.	Andesitic volcanic flows and tuffs, with interbedded tuffaceous, slaty and quartzose sedimentary rocks, more or less metamorphosed into schists, with intrusive quartz-feldspar and gabbro-diorite porphyrites.
Sutton formation	Lower Jurassic	Intercalations of crystalline limestones in Vancouver volcanics.
Vancouver volcanics	Largely lower Jurassic but probably includes Triassic and middle Jurassic, and possibly Palaeozoic members.	Metamorphic andesites and augite andesites, amygdaloids, porphyrites, tuffs and breccias; with dacite tuffs, and intrusive dykes and sills of andesite and basalt porphyrites.
Nitinat formation	Jurassic or Triassic	Marbles and metamorphic varieties, garnet-diopside rocks, and amphibolites.
Leech River formation	Carboniferous	Slates, slaty schists, greywackes and quartz and quartz-feldspar schists.

Table 2.2. Formations of the Upper Cretaceous Nanaimo Series (Clapp, 1917).

Formation	Rock Type
Gabriola formation	Chiefly sandstones
Northumberland formation	Conglomerates, sandstones and shales
DeCourcy formation	Chiefly sandstones
Cedar District formation	Chiefly shales
Duncan formation (equivalent of Cedar District, Protection and Ganges formations)	Sandstones and shales
Protection formation	Chiefly sandstones
Ganges formation	Shaly sandstones and sandy shales
Extension formation	Conglomerates and sandstones
Haslam formation	Shales and sandstones
Benson formation	Basal conglomerate and arkose

the study area by Muller and Jeletsky (1970) is discussed in the following section on regional geology.

2 (ii) REGIONAL GEOLOGY

The oldest rocks found in the study area are those of the Vancouver Group ranging in age from the Lower to Middle Jurasic (Table 2.1). These include the andesites and basalts of the Vancouver volcanics, crystalline limestone of the Sutton formation, hornblende-augite andesite of the Sicker volcanics and tuff, cherty tuff and slate of the Sicker sediments (Clapp, 1912).

The Vancouver Group volcanics are a metamorphosed sequence of pyroclastic rocks, 3,000 metres (10,000 ft.) thick. These outcrop only to a minor extent in the Chemainus River drainage basin. Numerous lenses of metamorphosed limestone interspersed in the Vancouver volcanics make up the Sutton formation. These are thought to be accumulations of marine organisms which lived on the shores of volcanic islands during the time when the Vancouver volcanics were erupting. Overlying these are the metamorphosed volcanics and sediments of the Sicker Group. Exposures of these may chiefly be seen along the Chemainus River (Clapp and Cooke, 1917).

A period of deformation and folding followed the Vancouver Group sequence, accompanied by the intrusion of the Saanich granodiorite, exposures of which are visible along the upper Chemainus River. The area was then uplifted and subjected to erosion, following which clastic sediments filled basins at the northeast and east end of the older rocks. Sedimentary rocks of the Nanaimo Series (Table 2.2) underlie part of the coastal area between Ladysmith and Crofton, and a large area around Duncan with northwestward extensions into Cowichan and Chemainus river valleys. They consist of conglomerate, sandstone, shales and coal deposits. The Nanaimo coalfield, one of the two major coalfields on the eastern coastal plain of Vancouver Island, lies between Lantzville to the north and Ladysmith in the south (Muller and Atchison, 1971).

For a detailed description of the geology of the Upper Cretaceous Nanaimo Group, including distribution and thickness, lithology, and age of the formations, the reader is referred to a study by Muller and Jeletzky (1970).

2 (iii) GLACIATION

The Nanaimo Lowland was overriden by ice during the Pleistocene, and the direction of ice movement is indicated by the form of many rock surfaces, some of the major indicators being striae, U-shaped valleys, lineations and stone trains (deposition of erratics) (Holland, 1964).

According to Holland (1964), the Pleistocene began with an accumulation of ice at several major centres and numerous subordinate ones. The distribution of present-day glaciers, to a degree, indicates where the major centres were located. Included among these was Vancouver Island.

The ice moved in a general south to southeast direction as indicated by striae, flutings, and stoss and lee topography (Fyles, 1955). Mountains in the area, such as Prevost, Tzuhalem, Erskine and Belcher, consisting of conglomerate and sandstone, present a gentle-sloping northwest flank, which rises to their summits and then drops off 150 to 180 metres (500-600 ft.) in natural cliffs. Boulders picked up by the ice as it crossed and moulded these mountains are now found as erratics at distances of 8 to 11 kilometres (5-7 miles) south of their bedrock source.

The highest mountains in the Cowichan-Chemainus area, Mt. Coronation and Mt. Hall, reach elevations of almost 1290 metres (4300 ft.) and were, therefore, covered by the ice sheet, which, on Vancouver Island extended to at least 1,650 metres (5,500 ft.). They also supported cirques carved by local glaciers (Armstrong *et al.*, 1965).

Armstrong *et al.* (1965), on the basis of stratigraphic studies between 1950 and 1963, supplemented by more than 130 radiocarbon dates, showed the need for defining several new geologic-climate units for the late Pleistocene in southwestern British Columbia. The last major glaciation has been defined as the Fraser glaciation, which included three glacial episodes, namely, the Evans Creek Stade, the Vashon Stade and the Sumas Stade (Table 2.3).

Radiocarbon dating of the Quaternary history of southern British Columbia, including the study area, has been documented by Dyck *et al.* (1965, 1966), and Fulton (1971). This period covers three major geologic-climatic episodes, Olympia Interglaciations, Fraser Glaciation and Postglacial, and the reader is referred to these studies for more detail.

Halstead (1968), in describing the Cowichan Ice Tongue in relation to age dating stated:

"Wood collected from subtill fluvial deposits in Cowichan Valley at Skutz Falls and Marie Canyon have been radiocarbon dated at 21,070 ± 290 yr. B.P. (G.S.C.-195) and 19,150 ± 250 yr. B.P. (G.S.C.-210) respectively (Dyck *et al.*, 1965). Therefore the Cowichan Ice Tongue moved into the Cowichan Valley less than 19,000 yr. B.P."

"Radiocarbon dates on shells collected from the silty, stony clays that blanket the Vashon drift indicate that the area was free of ice by 12,800 yr. B.P. (G.S.C.-418) (Dyck *et al.*, 1966)."

Table 2.3. Summary of Late Pleistocene events southeastern Vancouver Island (Halstead, 1958).

YEARS BEFORE PRESENT		GEOLOGIC-CLIMATIC UNIT Cowichan Valley	EVENT
			delta deposition Cowichan Bay
5,000			Cowichan River establishes glade
			retreat of seas
10,000		SUMAS STADE	deposition of ice-contact deltas, return to colder temperatures
	FRASER GLACIATION		marine invasion downmelting and wasting
15,000		VASHON STADE	Strait of Georgia ice covers the area
		EVANS CREEK STADE	Cowichan Ice Tongue Alpine glaciation
20,000		___?___?___?___?	
	OLYMPIC INTERGLACIATION		fluvial deposition

2 (iv) SURFICIAL GEOLOGY

Unconsolidated deposits exposed in sections of the sea cliffs indicate that the area has undergone repeated glaciations. These surficial deposits, at or near the surface, are related to the last glaciation, named the Fraser Glaciation (Armstrong *et al.*, 1965). They overlie the bedrock at high altitudes in places, and form fairly continuous cover below elevations of 900 metres (300 ft.).

Collectively, these unconsolidated deposits associated with the advance and wasting of the last major ice sheet can be referred to as Vashon drift, and include clay, silt, sand, gravel and mixtures of these which constitute a unit called till. Their distribution and stratigraphic relationships are shown on published maps and have been described in associated reports produced by the Geological Survey of Canada (see Bibliography). These unconsolidated deposits are the parent materials from which the soils were developed. Where thick enough, these deposits provide for the storage and movement of groundwater and are the source of much of the sediment load carried by the rivers. Their occurrence and distribution are significant in considering the ecology of the estuary environments.

Deltaic gravel deposits along the Cowichan River are a source of sand and gravel. These deposits fall within the jurisdiction of the North Cowichan municipality, which controls gravel operations through a soil removal by-law and zoning regulations for built-up areas. Details of borrow pits in the Chemainus-Duncan area may be found in a paper by Leaming (Geological Survey of Canada, 1968).

2 (v) DELTAIC ENVIRONMENTS

Mathews *et al.* (1970), discussing postglacial crustal movements in southwestern British Columbia, stated that, following the advance of the ice of the Sumas Stade of the Fraser Glaciation, "land again became mergent, and during the period 9,000 to 6,000 years ago sea level stood approximately 10 metres (33 ft.) below the present shore in some parts of the area."

Records of this low relative stand of the sea in postglacial time are found in many wave-cut benches developed in weak Pleistocene sediments, and extending approximately 10 metres (33 ft.) below the presumed level of modern wave erosion. Ladysmith Harbour at the northern limit of the study area is an example of a drowned postglacial river mouth.

According to Mathews *et al.* (1970), sea level shifts since 8,000 years ago appear to be dominantly eustatic, at which time isostatic movements were essentially complete. The shore has stood close to its present level for the last 5,500 years, during which time the Cowichan and Chemainus rivers have built sizeable deltas, with accumulations of clays, silt and peat.

Deposits related to modern sea level include spits, offshore bars and tidal lagoons. All these features are visible in the vicinity of the Chemainus River delta, where they have been formed by the interaction of Willy Island and the Shoal Islands, with the adjacent shoreline morphology and longshore transport of sediments.

1. LADYSMITH HARBOUR:

Along the southwestern shore of Ladysmith Harbour, mini-deltas are forming at the confluence of the Bush, Rocky, Holland and Stocking creeks as they discharge into the marine waters of the tidal inlet. Quantitative data relating to sediment distribution and types maintaining the deltas is unavailable, but some qualitative reports exist (Dobrocky SEATECH Ltd., 1974; Patterson, 1975).

In November, 1974, a photographic survey of the seabed in Ladysmith Harbour was carried out by Dobrocky SEATECH Ltd., for the Department of Lands, Forests and Water Resources. The objective was to provide an assessment of the accumulation of wood debris and logs on the bottom of the harbour. Results of the survey included a visual estimation of the substrate. A light to heavy accumulation of silt was observed on the wood debris covering the bottom at most stations.

Visual observations in the same month (November, 1974) by Fisheries Operations, Environment Canada, showed that, for the seven sites observed, silts and clays predominated in the intertidal zone at the head of the inlet, while off the mouth of the creeks, a wide variety of substrates existed, with varying amounts of coarse gravel, sand, silt and clay (Table 2.4 - Patterson, 1975).

2. CHEMAINUS:

Four major morphological units which characterize the Chemainus River delta, are the salt marsh, tidal flats, tidal channels and barrier islands. A description of these units and the basic mechanisms effecting sedimentation in each can be found in an environmental study of the Chemainus River delta by Laing (1975).

The following summary of the delta morphology and sediment types and distribution is taken from this work:

> "Constituting the nearly flat, most landward portion of the delta, the salt marsh is densely vegetated and dissected by meandering tidal and river channels, one to two metres deep.
>
> Thick growth of *Hardeum jubatum*, *Potentila anserina*, *Juncus balticus* and *Achillea millefolium* cover the upper part of the salt marsh. Algal mat

Table 2.4. Results of substrate sampling, Ladysmith Harbour (Patterson, 1975) (Percentages based on visual estimates).

Substrate	Bush Creek			Holland Creek middle intertidal	Area #4 Domans Log Dump Pacific Log Dump		Head of Harbour (adjacent to Sawmill)	East side of inlet
	Middle Intertidal 60 m. deep	Lower Intertidal to shore	Harbour area adjacent to Bush Creek		Supratidal	Upper-middle intertidal		
Gravel 2-4" (clean)	30%							
Gravel 2-4" (silted)			40	20	10			45
Gravel ¼-2" (clean)		5			30			
Gravel ¼-2" (silted)	10		50	50		20	10	
Sand	40	15		20	60	60		35
Silt/mud/clay	20	80	10	10		20	90	10
STATION NO.	S-1	S-2	S-3	S-4	S-5	S-5	S-6	S-7

populations are virtually non-existent and very little vertical accretion is taking place, as the only sediment supplied to this area is from waters of unusually high tides. Peat, in a layer a foot or more thick, underlies all of the higher salt marsh. Roughly wedge-shaped, this peat layer thins seaward. No marine fauna was noted.

Proceeding seaward, the effect of more frequent washing by high tide waters is clearly visible. Algal mats of the blue-green algae, *Oscillatoria* sp. begin to appear and the flowers and grasses of *Triglochin maritima, Carex lyngbyei* and *Rumex salicifolius* cf. take over as the dominant flora.

These flora are then rapidly replaced by *Salicornia virginica*, which becomes the sole plant along the seaward edge of the salt marsh. Here it grows first in dense fields, then gradually diminishes to scattered single plants on the outermost edge of the salt marsh. Along with the rise of *Salicornia virginica*, the blue-green algal populations increase until the whole of the sediment surface is covered by a mat up to an inch thick.

Probably the most important single mechanism of vertical accretion on both the salt marsh and the tidal flats is the work of the algal mats."

These trap sand and silt washed in by the tidal waters, which would not normally be deposited in the area. Sediment particles are fixed and entwined by the mucilaginous, filamentous algae which then grow over the trapped sediment and begin to trap new sediment.

A portion of the landward area of the salt marshes has been reclaimed by the construction of dykes built across both the marsh surface and the smaller tidal channels. The Esquimalt-Nanaimo railway spur line to the Crofton paper mill also crosses the marshes, and with the exception of a few small culverts installed to allow the freshwater creeks to discharge onto the tidal falts, the landward intrusion of seawater has been virtually cut off.

The most extensive morphological unit of the Chemainus delta intertidal zone is the area of tidal flats, extending from the seaward limit of the salt marshes to the break in slope of the delta platform, on the eastern side of the Shoal Islands. They are generally unvegetated, except for a thin mat of blue-green algae (*Oscillatoria* sp.) which covers most of the surface sediments. These are comprised mainly of sand, with some silt, and generally contain shell hash, and wood chips or bark. The flats are incised by numerous tidal channels averaging 0.3 to 1 metre (1 to 3 ft.) deep.

Two types of tidal channel can be distinguished on the Chemainus delta. The channels at the southern end have little freshwater influence, and appear to have cut deeper into the landward side of the salt marsh. They remain partially filled with stagnant sea water at all times. Where the Chemainus River enters the delta at the northern end, the channels carry both salt and fresh water, and drain a large area of both the marshland and the tidal flats.

Pebbles and coarse sand occur on the beds of all the major tidal and river channels and in beach deposits around all the islands. This material is derived from local erosion of the island bedrock and from the bed-load material transported by the Chemainus River. Silts and clays predominate in the areas of the salt marsh and immediately adjacent algal mats. They also cover the surface of the long sheltered bay on the southwest side of Willy Island.

A unique feature of the Chemainus delta is the Shoal Islands, a group of barrier islands which lie across the river mouth. The largest of these, Willy Island, is over 1.5 kilometres (1 mi.) long and almost 0.8 kilometres (0.5 mi.) wide. Erosion has divided the Shoal Islands into two parallel strings. The outer string is composed of the Cedar District shales, while the inner string exhibits the sandstones and conglomerates of the Protection and Extension formation, visible on Mainguy Island and the island to the south of it (Laing, 1975). These islands have provided protection from the currents of Stuart Channel, thus enabling the delta to build behind and around them.

3. COWICHAN:

Little is known about the types and distribution of the sediments of the Cowichan River delta. A few bottom sediment samples from Cowichan Bay and Satellite Channel have been collected and analyzed in connection with a series of quantitative benthic surveys made by scientists from the University of Victoria between 1965 and 1967 (Ellis, 1968).

A generalized distribution map of sediments in Cowichan Bay and Satellite Channel (Dunnill and Ellis, 1969) shows a marked progression in the Satellite Channel trough from very fine-grained sediments at the western end, near the mouth of the Cowichan River, to coarser-grained sediments in the east. Sediment grain size analyses show a mean silt-clay fraction of 95.4% in Cowichan Bay, 82.2% at the mouth of the bay, 40.3% at Satellite Channel Centre and only 29.9% at Satellite Channel East.

In the month of July, 1975, seven sediment cores were taken by the Pacific Biological Station at stations in the intertidal zone of the Cowichan estuary, for an analysis of heterotrophic activity (J. Sibert, pers. comm.). Unfortunately, grain size analyses of the sediments were not made. However, it is the intention of these scientists to include this parameter in future biological studies of the Cowichan estuarine ecology. Additional benthic sampling at the same stations was carried out by the Pacific Environment Institute in September, 1975, and the results, as yet unpublished, will include sediment data (C. D. Levings, pers. comm.).

2 (vi) SOILS

Soils of the southeastern sector of Vancouver Island, including the Chemainus-Cowichan area, have been well documented by the Federal Department of Agriculture in co-operation with the University of British Columbia and the British Columbia Department of Agriculture (Day, Farstad and Laird, 1959), and more recently by the British Columbia Forest Service (Keser and St. Pierre, 1973).

The soils of this region are those classified under the Lower Nanaimo Lowlands zone. Soils representing the Podzolic, Brunisolic, Regosolic, Gleysolic and Organic orders are common. Land forms on Vancouver Island have resulted primarily from the recent glaciation which covered the entire island and ended 10,000 to 12,000 years ago. Consequently, soil parent materials are mainly of glacial origin, and consist of tills and glacio-fluvial materials, as well as marine deposits, fluvial Quadra sediments, and organic and recent fluvial deposits.

The most prominent arable soils are the Fairbridge silt loams which predominate on the west side of Cowichan Bay and in the area to the north and west of Duncan, and the Chemainus silt loam which is visible in the deltaic environment of the Cowichan and Chemainus rivers. The Fairbridge soils are rated among the most desirable for agriculture on Vancouver Island, being well drained, gently sloping and having few or no stones. Most of the Chemainus soils are also of first-class capability for agriculture, though scattered pockets with sandy textures are rated slightly lower than the silt loams. A complete description of the soils indigenous to the study area can be found in Appendix 2.1.

Engineering properties of soils in the Duncan area have been analysed in connection with a proposal for dyke construction on the Cowichan River, approximately two miles upstream of the mouth (Underwood, McLellan and Associates Ltd., 1974). Included in the proposal are the results of the analyses of the soil profiles, grain size, Atterberg limits and moisture content, for seventeen test pits, by R.M. Hardy and Associates Ltd. (1974).

3. CLIMATOLOGY

3 (i) GENERAL DESCRIPTION

The Cowichan and Chemainus River estuaries in common with all other estuaries on the southeast coast of Vancouver Island, experience a modified maritime climate, also referred to as a cool summer mediterranean climate in the Koppen classification system. Since they are in the rain shadow from the mountains of Vancouver Island and the Olympics and are well protected by the Saanich Peninsula and Gulf Islands, they have a drier and generally more pleasant climate than most mainland estuaries.

Both estuaries exhibit the dry summer-wet winter pattern of the British Columbia coast. Prevailing winds are from the east to southeast, although of somewhat lower strength than those over the open Strait of Georgia, due to the protection offered by the Gulf Islands. Mean annual precipitation is less than 1,270 millimetres (50 in.), bright sunshine averages somewhat above 1,800 hours annually (1941-1970 records), and the annual frost-free period averages close to 200 days.

3 (ii) CLIMATOLOGICAL STATIONS

Long-term temperature and precipitation records are available from stations at Cowichan Bay and Duncan, and precipitation data only from Chemainus and Crofton. Records of the hours of sunshine have been kept at the Cowichan Bay station since July 1933. An anemometer, recording both wind speed and direction, was operated in Chemainus Harbour from May, 1971 to May, 1972. The short-term records obtained reveal the main wind patterns that prevail on Chemainus Harbour. No wind data are available for the Cowichan estuary. Records from the Victoria International Airport provide some information on the general wind pattern of the area, though winds on the estuary may vary considerably from those recorded at the airport. A comparison of the data records from Chemainus Harbour and Victoria International Airport (Figures 3.2 and 3.3) shows the need for onsite monitoring to establish local conditions.

Tables 3.1 and 3.2 summarize the available weather data and climatic records for the weather stations in the Cowichan-Chemainus area (Figure 3.1).

3 (iii) PRECIPITATION

The Cowichan estuary shows the marked wet winter-dry summer regime of the British Columbia coast. The station at Cowichan Bay records, on the average, less than 25 millimetres (1 in.) of precipitation in July, but over 150 millimetres (6 in.) in each of December and January. The heaviest 24-hour rainfall, for the 30-year period, 1941 to 1971, was recorded in the month of January at 97 millimetres (3.80 in.) (Can. Department of the Environment, 1971).

The mean annual precipitation is 961 millimetres (37.85 in.) making the area one of the driest on the coast. Snowfall averages about 56 centimetres (22 in.) per winter. The greatest snowfall ever recorded in one day was 50.8 centimetres (20.0 in.) which occurred in the month of February. Precipitation occurs on less than half the days of the year (157 days on the average). See tables 3.2 and 3.3 for detailed 1941-1970 precipitation normals for Cowichan Bay.

Mean annual precipitation values for the Chemainus River estuary can be approximated using records from Chemainus to the north and Crofton to the south. On this basis, one would estimate a value over the estuary of 1,100 millimetres, which reflects the local trend toward increasing precipitation as one moves northward from Cowichan Bay. Mean annual snowfall on the

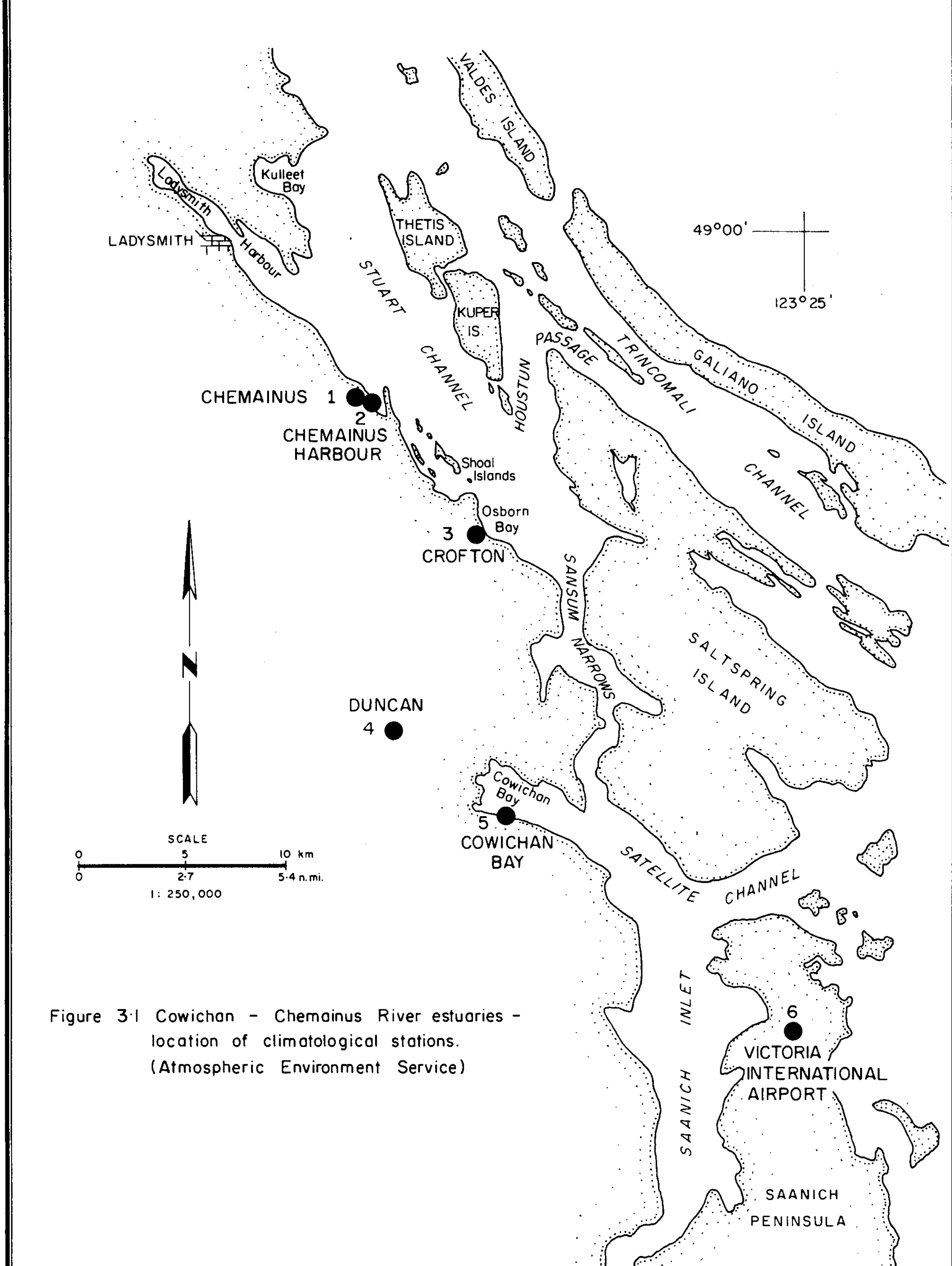


Figure 3·1 Cowichan – Chemainus River estuaries – location of climatological stations. (Atmospheric Environment Service)

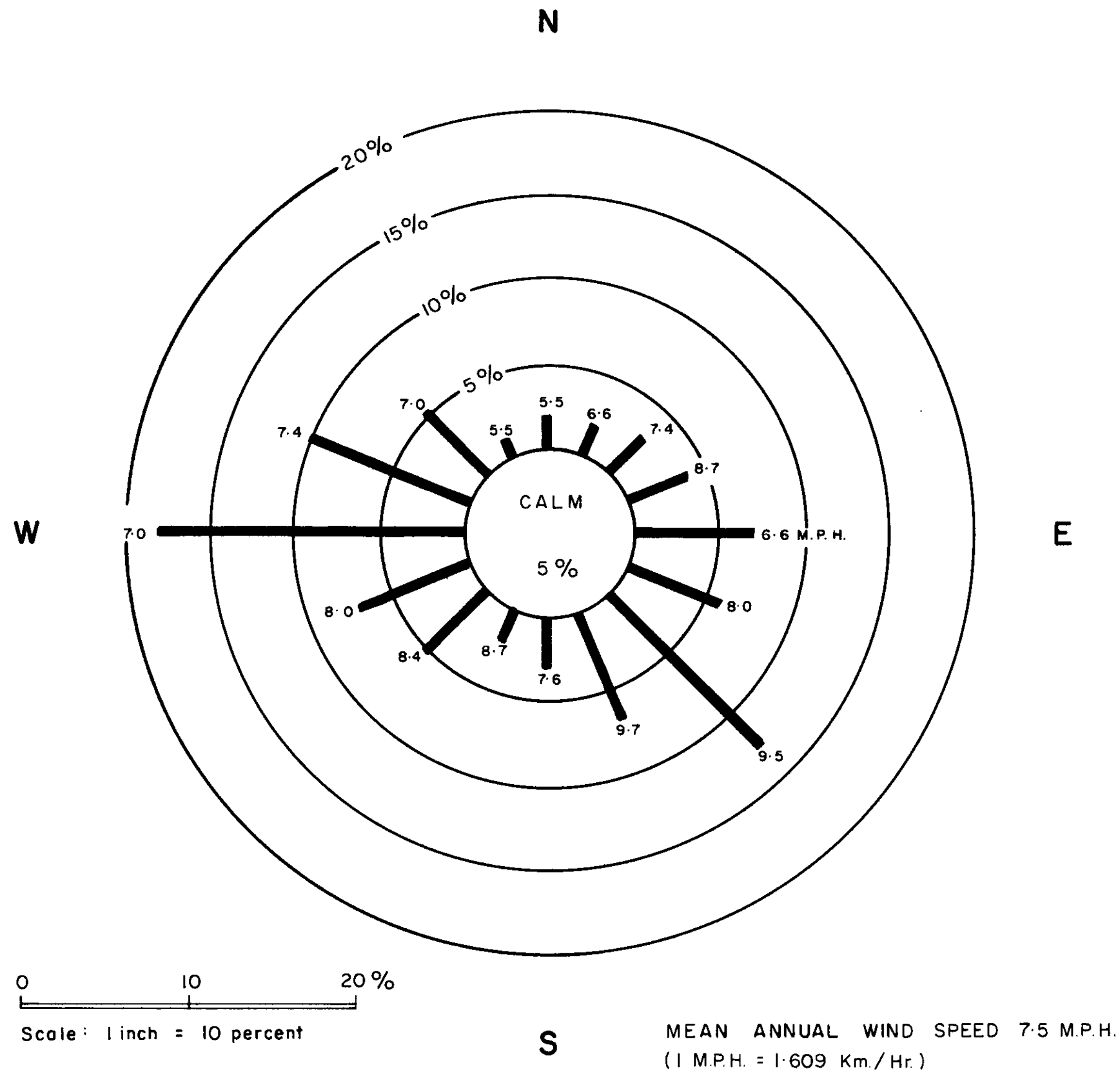
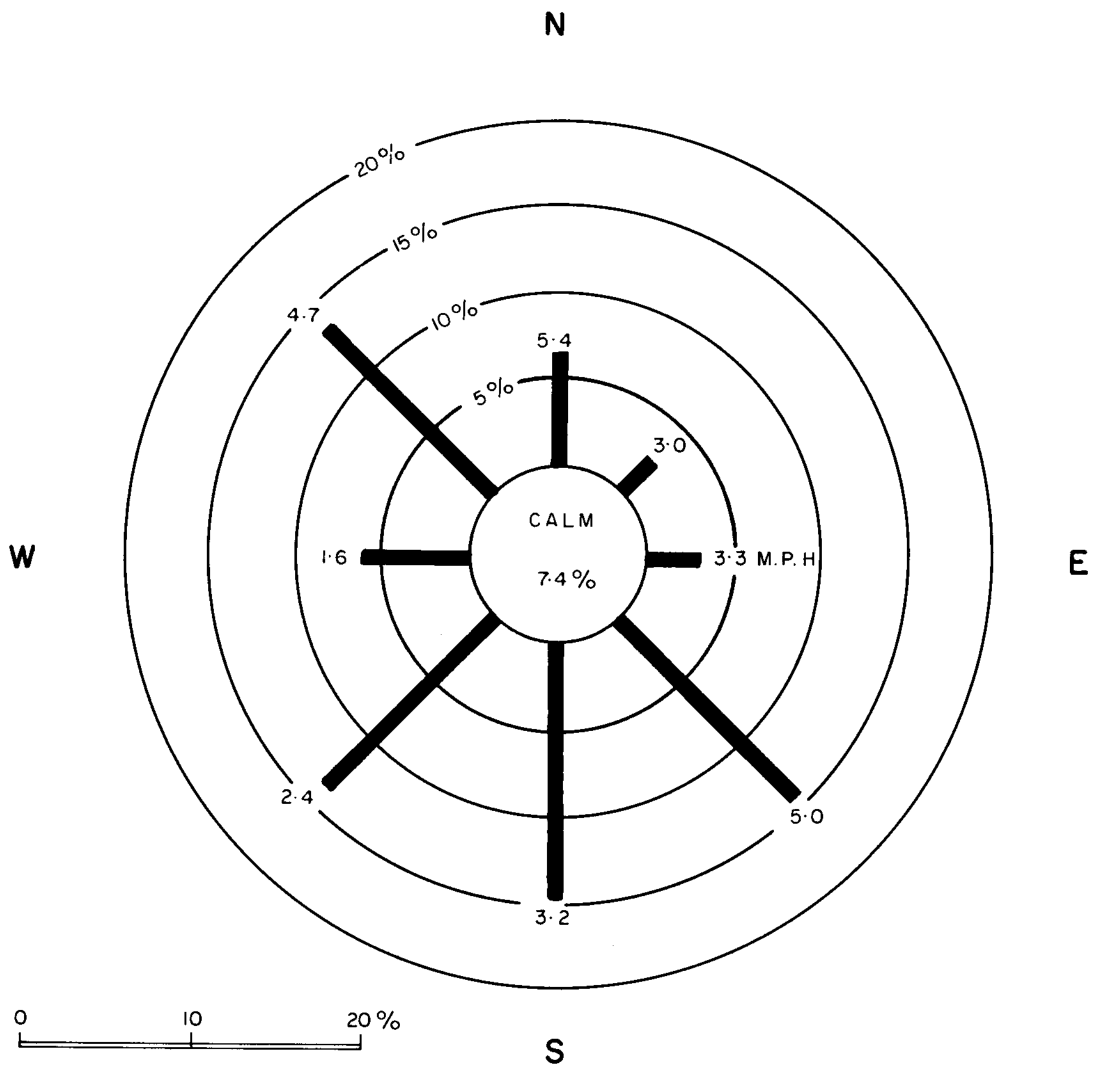


Figure 3·2 Victoria International Airport – Wind Rose Percentage Frequency and Mean Wind Speed by Direction – 1955 to 1972. (Atmospheric Environment Service)



MEAN ANNUAL WIND SPEED 3·6 M.P.H.
(1 M.P.H. = 1·609 Km./Hr.)

Figure 3·3 Chemainus Harbour B. C. – Wind Rose
Percentage Frequency and Mean Wind
Speed by Direction – May 1971 to Dec. 1972.
(Atmospheric Environment Service)

Table 3.1. Weather data for the Cowichan-Chemainus area, Vancouver Island, B.C., available from Atmospheric Environment Service (see also Figure 3.1).

<u>Chemainus</u> 48°56'N 123°43'W 70' asl

1.1. Precipitation January 1919 - Continuing

<u>Chemainus Harbour</u> 48°56'N 123°42'W 0' asl

2.1. Wind May 1971 - Continuing

<u>Crofton</u> 48°49'N 123°40'W 100' asl

3.1. Precipitation January 1921 - December 1954
September 1967 - December 1968

<u>Duncan</u> 48°47'N 123°43'W 28' asl

4.1. Temperature and Precipitation January 1926 - June 1962.

<u>Cowichan Bay</u> 48°42'N 123°37'W 33' asl

5.1. Temperature and Precipitation October 1913 - September 1918, January 1924 - Continuing

5.2. Sunshine July 1933 - July 1936
April 1937 - June 1937
July 1938 - Continuing

<u>Victoria International Airport</u> 48°39'N 123°26'W 67' asl

6.1. Wind June 1941 - July 1964
Continuing from hourly reports

Table 3.2. Summary of climatic records for the Cowichan-Chemainus area, Vancouver Island, B.C. (Atmospheric Environment Service records 1941 - 1970).

1. Chemainus

1.1. Precipitation

Mean annual total precipitation	1176 mm
Mean annual rainfall	1114 mm
Mean annual snowfall	61.5 cm

1.2. Annual Number of Days with:

Measurable precipitation	134 days

1.3. Average Annual Hours of Bright Sunshine 1800-1850 hours (estimated)

2. Chemainus Harbour

2.1. Wind

Prevailing wind direction by hours	South, Southeast
Prevailing wind direction by miles	Southeast
Mean annual wind speed	5.8 km/hr

3. Crofton

3.1. Precipitation

Mean annual total precipitation	1029 mm
Mean annual rainfall	963 mm
Mean annual snowfall	65.5 cm

3.2. Annual Number of Days with:

Measurable precipitation	163 days

Table 3.2 (cont'd).

4. Duncan

4.1. Temperature

Mean temperature - Annual	10.2°C
Mean temperature - January	2.1°C
Mean temperature - July	18.6°C
Extreme maximum temperature	41.1°C
Extreme minimum temperature	-20.6°C

4.2. Precipitation

Mean annual total precipitation	1042 mm
Mean annual rainfall	967 mm
Mean annual snowfall	74.9 cm

4.3. Annual Number of Days with:

Frost	85 days
Measurable precipitation	143 days

4.4. Frost-Free Period

April 28 - October 13	167 days

5. Cowichan Bay

5.1. Temperature

Mean temperature - Annual	9.6°C
Mean temperature - January	2.2°C
Mean temperature - July	17.3°C
Extreme maximum temperature	35.6°C
Extreme minimum temperature	-16.1°C

5.2. Precipitation

Mean annual total precipitation	961 mm
Mean annual rainfall	906 mm
Mean annual snowfall	56.6 cm

Table 3.2. (cont'd).

5.3. Annual Number of Days with:

Frost	54 days
Measurable precipitation	157 days

5.4. Frost-Free Period

April 6 - November 11	218 days

5.5. Average Annual Hours of Bright Sunshine 1,803 hours

6. Victoria International Airport

6.1. Wind

Prevailing wind direction by hours	West
Prevailing wind direction by miles	Southeast
Mean annual wind speed	12.1 km/hr

6.2. Annual Number of Days with:

Thunder	2.6 days

6.3. Cloud Cover

Mean annual cloud cover	6.4 tenths
Month with lowest cloud cover - July	4.2 tenths
Month with highest cloud cover - January	7.9 tenths

6.4. Fog - Visibility Less than 5/8 of a Mile

Annual number of days with fog	26.1 days
Month with greatest average - October	5.3 days
Month with least average - May, June	0.5 days

Chemainus estuary is also believed to be slightly greater than that at Cowichan Bay, and is probably close to the 61 centimetres (24 in.) recorded at Chemainus. Measureable snowfall occurs there an average of 8 days per year. Precipitation occurs on 134 days per year.

The dry summer-wet winter pattern of the British Columbia coast described previously also applies equally to the Chemainus River estuary. Records from Chemainus and Crofton would indicate that, while the estuary receives less than 25 millimetres (1 in.) of precipitation in July, it receives over 150 millimetres (6 in.) in each of the months of November, December and January. The heaviest snowfall occurs in January and is estimated to average just less than 30 centimetres during that month over the estuary. The greatest 24-hour rainfall recorded at Chemainus is very close to that at Cowichan Bay over a similar period of time (about 50 years). The greatest one-day snowfall recorded during the 30-year period, 1941 to 1971, was 70 centimetres (27.5 in.), and occurred during the month of February (Can. Department of the Environment, 1971).

3 (iv) TEMPERATURE

The moderating effect of Cowichan Bay can be seen in the range of temperatures that prevail at the estuary. The annual mean daily temperature is 9.6°C (49.2°F), with the extremes ranging from a winter low of -16.1°C (3°F) to a summer high of 35.6°C (96°F) (Can. Department of the Environment, 1971). Frost has never been recorded in June, July, August or September, and only rarely in May and October. The average length of the frost-free period (above 0°C) is 218 days, occurring between April 6 and November 11.

Lacking specific measurements of temperature on the Chemainus estuary, it can be assumed that the temperatures will be very similar to those recorded on the Cowichan estuary and a little more moderate than those at Duncan, which is inland away from the moderating influence of the ocean.

3 (v) WIND

As previously stated, the closest records available for estimating the winds over the Cowichan estuary are from Victoria International Airport (Figure 3.2), although they are not fully representative of the estuary winds. It is assumed that east to southeast storm winds prevail, although of somewhat lower strength than those over the open Strait of Georgia. Land-sea breezes are expected to be very frequent in summer introducing a certain frequency of east-west winds to the distribution over Cowichan Bay.

Wind records for Chemainus Harbour, obtained by Western Canada Hydraulics Limited 1971 and 1972, provide the only source of available data for the Chemainus area. Though the data may be slightly influenced by the higher terrain of the surrounding area, the station was close enough to be reprerstative of the estuary. The wind rose (Figure 3.3), based on 20 months of data, exhibits a prevailing southerly wind (southeast, south to southwest). Northwest winds occur next in frequency. The mean wind speed is only 5.8 kilometres per hour (3.6 mph), while the strongest recorded hourly wind reached 40 kilometres per hour (25 mph) from the northwest. Periods of calm were recorded about 7.5% of the time.

3 (vi) OTHER PARAMETERS

Direct measurements of other parameters, such as humidity, evaporation, radiation, cloud cover and fog, are not available for the study area. However, these would not vary greatly from recorded values at Victoria International Airport.

Sunshine records have been kept at Cowichan Bay since 1933, where an average of 1803 hours of bright sunshine are measured annually. Comparable figures are over 2,100 hours at Victoria (Gonzales) to the south, and just over 1,000 hours at Prince Rupert on the north coast.

3 (vii) AIR POLLUTION POTENTIAL

No specific measurements of wind speed or inversion frequency have been made at either the Cowichan or Chemainus estuaries. However, consideration of the general wind and temperature regimes of southeastern Vancouver Island along with the short period of wind records for Chemainus Harbour (May, 1971 to May, 1972) allows one to infer the basic factors related to the dispersion of air pollutants in the area.

The northwest to southeast orientation of the mountains of Vancouver Island and of the Gulf Islands, coupled with the east to west orientation of major river valleys such as that of the Cowichan, exerts strong topographic control on the low-level wind flow in the area. This topography channels storm winds up and down the coast, and exerts an influence on the land breeze-sea breeze circulations which develop frequently in the area. As a result, for example, a somewhat higher frequency of east-west winds would be expected in Cowichan Bay than observed at Chemainus Harbour, where southerly and northwesterly winds dominate (Figure 3.3). Mean wind speeds in the area are very light and periods of calm frequent. Figures for Chemainus Harbour are 5.8 kilometres per hour (3.6 mph) and 7.4 per cent, respectively. This suggests a high frequency of days with insufficient air movement to achieve horizontal dispersal of air pollutants.

Although no measurements of inversion frequencies have been made on the estuaries involved, regional information suggests a high frequency of overnight and early morning inversions year-round with quite frequent occurrence through the day as well. These conditions indicate the potential for frequent build-up of local pollutant concentrations. However, during much of the year, the relatively high frequency of Pacific storms tends to prevent serious build-ups of air pollutants, thus minimizing the chance of lengthy periods of air pollution.

4. HYDROLOGY AND WATER QUALITY

4 (i) HYDROLOGY

The Cowichan, Koksilah and Chemainus rivers and their tributaries discharge into the Cowichan-Chemainus estuary and exhibit the unique characteristics of Vancouver Island and coastal river systems. That is to say, the maximum flows occur during the winter months as the result of rainfall, instead of during the snow-melt generated spring freshet period of May through July, which is typical of rivers draining interior mainland basins. These characteristics of runoff and river discharge have been documented by MacKay (1966).

The correlation of climate to runoff shows that on Vancouver Island the major precipitation falls during the winter months, some in the form of snow at higher elevations. Precipitation and runoff records indicate that snow-melt is not the predominant hydrologic factor, as in many areas of the mainland, but rather it is precipitation in the form of rain.

At the northern limit of the study area, four small creeks, namely Bush, Rocky, Holland and Stocking creeks discharge into Ladysmith Harbour. The discharges of these creeks and the local inflows to the Cowichan-Chemainus estuary, not included in the three main river basins, are not measured by the Water Survey of Canada.

It should be noted that all discharges measured by the Water Survey of Canada are recorded in cubic feet per second (cfs), and conversions to cubic metres per second (cms) are given in the interest of uniformity of giving metric units wherever possible in this report.

1. COWICHAN AND KOKSILAH RIVERS:

The Cowichan River originates in Cowichan Lake at an elevation of 159 metres (530 feet), flows eastward for about 47 kilometres (29 mi.) and discharges into Cowichan Bay near Duncan, (Figure 1.2). With its main tributaries, Somenos and Quamichan creeks, it drains an area of approximately 90,000 hectares (350 sq. mi.) of generally hilly and mountainous topography, reaching elevations of 900 metres (3,000 ft.) in the vicinity of Cowichan Lake.

The longest period of discharge records for the Cowichan River is available from the flow-gauging station at Cowichan Lake, where records have been kept from January, 1913, to January, 1919, and from September, 1940, to date. Other stations on the Cowichan River system are located on the Cowichan River near Duncan, Somenos Creek near Duncan, Quamichan Creek at the outlet of Quamichan Lake, and on the Koksilah River at Cowichan Station. A complete list of streamflow stations for the Cowichan-Chemainus River systems, showing their location and period of record, can be found in Appendix 4.1 (Water Survey of Canada, 1973).

The long-term (40 years) average of the mean monthly flow at Cowichan Lake, Station No. 08HA002, is 45 cubic metres per second (1590 cfs). Figure 4.1 shows a hydrograph of streamflow data for a typical year at this station. The largest mean annual flow recorded to date was 60 cms (2110 cfs) for the year 1968 (Water Survey of Canada). Other record flow data are listed in Table 4.1. Recorded flows for Station No. 08HA011, near Duncan, are generally slightly higher than those obtained at Cowichan Lake.

During the winter months, discharge reaches a maximum, and runoff in the mountainous upper reaches of the river basin is probably 100 per cent, although some precipitation would fall

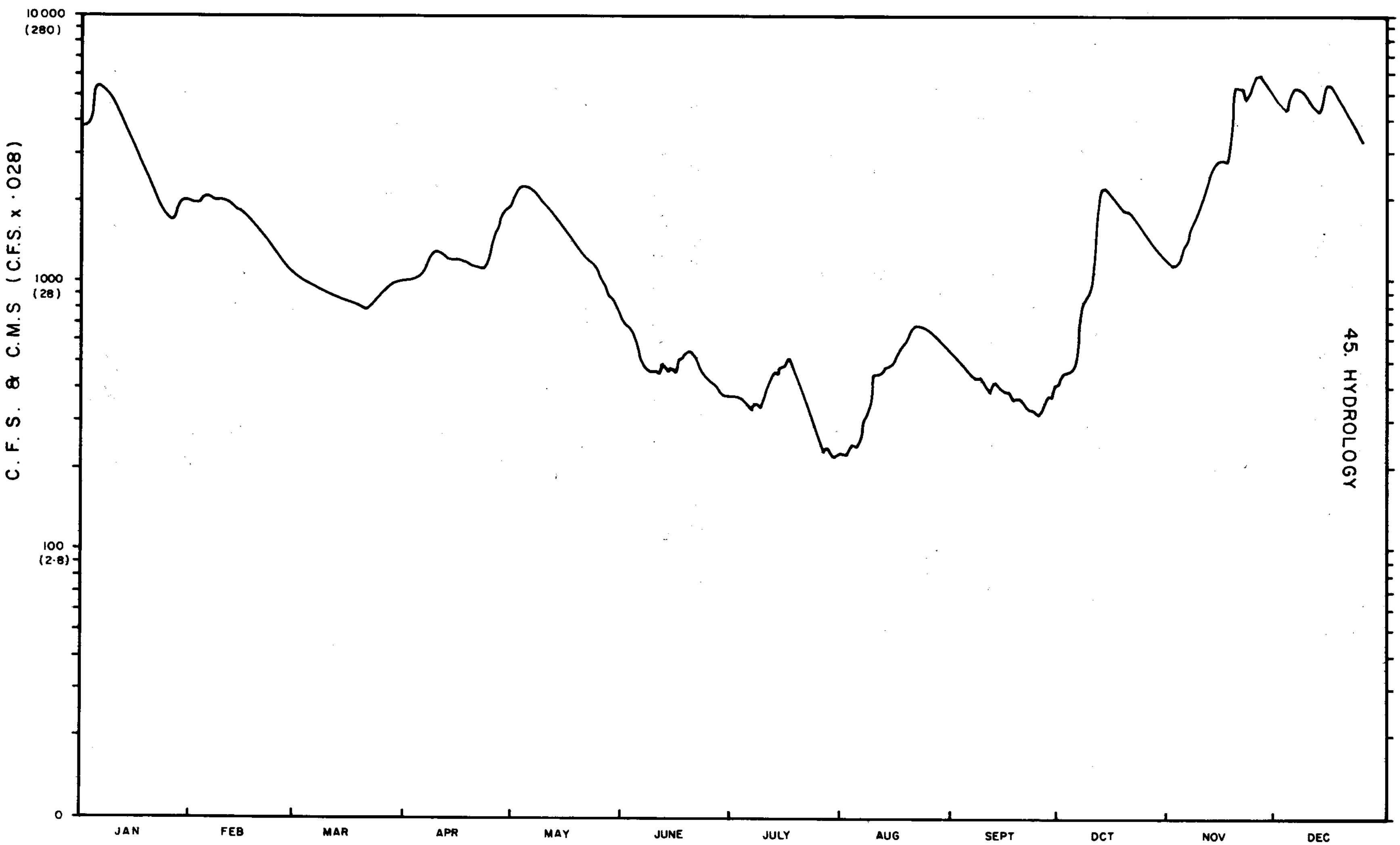


Figure 4.1 Discharge hydrograph for 1962, Cowichan River at Lake Cowichan (Sta. 08HA002)

Table 4.1. Cowichan river flow records measured at Lake Cowichan (Water Survey of Canada, 1973).*

	cms	cfs	Date
maximum daily flow	325	11,500	Jan. 21, 1968
minimum peak daily flow	94	3,330	Dec. 23, 1942
minimum daily flow	0.4	15	Sept. 10, 1944
largest mean annual flow	60	2,110	1968
smallest mean annual flow	25	898	1941
maximum mean monthly flow	181	6,400	Dec., 1964
minimum mean monthly flow	1.1	40.2	Sept., 1944

Table 4.2. Chemainus river flow records measured near Westholme (Water Survey of Canada, 1973).*

	cms	cfs	Date
maximum daily flow	455	16,100	Jan. 19, 1968
minimum peak daily flow	104	3,680	Dec. 17, 1969
minimum daily flow	0.1	2.5	Dec. 2, 1956
largest mean annual flow	25	897	1968
smallest mean annual flow	13	461	1957
maximum mean monthly flow	99	3,500	Jan., 1968
minimum mean monthly flow	0.3	12.1	Aug., 1958

* all discharges measured by the Water Survey of Canada are recorded in cubic feet per second (cfs).

as snow and be temporarily retained in snowfields (Halstead, 1967). Freezing conditions are sometimes experienced, but the occurrence of ice in the lake and river is said to be rare. Based on sixty-nine observations between 1949 and 1969, water temperatures for the Cowichan River ranged from 0°C (32°F) to 18°C (64°F) (Water Survey of Canada, 1973).

During the summer months, runoff reaches a minimum and the base flow of the river is derived from groundwater. There is, therefore, a strong correlation between the amount of precipitation, the amount of runoff, and the river flows recorded for the system. These are of considerable interest to the biologist, since the biological conditions in the river, including the movement of fishes, are affected by the volume of flow.

The Cowichan River is characterized by four main changes in slope. In the upper reaches, between Cowichan Lake and Skutz Falls, the gradient is in the order of 1.15 metres per kilometre (6.2 ft. per mile). Between Skutz Falls and Holt Creek, a distance of 14.5 kilometres (9 mi.), the steepest gradients are found, and in places reach almost 8 metres per kilometre (40 ft. per mile). Skutz Falls has a total drop of 5.4 metres (18 ft.) in a run of 90 metres (295 ft.). Downstream between Holt Creek and Somenos Creek, a distance of 10 kilometres (6 mi.), the river becomes less steep, with gradients again in the order of 1.15 metres per kilometre (6.2 ft. per mile). The gradient then becomes almost flat between Cowichan Bay and the junction of Somenos Creek, 3.2 kilometres (2 mi.) upstream from the river mouth.

The lower reaches of the river are subject to tidal fluctuations which have a record extreme of 1.8 metres (6 ft.) above mean tide, and have affected river levels as far as Somenos Creek. The major portion of the Cowichan-Koksilah river lowlands, that is, the area below the Esquimalt and Nanaimo Railway bridges, is subject to flooding during peak winter flows, and some areas are subject to tidal flooding. Some dyking has been carried out, but protection is generally inadequate. Flood control proposals are reviewed in the Land Use Section of this report.

The Cowichan River is regulated at the outlet of Cowichan Lake, while further downstream diversions for water supply to the town of Crofton are made. B.C. Forest Products Ltd. (Crofton pulp mill) also uses water from the Cowichan River and must regulate its water requirements to conform with the Cowichan Lake storage 'provisional rule curve' established in 1970 by the Water Resources Service of the British Columbia Department of Lands, Forests, and Water Resources.

The Koksilah River, typical of intermediate-sized streams on the east coast of Vancouver Island, drains an area of 30,000 hectares (114 sq. mi.), rising to an elevation of more than 600 metres (2,000 ft.) on the slopes of Waterloo Mountain. Lacking a lake source, the river is subject to flash floods, sedimentation problems and low summer flows. Marble Falls, located 16 kilometres (10 mi.) above the estuary, limits the distribution of anadromous salmon and trout to the lower portion of the river and to tributaries entering the river below the Falls, (Lill, Marshall and Hooton, 1975).

Streamflow records for the Koksilah River were first obtained in 1914. Between 1914 and 1917 there are only two complete years of data (1915 and 1916). At this time, continuous recording of streamflow was discontinued, and was not resumed until 1954. The mean annual discharge for the period 1960 to 1973 was 10 cubic metres per second (356 cfs), measured at Cowichan Station. The largest monthly flow prior to 1973 was 46 cubic metres per second (1630 cfs) recorded in December, 1966 (Water Survey of Canada, 1973).

2. CHEMAINUS RIVER:

The Chemainus River originates on the eastern slopes of Mt. Landalt, flows eastward for some 53 kilometres (33 mi.) and discharges into Stuart Channel just north of Crofton. The river is fed by numerous small creeks, which, when combined with the main stream, drain an area of approximately 37,800 hectares (146 sq. mi.).

The long-term average (20 years) for the mean monthly flow measured near Westholme, approximately 1.6 kilometres (1 mi.) upstream of the river mouth, is 19 cms (670 cfs) (Water Survey of Canada, 1973). Figure 4.2 shows a hydrograph of the streamflow data for a typical year, at this station. The largest mean annual flow recorded to date was 25 cms (897 cfs) in 1968, and the smallest was 13 cms (461 cfs) in 1957. Other record flow data are listed in Table 4.2. Temperatures for the Chemainus River, based on thirty-eight observations between 1954 and 1970, ranged from $0^{o}C$ ($32^{o}F$) to $21.5^{o}C$ ($71^{o}F$).

The river gradient in the lower reaches averages 1.5 metres in 300 metres (5 ft. in 1000 ft.), rising sharply to 30 metres in 300 metres (100 ft. in 1000 ft.) through the Copper Canyon area. In the upper reaches, the river flows through more gently sloping terrain with an average gradient of 3.6 metres in 300 metres (12 ft. in 1000 ft.).

An obstruction located 12 kilometres (7.5 mi.) upstream of the mouth constitutes an almost complete barrier to salmon, but is negotiable by steelhead. Stream substrate in the canyons is mainly boulders and bedrock. The lower river is characterized by extensive gravel areas highly suited to salmonid spawning (Hooton, 1975).

4 (ii) WATER QUALITY

Water quality data are available for nine years (between 1954 and 1965) for Stuart Channel and Osborn Bay (Waldichuk,

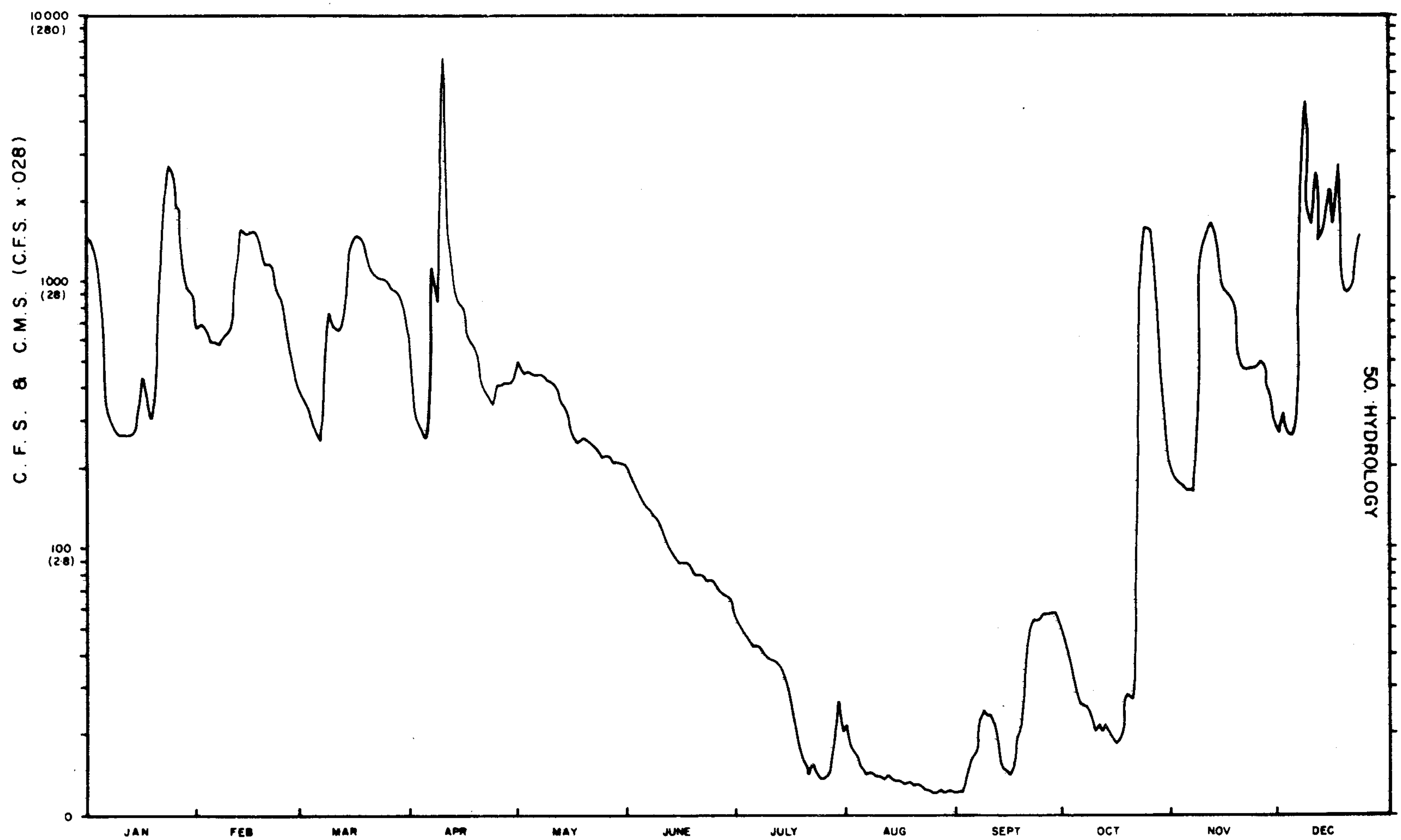


Figure 4.2 Discharge hydrograph for 1970, Chemainus River near Westholme (Sta. 08HA001)

et al., 1968). For the northern and southern limits of the estuary, that is, Ladysmith Harbour and Cowichan Bay, data are sparse.

Data collected during the period 1968 to 1971 for stations on the Cowichan River near Duncan and the Chemainus River near Westholme are available from the Water Quality Branch, Inland Waters Directorate. A student project carried out in the summer of 1971 for the Inland Waters Directorate provides additional data for stations on the Cowichan River at Cowichan Lake, Koksilah River at Cowichan Station, Bings Creek near Duncan and Bonsall Creek near Highway #1.

The following is a summary of findings from a short water quality survey of the Cowichan, Nanaimo and Campbell rivers in 1973, by the Inland Waters Directorate.

> "The degree to which single grab samples taken at one point are representative of water quality over two- and five-day periods in short reaches of three rivers on Vancouver Island, B.C., had been assessed by the Water Quality Branch. Spatial variations, i.e. differences upstream and downstream as well as lateral, and temporal variations were measured at three stations on the Nanaimo, Cowichan and Campbell rivers. These rivers had been monitored over several years on a monthly and quarterly basis.
>
> Although spatial variance was generally exceeded by the temporal variance, measurements of total inorganic carbon and zinc exhibited spatial variation in the Nanaimo River as did Kjeldahl nitrogen in the Cowichan River.
>
> In this study, temporal variation with regard to total phosphate and total inorganic carbon concentrations was significant in both the Nanaimo and the Cowichan

rivers. On the Cowichan River all parameters measured showed significant temporal variation with the exception of zinc. These variances were found to relate to changes in flow over the study period. Table 4.3 indicates mean values and 95% confidence levels for a variety of measured parameters in the Cowichan River."

Taylor (1969) reviewed the physical and chemical aspects of the Cowichan River. He stated that "In August, 1949 the Department of Mines and Technical Surveys listed the colour value of the Cowichan River at 5 which from 'Standard Methods', indicates between 51 and 100 ppm of substances in solution. The river could be classified as nearly clear".

Taylor (1969) concluded from results of work conducted on Cowichan Lake (Carl, 1937) and from isolated data collected on the Cowichan River during the period 1949 to 1969, that the river was slightly alkaline, well supplied with oxygen and had a TDS (total dissolved solids) range between 40 and 70 ppm. This wide range of values reflected the techniques used to make the calculations, and appeared to be substantially higher than the calculated values for a station at Duncan for the period 1968 to 1971, where TDS values ranged from 26 to 33 ppm (Environment Canada, 1974a).

A pH survey done in December, 1964, recorded values ranging from 7.2 to 7.5, between Cowichan Lake and Cowichan Bay (Taylor, 1969). These values agree closely with those recorded by the Inland Water Directorate from 1968 to 1971, when pH values ranged from 7.1 to 7.8 (Environment Canada, 1974a).

In 1973, the Environment Protection Service conducted a shellfish-growing-water sanitary survey of Cowichan Bay (Low and Tevendale, 1973). Bacteriological, chemical and physical data were collected for a series of stations in the intertidal zone of Cowichan Bay, and in the offshore area of Cowichan Bay, Genoa

Table 4.3. Grab sample verification of Cowichan River samples (Inland Waters Directorate, 1973).

	Two-Day Mean ± 2 S.D. (mg/1): Station Above and Station Below	Routine Station
Cu	.0008	.0013
	± .0017	± .0020
Fe	.289	.3688
	± .489	± .6992
Zn	.0008	.0010
	± .0021	± .0017
K-N	.0718	.0645
	± .0276	± .0042
N	.0873	.0870
	± .0672	± .0608
P. Tot.	.0500	.0690
	± .0716	± .1373
TIC	4.22	4.33
	± .30	± .51
TOC	2.95	3.02
	± .89	± 1.43

Bay, Sansum Narrows and Satellite Channel. Dissolved oxygen concentrations in samples collected on December 6, 1973, at stations at the mouth of Cowichan River and Tzouhalem Road, on the south and north arms, were in the range of 10 to 12 mg/l, while concentrations of copper, lead, zinc and cadmium were each less than 0.03 mg/l.

Early studies of water quality in Stuart Channel and Osborn Bay were carried out preparatory to waste disposal from the pulp mill at Crofton (Waldichuk, 1954, 1955, 1958). Studies continued after the pulp mill went into operation in 1957, and between 1954 and 1965 eleven surveys were carried out with observations made of salinity, temperature, dissolved oxygen, pH, and alkalinity.

In January, 1973, a two-day water quality survey at the marine receiving area of the Crofton mill outfalls was carried out for B.C. Forest Products Limited (Ellis, 1973). Surface water temperatures ranged from $6^{\circ}C$ to $7^{\circ}C$, with dissolved oxygen values in the order of 5.1 to 5.3 mg/l, and pH readings of about 7.5. Dissolved oxygen calibrations were not satisfactory, and the above values must be treated as relative arbitrary units (Ellis, 1973).

Summer data were obtained by Waldichuk *et al.* (1968). Data obtained in the vicinity of the mill outfall between July, 1957 and May, 1965, showed surface water temperatures ranging from $14^{\circ}C$ to $18^{\circ}C$, dissolved oxygen concentrations between 6.8 and 12.6 mg/l, and pH readings from 7.4 to 8.4. For complete details of the stations covered and observations made, the reader is referred to the original report.

Water quality measurements were made in Chemainus Bay by the Environmental Protection Service, in conjunction with surveys conducted in August, 1968, and July, 1969, following the herring kill in the vicinity of the MacMillan Bloedel Limited sawmill complex in November, 1967 (Kussat, 1969, 1970). These surveys are discussed in more detail in the Pollution Section of this report.

The following is a brief summary of the dissolved oxygen content and water temperature of the surface water at 12 stations in Chemainus Bay (Kussat, 1968, 1970). The results of the water quality tests in the 1970 survey would seem to indicate an improvement over the conditions observed in previous years.

	Depth m	Diss. O_2 mg/l	Temp. ^{o}C
August, 1968			
average of 10 stations	0	6.7	22.5
range		4.9-8.0	20.7-23.4
July, 1970			
average of 8 stations	0	8.6	20.2
range		6.0-11.5	19.1-22.2

However, it should be noted that, while spontaneous surveys such as the aforementioned provide some data relating to the environmental quality of the area concerned, these data may not be representative of mean conditions on a diurnal and seasonal basis. The need for environmental monitoring on a regular basis is becoming increasingly evident, if baseline data are to be acquired for high priority areas, that is, where development is planned for the immediate future.

5. OCEANOGRAPHY

5 (i) INTRODUCTION

Little oceanographic work has been conducted on the Cowichan and Chemainus estuaries *per se*. However, relevant work has been done in the waters of Stuart Channel separating these two estuaries. Surveys in this channel were related to the installation of a pulp mill at Crofton during the 1950's and on the design of waste disposal facilities to minimize the adverse effects of effluent on fisheries in Stuart Channel (Waldichuk, 1954, 1955, 1958, 1960, 1962a, 1962b, 1962c, 1964). Studies have been continued on the environmental effects of pulp mill effluent on Stuart Channel, partly in connection with allegedly adverse effects on oyster production (Quayle, 1964; Jackson, 1965), and partly in preparation for expansion of the mill and a new effluent outfall in the mid 1960's (Waldichuk, *et al.*, 1968). More recent surveys of Stuart Channel involved oceanographic observations (Waldichuk, unpublished data) conducted concurrently with *in situ* physiological studies with coho salmon on the research barge *L. Pacifica* during June-July, 1974 (Davis, unpublished data).

Most of the oceanographic observations in the Cowichan River estuary and Cowichan Bay have been made in association with fisheries studies. Temperature, salinity profiles and surface current observations were conducted in the mid 1960's from the Pacific Biological Station in Nanaimo in association with major ecological studies of the salmonid fisheries of the Cowichan River system (Sparrow, unpublished data) Additional temperature, salinity and surface current data have been collected by the Marine Sciences Directorate in Cowichan Bay (Herlinveaux, unpublished data). Most recently, *in situ* temperature and salinity measurements were made at 30 stations over the intertidal zone at high tide, in conjunction with intensive ecological studies conducted on the estuary during July and September, 1975 (Levings, in progress).

Although Saanich Inlet lies somewhat to the south of the study area, it has a certain influence on water movements in Satellite Channel, and ultimately, in Cowichan Bay. The seasonal characteristics of Saanich Inlet have been described by Herlinveaux (1962). Water movements over the sill in Saanich Inlet were investigated during June-July,1966 (Herlinveaux, 1968).

Studies have been conducted by a number of investigators in Ladysmith Harbour, with respect to invertebrates and particularly oyster culture (see Invertebrate Biology Section). McAllister (1955, 1956) carried out one of the early studies in Ladysmith Harbour on a year-round basis to determine the seasonal variations of the oceanographic properties in this inlet system. Surveys were later conducted during 1967-68 to find any relationship of sewage pollution to the oceanographic regime,and between seasonal variations in flushing characteristics and coliform distributions (Waldichuk and Meikle, unpublished data). It could be inferred from the studies of the effects of Dodd Narrows on waters in Northumberland Channel in relation to flushing (Waldichuk, 1965), that there is a net flow southward through the narrows and possibly a substantial influence of pulp mill pollution from the Harmac pulp mill.

5 (ii) GENERAL OCEANOGRAPHIC CHARACTERISTICS

The waters of the Cowichan River-Chemainus River estuaries and Stuart Channel are generally vertically stratified by freshwater inflow. Unlike the waters of the channels in the San Juan Islands to the east, where waters everywhere are quite thoroughly mixed, tidal turbulence mixes waters vertically only in the narrow, constricted passes between the islands of the Gulf Island chain, e.g. Active Pass and Porlier Pass, and leaves the waters inside the islands vertically stratified. Input of fresh water from the rivers contributes to the salinity stratification, with the most pronounced effect occurring during the rainy seasons of autumn, winter and spring. During the summer warming period, the density stratification due to low-salinity water on the surface is enhanced by temperature stratification caused by solar insolation.

Salinities range from zero in the upper parts of the estuaries to nearly $30^{o}/_{oo}$ in bottom water of Stuart Channel. Temperatures usually vary from about $9^{o}C$ in bottom water (150 - 200 m) to as much as $20^{o}C$ at the surface in July. In winter, temperatures drop substantially at the surface to a low of $6\text{-}7^{o}C$, and even lower during cold winters. Dissolved oxygen distribution also exhibits a marked vertical stratification in Stuart Channel, which may range from a maximum of 11 mg/l in the surface layer to as little as 3.0 mg/l at 120 m during July. It is obvious that the vertical density stratification prevents regular aeration of the bottom waters. Stations occupied in Stuart Channel during July, 1959 are shown in Figure 5.1. The vertical distributions of properties along Section A-A'from Bare Point near Chemainus to Erskine Point on the west central coast of Saltspring Island are shown in Figure 5.2.

No biological productivity studies have been conducted in the Stuart Channel-Sansum Narrows-Satellite Channel system. However, it can be expected that the primary productivity is about equal to that of the Strait of Georgia (Parsons, *et al.*, 1969). Because the system is largely vertically stratified, there is probably a rapid depletion of nutrients in surface waters during the vernal and late summer phytoplankton blooms. As common to most Vancouver Island streams, there is likely little nutrient input from the Cowichan and Chemainus Rivers. It is noteworthy, however, that a considerable amount of humic substances is introduced by some of the smaller coastal streams such as Bonsall Creek, which drain low-lying marsh areas. Whether

59. OCEANOGRAPHY

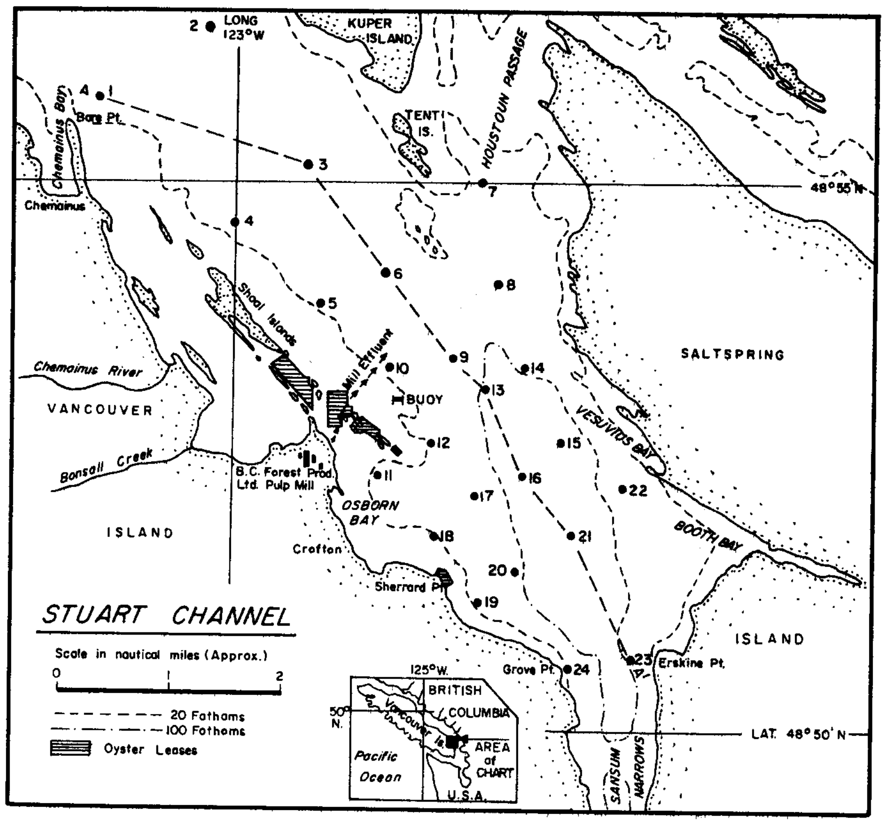


Figure 5·1 Chart of Stuart Channel in the vicinity of the pulp mill at Crofton, showing the effluent pipe - line and adjacent oyster leases. Stations occupied during the survey of July 1959 are given in heavy circles. (From Waldichuk, 1964)

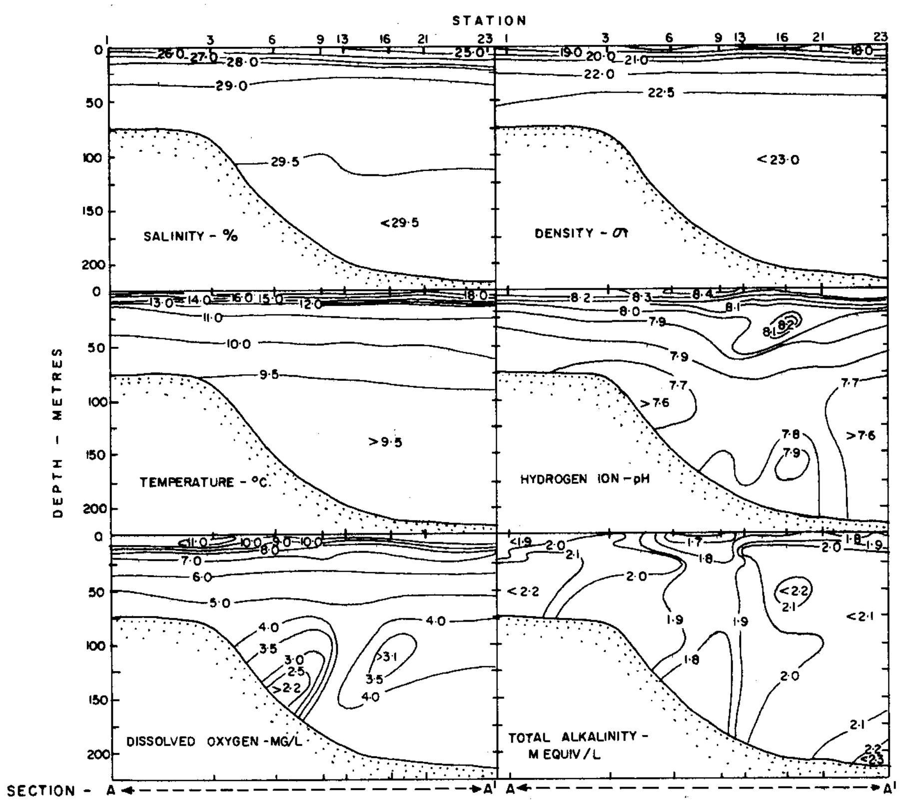


Figure 5·2 Vertical distributions of properties in a longitudinal section A - A' through Stuart Channel (see Fig. 5·1), observed July 8 - 11, 1959. (From Waldichuk, 1964) these substances contribute in any way to productivity in this area is uncertain, but studies on the east coast of Canada (Prakash, 1970) indicate that terrigenous organic matter can enhance coastal productivity. Observations during an oceanographic survey of Stuart Channel in April, 1959 (Waldichuk, *et al.*, 1968) indicated the presence of windrows of filamentous algae, which were probably associated with the spring bloom of phytoplankton, possibly stimulated, in part, by not only organic substances from runoff but also from the Crofton pulp mill.

5 (iii) TIDES

The reference port for tides in this area is Fulford Harbour, where a long series (23 years) of tidal observations has been made. Secondary ports in Stuart Channel are Ladysmith, Chemainus, Crofton and Preedy Harbour. In Satellite Channel, the secondary ports are Cowichan Bay and Maple Bay. For harmonic analysis in order to provide essential tidal predictions, at least 29 days of tidal records have been procured at secondary ports on Stuart Channel and Satellite Channel: Cowichan Bay, 29 days; Maple Bay, 344 days; Crofton, 424 days; and Chemainus, 29 days. The mean and large tidal ranges for Fulford Harbour and the secondary ports are given in Table 5.1.

The tides in the Stuart Channel-Sansum Narrows-Satellite Channel system are typically of the mixed type, consisting of mainly a diurnal tide and a smaller semi-diurnal component with a marked inequality between succeeding low and high waters. They are a blend of tides in the Strait of Georgia, which exhibit a marked time difference between highs of the diurnal and semi-diurnal components and the eastern Juan de Fuca tides, where the high of the semi-diurnal component nearly coincides with the high of the diurnal component, giving essentially a diurnal tide (one high and one low per day), for part of the lunar month.

Tides flood into the southern part of the Strait of Georgia relatively unimpeded through Juan de Fuca Strait, Haro and Rosario Straits and through Boundary Pass. Tides also flood into Stuart Channel from the south through Haro Strait, Satellite Channel and Sansum Narrows. However, they tend to be somewhat impeded through this route and the flood reaches Dodd Narrows from the north through the Strait of Georgia before it reaches it from the south through Stuart Channel (Waldichuk, 1965). Hence, flood tides from the south and north converge in the northern part of Stuart Channel during certain tidal ranges.

Table 5.1. Tidal characteristics at the reference and secondary ports in waters from Cowichan Bay to Ladysmith Harbour.

	Position Lat. N.	Position Long. W.	Duration Tidal Record Days[a]	Mean Tidal Range m	Mean Tidal Range ft.	Large Tidal Range m	Large Tidal Range ft.
REFERENCE PORT							
Fulford Harbour	48° 46'	123° 27'	23 years[b]	2.32	7.6	3.69	12.1
SECONDARY PORTS							
Ladysmith	48° 59'	123° 47'	14 months	2.59	8.5	4.05	13.3
Chemainus	48° 55'	123° 42'	29	2.68	8.8	4.15	13.6
Crofton	48° 52'	123° 39'	424	2.59	8.5	4.05	13.3
Preedy Harbour	48° 59'	123° 50'	29	2.62	8.6	4.05	13.3
Cowichan Bay	48° 44'	123° 37'	29	2.50	8.2	3.72	12.2
Maple Bay	48° 49'	123° 37'	344	2.41	7.9	3.66	12.0

a. except as shown b. continuing observations

5 (iv) CURRENTS

Current observations were made in Stuart Channel south of the outfall from the Crofton pulp mill from 1954 to 1965 (Waldichuk, 1955, 1958, 1964; Waldichuk, *et al.*, 1968). In addition, current meter and drift pole observations were made from Sept. 14 to Oct. 19, 1959, and from Sept. 15 to Sept. 24, 1959 respectively, for navigational purposes by the Canadian Hydrographic

Service (unpublished data).

1. TIDAL CURRENTS:

The tidal currents in Stuart Channel may reach 50 cm/sec (1 knot) at the surface, but usually average about 20 cm/sec (0.4 knot). In deeper water (18 m), the current is substantially weaker at 5-10 cm/sec (0.1 - 0.2 knot) and exhibits a great variability in direction, being almost rotary (Waldichuk, 1964). Figure 5.3 shows a set of polar diagrams of currents at different depths, while Figure 5.4 gives the variation of current speed and direction (along the NW-SE axis of Stuart Channel) in relation to tide height.

There appeared to be a residual flow southward in the upper 2m and at a depth of 10-15m, with a net northward flow at 5m over a 25-hour period of current measurements in Stuart Channel during July 1957 (Fig. 5.5) (Waldichuk, 1964). Whether this was a typical situation representing residual flows over a longer period of time is uncertain.

During a break in the effluent pipeline from the Crofton pulp mill in February 1958, it was possible to follow the surface movement of effluent in Stuart Channel in the absence of wind (Waldichuk, unpublished data). It was clear from those observations that effluent does not merely become caught in the northwest or southeast-setting tidal stream but may be transported across Stuart Channel into Houstoun Passage and thence into Trincomali Channel (Figure 1.1).

2. WIND-DRIVEN CURRENTS:

Because the waters of Stuart Channel and Sansum Narrows are sheltered by moderate elevations of land both on Vancouver Island to the west and on Saltspring, Kuper and Thetis islands to the east, there is little cross-channel wind of any consequence. A stretch of moderately open water extends for about 20 km

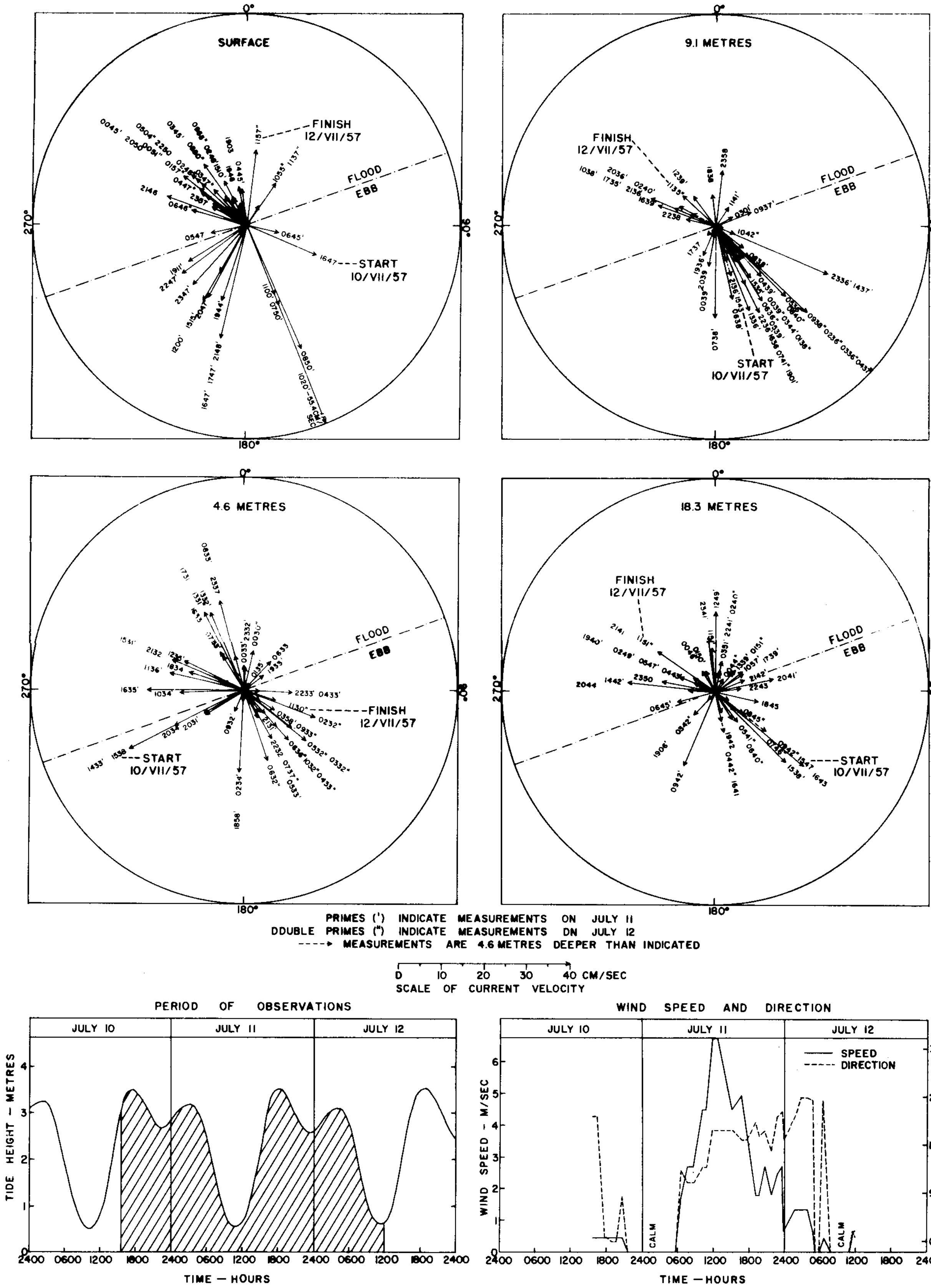


Figure 5·3 Polar currents diagrams for observations at various depths on Station O-2, near the site of the pulpmill outfall diffuser in Stuart Channel, July 10-12, 1957. Lower diagrams give the tides and winds at time of of current observations. (From Waldichuk, 1964).

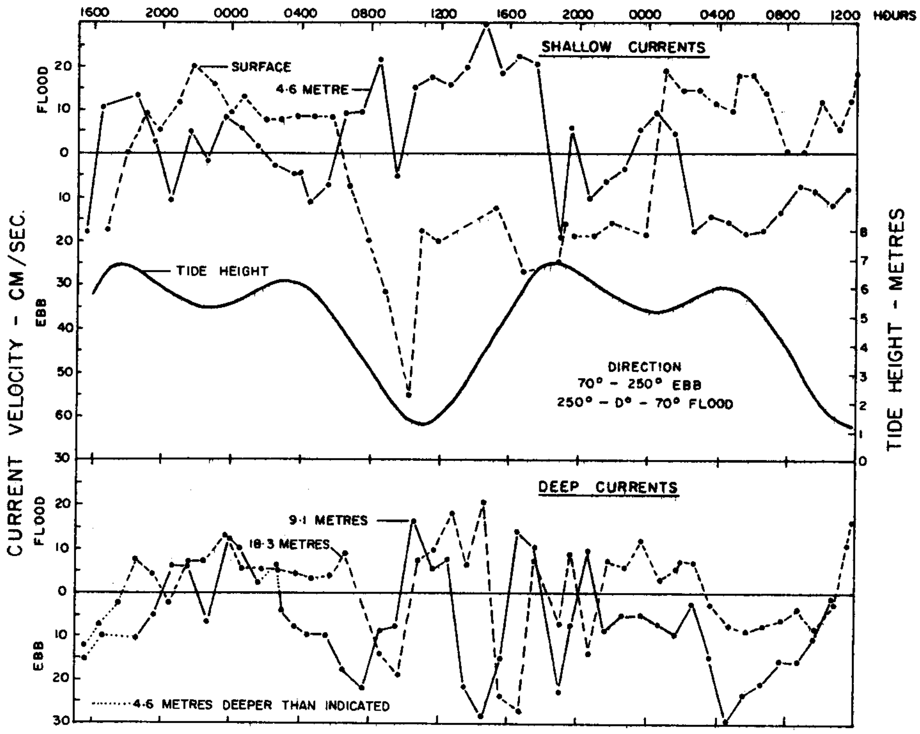


Figure 5·4 Variation of current velocities at various depths over a 44-hr. period of continuous observations at Station O-2, July 10-12, 1957. (From Waldichuk 1964)

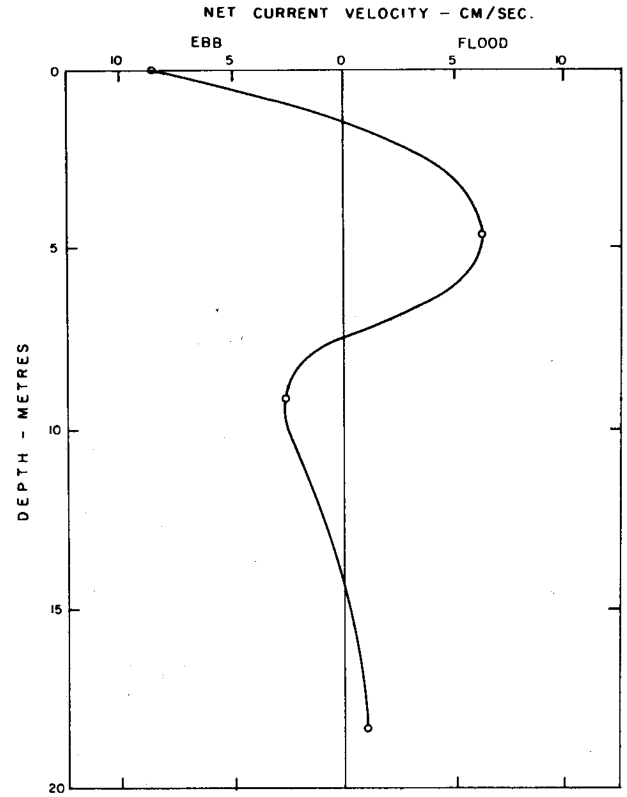


Figure 5·5 Profile of net (non-tidal) currents at station O-2, determined for the period, 2000 hr., July 10, to 2100 hr., July 11, 1957. (From Waldichuk, 1964).

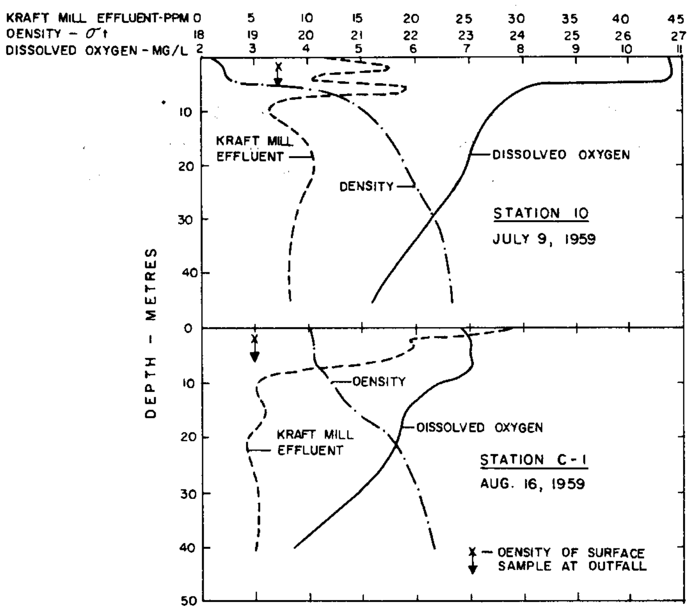


Figure 5·6 Profiles of density, kraft-mill effluent, and dissolved oxygen concentrations at stations near the outfall in Stuart Channel during the summer of 1959. (From Waldichuk, 1964)

(11 n.mi) over which winds can blow relatively unimpeded from the northwest or southeast. During the autumn and winter months, wind-driven surface currents with speeds of about the same magnitude as tidal currents can develop. However, the strong winds are of comparatively short duration, and wind-driven currents that may develop are not long lived.

Occasionally winds blow from the southwest, and these may transport surface water and any water-borne effluent from the Crofton pulp mill towards the northeast, particularly into Houstoun Passage. Likewise, northeasterly winds tend to move surface water and any contained effluent onto the Shoal Islands and into Osborn Bay. The movement of foam from the pulp mill outfall has been noted in that direction (Waldichuk, 1964).

Winds from the southeast would be the only ones expected to have any effects on surface currents in the Cowichan River estuary because of its orientation. However, winds blowing seaward from shore could have an upwelling effect as observed in Departure Bay (Waldichuk, Unpublished data; Henry and Murty, 1972). Wind-driven currents are inconsequential in the inner Chemainus River estuary owing to protection from the Shoal Islands.

5 (v) WAVES

For the same reason that wind-driven currents are not too prominent in Stuart Channel, large wind waves are relatively infrequent. Boats often come into Stuart Channel to seek protection from heavy seas in the Strait of Georgia. However, autumn and winter storms can make choppy conditions even in Stuart Channel, as observed during a survey in November 1954 (Waldichuk, 1955).

Effects of waves in the Cowichan River estuary would be most pronounced during strong southeast winds, since Cowichan

Bay is exposed to winds from this direction. The Chemainus River estuary would receive little more than local ripples or small waves developed within the confines of the Shoal Islands. The outer reaches of Ladysmith Harbour receive some impact of waves from the southeast but the inner harbour is reasonably well protected. Chemainus Harbour is open to wind-wave action from the north and northwest, but such waves have little ecological consequence in this industrialized harbour.

Measurements of winds and waves have been made in Chemainus Harbour by the Canada Department of Public Works, (1972) during 1971-72, in the interests of installation of a breakwater to protect shipping. As far as it is known, there have been no wave observations in other parts of the Stuart Channel-Sansum Narrows-Satellite Channel system.

5 (vi) FLUSHING RATE

The rate with which water is replaced in the Stuart Channel-Sansum Narrows-Satellite Channel system is important from the point of view of pollution control. Rapid replacement of waters means that wastes can be removed within a short period of time, and hence the assimilative capacity of the system through rapid dilution and dispersion would be greater than with a poorly flushed system. In those areas where mixing is intensive, i.e. in Dodd and Sansum Narrows, dilution and dispersion tend to be rapid. However, if a system is stratified, as in the case of Stuart Channel, surface waters are replaced moderately fast, while bottom waters tend to stagnate. This can be seen in the vertical dissolved oxygen distribution.

Tidal currents generally disperse effluent released in the surface layer quite rapidly. Murty (1973) showed theoretically how effluent discharged at some depth could form a bifurcated plume, while rising to the surface in stratified water, using

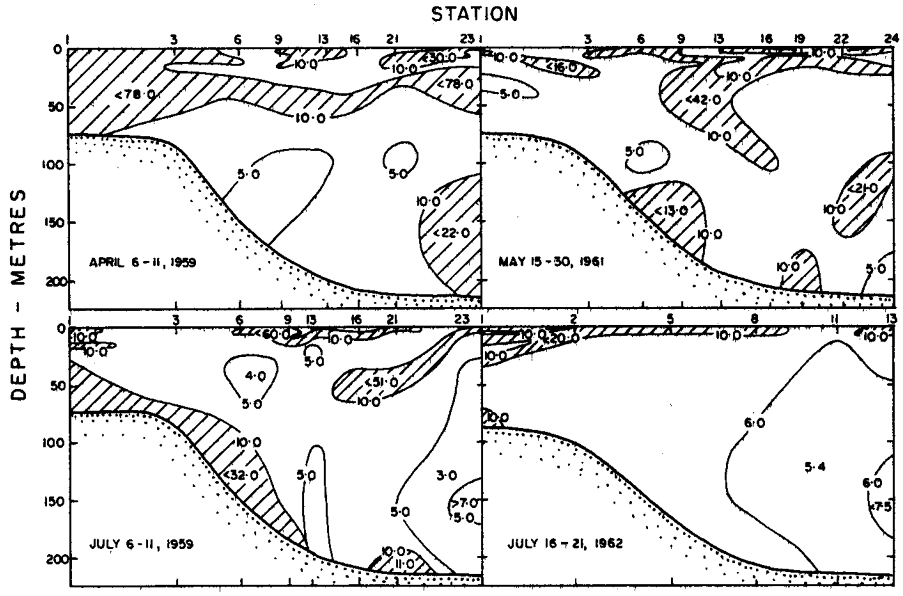


Figure 5·7 Kraft-mill effluent concentrations in vertical distributions through Stuart Channel, approximately along section A-A' shown in Fig. 5·1, as observed during different periods. (From Waldichuk, 1964)

Stuart Channel as an example.

Pulp mill effluent can be used as a tracer to follow water movement in Stuart Channel. It is initially confined to the surface layer where it mixes with relatively low-salinity water (Fig. 5.6). As it mixes with the water vertically in Dodd and Sansum Narrows, some of the effluent may return mixed in deep water on the next incoming tide. This it is possible to have lenses and pockets of effluent below the surface layer (Fig. 5.7). Some of these deeper concentrations of wastes can enter estuaries in the subsurface inflowing layer, which compensates in the salt balance for the sea water being carried away by the brackish surface layer containing the river water.

The capacity of the Stuart Channel-Sansum Narrows-Satellite Channel system to receive wastes is limited by the rate of dilution, dispersion and seaward transport. A larger volume of wastes could probably be discharged into Sansum Narrows without ill-effect than into Stuart Channel. In Stuart Channel, it would be essential to evaluate the rate with which pollutants are removed from the deep water under steady-state do not exceed a prescribed maximum "safe" level of contaminant, then the scheme and volume of waste disposal might be regarded as meeting criteria for water quality. However, the problem in the Crofton area was not so much the effect of deep-water contamination as the adverse effect of surface water pollution on oyster beds. Judging by the present poor quality of the oysters on leases nearest the outfall, the acceptable level of surface contamination was probably exceeded on a long-term, steady-state basis.

6. INVERTEBRATE BIOLOGY

6 (i) TERRESTRIAL INVERTEBRATES

The terrestrial invertebrate life of the area is not documented to any great extent. The amateur entomologist is referred to Guppy (1974) for a brief account of the insects of the area.

Stomach content analyses of fishes have revealed a significant proportion of terrestrial insects. Coleoptera (beetles), Hemiptera (true bugs), Homoptera (particularly Aphidae), Formicidae (ants) and Apidae (honey and bumble bees) were all well represented in trout stomach samples (Idyll, 1942; Sparrow, 1968).

6 (ii) FRESHWATER INVERTEBRATES

1. BENTHOS:

Benthic sampling of the upper Cowichan River and Oliver Creek by Idyll (1943) found the river to have relatively poor standing stocks of macroinvertebrates. The relative abundance of different groups of organisms sampled from different river habitats is presented in Table 6.1 and the species reported are included in Appendix 6.1.

Except for the deep water chironomids, the insect population of Cowichan Lake was found to be scanty (Carl, 1953). This paucity of insects was attributed to the lack of bottom vegetation, since most benthic organisms of this type usually associate themselves with water plants, both for food and protection. The amphipod *Hyalella azteca* was fairly abundant and well distributed. In general, the bottom fauna was sparse yet diverse.

Table 6.1 Percentage Occurrence, Average Weight and Number of Organisms in Different Habitats of the Upper Cowichan River and Oliver Creek (Idyll, 1943).

Organism	Pool	Rubble, Riffles	Gravel, Riffles	Weeds, Riffles	Oliver Creek
Caddisflies	4.1	59.2	60.2	2.2	21.4
Blackflies	0.05	0.2	1.3	80.5	3.5
Midges	11.4	4.6	1.5	2.8	32.0
Mayflies	14.1	11.9	10.2	5.8	25.7
Stoneflies	2.1	1.5	8.1	x	5.5
Dragonflies and damselflies	1.1	...	0.1	0.2	-
Aquatic beetles	0.8	x	5.4	0.2	0.5
Crustaceans	32.5	4.1	3.6	5.1	-
Molluscs	21.4	9.5	1.5	0.5	0.25
Annelids	5.7	0.4	1.1	2.4	3.4
Flatworms	2.7	7.6	2.3	x	0.45
Leeches	2.9	0.4	3.3	x	-
Craneflies	0.3	...	1.1	x	5.8
Miscellaneous	0.6	x	...	x	1.0
Average Weight (g/sq m)	29.07	23.31	7.22	13.29	8.25
Average No. (per sq m)	486	378	285	2521	536

x = present in insignificant percentage.

2. ZOOPLANKTON:

Carl (1953) found the following organisms to occur regularly in open-water samples of Lake Cowichan: the protozoans *Ceratium hirundinella* and *Dinobryon sertularia*; the rotifers *Notholca longispina*, *Keratella cochlearis*, *Polyartha trigla*, and *Ploesoma truncatum*; the copepods *Diaptomus oregonensis* and *Cyclops bicuspidatus*; and the Cladocera *Diaphanosoma brachyurum*, *Daphnia longispina* and *Bosmina obtusirostris*. Less common species are included in the list of freshwater and marine zooplankton in Appendix 6.2.

The plankton of the river is derived from populations in upstream, still-water zones and is a highly important food source for benthos and fish. However, no information other than the above was available.

6 (iii) MARINE INVERTEBRATES

1. BENTHOS:

Quantitative benthic investigations were carried out in Satellite Channel, Cowichan Bay and Stuart Channel by workers from the University of Victoria (Ellis, 1967a,b; 1968a,b). The benthos of Cowichan Bay, at 60 m (196 ft) in a 50% silt-50% clay sediment, was dominated, in terms of biomass, by the bivalves *Compsomyax subdiaphana* (202 g wet wt/sq m), *Macoma* (3 sp., 19 g/sq m), and *Yoldia* (3 sp., 19 g/sq m), and by the polychaetes *Pista cristata* (54 g/sq m) and *Sternapsis fossor* (6 g/sq m).

The Satellite Channel benthos, at 61 m (200 ft) in sediment composed of 19% sand, 46% silt, and 35% clay, was dominated, in terms of biomass, by the bivalves *Compsomyax subdiaphana* (933 g wet wt/sq m), *Yoldia* (3 sp., 30 g/sq m) and *Macoma* (4 sp., 29 g/sq m), the heart urchin *Brisaster latifrons* (338 g/sq m), the brittle-star *Ophiura sarsi* (30 g/sq m) and the polychaetes *Pista cristata*

(53 g/sq m) and *Sternapis fossor* (12 g/sq m).

The benthos of Stuart Channel, midway between Osborn Bay and Saltspring Island, at 202 m (663 ft) in a 16% silt-80% clay substrate, was dominated, in terms of biomass, by the heart urchin *Brisaster latifrons* (183 g wet wt/sq m), the echiuroid *Bonellia* (65 g/sq m) and the bivalve *Yoldia thraciaeformis* (31 g/sq m). Less abundant species included an anthozoan (10 g/sq m), the holothurians *Chiridota* (8 g/sq m) and *Molpadia intermedia* (3 g/sq m), and the polychaetes *Nephtys* sp. (4 g/sq m), *Terebellides stromi* (4 g/sq m) and *Ampharete arctica* (1 g/sq m). All of the species collected are included in Appendix 6.1.

In summarizing the previous benthic investigations, Ellis (1968d) described the following organisms as being ecologically significant in Stuart Channel: the errant polychaetes *Lumbrinereis* sp. and *Nephtys* sp.; the sedentary polychaetes *Ampharete arctica* and *Terebellides stroemi*; amphipods; copepods; the molluscs *Yoldia thraciaeformis*, *Acteocina* sp. and *Turbonilla* sp.; the echiuroid *Bonellia* sp. and the echinoderms *Brisaster latifrons*, *Chiridota* sp. and *Molpadia intermedia*. The benthic faunal communities associated with the normal sand, silt, clay substrate were labelled *Macoma* (occurring in shallow water to 50 m) and *Brisaster* (occurring in deeper waters).

In the area of heavy fibre deposition (see Figure 6.1) around the Crofton pulp mill outfalls, the normal *Macoma* community was replaced by a "Depauperate" community characterized by the malacostracan *Epinebalia pugettensis* and the polychaetes *Capitella capitata* and *Dorvillea rudolphii* (Ellis, 1970). Marine life of this community was poor in terms of number and variety of species, but not in terms of biomass. A more recent survey of the benthos around the outfalls (Ellis and Jones, 1975b) describes a Transition community associated with a 2.5 cm (1 inch) fibre deposit. It is characterized by masses of tubiculous worms (Paraonidae-Spionidae), two species of amphipod, *Epinebalia*

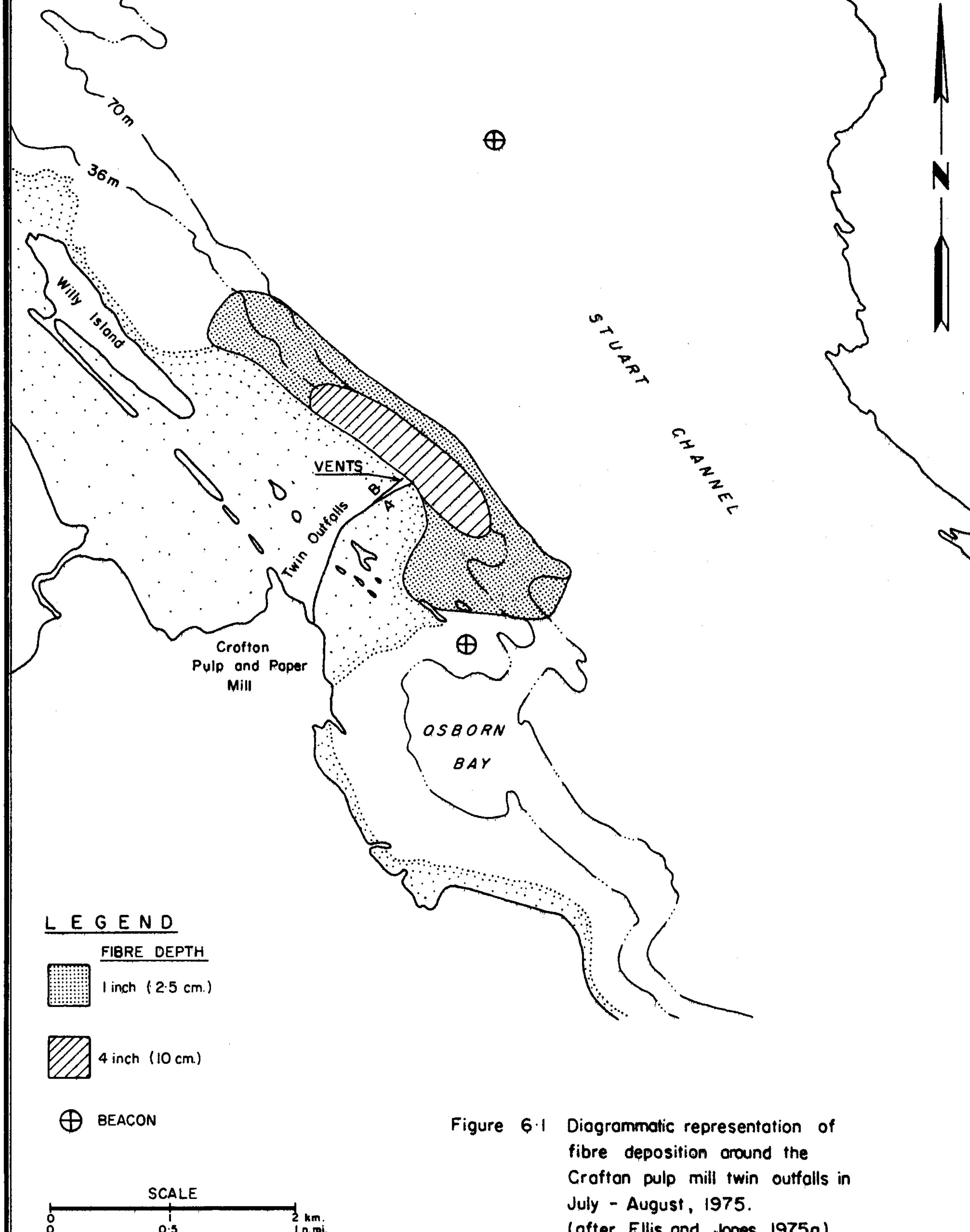


Figure 6·1 Diagrammatic representation of fibre deposition around the Crofton pulp mill twin outfalls in July - August, 1975. (after Ellis and Jones, 1975a) *pugettensis* and a large biomass (33.16 g dry wt/sq m). In deeper waters a transition community was noted to replace the normal *Brisaster* community in areas of 5-8 cm (2-3 inches) fibre deposit. It was described as a *Lucinoma* community owing to the presence of the large bivalve *Lucinoma annulata*.

In Chemainus Bay, where cellulose wastes blanket much of the substrate, the number and variety of benthic species was reported to be increasingly reduced towards the head of the bay. Ketcham (pers. comm.) described only ten species from the head of Chemainus Bay, compared to approximately 45 species from samples at the mouth. Log handling wastes affect marine benthos by physically altering and by increasing the oxygen demand of the substrate (Kussat, 1970).

The shore faunas of Stuart Channel are typified by those of Coffin Island, which has both rocky and shell-sand shores. Collections made on Coffin Island throughout the summer of 1970 are described by Quayle (1970). He found that Foraminifera were very numerous, being lodged everywhere on the samples examined. Cnidaria were fairly numerous. The sea cucumber *Cucumaria miniata* and the starfishes *Pisaster ochraceus* and *Evasterias troschelli* were very common. Polychaetes, representing 13 families, were recorded. Thirty-six crustacean species were noted, the most common being the barnacle *Balanus glandula*,which formed a continuous band in approximately the middle third of the tidal zone. The shore crabs *Hemigrapsus oregonensis* and *H. nudus*, the isopod *Gnorimosphaeroma oregonensis* and the caprellid amphipod *Caprella aequilibra* were all very numerous. The molluscs were well represented by over 50 species, the most numerous being *Mytilus edulis, Saxidomus giganteus, Mytilimeria nuttalli, Lepidochitona lineata, Thais lamellosa, Acmea scutum pintadina* and *A. cassis olympica*. Ascidians occurred in considerable numbers, especially *Corella rugosa, Boltenia villosa, Cnemidocarpa joannoe* and *Pyura haustor*. The greatest variety of species were found below the three-foot tide mark and more particularly, at the zero tide mark, while the most favoured habitat was beneath rocks. The associations between the often gregarious species were varied and numerous. The species described in Quayle's report are included in Appendix 6.1.

The Pacific or Japanese oyster (*Crassostrea gigas*) was introduced to Ladysmith Harbour in 1925 to supplement the limited populations of the native oyster (*Ostrea lurida*). The species' spread was documented by Elsey (1932, 1934) and Elsey and Quayle (1939). It has since become a dominant species throughout much of the study region. It is the object of commercial and recreational harvesting (see Invertebrate Fisheries Resource Subsection) as well as being an excellent pollution indicator organism. Studies of both coliform and heavy metal (pulp mill) pollution have been based on the oyster and its ability to concentrate these pollutants (see Pollution Section).

A number of other species were introduced to the region with the import of both the Pacific and Atlantic (*C. virginica*, no longer found within the study area) oysters. The Japanese littleneck clam (*Venerupis japonica*) became a dominant species on many Stuart Channel beaches within five years. Other species introduced to the area with the oysters include the oyster drills *Ocenebra japonica*, and *Purpura clavigera*, the gastropod *Batillaria cumingi*, the soft-shelled clam (*Mya arenaria*) and the bryozoan *Schizoporella unicornis* (Quayle, 1964b; Powell, 1970).

The shipworm *Bankia setacea* is a serious menace to wooden structures in the study area. Infestation occurs year-round, but is greatest in late summer and early autumn (Neave, 1943). The average rate of growth of *Bankia* in Douglas fir in the study region is approximately 3 cm per month (Quayle, 1956a, b).

Nine species of pandalid shrimps, whose life histories were discussed by Butler (1964), are found in Stuart Channel.

These are the "smooth pink" (*Pandalus jordani*), "pink" (*P. borealis*), "prawn" (*P. platyceros*), "humpback" (*P. hypsinotus*, "coonstripe" (*P. danae*) and "sidestripe" (*Pandalopsis dispar*).

The benthos of the Chemainus and Cowichan estuaries has not been adequately described. However, the following notes were found. Laing (1975) noted the predominance of the shore crabs *Hemigrapsus nudus* and *H. oregonensis* throughout the tidal flats of the Chemainus delta. He also reported the abundance of the burrowing shrimp *Callianassa californiensis* and polychaete worms on the tidal flats. Kennedy and Waters (1974) noted the presence of numerous crabs and "clam holes" on the mud flats of the Cowichan estuary. Samples were taken of mud, sand and gravel substrates on the estuary and these samples revealed a mixed freshwater and marine infauna. Chironomids, other dipteran larvae and pupae, and sabellid polychaetes were very numerous in the mud and sand samples. In addition, other polychaetes (Ampharetidae and Terebellidae), amphipods and miscellaneous species were recorded.

A brief survey of the intertidal fauna off the Shoal Islands was recorded in a cruise report of the CSS *Vector* (Levings, 1973). Periphyton was abundant, while oysters were sparse and reduced in size west of the Crofton pulp mill outfall. The fauna on the southern tip of Willy Island was observed to be much more diverse, and the lagoon areas around the Shoal Islands were not noticeably stained with Kraft mill effluent.

The previous notes do not give a representative picture of the great biomass and productivity present in the delta areas. Work in progress by scientists of the Pacific Biological Station and Pacific Environment Institute on the Cowichan River estuary will serve to partially fill this void of knowledge (see Appendix 1.2). The reader is referred to the Fraser and Squamish reports (Hoos and Packman, 1974; Hoos and Vold, 1975) for a general discussion of estuarine benthos in the Strait of Georgia. Other general descriptions of the intertidal life of the region can be found in McKinnon (1974) and Ricketts and Calvin (1968) or Kozloff (1973), or in the publications of the B.C. Provincial Museum (Quayle, 1960; Cornwall, 1955; Griffith, 1967).

2. PLANKTON:

Little information concerning the plankton of the study area exists at present. The reader is referred to the Squamish and Fraser River reports (Hoos and Packman, 1974; Hoos and Vold, 1975) for a review of estuarine and marine plankton in the southern Strait of Georgia.

Kussat (1968) noted that the plankton from Chemainus Bay was limited in number and kinds, and that samples contained an abundance of logging and milling debris. Sampling stations outside the bay, yielded a variety of diatom species and various forms of coelenterates and crustaceans. A 1969 survey report (Kussat, 1970) includes the relative abundance of some plankton taxa.

Continuous surface zooplankton tows covering 22 miles in Cowichan Bay and adjacent waters were completed on July 14, 15 and 16, 1975 by investigators from the Pacific Biological Station; however, their findings have not yet been published (see LeBrasseur, Appendix 1.2).

Though not considered as being zooplankton, it is noted that the squid *Loligo opulescens* spawns in Cowichan Bay in late July. Vast numbers have been caught during the 1973/74 and 1974/75 programs of the Fisheries and Marine Service (B. Hillaby, pers. comm.). The jellyfish *Aequorea aequorea*, has been observed in large numbers during August (Waldichuk, pers. comm.) in Saanich Inlet on the ferry run between Mill Bay and Brentwood Bay, and probably extends its range into Satellite Channel of the study area.

Table 6.2. Annual Reported Landed Values of the Invertebrate Fisheries in Statistical Areas 17 and 18 in $000's from 1967 to 1973. (Compiled from Area Worksheets, Econ. Br., Pac. Reg., Fish. and Mar. Serv.)

	Prawns	Shrimp	Clams	Crab	Abalone	Oyster
Area 17						
1973	6	34	47	5	3	157
1972	3	38	33	1	*	117
1971	2	18	65	4	*	91
1970	4	12	46	3	*	71
1969	*	44	26	3		97
1968	*	96	26	2		115
1967	*	91	32	3		126
Area 18						
1973	1	62	13	6	2	
1972	1	61	121	5	3	
1971	*	19	43	5	*	
1970	*	10	14	3	1	
1969	*	*	7	3		
1968	*	1	10	2		
1967	*	5	6	2		

*nil value

6 (iv) INVERTEBRATE FISHERIES RESOURCE

Annual landed values for the invertebrate fisheries of statistical areas 17 and 18, within which the study area is located are presented in Table 6.2. In addition to being a commercial resource, invertebrate stocks contribute to the recreational value of the area.

Molluscan aquaculture in British Columbia centres on oyster culture which is an important natural resource of the study area. Ladysmith Harbour, the Crofton-Chemainus area and Thetis Island are the most important oyster producing areas of British Columbia. Virtually all culture has been intertidal, on grounds leased from the Provincial government. The grounds are located on sheltered and firm mud, sand and/or gravel flats, which are often estuarine in nature. Many of the most productive grounds of the area are now closed owing to pollution. Figures 11.1, 11.2, 11.3 illustrate the existing oyster leases and areas closed to the taking of shellfish in the study region.

Pendrell Sound (northern Strait of Georgia), and to a lesser extent Ladysmith Harbour, are unique areas in that oyster spatfall is regular and can be predicted. These regions are used for oyster seed collection by commercial growers (Quayle, 1959a,b, 1971). After a period of development, the seed oysters (local or imported) are spread on leased oyster grounds. Clusters are broken apart and relaid after one year to prevent them from becoming misshapen through crowding. They may be moved to a location known to be a good fattening area later in development. When they are of marketable size (10 to 15 cm, or 4 to 6 inches) and considered in prime condition by the grower, they are harvested at low tide and placed on floats. These floats are towed at high tide, to the oyster house, where the oysters are removed washed, shucked and packed. Approximately 120 Pacific oysters or 2,000 native oysters are required to produce one gallon of meat (Porter, 1969). Processing for the wholesale market adds little value to the harvest, and shells are sold for processing into chicken feed. Almost all of the oyster companies are family-sized enterprises that operate their own packing plants. A number of problems plague the oyster industry. They include marketing difficulties, pollution, little technological advancement, and insecurity of tenure on leases (Porter, 1969).

Some growers also harvest "wild" oysters from outside registered leases or from restricted leases. These oysters must be cleansed of any bacterial contamination before being marketed. They may be relaid on registered grounds for a minimum of two weeks, or they may be artificially purified at the oyster depuration plant in Ladysmith using UV treated seawater. The plant was constructed in 1969 and operated under a federal-provincial cost-sharing program. Commercial operation began in 1971 and depuration costs to the grower are competitive with the traditional relaying process (Devlin and Neufeld, 1971; Devlin, 1973).

"Wild" oysters have become an important recreational resource for the area. A provincial oyster reserve where oysters are laid for recreational harvesting, is located at Boulder Point (see Figure 11.3). Oysters are mentioned as a major attraction in many of the coastal resort brochures. However, there are negative aspects to their recreational value. Their sharp, jagged shells present a hazard to bathers, and this problem may become more serious as the demand for suitable beach areas increases and the Pacific oyster becomes more widespread. Moreover, oysters may be collected by recreation-seekers in sewage-polluted areas, with the hazard of contracting disease such as infectious hepatitis.

Stuart Channel, particularly Sansum Narrows, is one of the major shrimp trawling grounds of British Columbia. Prawn trapping is carried out on a smaller scale by salmon fishermen in the off-season (Porter, 1969). The species which contribute to the commercial fishery, in order of decreasing importance, are the "smooth pink" (*Pandalus jordani*), "pink" (*P. borealis*), "prawn" (*P. platyceros*), "sidestripe" (*Pandalopsis dispar*), "humpback" (*Pandalus hypsinotus*) and "coonstripe" (*P. danae*). Reported landings (Table 6.2) underestimate the value of this resource, as much of the catch is sold directly to the public off the boats (C. Newton, pers. comm.).

Three species of clams are harvested from the area, including butter (*Saxidomus giganteus*), Japanese littleneck (*Venerupis japonica*), and native littleneck (*Protothaca staminea*). However, many of the clam beds of the area are found within areas closed to the taking of shellfish.

7. FISH

7 (i) GENERAL DISCUSSION

In terms of variety and abundance of salmonid species and the degree of utilization of fish stocks by commercial, recreational and Indian food fisheries, the Cowichan is recognized as one of the most important rivers on Vancouver Island. The productivity of the Cowichan is attributed to an extensive system of accessible, low gradient waterways in which ample spawning gravel and abundant, diverse rearing habitats are present. Cowichan Lake provides some stabilizing influence on mainstem streamflows; however, past and present logging practices have reduced its capacity to stabilize the system (B. Hillaby, pers. comm.).

The Koksilah and Chemainus rivers support sizeable, but smaller, fish populations than does the Cowichan. These two rivers are typical of intermediate-sized streams on the east coast of Vancouver Island. Lacking a lake source, they are subject to flash flooding, sedimentation problems and low summer flows. Marble Falls, located about 16.1 km (10 miles) above the Cowichan-Koksilah estuary, and Copper Canyon Falls, about 12.9 km (8 miles) above the Chemainus estuary, limit the distribution of anadromous salmon and trout (with the exception of summer steelhead in the latter river system) to the lower portion of the rivers and to tributaries entering the rivers below the falls.

A number of smaller streams within the study area also support anadromous fish populations. The more important of these are Bonsall Creek, flowing onto the southern end of the Chemainus estuary, and Bush, Rocky, Holland and Stocking creeks, which flow into Ladysmith Harbour over individual estuarine deltas. Chum (*Oncorhynchus keta*) and coho (*O. kisutch*) salmon, as well as steelhead (*Salmo gairdneri*) and cutthroat (*S. clarki clarki*) trout, utilize these streams.

Increasing industrial, agricultural and urban encroachment on the Cowichan and Chemainus estuaries and the watersheds are affecting the fish productivity of these systems. Developments and their ramifications on fish production are discussed in the Pollution and Effects of Development Sections of this report.

A list of fish species sampled on the Cowichan River estuary by the Fisheries and Marine Service between March and September, 1973 is presented in Appendix 7.4. Other fishes, both freshwater and marine, recorded from the study area, as compiled from the available literature are presented in Appendix 7.5. For an annotated bibliography on Georgia Strait fishes, the reader is referred to McInnes, Nash and Godfrey (1974).

1. SALMON:

The Cowichan River system supports large runs of chinook (*Oncorhynchus tshawytscha*), coho and chum salmon. The spawning beds of these species are distributed throught the mainstem with coho also utilizing the accessible tributary streams. A few sockeye (*Oncorhynchus nerka*) and pink (*O. gorbuscha*) salmon may enter the system; however, reports of their occurrence are rare. Landlocked sockeye or kokanee are found in Cowichan Lake. Neave (1949) reported that kokanee from the lake are of a small size compared with those from certain mainland lakes and are only moderately plentiful.

The Chemainus River also supports sizeable runs of chinook, coho and chum salmon, although the close proximity of major, more widely known salmon rivers (Nanaimo and Cowichan) tends to overshadow its value.

The salmon of the Chemainus and Cowichan systems contribute to different fishing stocks. The Chemainus River is the southern limit of fish migrating through Johnstone Strait, whereas the majority of Cowichan River fish migrate through the Juan de Fuca Strait (A.W. Argue, pers. comm.).

(a) Coho Salmon (*Oncorhynchus kisutch*). Maturing coho salmon congregate in Cowichan Bay from late September to early November. Upriver migrations commence with the first fall rains, usually by mid-October, and continue through December. Tagging studies conducted on the Cowichan in 1943 and 1944 (Pritchard, 1945) established that two discrete runs of coho ascend the headwaters above Skutz Falls

The spawning period in both the Cowichan and Koksilah rivers extends from late September through January, usually peaking in November.

In the Cowichan system, spawning coho penetrate virtually all accessible waters, with the majority of fish being distributed throughout Cowichan Lake tributaries and in the mainstem above Skutz Falls.

Koksilah River coho spawn predominately in the mainstem immediately downstream of Marble Falls and in the lower tributaries. A few coho, along with steelhead trout, are able to ascend Marble Falls in years when favourable water levels prevail.

The rearing distribution of juvenile coho in the Cowichan and Koksilah rivers is extensive. This is a function of the widespread spawning distribution of adults and the tendency of emergent fry to migrate both upstream and downstream in search of suitable rearing habitat.

It has been established that coho production is largely governed by minimum streamflow conditions during the juvenile freshwater residence period (Neave and Wickett, 1948). A comparison was made between the recorded minimum summer discharge of the Cowichan River and the annual average gillnet catch per fishing day in the Juan de Fuca area (see Figure 7.1). The gillnet catch in any year tended to vary directly with the minimum summer discharge recorded two years earlier (Can. Dept. Fish., 1965).

Coho salmon appear in the Chemainus River in mid-October, with spawning occurring from late October to mid-January, peaking in late November. Copper Canyon Falls limits coho production to the lower 12.9 km (8 miles) of the river.

Table 7.1 gives coho salmon escapement data for the rivers and streams of the area. The Cowichan River supports the largest coho stock on Vancouver Island.

Table 7.1. Maximum, Minimum and Average Annual Coho Salmon Escapements from 1963 to 1973 (Can. Dept. Environ. 1963-1973a).

	Maximum	Minimum	Average
Bonsall Cr.	3,000	75	1,150
Bush Cr.	290	60	160
Chemainus R.	1,200	100	450
Cowichan R.	75,000	9,000	43,000
Holland Cr.	160	40	75
Koksilah R.	35,000	1,800	6,700
Rocky Cr.	65	0	19
Stocking Cr.	100	8	29

Large numbers of coho grilse remain in Cowichan Bay through June and July. Tagging programs indicated that a major portion subsequently wintered in Saanich Inlet (Sparrow, 1967, 1968a). Stuart Channel taggings in 1963-64 revealed that although

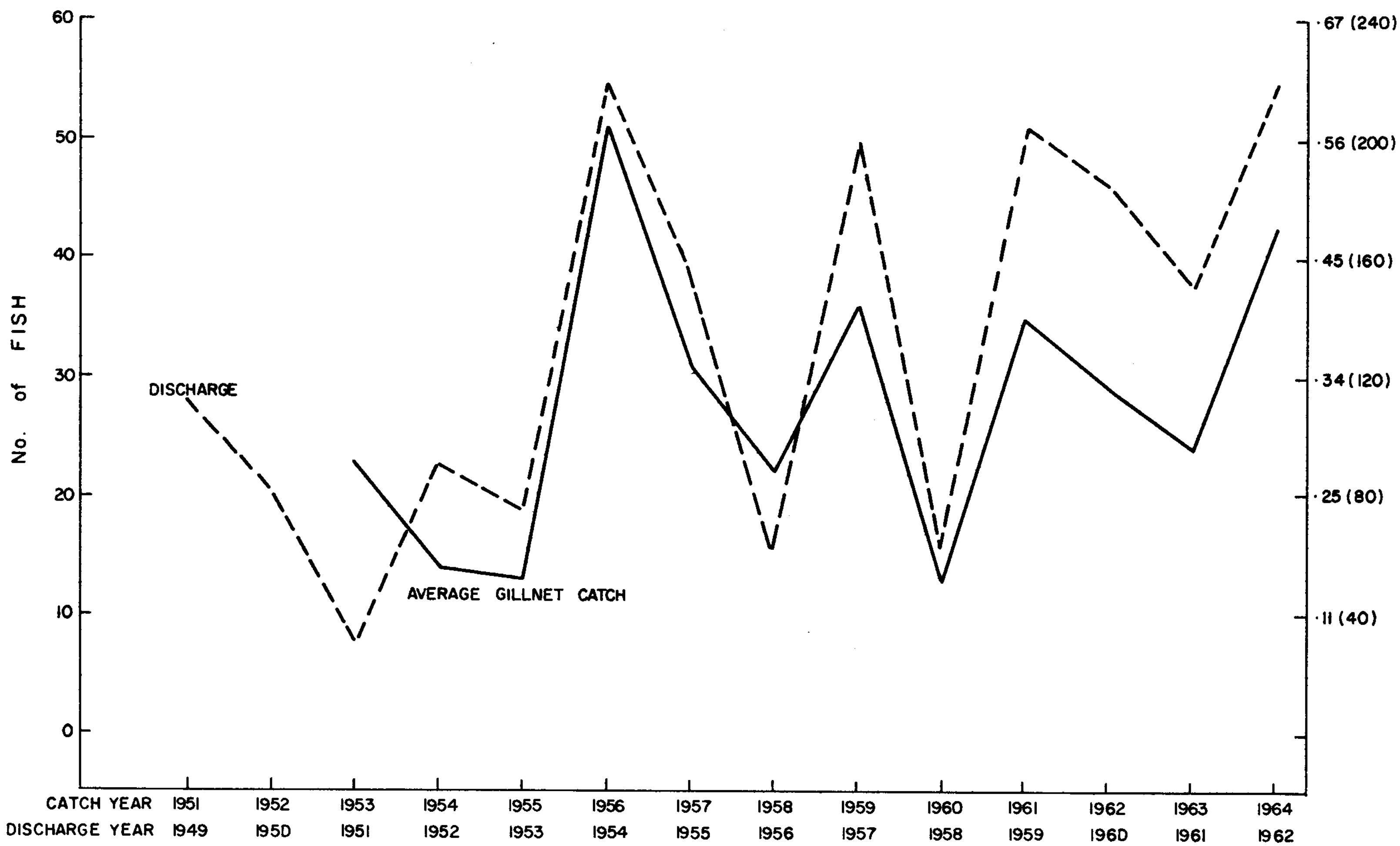


Figure 7·1 Annual average gillnet catch of coho salmon per fishing day in area 20 and low summer discharge in the Cowichan River two years previously. (Can. Dept. Fish., 1965).

a large number of these grilse remained in the southern Strait throughout the summer, a large proportion moved progressively northward along the eastern side of the Strait as the season advanced (Can. Dept. Fish., 1965). Grilse tagging locations in Saanich Inlet and Stuart Channels (Argue and Heizer, 1974) would indicate that these are relatively important rearing areas.

(b) Chum Salmon (*Oncorhynchus keta*). Chum salmon ascend the Cowichan and Koksilah rivers from mid-October through December. Spawning peaks during the latter half of November and is complete by late January.

Chum salmon spawn mainly in lower portions of the mainstems and in sloughs and side channels which are accessible during high water. In the Cowichan River, major spawning occurs in the Riverbottom Road area below Skutz Falls, and in the region from the Island Highway Bridge downstream to the vicinity of Somenos Creek. In the Koksilah, spawning chums are distributed throughout the mainstem from Marble Falls downstream to the Cowichan confluence (Figure 1.2).

The Chemainus River chum run is similar to that of the Cowichan. The salmon enter the stream in early October and spawning occurs until the end of December, with the peak being in late-October. Spawning takes place in the first 6.4 km (4 miles) of the river mainstem.

Table 7.2 gives chum salmon escapement data for the rivers and streams of the area. The Cowichan stock is among the largest native to Vancouver Island streams. The southern Vancouver Island sub-area (which includes the Cowichan, Koksilah, Chemainus and Goldstream rivers) chum salmon escapement average is 12-13% of the total for the Johnstone Strait-Fraser River study area (Anderson, 1974).

Table 7.2. Maximum, Minimum and Average Annual Chum Salmon Escapements from 1963 to 1973 (Can. Dept. Environ., 1963-1973a).

	Maximum	Minimum	Average
Bonsall Cr.	750	75	216
Bush Cr.	6,750	750	3,316
Chemainus R.	35,000	2,000	11,523
Cowichan R.	100,000	35,000	58,636
Holland Cr.	3,100	1,500	5,397
Koksilah R.	7,500	1,500	3,682
Rocky Cr.	200	0	48
Stocking Cr.	6,750	1,050	2,861

The majority of chum fry migrate directly to the estuary upon their springtime emergence. They are the dominant element of the fish population of the lower river during this period. The large size of some fry (66 mm) trapped below White Bridge in the Cowichan River in 1965 and 1966 would suggest that some degree of freshwater rearing occurs (Sparrow, 1968c).

In the Lynn Creek system (at Deep Bay, Vancouver Island) chum fry assumed estuary residence for 30 days or more, the average time falling between 1 and 2 weeks (Mason, 1974). Here, they fed on freshwater, estuarine and marine food organisms and, in doing so, were exposed to marked daily fluctuations in salinity that demanded active selection of fresh water on ebbing tides, day and night. In this report, Mason (1974) noted that to avoid man-made changes that lead to deterioration of estuaries, planning programs must consider the dependency of the fry on a stable and productive ecosystem.

Walker, Lister and Harvey (1969) reported that an average of 29 and 48 days, respectively, elapsed from the time of tagging of chum salmon at Deepwater Bay in Johnstone Strait, until recovery of tagged carcasses on the spawning grounds of the Chemainus and Cowichan rivers. These time periods include both travel and freshwater residence intervals.

A tagging experiment carried out in the Big Qualicum estuary in 1961-62 provides some information on the estuary residence period of migrating salmon. Walker and Lister (1965) indicated that the majority of chum salmon migrating to the Big Qualicum River was within, or close to, the estuary for one and a half weeks. Other stocks from the east coast of Vancouver Island probably have much the same migration pattern as the Qualicum fish.

(c) Chinook salmon (*Oncorhynchus tshawytscha*). Chinook salmon returning to the Cowichan and Koksilah rivers congregate in the Cowichan Bay area in August and September ("summer run") prior to moving upstream. Spawning activity usually peaks during the second or third week in October. There is also a lesser population of relatively small-sized "spring run" chinook, which mature in the deep pools of the upper river and in Cowichan Lake before spawning in the fall (Neave, 1949).

Spawning in the Cowichan River occurs throughout the mainstem, with the majority of fish selecting the middle and upper reaches. Spawning chinook found in the lower reaches of a few Cowichan Lake tributaries are thought to comprise the "spring run" race. In the Koksilah River, spawning is confined to the mainstem downstream of Marble Falls and Kelvin Creek.

Chemainus River chinook spawn during September and October, with peak activity occurring in the first or second week of October. Spawning takes place in the lower river below Copper Canyon Falls. This small run persists despite heavy Indian and angling pressures.

Escapement estimates for chinook to the Cowichan River (1963 to 1973) ranged from 3,000 to 15,000, averaging 7,500. The only chinook stock on Vancouver Island of comparable size is that of the Somass River. Escapements to the Koksilah varied from 75 to 400, averaging 245, while Chemainus River escapements varied from 0 to 100, averaging 54.

Lister *et al.* (1971), investigated the emergence and migration timing of Cowichan River juvenile chinook salmon. Juvenile migration within the river system is comprised of two major groups: fry emerging in March and April and dispersing throughout the system, and smolts migrating seaward during late May and June. Rearing potential for juvenile chinook appears greatest in the floodplain area, where low gradients and numerous river bifurcations and meanderings create ideal habitat.

Unpublished data on the migration timing and early sea-life of chinook salmon of the Cowichan River system remains on file at the Pacific Biological Station (Sparrow, 1968b).

2. STEELHEAD (*Salmo gairdneri*):

Steelhead arrive at the Cowichan, Koksilah and Chemainus rivers as early as October and continue to enter until mid-May. Spawning activity peaks in March or April in the Cowichan and Chemainus Rivers.

Neave (1949) separated Cowichan steelhead into winter (October-March) and spring (late March-mid May) races. Winter-run fish reportedly spawn from early January to late March throughout the Cowichan mainstem and in the Robertson River. Spring-run fish spawn in April and May, primarily in the lower river, but also in lake tributaries (Bull, 1966).

Koksilah River steelhead stocks are believed to be comparable in timing and racial composition to those of the Cowichan. Spawning takes place in the mainstem and in tributaries downstream of Marble Falls. However, some steelhead (as well as coho salmon) may ascend the falls when favourable water levels occur.

The Chemainus River supports distinct winter and summer runs of steelhead. Summer steelhead are noted for their ability to overcome obstacles and ascend streams for greater distances than are usual for the winter race (B.C. Dept. Rec. and Cons., 1973). The prolonged freshwater residence period of the summer run requires the protection of the deep canyon pools of the river's mid-section. Winter fish do not display a marked tendency to seek out headwater spawning areas. On the basis of these behavioural differences, it is probable that summer steelhead spawn exclusively in the upper system, while winter populations spawn downstream of the Copper Canyon Falls obstruction.

Steelhead emergence timing is unknown for these rivers, but it likely begins in late-May, peaking in the latter part of June to mid-July (Withler, 1966).

Most steelhead fry spend their first summer in their natal stream or adjacent to their birthplace in the mainstem. In late fall, sub-yearlings generally migrate from the colder headwaters to the warmer lower reaches. They return to the headwaters in the summer months, and then retreat again to the lower river as second year fingerlings. Most juveniles undergo smolt transformation in the spring of their third year, and their seaward migration occurs approximately from mid-April to mid-May. Some may remain in brackish water of the estuary for a time before leaving the river system entirely.

3. RESIDENT FRESHWATER SPECIES:

Cutthroat trout (*Salmo clarki clarki*) are found in nearly all streams and lakes of coastal British Columbia. Spawning occurs in small streams, usually during the period of February to May. Fish reproduce after three to four years, and spawning more than twice is exceptional. Cutthroat juveniles remain in fresh water for varying periods - some entering the sea when quite small, while others remain indefinitely in lakes and streams.

Within the Cowichan, Chemainus and Koksilah systems, the cutthroat trout is the most widely distributed of the salmonid species, occurring in waters inaccessible to anadromous fish. Cutthroat, frequenting lower river areas, are mainly anadromous and lead an estuarine existence, moving in and out with the tide. Anadromous fish migrate upriver in the fall to feed on the eggs of spawning salmon, and again in the spring to spawn themselves. Sexually mature individuals have been encountered in November and December, although the majority of fish spawn in February and March. Spawning takes place in tributary streams.

The fry of cutthroat trout probably emerge from the spawning gravel over a period similar to that of steelhead, beginning in late May and peaking in the latter part of June to mid-July. The main downstream dispersal of yearling or older juveniles from the small, natal streams into the mainstem of the Cowichan River takes place in spring, coinciding with the movement of coho fry on which the cutthroat feed extensively.

Dolly Varden char (*Salvelinus malma*) are the most widely distributed salmonid species in the province. Both anadromous and resident populations are common. Spawning takes place in the fall, generally between mid-August and early November, when the fish are in their fifth year.

According to Neave (1949), Dolly Varden are quite numerous in Cowichan Lake, particularly in the western portions where they frequent stream mouths. They are commonly encountered in the Cowichan mainstem and in various tributaries in winter and spring. The species is scarce in the lower reaches of the Cowichan River and no sea-run individuals have been recorded.

Beyond the established presence of Dolly Varden in the Koksilah system, little is know of the species' movements or distribution here. A small population of Dolly Varden may also exist in the Chemainus River (R.S. Hooton, pers. comm.), but its presence is not documented.

The non-migratory or resident form of the rainbow trout (*Salmo gairdneri*) is widespread throughout coastal and interior British Columbia streams. The life history of resident rainbow trout is similar to that of steelhead, with the exception that lakes are often substituted for the ocean environment. First spawning occurs at an age of three or four years.

Rainbow trout are distributed throughout the Cowichan and Koksilah rivers at all times of the year. Taylor (1963) reported that Cowichan rainbows occurred in greatest abundance in the upper three miles of the river near the Cowichan Lake outlet, particularly during the period from September to May. Neave (1949) recorded similar findings. Fish under two years of age are numerous in the rivers at all seasons.

The majority of rainbow trout spawning occurs in the mainstem of the Cowichan River, from January to March. Repeat spawning is rare (Bull , 1966).

Numerous fry and juvenile rainbow trout were observed in the upper Chemainus mainstem, and in Solly and Chipman creeks, by a Fish and Wildlife Branch survey crew (B.C. Dept. Rec. and Cons., 1973).

The brown trout, native to western Europe and the British Isles, (*Salmo trutta*) has been successfully introduced in the Cowichan and Little Qualicum rivers. These stocks originated from eggs purchased between 1932 and 1935 from Wisconsin and Montana by the former Federal Department of Fisheries and Marine (D.E. Marshall, pers. comm.). Spawning was first observed in 1937 (Carl, 1938a). Unlike other trout species, brown trout characteristically spawn in the fall and early winter.

Brown trout are most frequently encountered above Skutz

Falls, though they are distributed throughout the Cowichan River (Bull, 1966). The species has been observed and occasionally caught in the lower Koksilah River. Occasional "sea-run" individuals are reported by anglers.

Neave (1949) cited spawning activity in most major tributaries above Skutz Falls; however, brown trout spawning behavior is not well understood. Sexual maturity is reached after three or four years, with spawning and fry emergence timing being similar to that of coho salmon.

The brook trout (*Salvelinus fontinalis*), introduced to the system, is found in the upper reaches of Cowichan River tributaries and in Somenos Lake, but they are not abundant.

Brown bullhead (*Ictalurus nebulosus*) and smallmouth bass (*Micropterus dolomieui*) were introduced to Fuller Lake (near Chemainus)in the early 1900's, but nothing is known of their behaviour or life histories there. The bullhead has also been reported from Somenos Lake (Carl, 1953).

The threespined stickleback (*Gasterosteus aculeatus*) is found in fresh and brackish water. The species is an important component of the diets of game fish and fish-eating birds, especially the common merganser (*Mergus merganser*). Breeding takes place throughout the summer months.

The prickly sculpin (*Cottus asper*) and coast range sculpin (*C. aleuticus*) are widely distributed in all the river and streams of the area. They can tolerate brackish water and are an important forage fish. Spawning in both species occurs from mid-February to June, and there is some evidence of downstream migration prior to spawning in fish living close to the sea (Carl, Clemens and Lindsey, 1959).

It is possible that carp (*Cyprinus carpio*) could introduce themselves into the Cowichan and/or Chemainus River systems. Barraclough and Robinson (1971) reported that juveniles were transported across the Strait of Georgia in low salinity water pockets of the Fraser River plume,and that they recovered specimens as far west as Porlier Pass and Active Pass.

4. MARINE SPECIES:

Extensive sampling was conducted by the Fisheries and Marine Service from March to September, 1973 on the Cowichan estuary using pole net, beach seine, tow net and purse seine techniques (D. Goodman, pers. comm.). Herring (*Clupea harengus pallasi*), threespine stickleback (*Gasterosteus aculeatus*), shiner perch (*Cymatogaster aggregata*), chinook salmon (*Oncorhynchus tschawytscha*), coho salmon (*O. kisutch*), chum salmon (*O. keta*) and prickly sculpin (*Cottus asper*) were the most abundant species found in the estuary area. A complete list of species collected is presented as Appendix 7.1.

Many flatfishes, particularly juveniles, may be found within the study area or on the tidal flats associated with the estuaries. Species likely to be found include the Pacific and speckled sanddabs (*Citharichthys sordidus*, *C. stigmaeus*), arrow-tooth flounder (*Atheresthes stomias*), petrale sole (*Eopsetta jordani*), rex sole (*Glyptocephalus zachirus*), flathead sole (*Hippoglossoides elassodon*), hydbrid sole (*Inopsetta ischyra*), butter sole (*Isopsetta isolepis*), rock sole (*Lepidopsetta bilineata*), yellowfin sole (*Limanda aspera*), slender sole (*Lyopsetta exilus*), C-O sole (*Pleuronichthys coenosus*) and sand sole (*Psettichthys nelanosticus*) (Hart, 1973).

Silver smelt (*Hypomesus pretiosus*), capelin (*Mallotus villosus*) and long-finned smelt (*Spirinchus thaleichthys*) are found in the area. Long-finned smelt spawn in fresh water, and the fry, upon emergence, are swept into the estuary, where they may spend considerable time prior to moving offshore. Silver smelt and capelin spawn on the beaches of marine or estuarine areas, but little is known of the larval and juvenile fishes since they move offshore quite rapidly (Hart and McHugh, 1944).

Although only rarely, pilchards (*Sardinops sagax*) occasion Stuart Channel and Cowichan Bay (Foerster, 1941). Another clupeid, the American shad (*Alosa sapidissima*), may also have established spawning runs in the Cowichan and Chemainus areas, as its distribution is spreading rapidly since the species introduction to California.

A large herring (*Clupea harengus pallasi*) stock is located in the Gulf Islands area. Estuaries and nearshore waters are important rearing areas for these fish, and they are relatively abundant in the study area. Little spawning occurs near the Cowichan and Chemainus estuaries proper. However, the east side of Genoa Bay on Cowichan Bay and the shore north of Cherry Point, southeast of Cowichan Bay, are occasionally used for spawning (L. Webb, pers. comm.). Substantial spawning occurs in and north of Ladysmith Harbour, around Dunsmuir Island, Coffin Point, Coffin Island, Evening Cove, Kulleet Bay and Yellow Point. Patterson (1975) mapped the spawning sites in Ladysmith Harbour from 1956 to 1974, and the reader is referred to this report for details.

Arrow (*Clevelandia ios*), blackeye (*Coryphopterus nicholsi*), and bay (*Lepidogobius lepidus*) gobies may all be found within the study area. These small fish are eaten by rockfish, sculpins,greenlings and birds (Hart, 1973).

7 (ii) THE FISHERIES RESOURCE

1. COMMERCIAL FISHING:

Summaries of the commercial fisheries in British Columbia are given by Shepard and Stevenson (1956) and Aro and

Shepard (1967). The Fraser River report summarizes much of that information (Hoos and Packman, 1974).

Catches of chinook and coho salmon are made in areas generally remote from parent streams. In the Strait of Georgia area, both resident, or "inside", coho stocks (which spend their entire ocean life within the Strait) and "outside" coho stocks (which rear in open waters and are available for exploitation in the Strait of Georgia area for a relatively short period on their return from the ocean to spawn) are available to both the sport and commercial fisheries (Can. Dept. Fish., 1965). The degree of residency is largely dependent upon environmental factors local to the Strait of Georgia area. Residency may also be determined by the geographical location of the stream, and by the timing and size of the smolts leaving the streams (D.E. Marshall, pers. comm.).

Cowichan chinook and coho stocks contribute to the west coast of Vancouver Island troll fishery, and the Juan de Fuca and Satellite Channel net fisheries. Chemainus stocks contribute to Strait of Georgia and Johnstone Strait net fisheries (A.W. Argue, pers. comm.).

Tagging of coho grilse in the Stuart Channel wintering area in 1963-64 indicates that this stock constitutes the main foundation for the spring and early summer blueback fishery along the eastern side of the Strait of Georgia. Those tagged in Saanich Inlet were subsequently recovered in the Inlet and the southern Gulf Islands area (Can. Dept. of Fish., 1965).

Chum salmon migrate directly to the open ocean and are harvested near maturity on their home migration runs. Ocean tagging indicated that the majority of Cowichan-Koksilah chum salmon return via Juan de Fuca Strait with a small proportion passing through Johnstone Strait. The principal Canadian net fisheries exploiting Cowichan-Koksilah chum salmon operate in

Juan de Fuca Strait and Satellite Channel. The latter fishery is sustained primarily by Cowichan-Koksilah chum stocks. The average annual catch of this fishery (1960 to 1973) is 18,000 chum salmon.

Lill, Marshall and Hooton (1975) used established catch-to-escapement ratios to estimate the value of the Cowichan-Koksilah salmon stocks to the commercial fishery. The average annual wholesale commercial value of chinook, coho and chum salmon originating from these rivers was $2,186,814., (based on 1973 prices).

The study area, from Satellite Channel to Ladysmith Harbour, is presently closed to commercial salmon net fishing. Troll fishing catches from the area are reported by statistical area (Area 17 and 18).

A viable and productive herring food fishery is located in the Gulf Islands area. Although the study area is closed to herring fishing it no doubt figures in herring production as a rearing location.

2. SPORT FISHING:

(a) Freshwater sport fishing. Historically, angling in the Cowichan Valley was considered unparalleled, and the area remains attractive, if not more so, to the sport fisherman today. The Chemainus River also supports an active fishery, although it is less popular than the neighbouring Cowichan and Nanaimo rivers. The study area is close to major urban centres, offers year-round fishing opportunities for a variety of abundant gamefish species, is readily accessible, and yet is largely natural and unspoiled.

Steelhead and cutthroat trout fishing support the bulk of freshwater fishing activity, and these are centred on the lower reaches of the Cowichan, Koksilah and Chemainus rivers.

Withler (1972) strongly recommended that the lower mainland coast and Vancouver Island be included in intensive steelhead management schemes, as a result of increased rates in fishing pressure arising from the conflict between increasing demand and limited opportunity.

Fishing for adult steelhead traditionally begins on Boxing Day and takes place mainly in January and February. Young steelhead are frequently taken by trout fishermen as the fish descend to the sea as smolts, but the minimum legal length of 20.3 cm (8 inches) prevents the legal exploitation of yearlings and most two-year fish.

B.C. Fish and Wildlife Branch questionnaire surveys have shown the Cowichan to rank consistently high in terms of catch and angler effort amongst the over 300 steelhead producing streams throughout the province. In fact, the river sustains twice the number of angler-days of any other Vancouver Island stream (an exception being the 1973-74 season). The following table (Table 7.3) is condensed from the steelhead questionnaire results, and serves to illustrate this further.

Table 7.3. Average Annual Steelhead Catch Data, 1966-67 to 1973-74.

River	No. Anglers	Angler Days	Catch
Cowichan	1794	8731	1823
Koksilah	313	286	1321
Chemainus	189	847	207

Economic evaluation of recreation resources benefits is complicated and consequently there is little information available. Pearse Bowden Economic Consultants (1971) estimated, on the basis of 1969-70 values and information, that resident anglers spent an average of $15.00 for each day they fished. Similarly the best estimate of the value of a day of freshwater sport fishing was between $5.00 and $10.00 per angler.

(b) Tidal sport fishing. The 1970 Fisheries Service annual report (Can. Dept. Fish. For., 1971) noted that over 40% of British Columbian sport vessels concentrate in the southern Gulf Islands, Saanich Inlet, and Howe Sound. Chinook and coho marking programs (Neave, 1941a,b, 1949; Neave and Pritchard, 1942; Sparrow, 1968a, b,c) show that a significant proportion of Cowichan-Koksilah (and Chemainus, by extrapolation) fish take up residence in the Strait of Georgia rather than migrating to the open ocean, and these, therefore, make up an important component of the sport fishery catch.

The Cowichan Bay area is particularly noted for its late summer and fall fishery of maturing chinook and coho salmon The fish are renowned for their abundance and size, and a great many prize winning fish (e.g. B.C. Salmon Derby) are taken in these waters.

The estimated annual tidal sport catch of salmon, fishing effort in boat-days and the catch per boat-day for the Cowichan and Ladysmith subdistricts (Areas 17 and 18) from 1967 to 1974 are appendixed (Appendix 7.2). Annual catches (since 1967) average approximately 20,000 for both areas and show an upward trend, most marked in the Ladysmith area (52,000 fish in 1974). The average catch per boat-day of approximately 1.4 a and 0.4 salmon for areas 17 and 18, respectively, has remained relatively constant.

Mos and Harrison (1973) surveyed recreational boating activity in the Strait of Georgia by British Columbia residents. Their results showed that over one-third of the residents in the Duncan, Gulf Islands and Ladysmith areas own boats, and that over two-thirds of boat use is for angling purposes. The appendixed results for the areas illustrate the extensive interest and participation of local residents in the tidal fishery (Appendix 7.3).

3. INDIAN FOOD FISHERY:

One of the largest Indian communities on Vancouver Island resides in the Cowichan Valley. An annual salmon food fishery is conducted primarily on the lower Cowichan River and augments the food supply of many Indian households in the area. Historical fishing methods including spear and gaff are used to fish the salmon. Limited gillnetting is conducted by the elderly or infirm.

The estimated annual catch of chinook, coho, chum and steelhead (1960 to 1973) averaged 603, 1309, 2772, and 106 (1966-1973) fish, respectively. Up to 7,000 fish are taken some years, with the majority of the catch usually being chum salmon (Lill, Marshall and Hooton, 1975). The Chemainus River does not support a sizeable Indian food fishery since the drastic decline in salmon stocks in the early 1960's (R.S. Hooton, pers. comm.)

The Indian food fishery is not only important as a food source, but is one of the few remaining links with a traditional lifestyle.

8. FLORA

The flora of an area provides the habitat upon which the fauna are dependent, directly or indirectly, for both food and cover. In the case of an estuary, natural terrestrial, salt marsh, tidal and subtidal floras are essential in providing the fish, wildlife and waterfowl resources we both enjoy and exploit.

The flora of the Cowichan-Chemainus area is discussed under three headings, aquatic, deltaic and terrestrial flora. Published information specific to the area is sparse. Species identified from the Cowichan and Chemainus estuaries are presented in Appendix 8.1.

8 (i) AQUATIC VEGETATION

1. FRESHWATER:

Sampling completed over a one year period in Cowichan Lake (Carl, 1953) identified the following phytoplankton species: *Staurastrum avicula, S. gracile, S. cuspidatum, S. artiscon, Xanthidium antilopaeum* var. *polymazum, Micrasterias apiculata, Sphaerocystis schroeteri, Gloeocystis gigas,* and *Bulbochaete* sp. among the green algae; the diatoms *Tabellaria fenestrata, T. flocculosa, Fragillaria crotonensis, Asterionella formosa, Melosira crenulata,* and *Surirella* sp.; and the blue-green algae *Coelosphaerium kuetzinginum , Gloetrichia echinulata, Nostoc* sp., and *Aphanizomenon flos-aquae.* Of these, only a few occurred regularly in samples taken in open water. These included *Tabellaria fenestrata, Asterionella formosa* and *Coelosphaerium kuetzinginum.* Small *Nostoc* sp. colonies were recorded from all but the deepest benthic samples, particularly during the early summer.

Vascular aquatic plants were relatively few in numbers and kind in Cowichan Lake. However, productive areas were located in small bays or along shallow shores. Such species as pondweed (*Potamogeton amplifolius, P. epihydrus* var. *nuttalli, P. robbinsii, P. richardsonii*), water buttercup (*Ranunculus aquatilis*), water milfoil (*Myriophyllum spicatum*), water lily (*Nuphar polysepalum*), ivy-leaved duckweed (*Lemna triscula*), hair-leaved rush (*Juncus supiniformis*), water moss (*Fontinalis anti-pyrectica*), horsetail (*Equisetum limosum*), water lobelia (*Lobelia dormanii*), *Nitella* sp., stonewort (*Chara* sp.) and buckbean (*Menyanthes trifoliata*) were recorded from these protected localities.

Although a single year's sampling could not be considered as conclusive evidence, Carl (1953) did not consider Cowichan Lake as being highly productive of phytoplankton.

Quamichan Lake, which lies within the Cowichan River watershed is a highly eutrophied water body. It is ringed by a thick belt of reeds, mostly *Scirpus robustus*. Water lilies (*Nuphar polysepalum*) and water weed (*Potamogeton pusillus*) are found in certain areas (Mottley and Carl, 1953). Occasional summer fish kills in the lake are presumed to be caused by low oxygen conditions owing to the decomposition of heavy growths of blue-green algae (Neave, 1945; Waldichuk, 1955). Willis, Cunliffe and Tait Ltd. (1975) have reviewed the lake's status.

2. MARINE:

Primary production related parameters observed on the Cowichan estuary during July 1975 are being investigated presently by the Pacific Biological Station (see Sibert, Appendix 1.2).

The oceanography of Ladysmith Harbour, as it applies to phytoplankton, was discussed in detail by McAllister (1955). Four phytoplankton blooms were found to occur in the harbour over the summers of 1954 and 1955. Midsummer blooms were thought to be the result of advection of Stuart and Trincomali Channel water masses and entrainment of plankton and nutrients at the interface between low salinity surface waters and deeper waters. The decomposition of large amounts of eelgrass and sessile algae in the inner harbour in late summer was also accompanied by a phytoplankton bloom.

The generic sequence of phytoplankton from spring to autumn was as follows: *Thalassiosira*, *Chaetoceros*, *Skeletonema*, *Chaetoceros*, and a complex of dominant genera in late summer. The generic composition of inner harbour phytoplankton was generally different from that of the outer harbour.

Plankton hauls, conducted as part of an Environmental Protection Service environmental survey, recovered various phytoplankton species from Chemainus Bay. They included the diatoms *Biddulphia*, *Chaetoceros*, *Ditylium*, *Coscinodiscus* and *Eucampia*, as well as the dinoflagellate *Noctiluca* (Kussat, 1970).

The colourless blue-green alga *Thiothrix* sp. has been reported growing extensively on decaying bark debris in certain locations in Ladysmith Harbour (Dobrocky SEATECH Ltd., 1975). The plants are saprophytic upon decaying organic matter and indicative of reducing (anoxic) conditions within the substrate (Goddard, 1975). These organisms are, no doubt, widespread throughout the study area where cellulose materials litter the substrate.

Research on the macrophytic algae of the Strait of Georgia has been reviewed by Foreman and Root (1975). No recent work, other than an on-going study by Austin (see Appendix 1.2) on the growth forms of unattached algae of Thetis Island, has been done within this study area. Significant kelp beds are not located within the study area, although numerous beds were once surveyed northeast of the Saanich Penninsula and around the outer Gulf Islands (Cameron, 1916). Studies of estuarine and mudflat ecology have been centred on the Fraser and Squamish estuaries, and the reader is referred to the reports on these two locations (Hoos and Packman, 1974; Hoos and Vold, 1975) for a review of work to date of publication.

A little analyzed floral group is the benthic fungi. Hughes (1969) identified the Fungi Imperfecti *Humicola alopallonella* (common), *Monodictys pelagica* (common) *Phoma* sp., and *Zalerion maritimum* (very common) and the ascomycetes *Ceriosporopsis halima, Lignincola loevis, Lulworthia medusa, L. floridana, Microthelia maritima* and *Pseudoeurotium rilstonii* from samples taken within the study area. These marine fungi are all wood-boring forms.

Eelgrass beds within the study area have not been surveyed in detail. Harris (1953) reported eelgrass to be "vigorously abundant" in Cowichan Bay and "common in the waters adjacent to Chemainus". Eelgrass beds occur on both the Cowichan and Chemainus River estuaries. Kennedy (pers. comm.) noted eelgrass on the most northernly mudflats of the Cowichan River delta, where little or no log boom storage occurs. Laing (1975) noted eelgrass beds on the tidal flats of the Chemainus River delta, seaward of the Shoal Islands. A photographic survey of the tidal flats (Balch, 1974) along the Crofton pulp mill twin outfalls showed eelgrass covering much of the area. Eelgrass beds in Ladysmith Harbour are reported to be somewhat reduced (Patterson, 1975).

8 (ii) DELTAIC VEGETATION

The following discussion of deltaic flora on the Cowichan and Chemainus River estuaries, the maps of plant community types (Figures 8.1 and 8.2) and the list of floral species identified from the estuaries (Appendix 8.1) are based on vegetation surveys by Kennedy and Raymond (1974) and Kennedy (in progress).

The flora of the Chemainus River delta remains largely undisturbed by development and is affected only by agriculture. The distribution of plant community types on the delta is determined by the ratio of freshwater to saltwater influence and the two main plant communities on the delta are based on the predominance of either fresh water or salt water (see Figure 8.1).

A rush (*Juncus* sp.) and sedge (*Carex* sp.) community type reflects a predominant freshwater influence and is found in areas influenced by the Chemainus River, Bonsall Creek and in low-lying areas dyked off from the sea. Areas subject to a saline influence are dominated by the highly salt tolerant glasswort (*Salicornia virginica*) and seashore saltgrass (*Distichlis spicata*). Dense growths of foxtail barley (*Hordeum jubatum*), cinquefoil (*Potentilla pacifica*), seaside arrowgrass (*Triglochin maritimum*), orache (*Atriplex patula*) and yarrow (*Achillea millefolium*) are also found in this community type. Grasses (Gramineae) and daisy (*Erigeron philadelphicus*) become predominant landward, and glasswort becomes predominant seaward.

The glasswort-covered areas demarcate the edge of the salt marsh and the beginning of the intertidal mudflats to seaward, which are covered by an algal mat up to 3 cm thick. Rockweed (*Fucus* sp.) and green confetti (*Enteromorpha intestinalis*) are infrequent on the flats, occurring more often in tidal channels on the seaward portion of the delta. Eelgrass beds (*Zostera marina*) extend from areas always covered by at least 3-10 cm of water, out over the delta's subtidal flats.

Dykes on the delta, some up to 100 years old (Kennedy, pers comm.), interrupt the plant community type continuum previously described. However, flood channels extending some 700 m (2100 ft.) into dyked fields, are dominated by glasswort, saltgrass and bulrush (*Scirpus maritimus*).

The flora of the Cowichan River estuary is less well

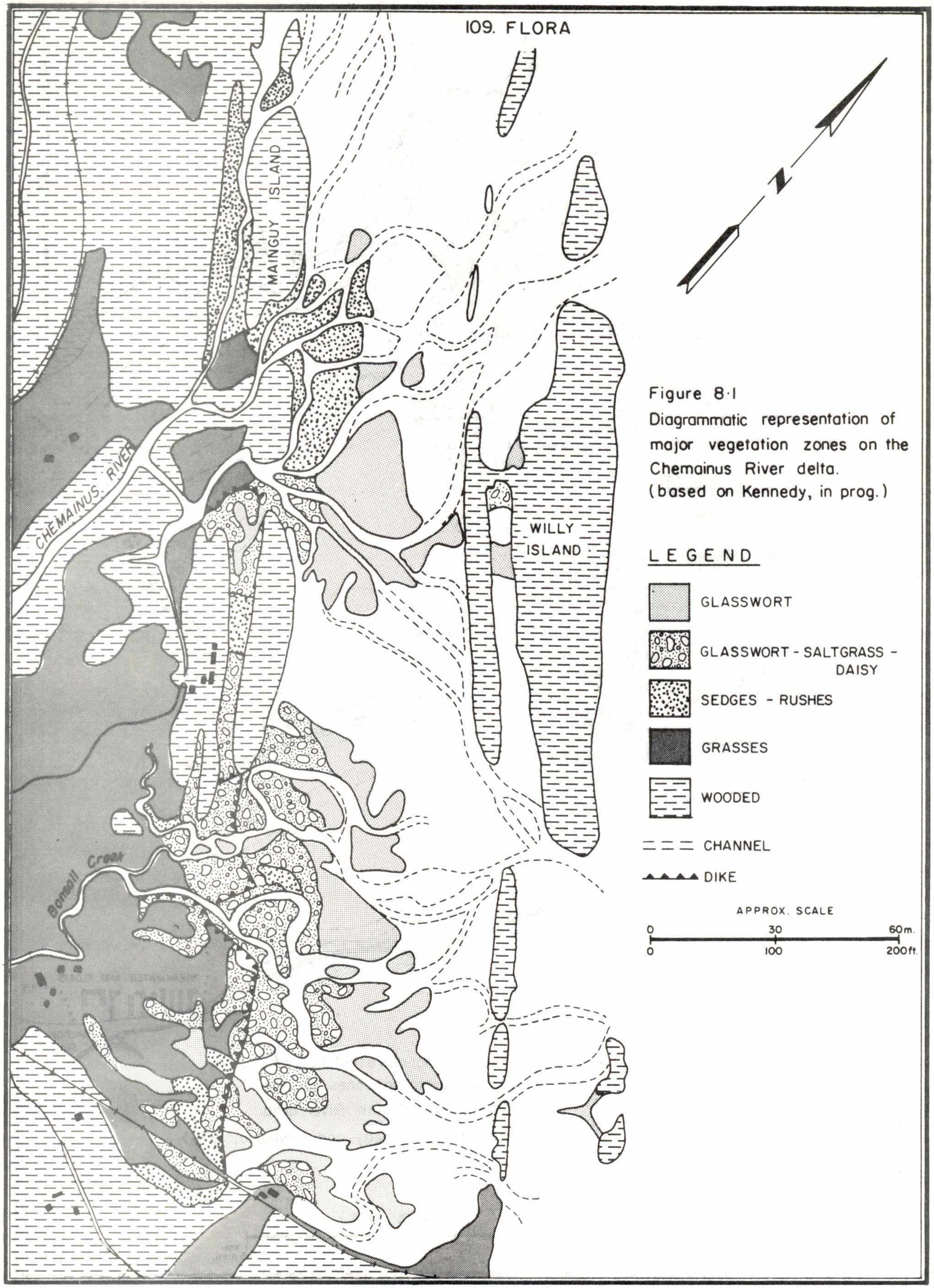


Figure 8·1
Diagrammatic representation of major vegetation zones on the Chemainus River delta.
(based on Kennedy, in prog.)

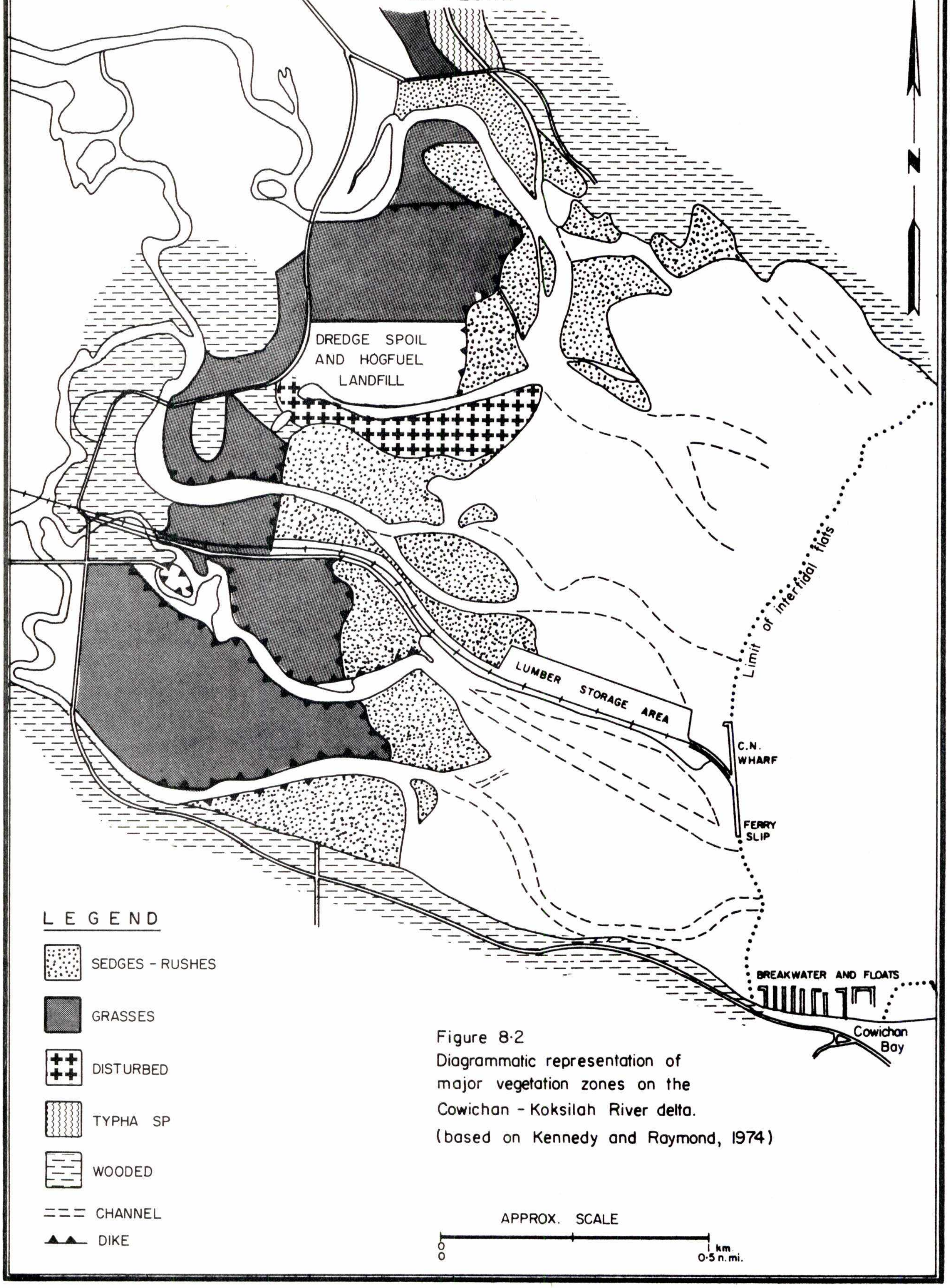


Figure 8·2
Diagrammatic representation of major vegetation zones on the Cowichan - Koksilah River delta.
(based on Kennedy and Raymond, 1974)

preserved as a result of greater demands by industry and agriculture. It reflects a freshwater influence across the entire delta, the predominant species being Lyngbye's sedge (*Carex lyngbyei*)and arctic rush (*Juncus arcticus*) (see Figure 8.2). Much of the salt marsh has been dyked and grazed by livestock, which alters floral community structures through alteration of floral requirements and grazing of uncompetitive species. Areas such as these are vegetated by grasses (Gramineae), dandelion (*Taraxacum* sp.) and wild rose (*Rosa* sp.) (Kennedy and Raymond, 1974). Some salt marsh and intertidal areas have been filled and are being used by forest products industries (see Land Use Section). Filling of these areas constitutes a permanent and complete loss of the normal, highly productive estuarine flora.

Salt marsh and mudflat communities are also located on the deltas of Bush, Holland and Rocky creeks and along the foreshore of Ivy Green Provincial Park in Ladysmith Harbour (Patterson, 1975).

An assessment of the productivity of the tidal flats of the Cowichan River estuary and identification of an algal collection are presently in progress (see Appendix 1.2).

8 (iii) TERRESTRIAL VEGETATION

The study area lies within the coastal Douglas fir biogeoclimatic zone (Krajina, 1965), and is characterized by low summer rainfall and a mediterranean subhumid climate. A number of generalized, typical forest associations are observed within this zone (Krajina, 1953).

The most widespread forest association, Doublas fir-salal, is comprised mainly of Douglas fir (*Pseudotsuga menziesii*), with a small amount of hemlock (*Tsuga heterophylla*). Salal (*Gaultheria shallon*) dominates the shrub layer, with lesser amounts of red huckleberry (*Vaccinium parvifolium*) and Oregon grape (*Berberis aquifolium, B. nervosa*). The herbs consist mainly of twayblade (*Listeria cordata*), princess pine (*Chimaphilla umbellata*), twinflower (*Linnaea borealis*), rattlesnake plantain (*Goodyera oblongifolia*) and a brown saprophyte (*Monotropa latisquamaea*).

Lichens are the most conspicuous feature of the Douglas fir-salal-lichen association. Lodgepole pine (*Pinus contorta*) and arbutus (*Arbutus menziesii*) are mixed with Douglas fir in the tree layer. Salal and Oregon grape dominate the shrub layer, although the hairy manzanita (*Arctostaphylos columbiana*) is also found. The important herbs are kinnikinnick (*Arctostaphylos uva-ursi*), hawkweed (*Hieracium albiflorum*), dogbane (*Apocynum androsaemifolium*), a grass (*Festuca occidentalis*) and wintergreen (*Pyrola picta* var. *dentata*). The *Peltigera* and *Cladonia* lichens dominate on the ground, whereas the bearded lichen (*Alectoria sarmentosa*) is most evident on the trees.

The Douglas fir-moss association occurs in wetter areas. Douglas fir, hemlock, red cedar (*Thuja plicata*), grand fir (*Abies grandis*) and in early stages of development, broad-leaved maple (*Acer macrophyllum*), red alder (*Alnus rubra*) and bitter cherry (*Prunus emarginata*) combine with the other species to form the tree layer. Young shade-tolerant tree species make up the shrub layer. Some saprophytes, such as Indian pipe (*Monotropa uniflora*) and coral root (*Corallorhiza maculata*), are mixed with the predominant mosses *Hylocomium splendens* and *Eurhynchium oreganum*.

Douglas fir, red cedar, grand fir, hemlock, white pine (*Pinus monticola*), broad-leaved maple and red alder are found in the Douglas fir-swordfern association. This association occurs where water seepage creates optimum growing conditions for Douglas fir. The shrubs consist of salmonberry (*Rubus spectabilis*) and the devil's club (*Oplopanax horridum*). Salal and red huckleberry occur only on rotten wood. The lush herb layer consists of swordfern (*Polystichum munitum*), may-leaves (*Achyls triphylla*), three-leaved tiarella (*Tiarella trifoliata*), Siberian miner's lettuce (*Montia sibirica*) and many other species. Abundant mosses occur, but there is a marked lack of lichens.

The western red cedar-grand fir-maidenhair fern association occurs in areas subject to periodic inundation, of which Douglas fir is intolerant. Deciduous species are common and white pine, hemlock and Douglas fir infrequent. The shrub layer consists of young tree species, salmonberry and devil's club. This association has the most luxuriant herb layer of all the associations. Maidenhair fern (*Adiantum pedatum*) is abundant and all the Douglas fir-swordfern species are present. In addition, such species as bugbane (*Trautvetteria grandis*), little buttercup (*Ranunculus uncinatus*), violet (*Viola glabella*), false hellebore (*Veratrum viride*) and bleeding heart (*Dicentra formosa*) are common. Mosses are abundant, but lichens are again absent.

Swampy areas, where the soil consists of black muck, support the red cedar-red alder-skunk cabbage association. The shrub layer is mainly comprised of shade tolerant tree species, with some salal and huckleberry. The herbs are usually peculiar to these locations. Skunk cabbage (*Lysichitum americanum*), water parsley (*Oenanthe sarmentosa*), water cress (*Cardamine angulata*), false lily-of-the-valley (*Maianthemum dilatatum*) and mitrewort (*Mitella ovalis*) are the predominant species. Mosses, especially *Mnium punctatum*, and liverworts occur abundantly on the soil and decaying logs.

The associations previously described may be arranged from top to bottom on an "ideal slope". The salal-lichen association supports the poorest tree growth, has coarse soils, and has no subsurface seepage water. The sword fern association has good tree growth, rich soils and abundant seepage. Salal and moss associations lie between these two extremes.

There is very little literature describing the actual distribution of flora in the study area. The following notes serve to give a general description of the two watersheds.

Much of the Cowichan valley is now second growth owing to timber being logged off during the past 40 years. Cowichan Lake is rimmed by a deforested belt extending up some 300 m (1000 ft.) from lake level. Riparian growth is approximately 20-25 years old (Taylor, 1963). The lower Cowichan valley supports mixed agriculture,with dairy farming and its attendant forage comprising the largest segment of this. Of the 312.3 hectares (7,808 acres) devoted to field crops, 256.4 hectares (6,410 acres) are used for hay production (Statistics Canada, 1973).

The Chemainus watershed supports a large and intensive logging industry. The lower 16.1 km (10 miles) of the river are bordered by farmland and second growth forest. The upper 26 to 32 km (16-20 miles), including the watersheds of Chipman and Reinhart creeks, have been largely clear cut since 1960. Little large scale reforestation has taken place, the countryside being barren, and, therefore, subject to rapid runoff and extremes in temperature. Herbiciding of riparian deciduous vegetation has added to the habitat disruption (B.C. Dept. Rec. and Cons., 1973).

For an annotated list of plant species found on Saanich Peninsula, which is considered representative of the present study area, the reader is referred to Szczawinski and Harrison (1972).

9. WILDLIFE

The Cowichan-Koksilah lowlands and estuary provide habitat for an abundant and diverse avian fauna. Mammals are still well represented, although man's activities and developments in the area have reduced the region's capacity to support large populations.

The Chemainus River estuary is highly valuable to both avian and mammalian faunas as well, and it remains the least disturbed of all the estuaries on southern Vancouver Island.

Information of value in assessing effects of development on wildlife of the study area, such as life histories, distributions, feeding and breeding, is not complete. In view of the richness of the fauna and its proximity to major urban centres, every consideration should be made to conserve these natural resources in the face of ongoing development.

A report by Trethewey (1974) is relied upon heavily in producing some of the following subsections.

9 (i) WATERFOWL

Waterfowl are among the most abundant birds in the study area. According to Trethewey (1974), an estimated 16,000 waterfowl winter or stop during migrations in the vicinity of Duncan. Of these, about 9,000 are dabbling ducks, 6,300 are diving ducks and the remainder are swans and geese, including black brant (*Branta bernicla nigricans*). Though over 14 species of waterfowl are known to nest in the Duncan area, most species migrate further north, and summer resident populations probably number less than 1,000.

The marshes and mudflats of the estuaries, and the low-lying areas fringing the Chemainus, Cowichan and Koksilah rivers and Somenos and Quamichan lakes are extensively utilized by dabbling ducks during winter. Prior to the opening of the hunting season, an estimated 5,000 to 6,000 dabblers can be found on the Cowichan estuary. Those birds not taken by hunters move to no-hunting areas around Somenos and Quamichan lakes and the Chemainus estuary, where they are joined by later migrants. Blood (1975) observed an average of 512 (range: 69-1733) dabblers on the Chemainus River estuary over the 1974-75 winter. Although no data were available, no doubt many more dabblers could be found inhabiting the flooded fields of the present study area, particularly in the vicinity of Somenos Lake.

Eight species of dabbling ducks are known to nest in the study region. They include mallard (*Anas platyrhynchos*), pintail (*A. acuta*), green-winged teal (*A. crecca*), blue-winged teal (*A. discors*), cinnamon teal (*A. cyanoptera*), European wigeon (*A. penelope*), American wigeon (*A. americana*), northern shoveler (*A. clypeata*) and wood duck (*Aix sponsa*). Nesting by the gadwall (*Anas strepera*) is suspected.

Canada geese (*Branta canadensis*), trumpeter swans (*Olor buccinator*) and whistling swans (*O. canadensis*) utilize habitat similar to that of the dabblers. Geese seldom use the Cowichan estuary during the hunting season, though the protected swans are often seen there. Introduced feral mute swans (*Cygnus olor*) and Canada geese nest within the study area. In fact, the Duncan area is the only major Canada goose nesting region known on Vancouver Island, according to Trethewey (1974).

Nesting areas favoured by geese and dabblers in the study region include the Chemainus and Cowichan estuaries, the margins of Somenos and Quamichan lakes, and the low-lying areas of the river flood plains. Additional nesting habitat becomes available during wet springs when agricultural land, particularly within the Cowichan Indian Reserve, cannot be worked. In addition, eight to ten goose nests may be found on a small island in Quamichan Lake annually. The wood duck nests in tree cavities and therefore, nesting by this species is limited by the number of suitable trees.

During the winter, diving ducks are found in areas of deeper water such as Kulleet Bay, the head and south shore of Ladysmith Harbour, Chemainus Bay, around the Shoal Islands Cowichan Bay, Somenos and Quamichan lakes and the river channels. Of the 17 species of diving ducks found in the area (listed in Appendix 9.1), only 4 are known to nest there. These are the common goldeneye (*Bucephala clangula*), harlequin duck (*Histrionicus histrionicus*), and hooded and common mergansers (*Lophodytes cucullatus*, and *Mergus merganser*) (Trethewey, 1974).

The Canada Land Inventory rates the entire foreshore of the study area as moderately important for waterfowl production and important as migration or wintering areas (Taylor and Carreiro, in press). This uniformity is misleading. Blood (1975) rated sectors of the Ladysmith-Chemainus area on the basis of observed bird usage. As illustrated by Figures 9.1 and 9.2, the Chemainus River delta and the smaller deltas of Ladysmith Harbour are of prime importance to diving and dabbling ducks. "The Chemainus River-Bonsall Creek estuary and Shoal Island mud flats is undoubtedly the habitat unit of highest importance in the Ladysmith-Chemainus region," reports Blood (1975). An ongoing study of migratory bird use on the Cowichan system by the same authors for the Canadian Wildlife Service will no doubt document the high importance of that system to migratory birds as well (see Appendix 1.2 for details).

The reader is referred to the Fraser River report (Hoos and Packman, 1974) for a more detailed discussion of waterfowl and the significance of estuaries to birds of the Pacific flyway.

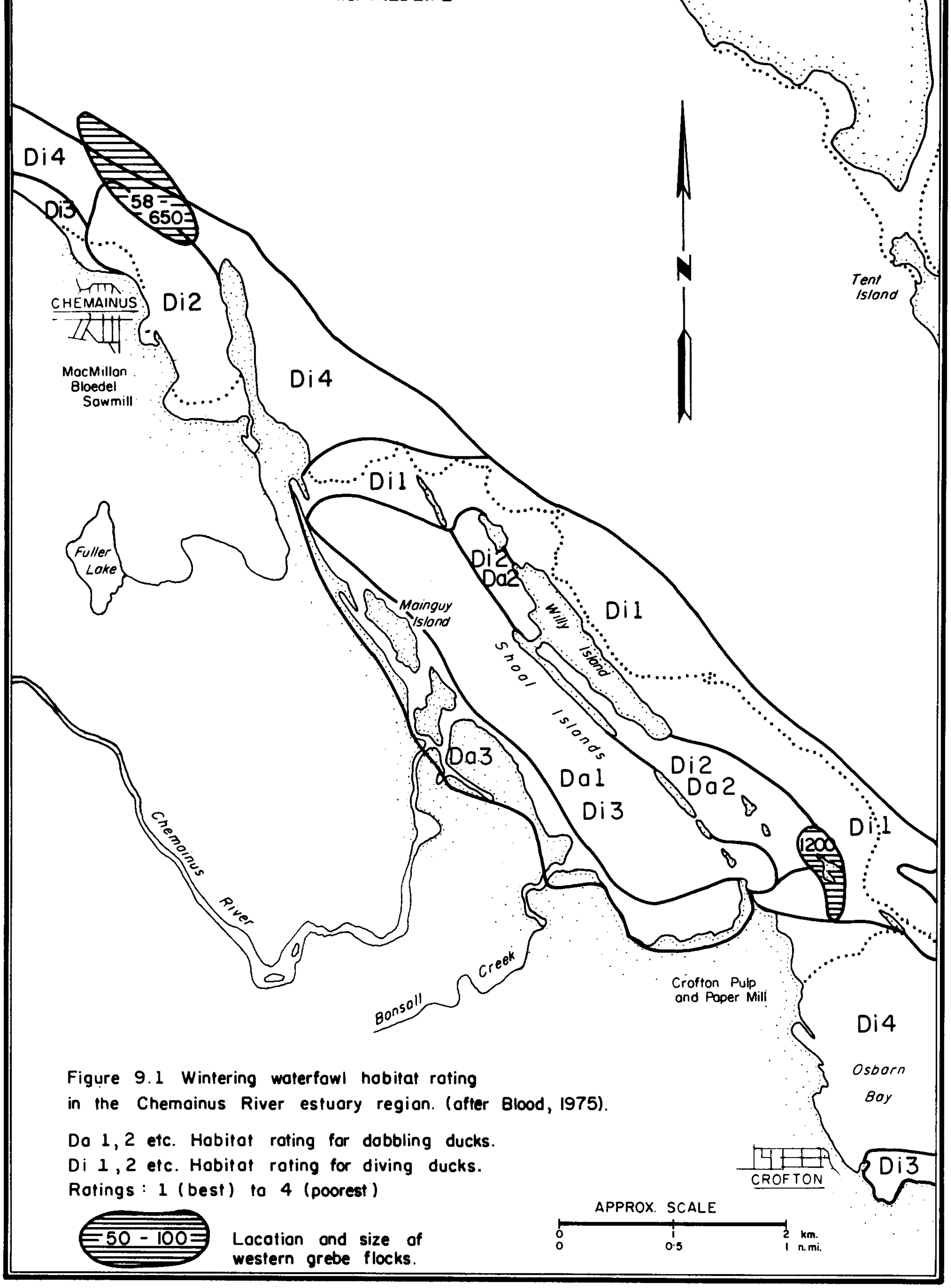


Figure 9.1 Wintering waterfowl habitat rating in the Chemainus River estuary region. (after Blood, 1975).

Da 1, 2 etc. Habitat rating for dabbling ducks.
Di 1, 2 etc. Habitat rating for diving ducks.
Ratings : 1 (best) to 4 (poorest)

Location and size of western grebe flocks.

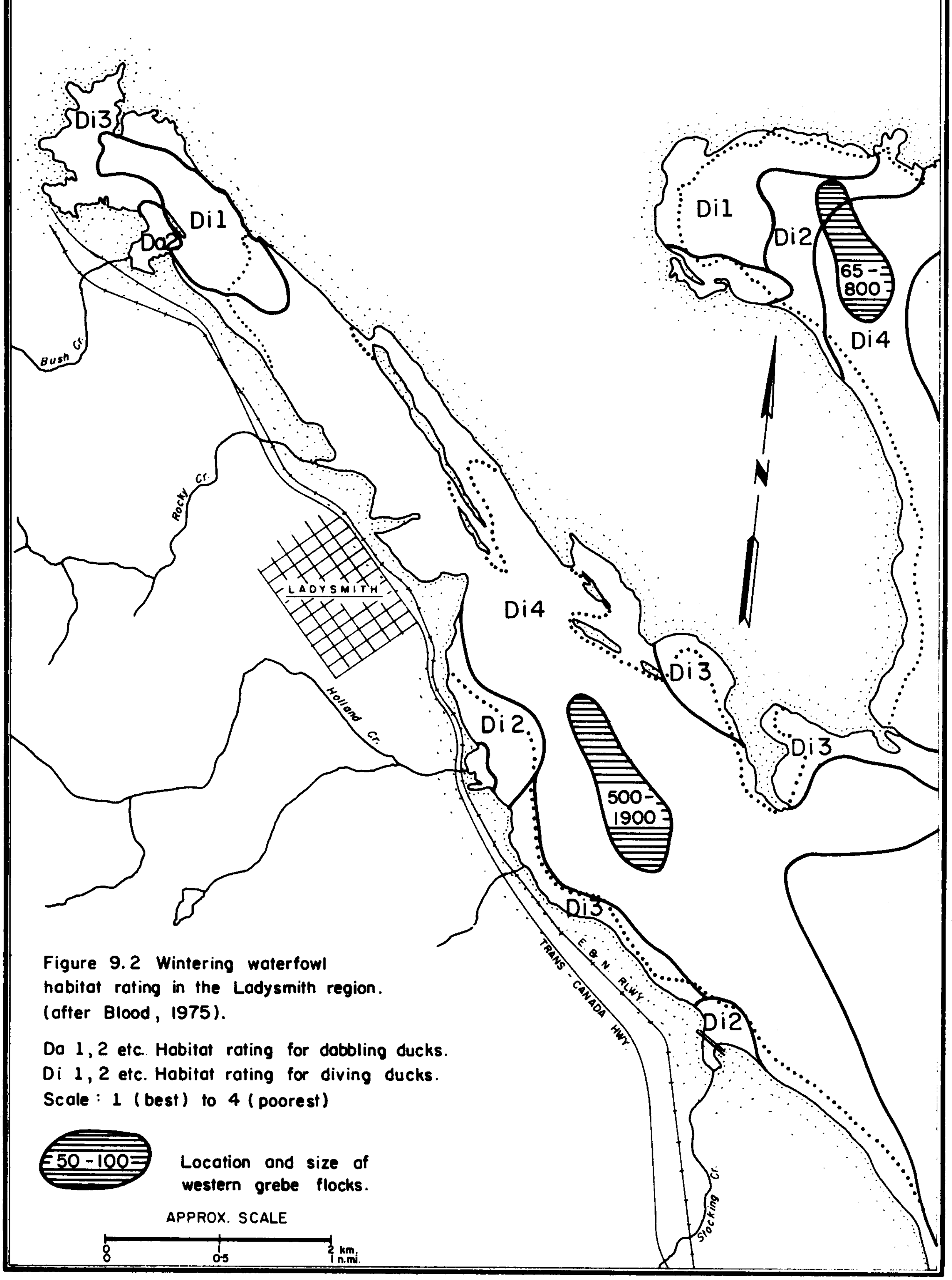


Figure 9.2 Wintering waterfowl habitat rating in the Ladysmith region. (after Blood, 1975).

Da 1, 2 etc. Habitat rating for dabbling ducks.
Di 1, 2 etc. Habitat rating for diving ducks.
Scale : 1 (best) to 4 (poorest)

50-100 Location and size of western grebe flocks.

9 (ii) SHOREBIRDS

The intertidal mud flats of the Cowichan and Chemainus estuaries, as well as damp or partially flooded fields, are important feeding areas for many species of shorebirds, including black oyster catchers (*Haematopus bachmani*), plovers (Charadriidae), sandpipers (Scolopacidae), phalaropes (Phalaropodidae), and avocets and stilts (Recurvirostridae).

The following species nest within the study area on the Cowichan and Chemainus salt marshes: killdeer (*Charadrius vociferus*), common snipe (*Capella gallinago*), and spotted sandpiper (*Actitis macularia*) (Trethewey, 1974).

Thirty-three other species of shorebirds are recorded from the lengthy and fairly varied shoreline of the study region. They are included in Appendix 9.1.

9 (iii) GULLS

Gulls are widespread throughout the study area. They were the second most commonly observed bird group in both the Ladysmith and Chemainus regions during the winter of 1974-75. Numbers recorded by Blood (1974) on the Chemainus River estuary that winter averaged 756 (range: 70-1652) in any given week. No habitat of exceptional importance could be delineated by the researchers. However, mud flats, the intertidal zone generally, sewage outfalls, and stream estuaries (mostly at salmon spawning times) were noted as typical bird-feeding areas.

The glaucous-winged gull (*Larus glaucescens*) is the predominant species of the study area, and it is known to nest on the Ballingall Islets in Trincomali Channel and elsewhere amongst the Gulf Islands. There are no known gull-nesting sites within the study region proper.

Bonaparte's gull (*L. philadelphia*) and the mew gull (*L. canus*) are the other abundant species of the area according to Tatum (1972). Other species are regularly seen in the region and are included in Appendix 9.1.

9 (iv) OTHER WATERBIRDS

In addition to aforementioned waterfowl, another 3,500 to 4,000 waterbirds, including loons, grebes, cormorants, murres, murrelets and guillemots, winter in Cowichan Bay, although most of these birds migrate elsewhere to nest (Trethewey, 1974).

Loons and grebes, which nest in freshwater habitats, move to marine areas to overwinter, and this is when they are most regularly seen. The horned grebe (*Podiceps auritus*) and western grebe (*Aechmophorus occidentalis*) are abundant winter visitors. The western grebe was the most numerous bird species observed in the Ladysmith-Chemainus region in the winter of 1974-75 (Blood, 1975).

Bare Point, bordering Chemainus Bay, supports a pelagic cormorant (*Phalacrocorax pelagicus*) nesting colony. Pelagic and double-crested cormorants (*P. pelagicus,* and *P. auritus*) and pigeon guillemots (*Cepphus columba*) nest elsewhere among the Gulf Islands, particularly in Galiano Strait. Isolation and freedom from disturbance seem to be essential for the continued existence of all seabird nesting.

Great blue herons (*Ardea herodias*) and kingfishers (*Megaceryle alcyon*) are very commonly seen, and other species which frequent the shallow intertidal mud flats of the Cowichan and Chemainus deltas are listed in Appendix 9.1.

9 (v) RAPTORIAL BIRDS

At least 22 species of birds of prey are recorded from the study area and are included in Appendix 9.1. However, many are rare or uncommon. The raptors are undoubtedly attracted by large numbers of prey species, including waterfowl, shorebirds, songbirds, small mammals and fish.

The bald eagle (*Haliaeetus leucocephalus*) is most regularly seen on the Bonsall Creek-Chemainus River estuary and is the most common raptorial bird of the study region. Nineteen were once observed on the estuary in winter (Blood, 1975).

Other raptors which occur in the study area include ospreys (*Pandion haliaetus*), peregrine falcons (*Falco peregrinus*), kestrel (*F. sparverius*), redtail hawks (*Buteo jamaicensis*), sharpshined hawks (*Accipiter striatus*), Coopers hawks (*A. cooperii*), marsh hawks (*Circus cyaneus*), great horned owls (*Bubo virginianus*) and short-eared owls (*Asio flammeus*).

Nesting is recorded in the study area for the goshawk (*Accipiter gentilis*), Coopers and redtailed hawks, bald eagle and osprey, while nesting by the kestrel, golden eagle (*Aquila chrysaetos*) and turkey vulture (*Cathartes aura*) is strongly suspected (Trethewey, 1974).

9 (vi) OTHER BIRD SPECIES

Six species of upland game birds, listed in Appendix 9.1, occur in the vicinity of Duncan,according to Trethewey (1974). Of these, two species - the ring-necked pheasant (*Phasianus colchicus*) and the California quail (*Lophortyx californicus*) are introduced, and four species - the ruffed grouse (*Bonasa umbellus*), the blue grouse (*Dendragapus obscurus*), the band-tailed pigeon (*Columba fasciata*) and mourning doves (*Zenaida macroura*) are native.

Little information is available concerning the numbers or distributions of these species. However, game birds support intensive hunter activity in the upper Chemainus and Cowichan watersheds. Pheasants, quail and doves are found in association with cultivated land, ruffed and blue grouse are found in deciduous wooded lowland areas and hilly wooded upland areas, respectively, and band-tailed pigeons are scattered throughout the region.

Crows (*Corvus caurinus*) are often seen along the foreshore of the study area, frequenting many of the same habitats as the gulls.

The lower Cowichan and Chemainus river valleys and the ocean perimeter support large populations and concentrations of terrestrial birds. Species recorded from the area are included in Appendix 9.1. The area is rural in nature, with local pockets of wildland and urban development. This creates the diversified habitat which supports a wide variety of avifauna.

9 (vii) MAMMALS

There are few data available on the distribution and abundance of mammals in the study area. However, through the use of species maps (Cowan and Guiguet, 1960) and the records of the B.C. Provincial Museum, a species list of mammals, as well as of amphibians and reptiles, was compiled (Appendix 9.1).

Probably the most abundant mammal in the region is the Townsend vole (*Microtus townsendi*), a species of field vole which inhabits the moist fields and sedge meadows of alluvial areas. The vole and the white-footed mouse (*Peromyscus maniculatus*), also common in the area, are vegetarians, and form an important link in the transfer of solar energy from plants to birds of prey.

Two species of shrew (*Sorex vagrans,* and *S. palustris*) and the red squirrel (*Tamiasciurus hudsonicus*) are native to the area. The house mouse (*Mus musculus*), Norway rats (*Rattus norvegicus*) and black rats (*R. rattus*) were introduced to the region with the coming of the white man. The muskrat (*Ondatra zibethica*) was brought to Cowichan Lake from the mainland in 1922, and these animals are now plentiful throughout the district. The nutria or coypu (*Myocaster coypus*), a fur farm escapee, has been reported as being wild in the Cowichan area.

Beavers (*Castor canadensis)* are reportedly found on Bonsall Creek, Chemainus and Cowichan rivers, and Quamichan Lake, but they are seldom seen since they are nocturnal, and live in holes in the banks of rivers rather than in lodges (McKinnon, 1974).

Of the eight species of bats found on Vancouver Island, the one most common to the study area is the little brown bat (*Myotis lucifugus*). This migratory bat is sometimes known to hibernate and stay the winter in the region.

The Cowichan-Chemainus area has a large, but fluctuating, population of Columbian blacktail deer (*Odocoileus hemionus columbianus)* (McKinnon, 1974). These deer often browse on the sedges and grasses of tidal marshes, particularly on the relatively unspoiled Chemainus delta. Logging upstream on both river systems has increased summer browse, but mature and regenerated forest cover remains on land of suitable slope and aspect. The upper Cowichan and Chemainus watersheds are considered by B.C. Fish and Wildlife Branch biologists to have no significant limitations to the production of ungulates (Class 1, C.L.I.) (B.C. Dept. Rec. and Cons., 1973).

A number of carninvores are also known to occur in the study area. The Vancouver Island wolf (*Canis lupus crassodon*) and the wolverine (*Gulo gulo luscus*) are rarely seen anywhere on Vancouver Island. However, the marten (*Martes americana*), short-tailed weasel (*Mustela erminea anquinae*), Vancouver Island mink (*Mustela vison evagor*), river otter (*Lutra canadensis*) and raccoon (*Procyon lotor*) are frequently sighted and are common in the area. The cougar (*Felis concolor*) and black bear (*Ursus americanus*) are seen less often but substantial populations of both are known to exist.

Of the marine mammals, only the killer whale (*Orcinus orca*, harbour porpoise (*Phocoena phocoena*), and harbour (or hair) seal (*Phoca vitulina richardi*) may be seen in the region with any regularity. The northern sea lion (*Eumetopias jubata*), northern elephant seal (*Mirounga angustirostrus*), Pacific striped dolphin (*Lagenorhynchus obliquidens*), Pike whale (*Balaenoptera acutorostrata*) and humpback whale (*Megaptera novaeangliae*) have been sighted in the region only infrequently.

9 (viii) WILDLIFE AND HUMAN INTERACTIONS

Previous reports of this series (Hoos and Packman, 1974; Hoos and Vold, 1975; Hoos, 1975) have stressed the recreational value of wildlife. Many of the waterfowl, gamebird and mammal species of the study area are highly prized by hunters. As well, non-consumptive wildlife-oriented recreation is becoming more important as people become increasingly urbanized.

Fur bearers, such as the weasel, marten, mink, beaver, muskrat and otter, occur in the region, but little trapping takes place. The warm climate of the area produces pelts of marginal quality (G. Turnbull, pers. comm.).

Hunting in the study area is primarily directed at waterfowl. The Cowichan estuary provides the best waterfowl habitat that is not closed to hunting on Vancouver Island south of

Chemainus. A heavy demand is placed on the area each year by duck hunters, because much of the estuary is readily accessible and because of its proximity to urban centres.

A recent study by Devereux and Caskey (1975) estimated the total number of hunter-days utilized in the Cowichan Bay area to be 700 during the 92-day hunting season. Of these, 107 hunter-days, or 17.8%, took place on the season's opening day. Daily hunter use trailed off as the season progressed and averaged an estimated 10-15 hunters per day (A.Ackerman, pers. comm.). The part of the estuary used for duck hunting encompasses all of the foreshore and intertidal zone where access is permitted. The area south of the south fork of the Koksilah River and Widgeon Island on the estuary have recently been closed owing to hunter-related complaints (Devereux and Caskey, 1975). The species most often taken are mallard (*Anas platyrhynchos*), wigeon (*A. americana*), pintail (*A. acuta*) and green-winged teal (*A. crecca*), with pintail and teal forming the majority of the birds killed. In addition, common snipe (*Capella gallinago*) are fairly numerous on the foreshore and in adjacent fields, and provide some hunting opportunity (Trethewey, 1974).

The Chemainus River delta is subject to little hunting pressure due to restricted access, since much of the estuary and most of the access routes are now privately owned. The estuary did at one time support intense waterfowl hunting (A.Ackerman, pers. comm.).

The Cowichan and Chemainus watersheds support intensive hunter activity. Grouse hunting (90% blue grouse, 10% willow grouse) attracts upwards of 150 hunters per day to the area, with hunters averaging one grouse per day (A. Ackerman, pers. comm.).

According to Ackerman (pers. comm.), deer hunting is also important in these two watersheds. Opening day (Sept. 6) of the 1975 deer season attracted approximately 200 hunters and 49 deer were taken from the area. On some days, 250 to 300 hunters may be afield in the Cowichan watershed, and 10 to 20% of these may bag a deer. The Chemainus watershed may support up to 100 to 150 hunters per day with a take of 10 to 30 deer. A count of activity, from 1967 to 1971, in the Chemainus watershed, appears in Table 9.1.

Table 9.1. Chemainus Watershed - Deer Hunter Use (B.C. Dept. Rec. and Cons., 1973)

Year	Average No. of Hunters per Day	Total Deer Harvested
1967	79	240
1968	69	187
1969	55	140
1970	91	155
1971*	51	70

* "Bucks only"experiment implemented.

The Cowichan and Chemainus estuaries and areas adjacent to them provide a wide variety of animal life, particularly birds, for the enjoyment of natural history groups and nature photographers. The closure of most of the municipality of North Cowichan (including Priest Marsh, and Somenos and Quamichan lakes) to the discharge of firearms allows waterfowl to remain there undisturbed and thus provides good opportunity for nature enthusiasts to observe them. The fields and marshes of the estuaries also provide diversified habitats which attract a variety of wildlife, and consequently, many naturalists.

Trethewey (1974) states: "a wide variety of species is as important to naturalists as are large concentrations of a few species, and species which are rare or uncommon seem to have a special appeal to birdwatchers. Because the Duncan area has large wintering populations of some bird species and is also visited by a wide variety of species, including some classed as rare or uncommon, the area is of special value to naturalists".

The Cowichan, Koksilah and Chemainus river corridors offer excellent fishing, camping, picnicking and scenery. Parts of the area, where accessible, are already being used by the public for picnicking and camping. Recreation in the area is more completely discussed in the Land Use Section of this report.

Requests to ban the use of firearms in the Cowichan River estuary have been made to the local authorities by naturalists and others living near the estuary because of excessive noise, irresponsible hunting practices and large numbers of unretrieved dead and wounded birds. Therefore, a study was initiated to assess a program of intensive enforcement and management in this area of high-density hunter use (Devereux and Caskey, 1975). Public objection to hunting in the area has been drastically reduced since this program of strict law enforcement and improvement of hunter practices through education has been implemented. The program of intensive enforcement will be continued in the future, because of its effectiveness in minimizing hunter-related conflicts.

The study area currently provides good to excellent habitats for a wide variety of wildlife. However, the carrying capacity for several species, particularly for waterfowl, could be enhanced through better management. More attractive habitats on the Cowichan and Chemainus estuaries and on Somenos and Quamichan lakes would provide more recreational opportunity for both hunters and naturalists (Trethewey, 1974). There is a marked trend to non-consumptive, recreational uses of these areas, such as bird-watching and photography, and greater attention must be given to the needs of such activities.

10. LAND AND WATER USE

10 (i) PRESENT LAND USE

Figures from the Census of Canada for the years 1951 and 1971 show that the Cowichan Valley census subdivision (Ladysmith Harbour to Mill Bay), has experienced a steady growth in population from 24,535 to 38,988 (Table 10.1). This represents an increase over the twenty-year interval of 59%, or an average of 2.95% per year, slightly below the 3.26% annual average for the entire province.

Population changes for the Cowichan Valley Regional District for the years 1966 to 1971 (Stinson - unpublished rept.), indicate that the rate of growth for the urban areas was lower than that for the electoral areas (Figure 10.1). Duncan's total rate of growth for the five-year period was 2.07%; Ladysmith's 7.7%; and Lake Cowichan's 0.42%; all well below the Provincial total of 16.3% for the five years. The electoral areas (Census of Canada subdivision A), increased in population by a total of 17.9%, averaging 3.58% per year. Electoral area "D", comprised mainly of lands adjacent to the Cowichan River estuary, experienced an average yearly growth rate of 8.8%.

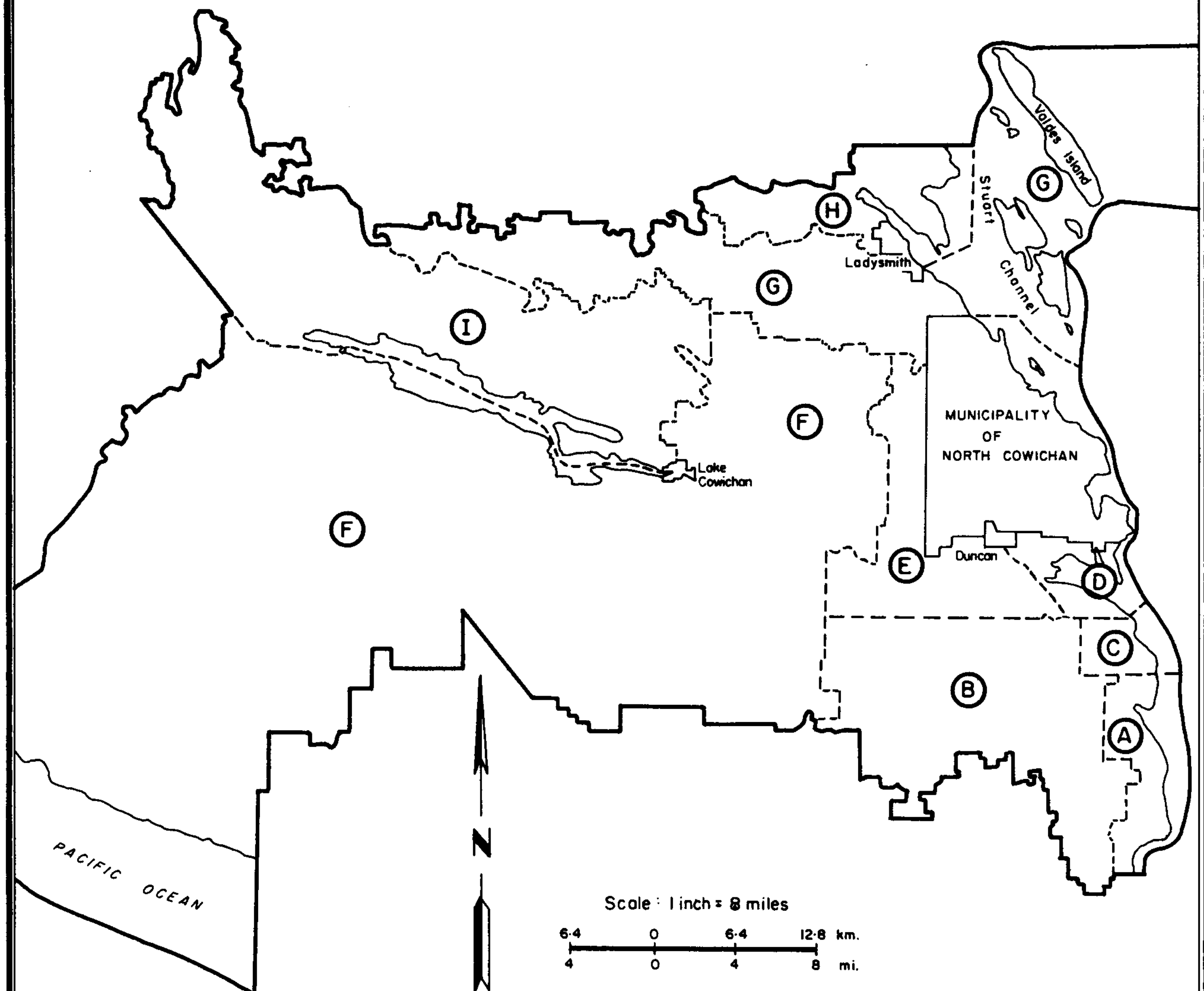
Because of this area's extraordinary population growth, and because of increasing fear that conflicts in land and water use would be exceedingly great, if all development schemes for the south shore uplands and the Cowichan River estuary were to proceed together, the Regional District commissioned a study for a community plan for electoral area "D". This was completed in March, 1975, (Urban Programme Planners), taking into consideration the conclusions of a recent report on the development alternatives for the Cowichan and Koksilah Estuaries, by the Cowichan Estuary Task Force (1974), the conclusions of which are reviewed later in this section.

Table 10.1. Population for Census Subdivisions - Cowichan Valley (Statistics Canada, 1975).

	1951	1961	1966	1971
North Cowichan	6,665	9,166	10,384	12,170
Subdivision A	9,872	11,529	11,804	14,171
Indian Reserves	1,492	2,006	1,997	2,231
Duncan	2,784	3,726	4,299	4,388
Ladysmith	2,094	2,173	3,410	3,664
Lake Cowichan	1,628	2,149	2,353	2,364
Cowichan Valley (Total)	24,535	30,749	34,247	38,988

Note: Between 1951 and 1961, boundary changes occurred in Subdivision A, Indian Reserves and Lake Cowichan

Between 1961 and 1971, boundary changes occurred in Subdivision A and Lake Cowichan.



Note: Total of electoral areas (A to I) = census subdivision A

Figure 10·1 Cowichan Valley regional district electoral areas.
(Department of Municipal Affairs, Province of British Columbia, 1975)

The Municipality of North Cowichan is the largest municipal area on Vancouver Island, covering 19,000 hectares (73, sq.mi.). Included within its boundaries are the communities of Chemainus, Westholme, Crofton, Maple Bay and Somenos. The logging and sawmilling industry is the mainstay of Chemainus, while Crofton is supported by the pulp and paper industry. Maple Bay, located on the bay of the same name in Sansum Narrows, has developed as a residential and a recreational area. Somenos, 8 kilometres (5 mi.) west of Maple Bay, is a small agricultural centre for the farming communities of the district.

The City of Duncan, located in the Cowichan River Valley, 10 kilometres (6 mi.) west of Cowichan Bay, and 61 kilometres (38 mi.) north of Victoria, is the largest settlement in the Cowichan-Chemainus area. In 1971, it had a population of 4,388, with approximately 7,000 additional inhabitants in a large suburban area extending into the neighbouring North Cowichan Municipality.

Duncan, as in the past, is still a service city for the surrounding areas, providing such facilities as a modern 112 bed hospital, secondary schools, a radio station and a weekly newspaper (The Cowichan Leader). Nearby recreational facilities include excellent salmon fishing at Cowichan Bay, and lake and stream fishing for steelhead or trout on the Cowichan and Koksilah rivers. An abundant population of upland game birds, waterfowl, and deer attract hunters during the open season. Sport fishing and hunting in the Cowichan-Chemainus area are described in detail in sections 7 Fish and 9 Wildlife.

Several large Indian reserves covering a total of 5,400 hectares (21 sq.mi.) occupy much of the lower Cowichan Valley between Duncan and Cowichan Bay. A population of 2,231 Indians (Statistics Canada, 1972) inhabits the reserves, with farming, fishing and a local knitting industry providing its main means of support. The "Cowichan" sweaters, knitted from raw sheep's wool, are eagerly sought by outdoor sportsmen for their heavy, warm and water-resistant qualities. "One Victoria dealer alone sells about 6,000 sweaters each year, worth almost $120,000 to the knitters" (Duff, 1964).

The second largest settlement in the Cowichan-Chemainus district is the Town of Ladysmith, situated on the western side of a long (8.5 km), sheltered, natural harbour. Originally established as a shipping port for coal from the mines south of Nanaimo, the town developed rapidly, and by 1901 had a population of 4,000. With the closing of the coal mines and the smelter, built to refine copper ore from the Tyee mines, the focus of industry changed to lumber. Ladysmith Harbour provides good protection for log booming and storage, and there are two saw-mills presently situated on the harbour shore. As of February, 1973, sixteen leases for log booming and storage had been issued. Eight of these are owned by Crown Zellerbach Canada Limited, and the remainder by British Columbia Forest Products Limited, Pacific Logging Co. Ltd., Chemainus Towing Co. Ltd., and Cowichan Bay Forest Products Ltd. In 1973, the total annual revenue derived by the Crown from these leases, as well as for oyster culture and marinas, was $10,982.

Ladysmith Harbour, originally named Oyster Harbour, was once one of the most productive shellfish areas on the east coast of Vancouver Island (Patterson, 1975). However, closures on the direct marketing of oysters from the region have been imposed since 1964, owing to bacterial contamination. There are now indications that some local areas may be re-opened for commercial harvesting. This aspect is reviewed in more detail in the Pollution Section of this report.

A recent report (Cassidy and Cranny, 1974), prepared for the Archeological Sites Advisory Board of British Columbia, provides an inventory of heritage sites in the Ladysmith Harbour area. Four categories of prehistoric sites are listed and described, including coastal shell middens, campsites, burial islands and petroglyphs. In addition, three historic sites have been recorded. Two of these are in the vicinity of Ladysmith and the other is at Boulder Point on the western shore of the harbour entrance. An inventory of historic sites of the Cowichan and Chemainus areas is currently being compiled by the staff of the Provincial Museum in Victoria (Simonsen, pers. comm.). This information should be most valuable to the planners responsible for the development of the estuarine environment.

The Cowichan-Chemainus area has a good variety of facilities for transportation by road, rail and sea. The Trans-Canada Highway (Route No. 1) connecting Victoria with Nanaimo passes through Duncan and Ladysmith. Good secondary roads serve most of the communities in the region. Private industrial roads traverse the logging areas, but public access to them is limited. These roads are usually open to the public only on weekends, or when they are not being used by industrial equipment.

The Esquimalt and Nanaimo Railway, operated by Canadian Pacific Railways, provides a passenger and freight service from Victoria to Courtenay, serving Duncan, Chemainus and Ladysmith, and surrounding communities. A spur line from Hayward just north of Duncan provides a freight service to Cowichan Lake and Port Alberni. The Canadian National Railways operates a freight line from Victoria to Deerholme, 5 kilometres (3 miles) southwest of Duncan, Cowichan Bay and Cowichan Lake.

British Columbia Ferries provides frequent sailings from Swartz Bay near Victoria to Tsawwassen (Vancouver) and the Gulf Islands. Local ferries operate from Brentwood Bay (Saanich Peninsula) to Mill Bay (west side of Saanich Inlet), from Crofton to Vesuvius Bay (Saltspring Island), and from Chemainus to Thetis and Kuper Islands.

Four commercial shipping ports are located within the Cowichan-Chemainus district. These are, in order of total tonnage (short tons) of cargo handled for destinations in foreign countries, Crofton (883,129), Chemainus (332,510), Ladysmith (17,300) and Cowichan Bay (6,700) (Statistics Canada, 1975). Wood products, timber and lumber, plywood, pulp and paper for newsprint make up the bulk of the commodities handled for export. A comparison of the tonnages loaded for export in 1967 and 1973 shows a large drop for the ports of Chemainus, Ladysmith and Cowichan Bay, while the quantities of cargoes handled at Crofton have more than doubled in the same period (Table 10.2).

Table 10.2. Cargoes handled at east Vancouver Island ports, destined to foreign countries, 1967 and 1973 (Statistics Canada Shipping Report).

Port	Tons Loaded		Commodity
	1967	1973	
Crofton	394,581	883,129	Lumber and Timber Pulp and Newsprint Paper
Chemainus	491,103	332,510	Lumber and Timber
Ladysmith	46,986	17,300	Logs and Pulpwood
Cowichan Bay	9,685	6,700	Lumber and Timber

The recent increase in the use of the coastal waters for recreational boating has provided the necessary impetus for a rapid expansion of the marina business. At present there are five marinas on Cowichan Bay, with another seven located in the neighbouring areas of Genoa Bay, Maple Bay, Ladysmith Harbour and Chemainus. For the exact locations of these marinas and the facilities provided, the reader is referred to the Strait of Georgia small craft chart #3310, Victoria Harbour to Nanaimo (Canadian Hydrographic Service, 1973).

In 1973, a survey was made of the number of recreational boat owners using the Strait of Georgia, including the southeastern coast of Vancouver Island (Canada, Department of the Environment, 1974). The main purpose of the survey was to provide baseline data pertaining to the number, value and use of privately-owned recreational boats. Environment Canada, as a continuation of the 1973 survey, is currently engaged in an analysis of present marina policy. This also entails a review of the situation regarding facilities, moorings and berths available for small craft. This study is expected to be complete by the end of 1975 (M.C. Harrison - pers. comm.)(see Appendix 1.2).

Ivy Green Provincial Park, located at the head of Ladysmith Harbour, and having accommodation for 50 camping units provides the nature-lover with an opportunity to camp in an estuarine environment and observe the wildlife indigenous to the area. A small marine park for picnicking only, is located on Tent Island, (a small island off the south end of Kuper Island, 5 kilometres [3 miles] east of Chemainus). Access is by boat only and moorings are provided on the island (Figure 1.1). Other outdoor recreational and conservation areas are a class "A" Provincial park located on the Chemainus River, adjacent to the Maple Mountain municipal park near Crofton, and the Cowichan River footpath, built by the Cowichan Fish and Game Association. This path follows the course of the Cowichan River from the western outskirts of Duncan to Skutz Falls a distance of approximately 19 kilometres (12 miles).

The Cowichan and Koksilah rivers provide sufficient water to meet the needs of the major communities. Private wells, pumping water from permeable, unconsolidated deposits (Halstead, 1967) supply the local water needs of the urban and agricultural areas outside the regions covered by organized distribution systems.

The City of Duncan obtains its water supply from the Cowichan River, while Chemainus draws its water from the Banon Creek and Holyoak Lake watersheds. MacMillan Bloedel Limited, the main user in Chemainus maintains an emergency storage in Fuller Lake. The Crofton pulp and paper mill relies on Cowichan Lake for its operational requirements. Water consumption is controlled by a 'provisional rule curve' for Cowichan Lake storage, established by the provincial Water Resources Service in Victoria. Regulation of flow commences when the lake surface level drops to a pre-set elevation, following the winter high-water season, each year.

The towns of Ladysmith and Saltair Waterworks District obtain their water from the Holland Creek and Stocking Lake systems. A report on the water resources of Holland Creek, Banon Creek, Stocking Lake and Silver Lake watershed was prepared by the provincial Water Resources Service (1964). Existing supply systems were examined and recommendations made for the development of existing sources to meet future water demands in the Chemainus and Ladysmith-Saltair areas.

In 1972, the North Cowichan Municipality made application to the provincial Water Rights Branch for a licence to store and divert water from the Chemainus River. The Fish and Wildlife Branch of the Province of British Columbia has been opposed to the construction of the Chemainus Dam on the grounds that it would interfere with the migration and spawning of steelhead in the rearing habitat upstream of the proposed dam. Fish by-passes and ladders were not considered "a realistic proposition" (B.C. Dept. of Recreation and Conservation, 1975b). Subsequently, the Environment and Land Use Committee Secretariat issued a press release (March, 1975), announcing that the Department of Water Resources had been directed to undertake a comprehensive investigation of alternative water supply sources for North Cowichan.

The Cowichan and Chemainus River watersheds continue to support a large logging industry. Forty-five logging companies, twenty sawmills and one pulp mill (Crofton), form the basis of a forest industry which, in 1964, employed about 4,000 people (B.C. Dept. of Lands, Forests and Water Resources, 1974). Of the 50 major manufacturing industries in the Cowichan Valley, 19 manufacture wood products (B.C. Dept. of Economic Development, 1974).

Log storage and handling in the estuarine environment of Ladysmith Harbour have already been discussed. The Chemainus delta is presently used by MacMillan Bloedel Limited for log storage, as it is the closest sheltered area of water outside of Chemainus Bay (Laing, 1975). The logs are stored under the authority of provincial leases which cover most of the delta surface between the Shoal Islands and Vancouver Island.

Between 1964 and 1975, the forest industry greatly influenced the development of the Cowichan Estuary. Slegg Forest Products sawmill, built in 1968, and situated on 67 hectares (165 acres) of reclaimed estuary near the mouth of the Koksilah River, closed in March, 1974,and is now facing bankruptcy proceedings (Cowichan Estuary Task Force, 1974). In 1964 Western Lumber Carriers Limited (Westcan Terminals), filled 2.9 hectares (7.1 acres) of the estuary intertidal zone to provide an area for dryland sorting, bundling and lumber storage and shiploading facilities (Figure 10.2). Sooke Forest Products Limited extended this causeway to the west in 1967, adding an additional 4.2 hectares (10.3 acres) of land fill. A proposal for a 5.25 hectare (13 acre) extension, involving some 83,600 cubic metres (110,000 cu. yd.) of fill, was studied in 1971, but was subsequently cancelled. The most recent part of the estuary to be filled was 16.8 hectares (41.5 acres) of the upper intertidal zone in the centre of the bay (Figure 10.2). Construction of a sawmill and a planer mill for the manufacturing division of Doman Timber Sales Limited is now underway on this area of landfill.

139. LAND AND WATER USE

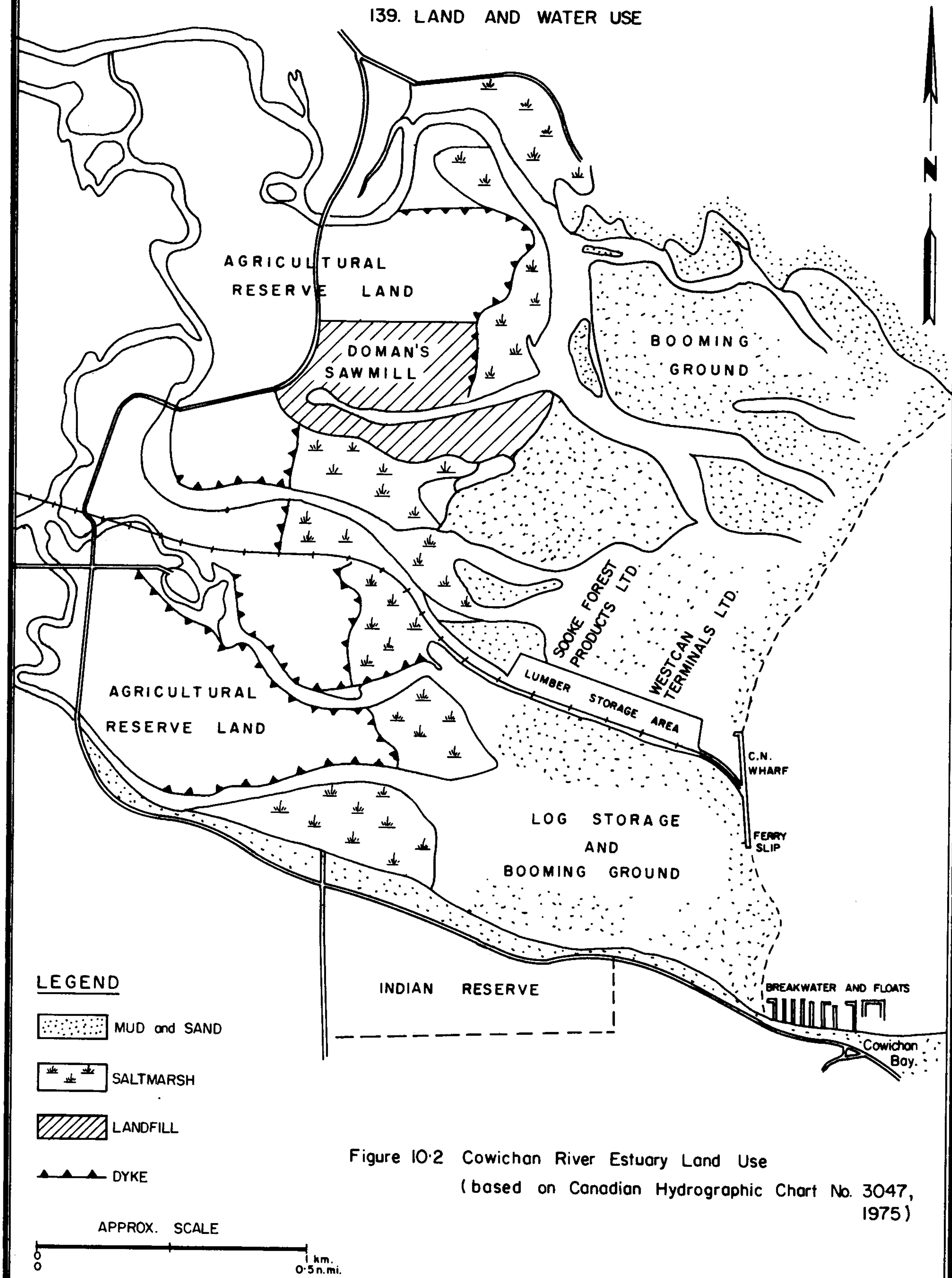


Figure 10·2 Cowichan River Estuary Land Use
(based on Canadian Hydrographic Chart No. 3047, 1975)

The south side of Cowichan Bay is used as a major log sorting and booming ground. MacMillan Bloedel Limited, one of the largest users (10,000 mcf/year), is phasing out its sorting and booming operation in the bay, and is developing a dryland sort at Deerholme, for the truck transfer of logs to Chemainus. B.C. Forest Products Limited, Mid-Island Timber Company and Newman Log Booming Limited are the other main booming-ground operators on Cowichan Bay.

The present use of land in the Cowichan River estuary has been evaluated in a community plan for Electoral Area D (Figure 10.1). (Urban Programme Planners, 1975.) The plan excludes Indian reserve lands. Agricultural land reserves were also excluded on the premise that by the nature of their classification, they are already designated for agricultural purposes.

Thus the use of 705 hectares (1,740 acres) was considered in the plan. This acreage was broken down as follows:

(1) "295 hectares (730 acres) of estuary water lot currently zoned for industry.

(2) "30 hectares (75 acres) of estuary flood plain....partially used for industry and outside the Agricultural Land Reserve.

(3)"380 hectares (935 acres) of dry land, most of this on the south side of Cowichan Bay. Of this, 48% (or 440 acres) have not been developed."

For a list of selected maps, charts and aerial photographs of the study area, the reader is referred to Appendix 10.2.

Practically all of the agricultural industry in the Cowichan-Chemainus area is concentrated in the more fertile regions between Duncan and Cowichan Bay, and in the lower Chemainus and Koksilah valleys. There is a total of 423 farms in the area, of which 372 are owner-operated and 51 tenant-operated. Approximately half of the farms (207) range in size from 10 to 69 acres. The remainder, with the exception of 6, are between 70 and 399 acres. Another 5 are between 400 and 759, while one is in the 760 to 1119 size range (Statistics Canada, 1972).

The total area of farmland is 11,500 hectares (28,378 acres), supporting a population of 1,809 or 4.6% of the total population in the Census district. Dairying is the principal enterprise and accounts for 50% of the farms having annual sales of $2,500 or more. This is followed by cattle, hog, sheep and poultry farming. Forage is the most cultivated crop, with vegetables, potatoes and small fruits being grown on the remaining land.

10 (ii) FUTURE DEVELOPMENT

In June, 1974, the Environment and Land Use Committee Secretariat of the Province of British Columbia, established a Task Force to consider and evaluate the appropriate development of the Cowichan Valley Estuary. A report summarizing the existing conditions and reviewing the development alternatives for the estuary, has been prepared. However, the results have not yet been published.

Subsequently, a report assessing the impact of four alternative development proposals on the wildlife and wildlife-related recreational resources of the estuary was prepared (Tretheway, 1974), at the request of the Provincial Secretariat to the British Columbia Environment and Land Use Committee. The report points out that the Cowichan River estuary is one of the largest estuaries on Vancouver Island, providing an excellent migratory and wintering habitat for waterfowl and other migratory birds.

142. Land and Water Use

On the basis of the information presented in the preceding report, members of the Canadian Wildlife Service have assessed the four development proposals for development of the Cowichan River estuary and flood plain. From the wildlife point of view, the acceptability of these developments, ranked from most acceptable to least acceptable, are as follows:

1. Recreational and agricultural dedication.
2. Maintenance of the status quo.
3. Limited industrial and residential expansion.
4. Industrial and commercial dedication.

The periodic flooding of the Cowichan and Koksilah rivers in the Duncan area, the estuary and the Cowichan Lake area is a major factor for consideration in planning the future development of the Cowichan Valley. In 1967, the cost of dyking in the Duncan area was estimated at $1,315,000, by the Water Investigations Branch, Victoria, with an additional $495,000 estimated for the cost of lowering the outlet of Cowichan Lake for protection of the Village of Lake Cowichan and the communities around the Lake (Wester, 1967).

More recently, a report was prepared on the proposed Cowichan River dyke for the Cowichan Indian Band Co-op of the Cowichan Indian Reserve (Underwood McLellan and Associates Limited, 1974). The agricultural lands of the Cowichan Indians Farm Co-operative have been flooded to some degree each year, and flood protection is necessary to maintain the expanding farming development program undertaken by the Cowichan Band.

Outside the boundaries of the Cowichan estuary and flood plains, agricultural expansion is limited by the fact that most of the land lies within the boundaries of the Esquimalt and Nanaimo Railway Company Land Grant. Thus, except for parcels of land which from time to time revert for non-payment of taxes, there are no Crown lands available for acquisition (B.C. Dept. Lands, Forests and Water Resources, 1974).

In addition to the studies being undertaken by the Environment Land Use Committee (E.L.U.C.), the Cowichan Valley Regional District has completed a community plan for Electoral Area D (Urban Programme Planners), and a plan for Electoral Area E is in progress (K. Stinson - pers. comm.).

The environmental and ecological impact of a proposed Vancouver Island natural gas transmission system is currently being reviewed by the B.C. Hydro and Power Authority. The proposed pipeline passes through Ladysmith, Westholme junction and to the west of Duncan. Sherard Point, south of Crofton, is the present termination point for the crossing of the pipeline from Vancouver to Vancouver Island. A preliminary assessment of the impact of the pipeline on the intertidal and foreshore zones at Sherard Point, concludes that "the effect of the pipeline on intertidal life will be temporary and not very serious" (Paish, 1974). A preliminary impact assessment of the effect of the pipeline crossings of the Vancouver Island rivers and streams, has also been made (Paish, 1974). The crossings of 69 streams were evaluated in terms of general and site specific fishery values. Included were 7 streams in the Cowichan-Chemainus study area, of which the Cowichan and Koksilah rivers were ranked high in terms of area sensitivity and general use for commercial and recreational fishing.

The future of development of some of the estuaries of British Columbia may soon be affected by the creation of ecological reserves. As of June, 1975, 62 ecological reserves had been established in British Columbia. The location, size, and type of biological community preserved have been tabulated in a publication by the Department of Lands, Forests and Water Resources (1975). The establishment of part of the Chemainus River estuary as an ecological reserve, is under consideration by the Department of Lands, Forests and Water Resources, Victoria (Pojar, 1975). The Chemainus estuary heads the list of ten estuaries on Vancouver Island covering a variety of ecosystems that should be preserved for scientific research and educational purposes, in order to obtain a better understanding of the natural processes forming the environment.

This knowledge, combined with an inventory of natural resources, should make possible effective management of the lands encompassed by the river systems, and ensure proper control for future development.

11. POLLUTION

11 (i) WATER POLLUTION

Water pollution in the Cowichan, Chemainus and Ladysmith areas can be placed into several general categories, namely domestic sewage, pulp mill wastes, logging, log handling and storage, shipping and recreational activities. Information specific to the study area only is discussed in this report. For expected effects of the various typical effluents upon the environment, the reader is referred to the Fraser and Squamish River estuary reports (Hoos and Packman, 1974; Hoos and Vold, 1975) and to Waldichuk (1974), or other references in the bibliography.

The Environmental Protection Service submission to the Estuary Working Group provides an up-to-date list of pollution sources in the area and can be found in Appendix 11.1 Figures 11.1, 11.2 and 11.3 give the locations of these sources.

EPS is also presently producing maps of the study area as part of the oil and chemical spill countermeasures series (see Hum, Appendix 1.2). These maps are an inventory of some of the existing and available resource information, compiled to aid in decision making and contingency planning in the event of an environmental emergency.

Invertebrates were collected from Cowichan Bay as part of a larger study and analyzed for heavy metal and chlorinated hydrocarbon content. Species collected included *Cancer magister*, *C. productus*, *Cardium corbis*, *Mya arenaria*, and *Abarenicola pacifica* . Relatively low levels of these pollutants were recorded (Bawden, Heath and Norton, 1973).

1. DOMESTIC SEWAGE:

Shellfish sanitary surveys provide water quality data

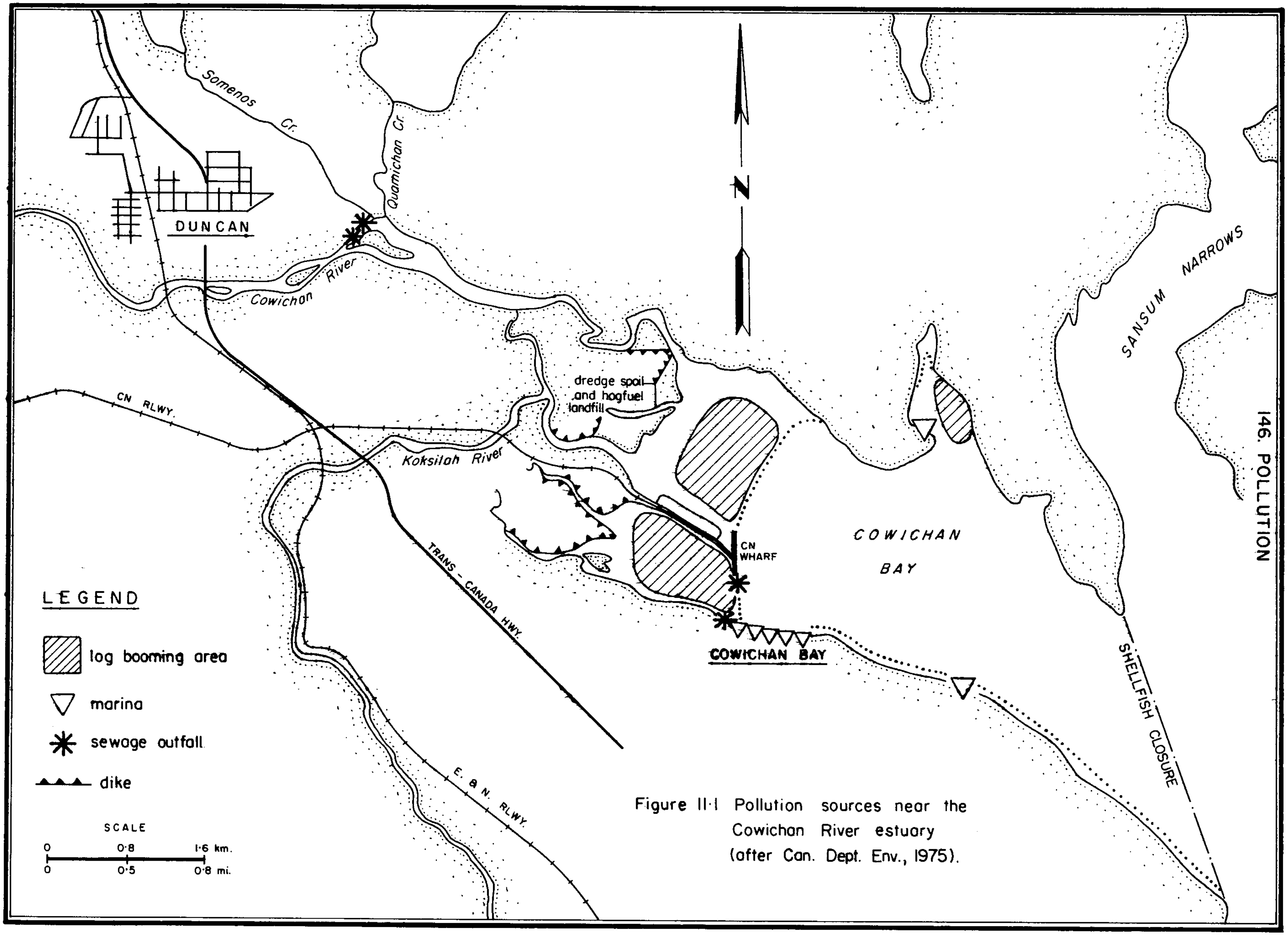


Figure II·1 Pollution sources near the Cowichan River estuary (after Can. Dept. Env., 1975).

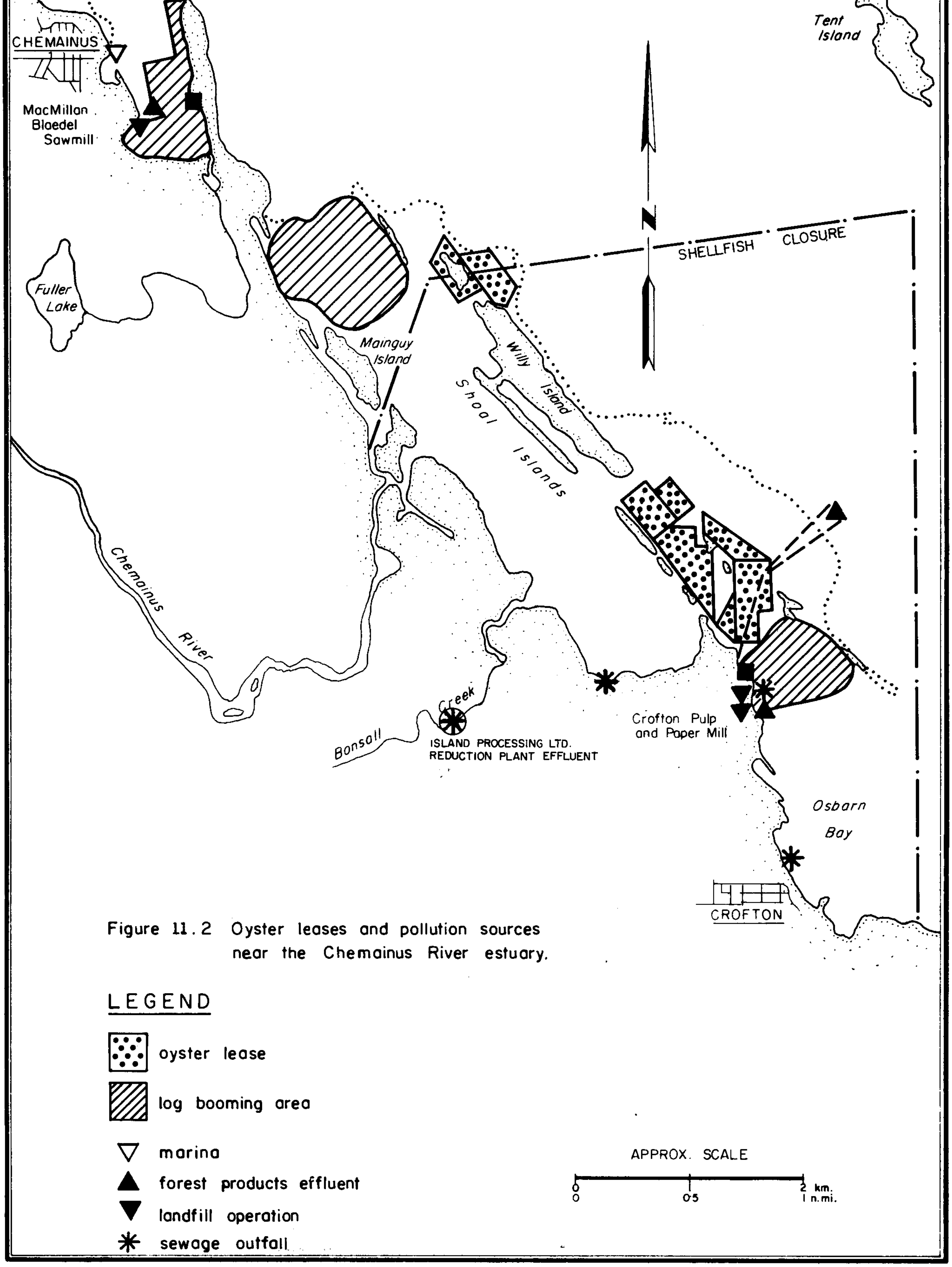


Figure 11.2 Oyster leases and pollution sources near the Chemainus River estuary.

148. POLLUTION

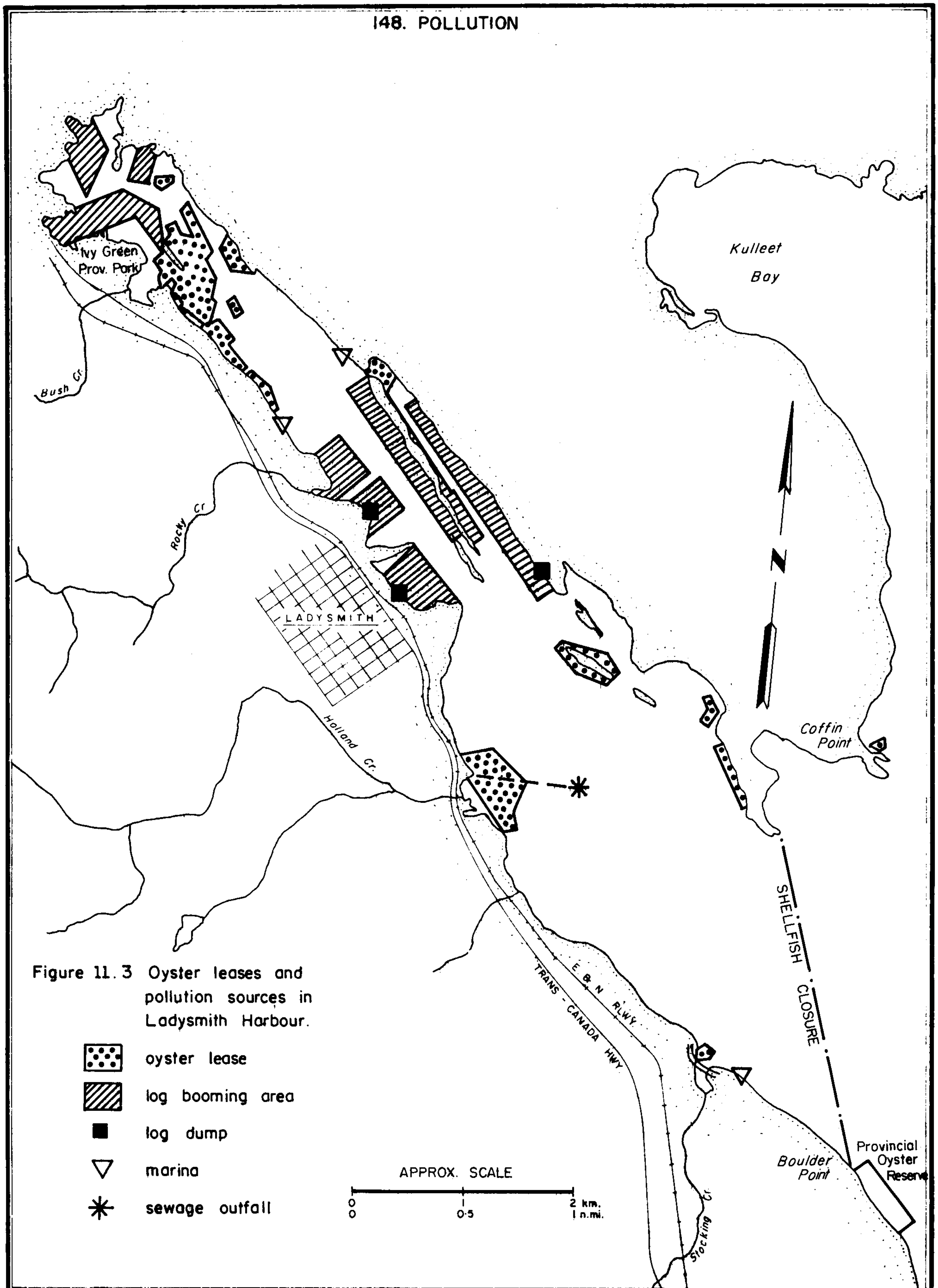


Figure 11.3 Oyster leases and pollution sources in Ladysmith Harbour.

for the study area, much of which is closed to the taking of shellfish owing to faecal pollution (see Figures 11.1, 11.2 and 11.3).

The high coliform counts responsible for shellfish closures in Ladysmith Harbour are attributed to land wash from septic tank ground disposal systems serving the waterfront and hinterland dwellings located in the drainage area, effluent from the town of Ladysmith sewage treatment plant, and occasional raw sewage overflows from the sewer forcemain system in the Arcady beach area (Tevendale, 1973a,b). The most recent sanitary survey (Cooper and Kay, in press) has recommended that the inner harbour, where 16 oyster leases are located, be reopened to commercial shellfish harvesting. This is subject to the elimination of a storm overflow system and the installation of improved sewage systems at Ladysmith Forest Products and Saltair Lumber.

The waters of Cowichan Bay are affected by sewage discharges into the Cowichan River, from the city of Duncan and district of North Cowichan discharges from the regional district of Cowichan Valley into Cowichan Bay, and landwash from the drainage basin (Low and Tevendale, 1974).

In addition, Crofton (district of North Cowichan) and the Crofton pulp and paper mill discharge sewage into Osborn Bay, while Chemainus (district of North Cowichan) discharges sewage into Stuart Channel at the mouth of Chemainus Bay.

The Island Rendering Co. discharges wastes into Bonsall Creek which flows onto the Chemainus delta. These wastes can become detrimental to the stream fauna during low flow periods through BOD loading and thermal problems.

The reader is referred to the Flushing Rate subsection (Oceanography Section) for a discussion of the oceanography of the study area as it relates to the capacity of the receiving water bodies to assimilate sewage and other pollution. The major possible effects of domestic sewage discharges on the receiving waters include increased turbidity, oxygen depletion, increased nutrient levels, addition of toxic substances, heat, pathogenic bacteria, odours and unsightliness. For a bibliography of sewage effects in marine and estuarine environments the reader is referred to Lehmann (1974). Sewage sources and details are listed in Appendix 11.1, part 1.

2. PULP MILLS:

The characteristics of pulp mill wastes and their environmental effects were discussed in the Squamish River estuary report (Hoos and Vold, 1975) and only details specific to the present study area are included in this report.

British Columbia Forest Products (BCFP) Limited operates a modern bleached sulphate (Kraft) mill at Crofton. The mill held two Pollution Control Board (PCB) discharge permits for forest products effluent until they expired in March, 1970 (Appendix 11.1, 2). The permits allowed up to 164,652,400 l/day (36,000,000 IGD) of Kraft effluent to be discharged approximately 1.4 km (4.700 ft.) offshore, and a further 15,910,650 l/day (3,500,000 IGD) of woodroom effluent to be discharged into Osborn Bay near the shoreline. The application for a new permit requests the discharge of 227,300 cu.m/day (50,000,000 IGD) of Kraft and newsmill effluent.

The net result owing to the existing oceanographic features (see the Oceanography Section) is that most of the mill effluent is dispersed in a south-southeasterly direction towards Sansum Narrows, with more limited northwesterly incursions directed to the Shoal Islands. There is some tendency for the effluent to concentrate in Booth Bay, directly across Stuart Channel from the effluent diffusers (Ellis, 1972b; Goyette and Nelson, 1973). Water quality determinations relating to the initial dilution zone around the Crofton mill outfalls have been completed on a routine basis by Dobrocky SEATECH Ltd. (Balch, 1974a; Ellis and Jones, 1974a,b) and by B.C. Research (B.C. Research 1974; McLeay and Walden, in progress). Kraft mill effluent (KME) has also been detected by various tests beyond the initial dilution zone.

The extent of the effluent field has been further delineated through determinations of zinc concentrations in Pacific oysters (Goyette and Nelson, 1973; Dobrocky SEATECH Ltd., 1973; Anderson, 1975). Zinc was released from a brightening agent, zinc hydrosulphite (more correctly zinc dithionite, ZnS_2O_4) used for groundwood in newsprint production. Evidence of bioaccumulation of zinc by oysters resulted in the industry converting to a new brightening compound, sodium hydrosulphite (sodium dithionite, $Na_2S_2O_4$), in September, 1973, which largely eliminated zinc from the effluent discharges (Environment Canada, 1973). However,the new brightening scheme, involving production of sodium hydrosulphite by the Borol process, results in sodium metaborate ($NaBO_2$) being discharged into receiving waters. A joint study was conducted by Services of Environment Canada in the Pacific Region on the ecological effects of boron in coastal waters (Environment Canada, 1973). Effects of major concern were related to inhibition of phytoplankton production, ultimately affecting food of fish and shellfish, particularly oysters. The foregoing co-operative investigation and further research with axenic cultures of phytoplankton (Antia and Cheng, 1975) showed little cause for conern. Bioassay and field results (Thompson, Davis and Drew, 1975) indicated no obvious other ecological hazard at presently discharged concentrations, nor any evidence of bioaccumulation in either fish or oysters.

The mill effluent has been detrimental to oysters found near the outfalls despite its submarine discharge. Visual physical and condition factor measurements carried out by D.B. Quayle from 1955 to 1963 on oyster leases in the area (Quayle, 1964);

and by the Department of Fisheries Resource Development Branch (Jackson, 1964) disclosed this fact. BCFP bought out the most severely affected leases, namely those of Biscoe, Barnes and Limberis (49 hectares or 120 acres), and although oysters still inhabit the area, they remain in poor condition. More recent determinations (Balch, 1974; Anderson, 1975) revealed a high negative correlation between zinc levels and condition factors and a distribution similar to that found in previous years. Condition factor was severely depressed in the vicinity of the outfalls. Reduced condition factors were noted further to the south, as far as Burgoyne Bay on Saltspring Island, than to the north where condition was generally high. Future surveys in the area could determine the rate of elimination of zinc and possible improvement of condition of oysters. Oysters transplanted out of the affected area in 1962 showed a marked improvement in condition (Jackson, 1963).

Sediment deposition in Osborn Bay has been examined during 1966 with *in situ* collectors to determine the contribution from the forest industry operations in Crofton (Werner and Hyslop, 1968b). Percentage of wood ranged from zero in northeastern Osborn Bay to 28% near the pulp mill outfall. Gases in sediments were examined at 13 locations during May, July and September, 1966 in Osborn Bay and decomposition gases were located at 2 stations nearest shore between the B.C. Forest Products wharf and the Crofton Government wharf (Werner, 1968; Werner and Hyslop, 1968a).

The extent of fibre deposition adjacent to the outfalls has also been determined. Ellis (1970) reported that the fibre bed extended from 1.6 to 3.2 km (1 to 2 miles) to the northwest and southwest of the outfall, with the coarse fraction extending approximately 305 m (1,000 ft.) offshore and to a depth of 45.7 m (150 ft.). The area of coarse fibre ranged approximately 0.4 km (1/4 mile) on each side of the outfall and formed a mat 10-15 cm (4-6 inches) or more thick. A broader survey of the general receiving area by Balch (1974) demonstrated consistent minor levels of volatile solids throughout the area to within 305 m (1000 ft.) offshore from the outfalls. The most recent survey (Jones and Ellis, 1975) reported that the 2.5 cm (1 inch) fibre isoline followed the 90 m depth contour closely, and that fibre deposits decreased rapidly offshore as the spread of fibres was primarily alongshore. Figure 6.1 illustrates the extent of fibre deposits. The benthos associated with these fibre deposits are discussed in the Invertebrates Section of this report.

The Crofton pulp mill diverts up to 2.8 cu. m/sec (100 cfs) of water from the lower Cowichan River. An impounding weir, maintained at the Cowichan Lake outlet, is operated under stringent rules to augment low summer flows and partially ameliorate the substantial diversion to the Crofton mill. However, critical low discharge periods occur and the available storage is sometimes not sufficient to supply adequate fall spawning migration flows. Low summer flows can lead to increased competition between juvenile salmonids for food and rearing space, increased predation, and elevated water temperatures (Lill, Marshall and Hooton, 1975).

3. LOGGING, LOG HANDLING AND STORAGE:

In the past, the Cowichan and Chemainus watersheds were heavily forested. The area has been actively logged since the 1800's and logging remains the area's primary industry. Extensive logging within the Cowichan and Chemainus watersheds has created less stable flow regimes resulting in increased rates of erosion and sedimentation. This can seriously affect fish production by smothering or dislodging incubating eggs or pre-emergent fry, by disrupting benthic invertebrate (fish food) populations and by decreasing the input of organic nutrients essential to fish food production (Hooton, 1974).

The drastic reduction in salmon escapements from the

Chemainus River (see Table 11.1) has been noted to coincide with the beginning, in the late 1950's, of extensive logging of the upper Chemainus watershed. The reduction in fish stocks, which has apparently reached its limit, is at least partially attributable to habitat disruption due to logging (Hooton, pers comm.).

Table 11.1. Ten-year average of salmon escapements for the Chemainus River (B.C. Dept. Rec. and Cons., 1973).

	Chum	Coho	Steelhead
1949-58	60,000	4,350	2,480
1959-68	9,350	348	453

The intertidal and subtidal flats of the Cowichan and Chemainus estuaries are extensively utilized for log storage. The effects of booming on the estuarine environment include shading and gouging of substrates, leaching of toxins and deposition of bark and wood fragments. These effects are not readily apparent on a short-term basis, however, the productivity of an estuary, especially in terms of fish, may be significantly reduced over longer time periods. From time to time, fish kills are reported from Cheaminus Harbour as dredging operations stir up sediments and bottom waters containing highly toxic hydrogen sulphide. Booming areas and log handling located within the study region are indicated in Figures 11.1, 11.2 and 11.3.

Slegg Forest Products has been closed and recently purchased by Doman Industries Limited. In expanding and reopening of the sawmill, Doman Industries Limited has filled in portions of extremely productive water courses draining the Cowichan Bay salt marsh. Much of the fill material dumped by Slegg Bros. (PCB application AR 1838) was hogfuel or sawmill waste (mainly cedar bark). The location of the landfill is very detrimental to the fish and wildlife utilizing the estuary. Besides the permanent loss of the natural, highly productive salt marsh, leachates from the fill material adversly affect water quality in the area and will continue to do so unless corrective measures are taken (Can. Dept. Environ., 1975). The surrounding area has numerous channels in which the toxicity of the leachate is especially harmful owing to limited dilution and flushing, and the fact that these areas are extensively utilized by rearing salmon. The toxicity of the mill wastes, especially to coho salmon in salt water was demonstrated in bioassays conducted by EPS (McLaren, 1973).

Certain conditions have been publicly placed on the proposed reopening of the sawmill by the Environmental Land Use Committee (ELUC). They are as follows:

(1) Dredging is to be confined to company property between dates to be established by the Fisheries and Marine Service and conducted in such a way as to minimize spreading of silts.
(2) Wood waste left on the property by previous owner is to be removed and waste material is to be moved 4.5 m (15') from all existing of proposed water channels. A dyke about 2.4 m (8') above normal high tide is to enclose the mill site and any waste material remaining on the site is to be covered with at least .9 m (3') of dredged material and black-topped.
(3) Temporary log storage in the bay is not to exceed 8 hectares (20 acres), subject to review on completion of more detailed fisheries studies.
(4) The company is to replace a .3 hectare (7 acres) marsh area to be infilled for the millsite, with an equal area lying to the north and owned by the company.

Marine log dumps are located in Burgoyne Bay (Saltspring Island), Chemainus Bay, Genoa Bay, Cowichan Bay and Ladysmith Harbour. The A-frame loose log dump on Cowichan Bay, operated by BCFP is the largest in the area and requires annual dredging of wood debris (Conlan, 1974a). Marine log dumping, which generates large amounts of wood and bark debris, is gradually being phased out in favour of dry-land sorting, owing to the need for more streamlined log handling practices and pressure from environmental agencies (Conlan, 1974a).

Substantial areas of Ladysmith Harbour are used for log booming and three log dumps are located within the harbour (see Figure 11.3). The seabed of the harbour has been surveyed photographically. Large areas of the seabed were seen to be covered with wood fragments and debris (Dobrocky SEATECH Ltd., 1974). The accumulation of debris was especially heavy (10 to +25 cm) beneath log booming areas, where sunken logs were sometimes observed to be piled 2 or 3 logs deep.

MacMillan Bloedel Limited operates a sawmill at Chemainus that discharges wastes into Chemainus Bay (Appendix 11.1, 3). Environmental surveys by the Environmental Protection Service (Kussat, 1968, 1970) have shown the aquatic environment in the vicinity of the hydraulic debarker to be "totally unsuitable for the survival of fish" and that the wood and bark deposits covering much of the substrate "reduced dissolved oxygen levels to lethal levels under certain tidal conditions". Unpublished benthic sampling data (Ketcham, pers. comm.) showed the bottom fauna to be increasingly reduced in kinds and number from the mouth to the head of the bay. Water quality and biological investigations conducted in both 1974 and 1975 relating to the discharge of sawmill wastes in the bay are presently in progress (see Ketcham, Appendix 1.2).

4. SHIPPING WASTES:

Crofton, Chemainus, Ladysmith and Cowichan Bay are significant wood products export centres (see the Land Use Section). Sewage discharges from freighters having no holding facilities can affect the area around docks. In addition, fuel leakage or spills, and the occasional loss of oil or cargo are inevitable.

5. WASTES FROM RECREATIONAL ACTIVITIES:

The study area supports a great deal of recreational activity, including 12 marinas (see the Land Use Section) which support substantial boating activity. Investigators have documented the effects of boating and marinas on the environment. McDaniel (1973) recorded that some hard debris littering the substrate around marinas may enhance epifaunal invertebrate populations. However, most litter, such as plastic bags, serve only to aesthetically degrade the environment. Fuel and oil are introduced to the waters through operation of marine motors (outboards in particular) and from inevitable leaks and spills (Jackivicz and Kuzminski, 1973; Nixon *et al.*, 1973). In addition, propeller wash may scour the substrate and resuspend fine sediments.

11 (ii) AIR POLLUTION

Air pollution sources in the study area and a few details of them are listed in Appendix 11.2. Most of the emissions in the Cowichan region are particulate in nature and are located somewhat removed from the estuary. The reader is referred to the Climatology Section of this report for the atmospheric conditions required for air pollutants to become hazardous.

The major air pollution problem in the area is the Crofton pulp and paper mill. Fly-ash and fine particles of "salt cake", one of the pulping chemicals, escape into the atmosphere and cause fallout problems in the immediate region. Hydrogen sulphide, one of the gases given off in the pulping process, and the atmospheric haze generated by the mill may affect property values in the immediate vicinity of the mill and noticeably affect human aesthetic appreciation of the environment at quite some distance depending on the wind direction (Porter, 1969).

The B.C. Pollution Control Branch has investigated ambient air quality in the vicinity of the pulp mill at Crofton and the B.C. Forest Products teepee burners at Lake Cowichan (B.C. Dept. Lands, Forests and Water Resources, 1975a,b). In both cases, measurable levels of pollutants remained low during the surveys.

11 (iii) POLLUTION CONTROL LEGISLATION

As in other parts of the province, water and air pollution in the study area is controlled by federal and provincial legislation. Major federal control of water pollution is done under Section 33 of the Fisheries Act, while provincial control is maintained under the B.C. Pollution Control Board Act. Pollution from ships, particularly with oil, is controlled by the federal Canada Shipping Act. Air pollution control comes under the federal Clean Air Act and the provincial B.C. Pollution Control Board Act. There are various other pieces of federal and provincial legislation, in addition to municipal by-laws, which control particular aspects of pollution affecting the environment and living resources. The federal Department of Environment role and jurisdictioned issues are given by (Shaw and Reuben, 1974). McLaren (1975) reviewed the federal approach taken to water pollution control, as it applies to those waters under federal government jurisdiction. One new item of federal legislation, which affects coastal waters, came into force on December 13, 1975. This is the Ocean Dumping Control Act (Canada Gazette, 1975), which was passed by the House of Commons on May 30, 1975, as Bill-37. The Act requires a permit for dumping of all materials, excluding certain prohibited substances, into the sea. Dredge spoils, for example, can only be discharged at designated points after careful documentation and issuance of a permit by the Department of the Environment.

12. EFFECTS OF DEVELOPMENT

A growing awareness of the effects of development on the natural resources of the coastal zone has focussed the attention of both government and industry on the problems associated with the discharge of sewage and industrial wastes into water and air.

Specific effects of the discharge of effluents from the Crofton pulp mill on the commercial oyster growing areas in the vicinity of the Chemainus delta, and the effects of municipal sewage and log storage on the oyster leases in Ladysmith Harbour, have been described in previous sections of this report.

Since 1955, research projects carried out jointly by government and industry in the Ladysmith and Crofton areas, have provided a better understanding of some of the causes and effects of industrial pollution. As a consequence, oyster leases at the head of Ladysmith Harbour have been re-opened.

The advent of the Esquimalt and Nanaimo Railway by 1900 opened up the forestry industry of the region and led to the development of natural bays and inlets, such as Chemainus Bay, Ladysmith Harbour, Osborn Bay and Cowichan Bay, as seaports and log storage areas. The use of the estuarine environment for log storage and handling is a common practice in British Columbia and is a major cause of environmental damage. While the short-term effects associated with this practice are not easily discernible, the long-term effects of wood bark on the local substrate,and the effect of wood decay on the quality of the receiving water bodies, have been well documented for areas within the Cowichan-Chemainus region. For a detailed description of the adverse impact of wood bark on the aesthetic, chemical and biological parameters of the receiving waters of estuaries and of the Squamish River Estuary in particular, the reader is referred to Hoos and Vold (1975).

The impact of land fill for industrial development, in the intertidal zone of the Cowichan River estuary, has been of growing concern to the wildlife biologists, fishery biologists and regional planners. Since 1962, 91 hectares (224 acres) of the lower estuary have been reclaimed for industrial development by the forest industry. Unless data are obtained relating to the biological productivity of the areas prior to filling, the effect of disruption on the food chains of the estuarine ecosystem cannot be quantitatively assessed. It is hoped that the present program of on-going research (see Appendix 1.2) will provide some answers regarding the possible re-colonization of the benthic organisms and the subsequent effect on the higher orders of the food chain. However, to fully understand the impact of this type of development, it would appear that an integrated program of inter-disciplinary research is needed, involving biologists, botanists, geologists, engineers and others.

Periodic flooding of the low land between the City of Duncan and the estuary by the Cowichan River has necessitated the construction of dykes. The effect of flooding of some of the reserve lands of the Cowichan Indian Band has been recently studied (Underwood, McLellan and Associates Limited, 1974). Additional dyking has been proposed to provide, sufficient river protection for the utilization of these lands for agriculture. The effect of river training and dyking on the hydrological characteristics of a river and its estuary has been discussed in one of the earlier reports in this series (Squamish River Estuary, Hoos and Vold, 1975). A report by the Provincial Water Investigations Branch on preliminary flood control proposals for the Cowichan-Koksilah Rivers (Wester, 1967) examined the effects of hydrological changes on the fish populations of the river, and the residential and agricultural lands in the river flood plains. Little is said about the deltaic environment or the effect of changes to the ecology of the estuary.

Future studies of the impact of commercial and industrial development on the estuarine environment, combined with a growing awareness of its importance as a primary resource area for fish stocks, wildlife and recreational facilities, may lead to the use of other areas of the coastal zone for industrial expansion.

13. CONCLUSION

The Cowichan and Chemainus River estuaries and Ladysmith Harbour, being situated in one of the most densely populated and rapidly expanding areas of Vancouver Island, are prime environments for future development. The following are some conclusions which can be drawn on the basis of the existing environmental knowledge compiled for this report.

1. The Cowichan River estuary is a vital recreational area, highly dependent on the coho and chinook salmon resources of both the Cowichan and Koksilah rivers. The area provides unexcelled opportunities for fishing, hunting and wildlife viewing.

2. The Cowichan River estuary serves as a vital nursery ground for the juvenile salmonids which are reared in the Cowichan and Koksilah River systems and which contribute to several commercial, recreational and Indian food fisheries. The marshlands of both the Cowichan and Chemainus River estuaries, and surrounding low-lying areas, support vast numbers of migrant waterfowl.

3. The Chemainus River estuary, a unique ecological system, has undergone little industrial or urban development to date. While it ranks high on the list of proposed ecological reserves, action should be taken to establish this status, before other less conservation-oriented demands are placed on it.

4. Developments on the Cowichan and Chemainus estuaries, and flood control in the tributary river systems, contribute to conflicts in resources use. There is a need for detailed examination of the environmental impacts of alternative river and estuarine development, in order to minimize damage to living resources for commercial, recreational and aesthetic uses.

5. Chemainus and Ladysmith Harbours are protected inlets receiving little runoff. They are susceptible to rapid pollution because of poor flushing characteristics. Chemainus Harbour is already rather badly degraded owing to wood wastes from sawmills and log storage. Ladysmith Harbour, a traditional oyster growing area, has become polluted by sewage.

6. To increase biological productivity of the estuaries, log storage and handling should be phased out and land-filling of intertidal areas should be more effectively controlled, and if possible, eliminated. Better sewage treatment and control of contaminated runoff is necessary for reinstatement of unrestricted oyster production and cleanup of bathing areas.

7. Research is required to quantify the ecological effects of estuarine development. This is particularly essential to evaluate its impact on the fish and wildlife of the Cowichan and Chemainus estuaries.

Integrated, interdisciplinary research projects, such as that carried out by the Cowichan Estuary Task Force in 1974, are of great value to regional planners. It is encouraging that government agencies, regional districts, municipalities and industry are promoting and planning development based on this type of study. However, it is of vital importance that not only the scope and integrated nature of the study be considered in planning for future development, but also the duration of the study.

In compiling this report, it has become apparent that in many instances, there are several sources for the same data relating to a specific subject. Reference to the original source of the data was not always given, though, where possible, these were checked and any variances noted. A list of government agencies responsible for the compilation and dissemination of data is given in Appendix 13.1., and it is recommended that these be used as the primary source for statistical data.

14. APPENDICES

Appendix 1.1. Sources of Information

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

1. Canada, Department of the Environment

    Environmental Protection Service

    Fisheries and Marine Service

    Fisheries Management
    - Southern Operations Branch
    - Pacific Environment Institute
    - Pacific Biological Station

    Ocean and Aquatic Sciences

    Environment Management Service
    - Canadian Wildlife Service
    - Atmospheric Environment Service
    - Lands Directorate
    - Inland Waters Directorate

2. Canada, Department of Indian and Northern Affairs

3. Canada, Department of Energy, Mines and Resources
    - Geological Survey of Canada (Coastal and Terrain Sciences)

4. Province of British Columbia

    Department of Recreation and Conservation
    - Fish and Wildlife Branch
    - Provincial Parks Branch
    - Surveys and Mapping Branch
    - Provincial Museum

    Department of Lands, Forests and Water Resources
    - Water Investigations Branch
    - Pollution Control Branch
    - Environment and Land Use Committee Secretariat
    - British Columbia Forest Service

    Department of Municipal Affairs

    Department of Industrial Development, Trade and Commerce

Appendix 1.1. (cont'd).

Department of Agriculture

Department of Mines and Petroleum Resources

5. British Columbia Forest Products Limited, Crofton Pulp and Paper Division

6. MacMillan Bloedel Limited, Harmac Division

7. Environmental and Engineering Consultants

   Dobrocky SEATECH Limited

   Tera Environmental Resource Analyst Limited

   R. C. Thurber and Associates Limited

   Underwood, McLellan and Associates Limited

   Urban Programme Planners, R.E. Mann Limited

   Willis, Cunliffe and Tait Limited

8. B.C. Research, the technical arm of the British Columbia Research Council

9. University of British Columbia

   Institute of Oceanography

   Institute of Animal Resource Ecology

   Westwater Research Institute

   Departments of Biology, Botany, Zoology, Soil Science, Geological Sciences and Geography

   Faculty of Forestry

   University of Victoria

10. Libraries

    University Libraries and Reading Rooms

    City of Vancouver and Municipal Public Libraries

    Vancouver Island Regional Library, Duncan

    Federal and Provincial Government Departmental Libraries

11. Cowichan Valley Natural History Society, Duncan, B.C.

12. Chemainus Valley Historical Society, Chemainus, B.C.

Appendix 1.2. On-going research of the Cowichan-Chemainus Rivers and their estuaries.

(i) Geology

Levings, C.D. (P.E.I.): Grain size analysis of sediments collected in conjunction with a survey of intertidal macro-benthos and habitats of the Cowichan River estuary, September, 1975.

(ii) Climatology

- continual monitoring of meteorological data, by Environment Canada, at stations located in Chemainus, Duncan, Cowichan Bay and Vancouver International Airport.

(iii) Hydrology, Water Quality and Pollution

- continual monitoring of water flow rates and water quality characteristics, by Inland Waters Directorate, at stations located on the Chemainus, Cowichan and Koksilah River systems.

Conlan, K.E. (U. Vic.): The biological effects of log dumping and storage in southern British Columbia. M.Sc. Thesis, in progress, Biology Dept.

Cooper, K.R. and B. Kay (EPS): "Shellfish growing water sanitary survey of Ladysmith Harbour, Kulleet Bay and Saltair, 1975".

Davis, J.C. (PEI): Water quality and oyster condition factor determinations conducted in May, 1974 in the vicinity of the Crofton mill outfalls.

Dobrocky Seatech Ltd. (Victoria): An investigation of effects of KME on *in situ* primary production near the Crofton mill outfalls for BCFP Ltd., Crofton Division.

Dobrocky Seatech Ltd. (Victoria): On-going water quality determinations and benthic assessment in the vicinity of the Crofton mill outfalls for BCFP Ltd., Crofton Division.

Ketcham, K. (HARMAC): An on-going receiving water and biological monitoring program in Chemainus Bay with respect to the Chemainus sawmill.

McLeay, D.J. and C.C. Walden (B.C. Research Proj. 1603): "Caged fish studies of toxicity in the environs of BCFP outfalls at Crofton". Prep. for Tech. Comm. of the Env. Consult. of B.C. Pulp and Paper Ind.

Appendix 1.2 (cont'd)

Nelson, H. (EPS): Surveys of heavy metal concentrations in shellfish in the vicinity of the Crofton mill outfalls conducted in June, 1974 and August, 1975.

Nelson, H. and D. Goyette (EPS): "Heavy metal concentrations in shellfish with emphasis on zinc contamination of the Pacific oyster, *Crassostrea gigas*".

Thompson, J.A.J.; J.C. Davis; and R.E. Drew (PEI, DOE): "Toxicity, uptake and survey studies of boron in the marine environment".

(iv) Biology

Austin, A. (U.Vic): A study of growth forms of unattached algae on Thetis Island.

Black, T. (UBC): A study of threespine stickleback (*Gasterosteus aculeatus*) ecology in selected estuaries including the Chemainus River estuary. M.Sc. Thesis, in progress, Zoology Dept.

Blood, D.A. and Assoc. (Lantzville, B.C.): Migratory bird use of the Cowichan River estuary. Rept. for the Canadian Wildlife Service.

Davis, J.C. (PEI): Oxygen uptake and swimming stamina studies with respect to pulp mill effluent using underyearling coho salmon conducted in May, 1974.

Foreman, R.E. (UBC): Identification of an intertidal benthic algae collection made in July, 1975 on the Cowichan River estuary.

Kennedy, K. (UBC): A study of estuarine plant associations on the Chemainus River estuary. M.Sc. Thesis, in progress, Plant Science Dept.

LeBrasseur, R.J. (PBS): Continuous surface zooplankton tows over 22 miles in Cowichan Bay and adjacent waters conducted in July, 1975.

Levings, C.D. (PEI): A survey of intertidal macrobenthos and habitats conducted in September, 1975 on the Cowichan River estuary.

Sibert, J.R. (PBS): Investigations into intertidal benthic and pelagic primary productivity and heterotrophic activity conducted in July, 1975 on the Cowichan River estuary.

Appendix 1.2 (cont'd)

Sparrow, R.A.H. (F. & W. Br., Victoria): Investigations into juvenile chinook and coho salmon distribution and migration timing in the lower Cowichan River and Cowichan Bay.

(v) General Studies

various resource studies and environmental impact assessments with respect to future development of the estuaries and environs, including:

a. B.C. Province Environment and Land Use Committee: contracted Tera Environmental Resource Analyst Limited to study the resources of Ladysmith Harbour and surrounding area, in conjunction with the Government's Ladysmith Harbour Planning Study.

b. Archeological Sites Advisory Board of British Columbia, Victoria: on-going research relating to heritage site inventories in the Ladysmith Harbour, Chemainus and Cowichan areas.

c. Cowichan Valley Regional District Planning Department - work in progress includes:

   - an overall Regional Plan for the regional district.
   - a community plan for electoral Area E, expected to be completed by early 1976.
   - preliminary planning for studies to be undertaken in 1976 of the recreational and industrial development capabilities of the Cowichan River estuary.

d. Canada Department of the Environment, Southern Operations Branch, Economics Unit: a study for the Small Craft Harbour Division, including an analysis of present marina policy and marina facilities, moorings and berths available for small crafts on the south-eastern coast of Vancouver Island.

Appendix 1.3. Metric Conversion Factors

ENGLISH UNIT x	CONVERSION FACTOR =	METRIC UNIT
acres	0.41	hectares
acre feet (1 acre-foot = 1 acre x 1 ft.)	1,233.5	cubic metres
cubic feet per second	0.028	cubic metres per second
cunit (100 cubic feet)	2.831	cubic metres
degrees Farenheit	5/9 (F-32)	degrees Celsius
fathom (6 feet)	1.83	metres
feet	0.305	metres
feet per second	30.48	centimetres per second
gallons (Imp.)	4.546	litres
gallons (U.S.)	3.785	litres
grains per standard cubic foot	2.188	grams per cubic metre
inches	2.54	centimetres
inches of Mercury	3.386	kilopascals (kPa)
knots (nautical miles per hour)	51.444	centimetres per second
miles	1.61	kilometres
miles per hour	1.61	kilometres per hour
nautical miles (Int.)	1.852	kilometres
ounces (fluid British)	28.41	cubic centimetres
ounces (fluid U.S.)	29.57	millilitres
parts per million	1.0	milligrams per litre
pound	0.4536	kilograms
pounds per cunit	0.02	kilograms per cubic metre (solid wood)
quart (British)	1.136	litres
square miles	259	hectares
standard cubic foot per minute (air pollution)	1.2	moles per second

Appendix 1.3. Metric Conversion Factors (cont'd)

ENGLISH UNIT	x CONVERSION FACTOR	= METRIC UNIT
standard cubic foot per minute (water pollution)	0.0005	cubic metres per second
ton (2,000 lbs)	0.9072	metric ton (1,000 kg)

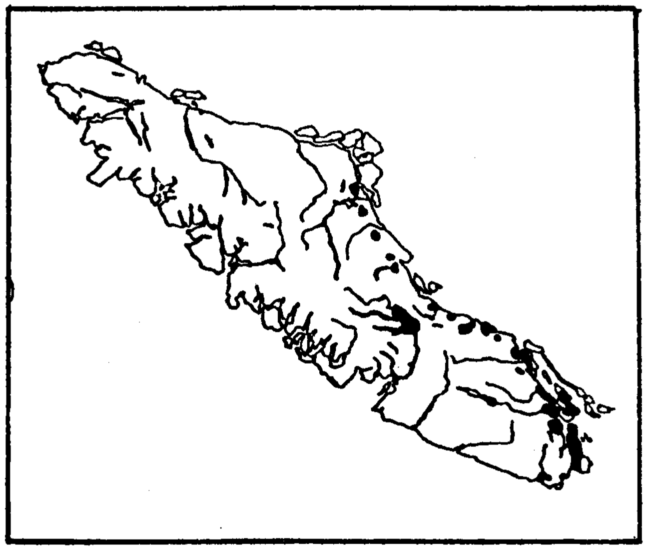
Note: Metric equivalents of measurements for use in hydraulic computations are taken from list on page v in, Environment Canada, Surface Water Data, B.C. 1974, Water Survey of Canada, Ottawa. The common usage of metric units, by the Water Survey of Canada and the United States Water Resources Division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

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
Palæozoic	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
Archæan	Temiskaming Keewatin	2,000 to 4,800

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

Appendix 2.2. Cowichan-Chemainus region soils classification. (Keser and St. Pierre, 1973)



COWICHAN CLAY LOAM

LOCATION: Mainly the Gulf Islands, Saanich Peninsula, Duncan and Alberni (24,680 acres)

CLIMATE:

Mean Temperature °C (°F)		Mean Precipitation mm (in.)	
Annual:	9.4 (49)	Annual :	1058 (41.64)
Jan. :	2.8 (37)	April-July :	35 (1.38)
July :	17.2 (63)	May - Sept.:	30 (1.20)

VEGETATION: The original forest vegetation consisting of red cedar, hemlock, alder and maple has been logged off. Second growth alder, willows, maple and red cedar now predominate.

TOPOGRAPHY: Very gently sloping to level.

DRAINAGE: Poorly drained; permeability of the A_1 horizon is intermediate while that of the other horizons is very low. The lower part of the A_1 horizon may be mottled and the subsoil upon drying out becomes very hard.

PARENT MATERIAL: Fine - textured marine sediments.

CLASSIFICATION: Dark grey Gleysolic; (Humic Eluviated Gleysol, 1970).

PROFILE DESCRIPTION:

Horizon	Depth inches	
A_{oo}	2- 1	Moss, leaves, needles, etc., largely undecomposed.
A_o	1- 0	Dark brown well decomposed organic matter, pH 5.0.
A_1	0- 8	Very dark brown (10 YR 2/2 moist, 4/2 dry) clay loam, strong medium subangular blocky and granular structure, friable. pH 5.2. Horizon boundary abrupt.

Appendix 2.2 (cont'd).

Horizon	Depth inches	
A_2	8-14	Brown (10 YR 5/3 moist, 7/3 dry) silt loam of massive to blocky structure. Slight mottling, very plastic and very hard. pH 5.2. Horizon boundary clear.
B_g	14-23	Pale brown (10 YR 6/3 moist, 2.5 Y 7/4 dry) silty clay, highly mottled (10 YR 5/6 amorphous, very plastic and very hard. pH 4.9. Roots rarely penetrate this horizon.
C_1	23-28	Pale brown (10 YR 6/3 moist, 7/3 dry) silty clay loam, highly mottled. Amorphous. pH 5.4.
C_2	28+	Pale brown (10 YR 6/3 moist, 7/3 dry) silty clay loam with amorphous to very coarse blocky structure; blackish organic stains and splotches on cleavage faces. Very slowly permeable; no roots. pH 5.8.

CHEMICAL DATA:

Hor	Depth inches	pH	O.M. %	N %	C/N ratio	P %
A_0	2- 0	5.0	50.37	0.89	32.8	
A_1	0- 8	5.2	11.04	0.36	17.8	0.08
A_2	8-14	5.2	0.96	0.05	11.1	0.01
B	14-23	4.9	1.52	0.06	14.7	0.02
C_2	28+	5.8	0.69	0.03	13.3	0.02

Hor	Depth inches	pH	Exchangeable cations (m.e./100gms)					Sum of Cations	% Base Sat.	Ex.Mn p.p.m.	Total Cu p.p.m.
			Ca	Mg	K	Na	H				
A_1	0- 8	5.2	8.06	5.50	0.69	0.42	18.85	33.52	43.7	22.37	50
A_2	8-14	5.2	2.00	2.20	0.18	0.22	5.30	9.90	46.4	.04	
B	14-23	4.9	9.18	7.46	0.27	0.61	6.34	23.86	73.5	.89	
C_2	28+	5.8	13.30	8.19	0.17	0.91	2.18	24.75	91.1	1.06	

Appendix 2.2 (cont'd).

Hor	Depth inches	Si	Fe	Al	Ti	Ca %	Mg	Na	K	P
A_1	0- 8	26.54	4.85	8.32	0.50	1.57	1.01			0.08
A_2	8-14	31.06	4.62	7.69	0.46	1.60	1.15			0.01
B	14-23	28.02	5.94	9.52	0.65	1.16	1.10			0.02
C_2	28+	29.19	5.46	9.03	0.61	1.83	1.38			0.02

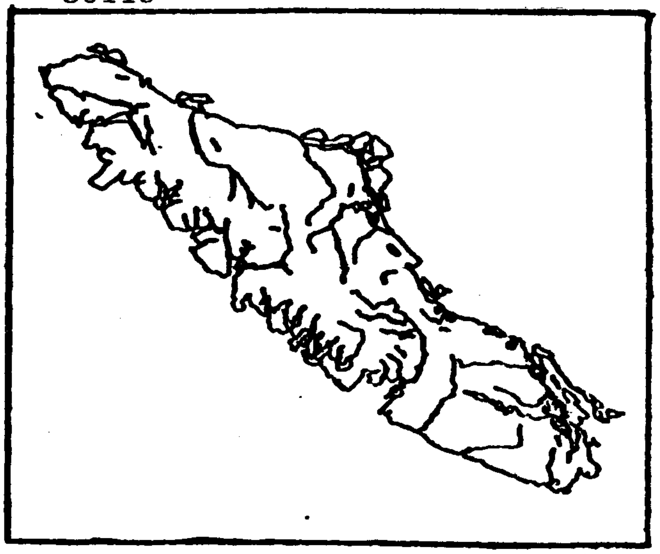
PHYSICAL DATA:

Hor	Depth inches	Sand 2-.05 mm	Silt .05-002 mm	Clay ,002 mm
A_1	0- 8	27.94	41.04	31.02
A_2	8-14	25.12	49.98	24.90
B	14-23	11.09	43.07	45.84
C_2	28+	13.10	49.86	37.04

Hor	Depth inches	Bulk density gms/cc	Moisture equivalent %	Permanent wilting %	Porosity Total %	Non-Cap. %
A_1	0 8	0.84	33.6	10.3	63.8	10.2
A_2	8-14	1.59	17.5	4.0	44.3	4.3
B	14-23	1.52	31.1	17.1	48.1	3.2
C_2	28+	1.47			52.4	4.0

	Depth of Soil inches						
	4	6	8	12	16	18	20
Available water inches	.8	1.2	1.6	2.4	3.3	3.7	4.2

Appendix 2.2 (cont'd).



FAIRBRIDGE SILT LOAM

LOCATION: Shawnigan Lake to Campbell River. The largest blocks occur south of Duncan (35,000 acres).

CLIMATE:

Mean Temperature °C (°F)		Mean Precipitation mm (in.)	
Annual:	9.4 (49)	Annual :	1176 (46.29)
Jan. :	2.2 (36)	April-July :	40 (1.56)
July :	17.2 (63)	May -Sept.:	35 (1.38)

VEGETATION: Douglas fir, maple, hemlock and an occasional arbutus, alder and willow. Salal commonly forms the understory.

TOPOGRAPHY: Very gently to gently sloping with a hummocky surface due to uprooting trees.

DRAINAGE: Well drained and permeability is moderate in the D horizon but very slow in the C.

PARENT MATERIAL: Fine-textured marine sediments.

CLASSIFICATION: Concretionary Brown; (Bisequa Mini Humo-Ferric Podzol, 1970).

PROFILE DESCRIPTION:

Horizon	Depth inches	
A_o	2- 0	Litter of needles, leaves and twigs over dark brown moderately well decomposed organic debris. pH 4.9.
AB	0- 1	Brown (7.5 YR 5/4 moist, 6/4 dry) silt loam of compound strong medium granular and weak fine subangular nuciform structure. About 25 per cent of the soil is medium sized (2-5 mm.) hard concretions. pH 5.5.

Appendix 2.2 (cont'd).

Horizon	Depth inches	
B_2	1-12	Brown to dark yellowish brown (10 YR 4/4 to 4/3 moist, 6/4 dry) silty clay loam of weak medium subangular blocky and strong coarse granular structure. Many hard concretions. Moderately friable. A few pebbles may occur. pH 5.7. Horizon boundary is diffuse.
B_3	12-19	Pale brown (10 YR 6/3 moist, 7/3 dry) silty clay loam, strong coarse blocky structure, a few concretions in upper part. pH 5.2. Horizon boundary abrupt.
C_1	19-24	Pale yellow (2.5 Y 7/4 dry, 6/4 moist) silty clay loam of coarse blocky structure. Very firm and very hard consistence. pH 5.6. Mottled. Gradual horizon boundary.
C_2	24+	Pale yellow silty clay loam as above. Black stains and splotches on cleavage faces. pH 6.0.

CHEMICAL DATA:

Hor	Depth inches	pH	O.M. %	N %	C/N ratio	P %
A_0	2- 0	4.9	9.66			
AB	0- 1	5.5	2.05	0.08	14.9	0.08
B_2	1-12	5.7	1.65	0.05	19.1	0.06
B_3	12-19	5.2	1.38	0.04	20.0	0.03
C_1	19-24	5.6	0.55	0.03	10.6	0.05
C_2	24+	6.0	0.55	0.02	16.0	0.05

Appendix 2.2 (cont'd).

Hor	Depth inches	pH	Exchangeable cations (m.e./100gms) Ca	Mg	K	Na	H	Sum of cations	% Base Sat.
AB	0- 1	5.5			0.10	0.96	5.90		
B_2	1-12	5.7	2.49	0.94	0.27	0.14	5.43	9.27	41.4
B_3	12-19	5.2	2.82	1.79	0.21	0.19	5.03	10.04	49.9
C_1	19-24	5.6	6.49	4.72	0.21	0.26	3.93	15.61	74.6
C_2	24+	6.0	10.35	7.55	0.15	0.30	2.35	20.70	88.6

Hor	Depth inches	Si	Fe	Al	Ti	Ca %	Mg	Na	K	P
AB	0- 1	28.01		8.12	0.64	1.74	1.50			0.08
B_2	1-12	28.05	6.24	8.67	0.65	1.60	1.71			0.06
B_3	12-19	27.85								0.03

PHYSICAL DATA:

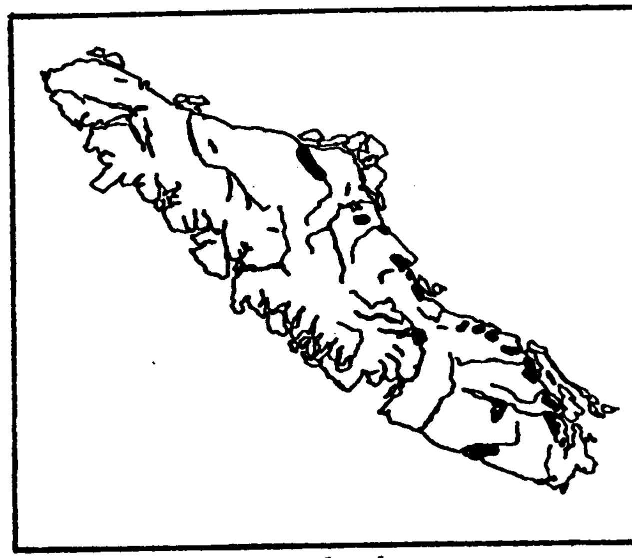
Hor	Depth inches	Sand 2-.05 mm	Silt .05-002 mm	Clay .002 mm
AB	0- 1	1.62	73.96	24.42
B_2	1-12	0.78	72.60	26.62
Concretions	1-12	0.48	69.38	30.14
B_3	12-19	3.14	67.51	29.35
C_1	19-24	2.00	63.51	34.49

Appendix 2.2 (cont'd).

Hor	Depth inches	Bulk density gms/cc	Moisture equivalent %	Permanent wilting %	Porosity Total %	Porosity Non-Cap. %
B_2	1-12	1.10	27.6	11.7	62.9	19.4
B_3	12-19	1.31	28.6	8.6	55.4	9.1
C_1	19-24	1.44			52.1	5.3
C_2	24+	1.51			49.3	5.8

	Depth of Soil inches					
	4	6	8	12	16	18
Available water inches	.7	1.1	1.4	2.1	3.2	3.7

Appendix 2.2 (cont'd).



CHEMAINUS COMPLEX

LOCATION: Scattered occurance throughout east coast of Vancouver Island (32,745 acres).

CLIMATE:

Mean Temperature °C (°F)		Mean Precipitation mm (in.)	
Annual:	9.4 (49)	Annual :	1269 (49.95)
Jan. :	2.2 (36)	April-July :	43 (1.68)
July :	17.2 (63)	May -Sept.:	38 (1.50)

VEGETATION: The vegetation is mixed. Some areas support valuable stands of hemlock and red cedar. Logged-off areas support a second growth of red alder and young conifers with a ground cover of sword fern, thistle thimbleberries and huckleberries. In other areas, maple, red alder, willows and cottonwood are dominant with a groundcover consisting of grasses and shrubs.

TOPOGRAPHY: Level to gently sloping.

DRAINAGE: Variable.

PARENT MATERIAL: Moderate and fine textured alluvium.

CLASSIFICATION: Alluvium; (Orthic Regosol, 1970).

PROFILE DESCRIPTION:

Horizon	Depth inches	
A_o	1- 0	Very dark brown well-decomposed leaf litter.
A1	0- 4	Dark brown to black (10 YR 2/2 to 2/1 moist, 4/2 dry) silt loam, strong medium granular structure. Friable and soft consistence. pH 6.2 Horizon boundary is abrupt.

Appendix 2.2 (cont'd).

Horizon	Depth inches	
C	4+	Grayish brown (10 YR 5/2 moist, 6/2 dry) silt loam, amorphous structure, friable consistence. Stratified. pH 5.9. Mottles start at 13 inches and become prominent at depth.

Soil texture ranges from fine sandy loam to clay loam with the most common texture being loam. The mapping units used were fine sandy loam to loam (17,570 acres) and silt loam to clay loam (15,175 acres). Occasionally pebbles may be present.

CHEMICAL DATA: (for Chemainus Silt Loam)

Hor.	Depth inches	pH	O.M. %	N %	C/N ratio	P %
A_1	0- 4	6.2	18.68	0.75	14.4	0.08
C	4+	5.9	2.34	0.09	15.1	0.07

Hor	Depth inches	pH	Exchangeable cations (m.e./100gms)					Sum of Cations	% Base Sat.
			Ca	Mg	K	Na	H		
A_1	0- 4	6.2	30.00	8.40	0.66	0.18	10.20	49.44	79.5
C.	4-12	5.9	7.60	1.40	0.32	0.28	3.77	13.37	71.9

PHYSICAL DATA: (for Chemainus Silt Loam)

Hor	Depth inches	Bulk density gms/cc	Moisture equivalent %	Permanent Wilting %	Porosity % Total	Porosity % Non-Cap.
A	0- 4	0.76	38.8	13.4	63.7	10.1
C	4-12	1.02	21.0	5.7	59.0	10.8

Appendix 2.2 (cont'd).

	Depth of Soil inches							
	4	6	8	12	16	18	20	24
Available water inches	.8	1.1	1.4	2.1	2.7	3.1	3.4	4.0

Appendix 4.1.

Cowichan-Chemainus River Estuaries Available Streamflow Data (Canada Department of the Environment, 1972).

NAME	GAUGE LOCATION	DISCHARGE RECORDS (Stage only *) (Misc. Meas. #)
Cowichan River at Lake Cowichan	48° 49" 34" 124° 03' 07"	13-19 20-21# 40-72
Cowichan River near Duncan	48° 46' 22" 123° 42' 44"	12#,13#,17#,55# 57-58# 60-72
Cowichan Lake near Lake Cowichan	48° 49' 28" 124° 03' 37"	13-21*, 52-72*
Somenos Creek near Duncan	48° 47' 08" 123° 41' 00"	21#, 64-69# 61-63
Somenos Lake near Duncan	48° 48' 13" 123° 42' 26"	61-69*
Bings Creek near Duncan (formerly Holmes Creek)	48° 47' 05" 123° 44' 30"	53-55
Bings Creek near the Mouth (formerly near Duncan)	48° 47' 22" 123° 43' 29"	61-72
Averill Creek near Duncan	48° 47' 50" 123° 42' 48"	61-63 64-66#
Quamichan Creek at Outlet of Quamichan Lake (formerly near Duncan)	48° 47' 17" 123° 40' 17"	54-56 71
Quamichan Lake near Duncan	48° 47' 19" 123° 40' 09"	54-56*
Koksilah River at Cowichan Station (formerly near Duncan)	48° 43' 39" 123° 40' 11"	12-13# 14-17, 61-72 54-60

Appendix 4.1 (cont'd).

NAME	* GAUGE LOCATION	DISCHARGE RECORDS (Stage only *) (Misc. Meas. #)
Patrolas Creek near Cowichan Station	48° 43' 25" 123° 39' 28"	64 65#
Chemainus River near Westholme	48° 52' 51" 123° 41' 10"	12-13# 14-17 53-72
Bonsall Creek above Whitehouse Creek	48° 51' 16" 123° 42' 47"	68

* Surface water data, reference index, Canada Water Survey of Canada.

Appendix 6.1.

List of Freshwater Invertebrate Organisms Recorded within the Study Region as Compiled from the Literature (Carl, 1953, except species marked *).

PHYLUM PROTOZOA

- *Ceratium hirundinella*
- *Dinobryon sertularia*
- *Glenodinium* sp.

PHYLUM PORIFERA

- *Spongilla* sp.

PHYLUM PLATYHELMINTHES

- *Planaria* sp.

PHYLUM ROTIFERA

- *Anuraea* sp. *
- *Asplanchna* sp. *
- *Conochilus* sp.
- *Gastropus* sp.
- *Keratella cochlearis* var. *tecta*
- *Notholca longispina*
- *Ploesoma truncatum*
- *Polyartha trigla*

PHYLUM NEMATODA

- unidentified species *

PHYLUM ANNELIDA

- Class Oligochaeta
  - *Lumbricus terrestris* *
  - *Stylaria* sp.
  - Tubificidae unidentified species

Appendix 6.1 (cont'd).

Class Hirudinea
- *Glossiphonia* sp. *
- unidentified species *

PHYLUM MOLLUSCA

Class Gastropoda
- *Helisoma trivolvis*
- *Lymnaea palustris*
- *L. stagnalis*
- *Menetus opercularis planulatus*
- *Physa blandi*
- *P. carltoni*
- *P. coniformis*
- *P. gabbi*
- *P.* sp.
- *Planorbis hornii*
- *Stagnicola lepida*
- *S. proxima rowellii*
- unidentified species *

Class Bivalvia
- *Anodonta beringiana*
- *Musculium lacustre*
- *M. ryckholti raymondi*
- *Pisidium variabile*
- *Sphaerium* sp. *

PHYLUM ARTHROPODA

Class Arachnida
- *Hydracarina* sp.
- unidentified species

Class Insecta
- Order Ephemeroptera unidentified species
- Order Odonata " "
- Order Isoptera " " *

Appendix 6.1 (cont'd).

Order Plecoptera unidentified species
Order Hemiptera " " *
Order Homoptera " " *
Order Neuroptera " " *
Order Coleoptera " " *
Gyrinidae unidentified species
Order Trichoptera unidentified species
Hydropsyche sp.
Order Diptera
Chironomidae larvae unidentified species
Simuliidae larvae unidentified species *
Tendipedidae larvae unidentified species
Tipulidae larvae unidentified species
unidentified species *
Order Hymenoptera
unidentified species *
Apidae unidentified species *
Formicidae unidentified species *
Class Crustacea
Subclass Branchiopoda
Alona sp.
Bosmina obtusirostris
B. sp. *
Daphnia longispina
D. pulex
D. sp. *
Diaphanosoma brachyurum
D. sp. *
Eurycercus lamellatus
Graptoleberis testudinaria
Leptodora kindtii
Pleuroxus denticulatus
Polyphermus pediculus
Scapholeberis mucronata

Appendix 6.1 (cont'd).

Sido crystallina
unidentified species *
Subclass Ostracoda
unidentified species *
Subclass Copepoda
Cyclops bicuspidatus
C. prasinus
C. sp. *
Diaptomus oregonensis
Subclass Malacostraca
Order Amphipoda
Anisogammarus confervicolus *
Eucrangonyx gracilis
Hyalella azteci

Appendix 6.2.

List of Marine Invertebrate Organisms Recorded from the Cowichan-Chemainus River Estuaries Study Area (species marked * = Ellis, 1967b, 1968b; ** = Quayle, 1970).

PHYLUM PROTOZOA

- *Folliculina expansa* **
- Foraminifera **

PHYLUM PORIFERA

- *Cliona* sp
- encrusting Demospongiae species **
- encrusting Hexactinellida species **
- unidentified species

PHYLUM CNIDARIA

- Class Anthozoa
  - *Epiactis prolifera* **
  - *Haliplanella luciae* **
  - *M. senile* var. *dianthus* **
  - *Pachycerianthus fimbriatus* **
  - unidentified species *
- Class Hydrozoa
  - *Aequorea aequorea* *
  - *Campanularia* sp. **
  - Campularidae unidentified species **
  - *Gonionemus vertens* **
  - *Halistaura cellularia* **
  - *Obelia longissima* **
  - *Polyorchis penicillatus* **
- Class Scyphozoa
  - *Aurelia aurita* **

Appendix 6.2 (cont'd).

PHYLUM CTENOPHORA

Cydippida unidentified species **

Pleurobrachia pileus **

PHYLUM PLATYHELMINTHES

Class Turbellaria

Leptoplana sp. **

Planocera sp. **

unidentified species *

PHYLUM NEMERTEA

Carinella sp. **

Cerebratulus spp. **

unidentified species ***

PHYLUM NEMATODA

Enoplus sp. **

marine, freshwater and terrestrial unidentified species

PHYLUM BRYOZOA

Alcyonidium mytili **

Bugula pacifica **

Membranipora membranacea **

Microporella ciliata **

Shizoporella unicornis **

S. sp. **

Tegella robertsoni **

unidentified species **

PHYLUM ANNELIDA

Class Polychaeta

Subclass Errantia

Antinoella macrolepida *

Aphrodita japonica *

Appendix 6.2 (cont'd).

Arctonoe fragilis **
A. pulchra **
Armandia brevis **
Castalia fusca **
Diopatra ornata *
Dorvillea rudolphii *
Eteone longa *
E. spetsbergensis *
Eulalia bilineata *
E. nigrimaculata *
E. sanguinea *
E. viridis **
Exogone gemmifera **
Gattyana cirrosa *
G. iphionelloides *
Glycera sp.
Goniada brunnea *
Halosynda brevisetosa **
Harmothoe extenuata * **
H. imbricata * **
H. lunulata *
Hemipodus borealis *
Lepidametria longicirrata *
Lepidonotus squamatus **
Lumbrinereis bifurcata *
L. latreilli *
L. sp. *
Malmgrenia lunulata *
Nephtys caecoides *
N. spp. *
Nereis agassizi **
N. pelagica **
N. procera **
N. vexillosa **

Appendix 6.2 (cont'd).

Nereis sp.
Ninoe gemmea *
Odontosyllis phosphorea *
Onuphis elegans *
O. iridescens *
Peisidice aspera *
Pholoe minuta *
Phyllodoce castanea *
P. maculata *
Platynereis dumerilii *
P. sp.
Podarke pugettensis ***
Sthenelais articulata *
Syllis alternata *
S. armillaris **
S. fasciata *
S. heterochaeta *
S. hyalina *
S. pulchra **
S. spenceri *

Subclass Sedentaria

Abarenicola pacifica
Amage anops *
Ammotrypane aulogaster *
Ampharete arctica *
Armandia brevis *
Artacama conifera *
Asychis similis *
Capitella capitata *
Chaetozone setosa *
Chone infundibuliformis *
Eudistylia gigantea **
Haploscoloplos elongata *
Laonice cirrata *

Appendix 6.2 (cont'd).

Maldane glebifex *
Melinna cristata *
Mesochaetopterus taylori *
Myxicola aesthetica **
Nicomache lumbricalis *
Pectinaria belgica *
Pherusa papillata *
Phyllochaetopterus prolifica *
Pista cristata *
P. fasciata *
P. moorei *
Polycirrus kerguelensis *
Praxilella affinis var. *pacifica* *
P. gracilis *
Praxilella sp.
Pseudosabellides spp. *
Scalibregma inflatum *
Serpula vermicularis **
Schizobranchia insignis **
S. nobilis **
Spio filicornis var. *pacifica*
Spirorbis sp. **
Sternapsis fossor *
Telepsavus costarum **
Terebella robusta **
T. sp. **
Terebellides stroemi *
Tharyx multifilis **
T. parvus *
Thelepus setosus *
Travisia brevis *
T. pupa *
unidenitified species *

Appendix 6.2 (cont'd).

PHYLUM MOLLUSCA

Class Amphineura

Subclass Aplacophora

Chaetoderma *

Ischnochiton mertensii **

I. sp. **

Mopalia ciliata **

M. mucosa **

Tonicella lineata **

unidentified species *

Class Gastropoda

Acanthodoris *

Acmaea cassis var. *olympica* **

A. mitra **

A. personna **

A. scutum var. *pintadina* **

Aceteocina sp. *

Aeolida papillosa **

Alectrion mendicus **

Alvinia sp. *

Austrotrophon sp. *

Balcis sp. *

Batillaria cumingi

Buccinum sp. *

Calliostoma costatum **

Clathrodrillia sp. *

Colus sp. *

Coryphella fusca **

Crepidula sp. *

Dendronotus iris **

Diaphana sp. *

Diaulula sandiegensis *

Diodora aspera **

Epitonium sp. *

Appendix 6.2 (cont'd).

Haminoea vesicula *
Hermissenda crassicornis **
Lacuna sp. *
Littorina scutulata **
L. sitkana
L. sp.
Lora sp. *
Mangilia sp. *
Margarites sp. *
Melibe leonina **
Mitrella gouldi
M. sp. *
Nassarius obsoletus
N. sp. *
Neptunea sp. *
Nudibranchia unidentified species *
Ocenebra interfossa
O. japonica
Odostomia lastre
O. sp. *
Oenopota sp. *
Polinices lewisii **
P. sp. *
Purpura clavigera
P. foliata **
Searlesia dira **
Tachyrhynchus sp. *
Thais emarginata **
T. lamellosa **
T. sp. **
Tritonia sp. **
Turbonilla spp. * **
unidentified species * **

Appendix 6.2 (cont'd).

Class Bivalvia

Acila castrensis *
Adontorhina sp. *
Anisodonta sp. *
Axinopsis sericatus *
A. viridis *
Bankia setacea
Cardita ventricosa *
Cardium corbis **
Chlamys hericia ***
C. vancouverensis *
Clinocardium fucanum *
C. nuttalli *
Compsomyax subdiaphana *
Crassostrea gigas **
Crenella columbiana *
Cuspidaria californica *
C. oldroydi *
Cryptomya californica **
Hinnites giganteus **
Lucinoma annulata *
L. tenuisculpta *
Lyonsia pugetensis *
Macoma alaskana *
M. brota *
M. calcarea *
M. carlottensis *
M. incongrua *
M. inquinata **
M. nasuta **
M. secta **
Modiolus modiolus *
Mya arenaria **
M. intermedia *

Appendix 6.2 (cont'd).

Mysella sp. *
Mytilimeria nuttalli
Mytilus californianus
M. edulis **
Nucula tenuis *
Nuculana cellulita *
Nuculana sp. *
Ostrea lurida **
Pandora bilirata *
P. filosa *
P. grandis *
Pecten caurinus
Pitar sp. *
Pododesmus macroschisma **
Protocardia centifilosa *
Protothaca staminea * **
Psephidia lordi *
P. ovalis *
Rochefortia tumida *
Saxicava arctica **
Saxidomus giganteus **
Tellina buttoni *
T. carpenteri *
Thyasira barbarensis *
T. bisecta *
Tresus capax
T. nuttalli **
Venericardia paucicostata *
V. ventricosa *
Venerupis japonica
Yoldia amygdalea *
Y. ensifera *
Y. myalis *

Appendix 6.2 (cont'd).

Yoldia thraciaeformis *
Y. sp.
Class Scaphopoda
Cadulus sp. *
Class Cephalopoda
Octopus dofleini

PHYLUM ARTHROPODA
Class Crustacea
Subclass Cirripedia
Balanus cariosus **
B. crenatus **
B. glandula
B. nubilis **
Chthamalus sp.
Petogaster sp. **
Sacculina sp. **
Subclass Branchiopoda
unidentified species
Subclass Ostracoda
unidentified species
Subclass Copepoda
Cyclops sp.
Diaptomus sp.
Myticola orientalis
unidentified species *
Subclass Malacostraca
Order Leptostraca
Epinebalia pugettensis
Nebalia sp.
Order Mysidacea unidentified species
Order Cumacea
Diastylis sp. *
unidentified species *

Appendix 6.2 (cont'd).

Order Isopoda
- *Cirolana sphaeromiformis* **
- *Gnorimosphaeroma oregonensis* **
- *Idotea* sp.
- *Limnoria lignorum*

Order Tanaidacea
- *Leptochelia*
- unidentified species

Order Amphipoda
- *Amphithoe humeralis* **
- *A. lacertosa* **
- *A. rubricata* **
- *Caprella equilibra* **
- *Metacaprella kennerlyi* **
- *Metopa* sp. *
- unidentified species *

Order Decapoda
- Suborder Natantia
  - *Heptacarpus paludicola* **
  - *H.* sp. **
  - *Hippolyte californiensis* *
  - *Lebbeus washingtonianus* **
  - *Pandalopsis dispar*
  - *Pandalus borealis*
  - *P. danae*
  - *P. goniurus*
  - *P. hypsinotus*
  - *P. jordani*
  - *P. montagui tridens*
  - *P. platyceros*
  - *P. stenolepsis*
  - *Spirontocaris* sp. **
- Suborder Retantia
  - Section Astacura

Appendix 6.2 (cont'd).

Callianassa californiensis
Upogebia pugettensis
Section Anomura
Hapalogaster mertensii **
Pagurus beringanus **
P. capillatus
P. caurinus
P. granosimanus **
P. hirsutiusculus **
P. stevensae
Petrolisthes eriomerus **
Section Brachyura
Cancer magister
C. oregonensis **
C. productus **
Fabia subquadrata **
Hemigrapsus nudus **
H. oregonensis **
Lophopanopeus bellus **
Oregonia gracilis **
Pinnotheres pugettensis
Pugettia gracilis **
P. producta **
P. richii **
Telmessus cheiragonus **
Subclass Branchiura
unidentified species

PHYLUM SIPUNCULIDA
unidentified species *

PHYLUM ECHIURIDA
Bonellia sp. *

Appendix 6.2 (cont'd).

PHYLUM PHORONIDA

Phoronis sp. *

PHYLUM BRACHIOPODA

Laqueus californianus
Terebratalia transversa **
unidentified species

PHYLUM ECHINODERMATA

Class Holothuroidea

Chiridota sp. *
Cucumaria miniata **
Eupentacta quinquesemita * **
Leptosynapta sp. **
L. transgressor *
Molpadia intermedia *
Parastichopus californicus **
Pentamera lissoplica *
P. sp. *
unidentified species *

Class Echinoidea

Brisaster latifrons *
Strongylocentrotus droebachiensis **
S. franciscanus **

Class Ophiuroidea

Amphiodia urtica *
Amphioplus strongyloplax *
Amphipholis sp. *
Ophiopholis aculeata **
Ophiura leptoctenia *
O. lutkeni *
O. sarsi *
unidentified species *

Appendix 6.2 (cont'd).

Class Asteroidea

Dermasterias imbricata **

Evasterias troschelli **

Henricia leviuscula **

Pisaster brevispinus **

P. ochraceus **

Pycnopodia helianthoides **

Solaster dawsoni **

S. stimpsoni **

PHYLUM CHORDATA

Class Ascidiacea

Boltenia villosa **

Botrylloides sp. **

Chelysoma productum **

C. columbianum **

Cnemidocarpa finmarkiensis *

C. joannoe **

Corella rugosa **

C. willmeriana

Katatropa vancouverensis **

Pyura haustor **

APPENDIX 7.1.

Cowichan River Anadromous Fish Escapement Data (Can. Dept. Environ., 1973).

Species	Years of Enumeration	Average Annual Escapement (1963-1972)	Date & Size of Max. Escapement	Date & size of Min. Escapement	Period of Spawning (peak underlined)	Downstream Timing
Sockeye						
Chinook	1963-1972	7,550	(1966) 10,000-20,000	(1967) 2,000-5,000	June-Sept.-Oct.-Nov.	(1965) Fry-42 mm Mar-April Finger-lings-60-80 mm late May-June.
Coho	1963-1972	44,400	(1971) 50,000-100,000	(1972) 9,000	Sept.-Oct. Nov.-Dec.	May 1-May 31 Peak April 7-May 20.
Pink						
Steelhead	1963-1972	2,600	(1971) 5,000-10,000	(1972) -	Nov.-Jan.-Mar.	
Chum	1963-1972	47,000	(1972) 90,000	(1971) 10,000-20,000	Oct.-Nov.-Dec.-Jan.	Mar.1-May 31 Peak April 20-May 20.

Most Recent Max. and Min. Figures Stated in Cases of a Tie.

APPENDIX 7.2.

Koksilah River Anadromous Fish Escapement Data (Can. Dept. Environ., 1973).

Species	Years of Enumeration	Average Annual Escapement (1963-1973)	Date & Size of Max. Escapement	Date & Size of Min. Escapement	Period of Spawning (peak underlined)
Chinook	1949-73	245	(1973) 400	(1968) 75	June-Sept.-Oct. Nov.
Coho	1949-1973	6709	(1964) 35,000	(1972) 1,800	Sept.-Oct.-Nov. Dec.
Steelhead	1949-1971	(1963-1968) 217	(1968) 400	(1963) 25	Nov.-Jan.-Mar.
Chum	1949-1973	3682	(1966) 7,500	(1971) 1,500	Oct.-Nov.-Dec. Jan.

APPENDIX 7.3.

Chemainus River Anadromous Fish Escapement Data (Can. Dept. Environ., 1973).

Species	Years of Enumeration	Average Annual Escapement (1963-1972)	Date & Size of Max. Escapement	Date & Size of Min. Escapement	Period of Spawning (peak underlined)
Sockeye					
Chinook	1930-35, 1937-1940, 1942 1948, 1951 1954, 1956-57, 1961-62, 1964-1972	53	(1939) 10,000-20,000	(1963) 0	Sept.-Oct.
Coho	1930-1935 1937-1940,42 1947-1972	450	(1957) 5,000-10,000	(1968) 100	Oct.-Nov.-Dec-Jan.
Pink	1930 1933-1935 1937, 1939 1942, 1952, 1955	No Run After 1955	(1935) 2,000-5,000	(1940) (1955-72) 0	Sept.-Oct. Prior to 1955
Steelhead	1930-1935 1937-1940 1942, 1947-72	200	(1952) 5,000-10,000	(1961) 50-100	Dec.-May Mar.-April
Chum	1930-1935 1937-1940,1942 1947-1972	11,275	(1950) 100,000+	(1971) 3,000	Sept.-Oct.-Dec.
		* 10 Year Average	Most Recent Max, and Min. Figures Stated in Cases of Ties.		

Appendix 7.4.

List of Fish Species Recorded from the Cowichan River Estuary during Sampling Conducted Between March and September, 1973 (D. Goodman, pers. comm.).

1. *Ammodytes hexapterus* (Pacific sand lance)
2. *Artedius lateralis* (smoothhead sculpin)
3. *Clinocottus acuticeps* (sharpnose sculpin)
4. *Clupea harengus pallasi* (Pacific herring)
5. *Cottus asper* (prickly sculpin)
6. *Cymatogaster aggregata* (shiner perch)
7. *Damalichthys vacca* (pile perch)
8. *Engraulis mordax* (northern anchovy)
9. *Gasterosteus aculeatus* (threespine stickleback)
10. *Hexagrammos stelleri* (white-spotted greenling)
11. *Hypomesus pretiosus* (surf smelt)
12. *Lampetra tridentatus* (Pacific lamprey)
13. *Leptocottus armatus* (Pacific staghorn sculpin)
14. *Liparis* sp. (liparids)
15. *Lumpenus sagitta* (Pacific snake prickleback)
16. *Microgadus proximus* (Pacific tomcod)
17. *Oligocottus maculosus* (tidepool sculpin)
18. *O. rimensis* (saddleback sculpin)
19. *Oncorhynchus keta* (chum salmon)
20. *O. kisutch* (coho salmon)
21. *O. nerka* (sockeye salmon)
22. *O. tschawytasha* (chinook salmon)
23. *Ophiodon elongatus* (lingcod)
24. *Pholis laeta* (crescent gunnel)
25. *P. ornata* (saddleback gunnel)
26. *Platichthys stellatus* (starry flounder)
27. *Salmo clarki clarki* (coastal cutthroat trout)
28. *S. gairdneri* (steelhead)
29. *Sebastes melanops* (black rockfish)
30. *Spirinchus thaleichthys* (longfin smelt)
31. *Syngnathus griseolineatus* (bay pipefish)

Appendix 7.5.

List of Fish Species, not Previously Mentioned, Recorded from the Cowichan-Chemainus River Estuaries Study Region.

1. *Agonus acipenserinus* (sturgeon poacher)
2. *Alosa sapidissima* (American shad)
3. *Anoplarchus insignis* (slender cockcomb)
4. *Atheresthes stomias* (turbot or arrowtooth flounder)
5. *Citharichthys sordidus* (mottled sanddab)
6. *C. stigmaeus* (speckled sanddab)
7. *Clevelandia ios* (arrow goby)
8. *Clinocottus embryum* (calico sculpin)
9. *Coryphopterus nicholsi* (blackeye goby)
10. *Cottus aleuticus* (coastrange sculpin)
11. *Eopsetta jordani* (petrale sole or brill)
12. *Eumicrotremus orbis* (spiny lumpsucker)
13. *Gadus macrocephalus* (Pacific cod)
14. *Glyptocephalus zachirus* (rex sole)
15. *Gobiesox maendricus* (flathead clingfish)
16. *Hippoglossoides elassodon* (flathead sole)
17. *Ictalurus nebulosus* (brown bullhead)
18. *Inopsetta ischyra* (hybrid sole)
19. *Isopsetta isolepis* (butter sole)
20. *Lampetra ayresi* (river lamprey)
21. *L. planeri* (brook lamprey)
22. *Lepidogobius lepidus* (bay goby)
23. *Lepidosetta bilineata* (rock sole)
24. *Limanda aspera* (yellowfin sole)
25. *Liparis dennyi* (marbled snailfish)
26. *L. pulchellus* (showy snailfish)
27. *L. rutteri* (ringtail snailfish)
28. *Mallotus villosus* (capelin)
29. *Micropterus dolomieui* (smallmouth bass)
30. *Oncorhynchus gorbuscha* (pink salmon)
31. *Parophrys vetulus* (lemon sole)

Appendix 7.5 (cont'd).

32. *Plectobranchus evides* (two spotted prickleback)
33. *Pleuronichthys coenosus* (C-O sole)
34. *Porichthys notatus* (midshipman)
35. *Poroclinus rothrocki* (whitebarred prickleback)
36. *Psettichthys melanostictus* (sand sole)
37. *Raja rhina* (longnose skate)
38. *Salmo gairdneri* (rainbow trout)
39. *S. trutta* (brown trout)
40. *Savelinus fontinalis* (brook trout)
41. *S. malma* (dolly varden char)
42. *Sardinops sagax* (pilchard)
43. *Sebastes* sp. (rockfish)
44. *Xiphister atropurpureus* (black prickleback)

Appendix 7.6. Estimated participation in recreational boating by Duncan-Gulf Island and Ladysmith residents in 1973 (Mos and Harrison, 1973).

	Duncan-Gulf Is.	Ladysmith
No. of households	10,540	2,604
No. of households owning one or more boats	3,417	815
Percent of households owning one or more boats	32.5	32.0
No. of primary boats	3,417	815
No. of secondary boats	1,005	408
Total No. of boats	4,422	1,223
Percent primary boat type:		
sail	9.8	1.8
outboard	52.9	66.7
inboard-outboard	13.7	20.4
rowboat, canoe and other	23.5	11.1
Average value of primary boats	2,084	1,763
No. of days of salt-water use by primary boats	64,957	21,964
No. of person-days of salt-water use by primary boats	168,888	55,350
Average proportion of primary boat use in salt-water (percent)	72.5	78.2
Percent primary boat activity:		
fishing	71.4	85.4
cruising	19.1	8.3
other	9.5	6.3
Average No. of days spent on boat outings	19.0	27.0
Average No. of persons on board	2.6	2.5
Average No. of salmon taken on board primary boat	14.8	30.4

Appendix 7.7. Salmon sport catch, fishing effort and success for tidal waters in statistical areas 17 and 18 (condensed from Salmon Sport Fishing Catch Statistics for B.C. Tidal Waters, annual reports 1967-1974, Dept. Environ., Fish. Oper.).

Area 17 - Ladysmith-Nanaimo

Period		Springs	Jacks	Coho	Grilse	Pinks & Others	Total	Effort	Average catch per boat day
		No.	No.	No.	No.	No.	No.	Boat Days	No.
Total	1974	1,970	4,075	27,425	18,045	435	51,950	33,149	1.6
"	1973	1,870	3,250	7,420	17,745	345	30,630	22,225	1.4
"	1972	3,710	6.145	5,105	12,145	320	27,425	23,763	1.2
"	1971	2,305	3,315	29,853	17,140	103	52,716	28,373	1.9
"	1970	1,275	2,450	10,600	17,325		31,650	25,275	1.2
"	1969	2,950	5,100	10,950	9.475	100	28,575	26,325	1.1
"	1968	2,820	4,070	8,480	15,070	160	30,600	20,050	1.5
"	1967	2,675	3,475	5,700	10,450	150	22,450	19,950	1.1

Area 18 - Duncan-Cowichan Bay

Period		Springs	Jacks	Coho	Grilse	Pinks & Others	Total	Effort	Average catch per boat day
		No.	No.	No.	No.	No.	No.	Boat Days	No.
Total	1974	4,220	3,610	6,260	3,032	1,402	18,524	28,392	0.7
"	1973	4,963	6,567	4,084	4,378	1,920	21,912	24,617	0.9
"	1972	3,289	3,900	4,185	5,620	820	17,814	21,337	0.8
"	1971	4,490	7,487	11,775	4,280	485	28,517	26,464	1.1
"	1970	3,950	6,050	9,775	7,100	150	27,025	29,050	0.9
"	1969	2,175	3,850	4,550	4,025	1,200	15,800	24,950	0.6
"	1968	2,760	4,650	10,490	3,830	1,490	23,220	27,580	0.8
"	1967	3,700	2,925	8,950	2,850	1,200	19,625	21,850	0.9

Appendix 8.1.

List of Floral Species Identified on the Cowichan River Estuary (Kennedy and Raymond, 1974) and Chemainus River Estuary (Kennedy, in progress).

(i) ALGAE

Enteromorpha intestinalis (green algae)
Fucus gardneri (rock weed)
Oscillatoria sp.

(ii) BRYOPHYTES AND LICHENS

Cladonia sp.
Eurhynchium oreganum
Polytrichum sp.
Rhacomitrium sp.

(iii) FERNS, SEDGES AND RUSHES

Athyrium filix-femina (lady fern)
Carex hindsii (Hind's sedge)
C. lyngbyei (Lyngbye's sedge)
C. obnupta (slough sedge)
C. sp. (sedge)
Eleocharis palustris (spike rush)
Juncus balticus (Baltic rush)
J. effusus (common rush)
Pteridium aquilinum (bracken fern)
Polypodium scouleri (polybody)
Polystichum munitum (sword fern)
Scirpus maritimus (bulrush)

(iv) GRASSES

Aira praecox (hair grass)
Anthoxanthum adoratum (vernal grass)
Bromus mollis (lop grass)
B. rigidus (ripgut)
Dactylis glomerata (orchard grass)
Distichlis spicata (saltgrass)

Appendix 8.1 (cont'd).

Draba sp. (whitelow-grass)
Elymus mollis (American dunegrass)
Festuca arundinacea (fescue)
F. megalura (foxtail fescue)
Gramineae (grasses)
Holcus lanatus (velvet grass)
Hordeum sp. (barley)
Poa sp. (bluegrass)

(v) HERBS

Achillea millefolium (yarrow)
Angelica lucida (sea-watch)
A. sp. (angelica)
Arctium minus (common burdock)
A. sp. (burdock)
Arenaria macrophylla (large-leaved sandwort)
A. paludicola (sandwort)
A. stricta (slender sandwort)
Asparagus officinalis (asparagus)
Atriple sp. (orache)
Barbarea orthoceras (wintercress)
B. vulgaris (common wintercress)
Bellis perennis (daisy)
Brassica sp. (mustard)
Camassia quamash (camas)
Cardamine integrifolia (bittercress)
Capsella bursa-pastoris (shepherd's purse)
Castilleja sp. (paintbrush)
Cerastium arvense (mouse-ear chickweed)
C. viscosum (sticky chickweed)
Cirsium spp. (thistle)
Clintonia uniflora (Queen cup)
Collinsia parviflora (blue-eyed Mary)

Appendix 8.1 (cont'd).

Cotula sp. (cotula)
Cuscuta salina (salt-marsh dodder)
Dicentra formosa (bleeding heart)
Draba sp. (sea mustard)
Epilobium angustifolium (fireweed)
Equisetum arvense (horsetail)
Erigeron philadelphicus (fleabane)
Erythronium oregonum (dogtooth-violet)
Fragaria chiloensis (coastal strawberry)
Galium trifidum (bedstraw)
Geranium molle (dovefoot geranium)
Glaux maribna (sea-milkwort)
Grindelia integrifolia (gumweed)
Heliotropium curassavicum (seaside heliotrope)
Hypericum formosum (St. John's wort)
Hypochaeris radicata (hairy cat's-ears)
Lactuca sp. (wild lettuce)
Lathyrus palustris (wild pea)
Lilaeopsis occidentalis (lilaeopsis)
Lloydia serotina (Loydia)
Lomatium nudicaule (pestle parsnip)
Maianthemum dilatatum (false lily-of-the-valley)
Montia parvifolia (montia)
Oenanthe sarmentosa (water parsley)
Orthocarpus sp. (orthocarpus)
Petasites frigidus var. *palmatus* (coltsfoot)
Plantago lanceolata (English plantain)
P. sp. (plantain)
Plectris congesta (rosy pink)
Polypodium scouleri (polypody)
Polystichum munitum (sword fern)
Potentilla pacifica (Pacific silver cinquefoil)
Rumex acetosella (sheep sorrel)

Appendix 8.1 (cont'd).

Rumex obtusifolius (dock)
Salicornia virginica (saltwort)
Sanicula crassicaulis (western snake-root)
Sedum spathulifolium (broad-leaved stonecrop)
Spergula arvensis (spergula)
Stellaria crispa (crisped sandwort)
S. sp. (chickweed)
Taraxacum officinale (dandelion)
Tellima grandiflorum (fringecup)
Trientalis latifolia (starflower)
Trifolium dubium (little yellow clover)
T. pratense (red clover)
T. repens (white clover)
T. wormskjoldii (springbank clover)
Triglochin maritimum (arrow-grass)
Urtica dioica (stinging nettle)
Vallerianella locusta (Vallerianella)
Vicia gigantea (giant vetch)
Zostera marina (eelgrass)

(vi) SHRUBS

Amelanchier alnifolia var. *alnifolia* (serviceberry)
Berkeris aquifolium (Oregon grape)
B. nervosa (Oregon grape)
Crataegus douglasii (hawthorn)
Cytisus scoparius (broom)
Gaultheria shallon (salal)
Holodiscus discolor (ocean-spray)
Linnaea borealis (twinflower)
Lonicera ciliosa (orange honeysuckle)
L. hispidula (hairy honeysuckle)
L. involucrata (black twinberry)
Osmaronia cerasiformis (Indian plum)
Pachistima myrsinites (pachistima)

Appendix 8.1 (cont'd).

Physocarpus capitatus (ninebark)
Ribes sanguineum (red currant)
Rubus laciniatus (evergreen blackberry)
R. pedatus (trailing blackberry)
R. spectabilis (salmonberry)
R. sp.
R. ursinus (Pacific blackberry)
Rosa nutkana (Nootka rose)
Sambucus racemosa (elderberry)
Spirea sp. (hardhack)
Symphoricarpos albus (snowberry)

(vii) TREES

Abies grandis (grand fir)
Acer macrophyllum (broad-leaf or big-leaf maple)
Alnus rubra (red alder)
Arbutus menziesii (arbutus)
Cornus nuttalli (dogwood)
C. stolonifera (red-osier dogwood)
Juniperus scopulorum (juniper)
Malus sp. (domestic apple)
Prunus virginiana var. *demissa* (chokecherry)
P. virginiana var. *melanocarpa* (chokecherry)
Pseudotsuga menziesii (Douglas fir)
Pyrus fusca (Pacific crabapple)
P. sp. (domestic pear)
Quercus garryana (oak)
Rhamnus purshiana (cascara)
Salix hookeriana (Hooker's willow)
S. scouleriana (Scouler's willow)
Thuja plicata (western red cedar)

Appendix 9.1.

Species Lists of Birds, Mammals, Amphibians and Reptiles of the Cowichan-Chemainus River Estuaries and Area, as Compiled from the Available Literature.

(i) BIRDS

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. *P. nigricollis* (eared grebe)
7. *Aechmophorus occidentalis* (western grebe)
8. *Podilymbus podiceps* (pied-billed grebe)
9. *Phalacrocorax auritus* (double-crested cormorant)
10. *P. penicillatus* (Brandt's cormorant)
11. *P. pelagicus* (pelagic cormorant)
12. *Ardea herodias* (great blue heron)
13. *Butorides virescens* (green heron)
14. *Casmerodius albus* (common egret)
15. *Botaurus lentiginosus* (American bittern)
16. *Olor columbianus* (whistling swan)
17. *O. buccinator* (trumpeter swan)
18. *Cygnus olor* (mute swan)
19. *Branta canadensis* (Canada goose)
20. *B. bernicla nigricans* (black brant)
21. *Anser albifrons* (white-fronted goose)
22. *Chen caerulescens* (snow goose)
23. *Anas platyrhynchos* (mallard)
24. *A. strepera* (gadwall)
25. *A. acuta* (pintail)
26. *A. crecca* (green-winged teal)
27. *A. discors* (blue-winged teal)
28. *A. cyanoptera* (cinnamon teal)

* nomenclature based on Godfrey (1966) and American Ornithologists Union (1973).

Appendix 9.1 (cont'd).

29. *Anas penelope* (European wigeon)
30. *A. americana* (American wigeon)
31. *A. clypeata* (northern shoveler)
32. *Aix sponsa* (wood duck)
33. *Aythya americana* (redhead)
34. *A. collaris* (ring-necked duck)
35. *A. valisineria* (canvasback)
36. *A. marila* (greater scaup)
37. *A. affinis* (lesser scaup)
38. *Bucephala clangula* (common goldeneye)
39. *B. islandica* (Barrow's goldeneye)
40. *B. albeola* (bufflehead)
41. *Clangula hyemalis* (oldsquaw)
42. *Histrionicus histrionicus* (harlequin duck)
43. *Melanitta deglandi* (white-winged scoter)
44. *M. perspicillata* (surf scoter)
45. *M. nigra* (black scoter)
46. *Oxyura jamaicensis* (ruddy duck)
47. *Lophodytes cucullatus* (hooded merganser)
48. *Mergus merganser* (common merganser)
49. *M. serrator* (red-breasted merganser)
50. *Cathartes aura* (turkey vulture)
51. *Accipiter gentilis* (goshawk)
52. *A. striatus* (sharp-shinned hawk)
53. *A. cooperii* (Cooper's hawk)
54. *Buteo jamaicensis* (red-tailed hawk)
55. *B. lagopus* (rough-legged hawk)
56. *Aquila chrysaetos* (golden eagle)
57. *Haliaeetus leucocephalus* (bald eagle)
58. *Circus cyaneus* (marsh hawk)
59. *Pandion haliaetus* (osprey)
60. *Falco rusticolus* (gyrfalcon)
61. *F. peregrinus* (peregrine falcon)
62. *F. columbarius* (pigeon hawk or merlin)

Appendix 9.1 (cont'd).

63. *Falco sparverius* (sparrow hawk or American kestrel)
64. *Dendragapus obscurus* (blue grouse)
65. *Bonasa umbellus* (ruffed grouse)
66. *Lophortyx californicus* (California quail)
67. *Phasianus colchicus* (ring-necked pheasant)
68. *Grus canadensis* (sandhill crane)
69. *Rallus limicola* (Virginia rail)
70. *Porzana carolina* (sora)
71. *Fulica americana* (American coot)
72. *Haematopus bachmani* (black oystercatcher)
73. *Charadrius semipalmatus* (semipalmated plover)
74. *C. vociferus* (killdeer)
75. *Pluvialis dominica* (American golden plover)
76. *P. squatarola* (black-bellied plover)
77. *Aphriza virgata* (surfbird)
78. *Arenaria interpres* (ruddy turnstone)
79. *A. melanocephala* (black turnstone)
80. *Capella gallinago* (common snipe)
81. *Numenius phaeopus* (whimbrel)
82. *Actitis macularia* (spotted sandpiper)
83. *Tringa solitaria* (solitary sandpiper)
84. *T. melanoleuca* (greater yellowlegs)
85. *T. flavipes* (lesser yellowlegs)
86. *Calidris ptilocnemis* (rock sandpiper)
87. *C. canutus* (red knot)
88. *C. acuminata* (sharp-tailed sandpiper)
89. *C. melanotos* (pectoral sandpiper)
90. *C. bairdii* (Baird's sandpiper)
91. *C. minutilla* (least sandpiper)
92. *C. alpina* (dunlin)
93. *C. pusillus* (semipalmated sandpiper)
94. *C. mauri* (western sandpiper)
95. *C. alba* (sanderling)
96. *Limnodromus griseus* (short-billed dowitcher)

Appendix 9.1 (cont'd).

97. *Limnodromus scolopaceus* (long-billed dowitcher)
98. *Micropalama himantopus* (stilt sandpiper)
99. *Stegenopus tricolor* (Wilson's phalarope)
100. *Lobipes lobatus* (northern phalarope)
101. *Stercorarius parasiticus* (parasitic jaeger)
102. *S. longicaudus* (long-tailed jaeger)
103. *Larus hyperboreus* (glaucous gull)
104. *L. glaucescens* (glaucous-winged gull)
105. *L. occidentalis* (western gull)
106. *L. argentatus* (herring gull)
107. *L. thayeri* (Thayer's gull)
108. *L. californicus* (California gull)
109. *L. delawarensis* (ring-billed gull)
110. *L. canus* (mew gull)
111. *L. philadelphia* (Bonaparte's gull)
112. *L. pipixcan* (Franklin's gull)
113. *L. heermanni* (Heerman's gull)
114. *Rissa tridactyla* (black-legged kittiwake)
115. *Xema sabini* (Sabine's gull)
116. *Sterna hirundo* (common tern)
117. *Hydroprogne caspia* (caspian tern)
118. *Uria aalge* (common murre)
119. *Cepphus columba* (pigeon guillemot)
120. *Brachyramphus marmoratus* (marbled murrelet)
121. *Synthliboramphus antiquus* (ancient murrelet)
122. *Cerorhinca monocerata* (rhinoceros auklet)
123. *Columba fasciata* (band-tailed pigeon)
124. *C. livia* (rock dove)
125. *Zenaida macroura* (mourning dove)
126. *Tyto alba* (barn owl)
127. *Otus asio* (screech owl)
128. *Bubo virginianus* (great horned owl)
129. *Nyctea scandiaca* (snowy owl)
130. *Glaucidium gnoma* (pygmy owl)

Appendix 9.1 (cont'd).

131. *Speotyto cunicularia* (burrowing owl)
132. *Asio otus* (long-eared owl)
133. *A. flammeus* (short-eared owl)
134. *Aegolius acadicus* (saw-whet owl)
135. *Chordeiles minor* (common nighthawk)
136. *Cypseloides niger* (black swift)
137. *Chaetura vauxi* (vaux's swift)
138. *Calypte anna* (Anna's hummingbird)
139. *Selasphorus rufus* (rufous hummingbird)
140. *Megaceryle alcyon* (belted kingfisher)
141. *Colaptes auratus* (common flicker)
142. *Dryocopus pileatus* (pileated woodpecker)
143. *Sphyrapicus varius* (yellow-bellied sapsucker)
144. *Dendrocopos villosus* (hairy woodpecker)
145. *D. pubescens* (downy woodpecker)
146. *Tyrannus tyrannus* (eastern kingbird)
147. *T. verticalis* (western kingbird)
148. *Empidonax alnorum* (alder flycatcher)
149. *E. hammondii* (Hammond's flycatcher)
150. *E. difficilis* (western flycatcher)
151. *Contopus sordidulus* (western wood peewee)
152. *Nuttallornis borealis* (olive-sided flycatcher)
153. *Alauda arvensis* (skylark)
154. *Eremophila alpestris* (horned lark)
155. *Tachycineta thalassina* (violet-green swallow)
156. *Iridoprocne bicolor* (tree swallow)
157. *Riparia riparia* (bank swallow)
158. *Stelgidopteryx ruficollis* (rough-winged swallow)
159. *Hirundo rustica* (barn swallow)
160. *Petrochelidon pyrrhonota* (cliff swallow)
161. *Progne subis* (purple martin)
162. *Perisoreus canadensis* (gray jay)
163. *Cyanocitta cristata* (blue jay)
164. *C. stelleri* (Steller's jay)

Appendix 9.1 (cont'd).

165. *Corvus corax* (common raven)
166. *C. caurinus* (northwestern crow)
167. *Nucifraga columbiana* (Clark's nutcracker)
168. *Parus rufescens* (chestnut-backed chickadee)
169. *Psaltriparus minimus* (common bushtit)
170. *Sitta canadensis* (red-breasted nuthatch)
171. *Certhia familiaris* (brown creeper)
172. *Cinclus mexicanus* (American dipper)
173. *Troglodytes aedon* (house wren)
174. *T. troglodytes* (winter wren)
175. *Thryomanes bewickii* (Bewick's wren)
176. *Telmatodytes palustris* (long-billed marsh wren)
177. *Salpinctes obsoletus* (rock wren)
178. *Mimus polyglottos* (northern mockingbird)
179. *Turdus migratorius* (American robin)
180. *Ixoreus naevius* (varied thrush)
181. *Catharus guttata* (hermit thrush)
182. *C. ustulata* (Swainson's thrush)
183. *Sialia mexicana* (western bluebird)
184. *S. currucoides* (mountain bluebird)
185. *Myadestes townsendi* (Townsend's solitaire)
186. *Regulus satrapa* (golden-crowned kinglet)
187. *R. calendula* (ruby-crowned kinglet)
188. *Anthus spinoletta* (water pipit)
189. *Bombycilla garrula* (Bohemian waxwing)
190. *B. cedrorum* (cedar waxwing)
191. *Lanius excubitor* (northern shrike)
192. *Sturnus vulgaris* (common starling)
193. *Vireo huttoni* (Hutton's vireo)
194. *V. solitarius* (solitary vireo)
195. *V. olivaceus* (red-eyed vireo)
196. *V. gilvus* (warbling vireo)
197. *Vermivora celata* (orange-crowned warbler)
198. *V. ruficapilla* (Nashville warbler)

Appendix 9.1 (cont'd).

199. *Dendroica petechia* (yellow warbler)
200. *D. coronata* (yellow-rumped warbler)
201. *D. nigrescens* (black-throated grey warbler)
202. *D. townsendi* (Townsend's warbler)
203. *Seiurus noveboracensis* (northern waterthrush)
204. *Oporornis tolmiei* (MacGillivray's warbler)
205. *Geothylpis trichas* (common yellowthroat)
206. *Wilsonia pusilla* (Wilson's warbler)
207. *Passer domesticus* (house sparrow)
208. *Sturnella neglecta* (western meadowlark)
209. *Xanthocephalus xanthocephalus* (yellow-headed blackbird)
210. *Agelaius phoeniceus* (red-winged blackbird)
211. *Icterus galbula* (northern oriole)
212. *Euphagus carolinus* (rusty backbird)
213. *E. cyanocephalus* (Brewer's blackbird)
214. *Molothrus ater* (brown-headed cowbird)
215. *Piranga ludoviciana* (western tanager)
216. *Pheucticus melanocephalus* (black-headed grosbeak)
217. *Passerina amoena* (Lazuli bunting)
218. *Hesperiphona vespertina* (evening grosbeak)
219. *Carpodacus purpureus* (purple finch)
220. *C. mexicanus* (house finch)
221. *Pinicola enucleator* (pine grosbeak)
222. *Acanthis flammea* (common redpoll)
223. *Spinus pinus* (pine siskin)
224. *S. tristis* (American goldfinch)
225. *Loxia curvirostra* (red crossbill)
226. *Pipilo erythrophthalmus* (rufous-sided towhee)
227. *Passerculus sandwichensis* (Savannah sparrow)
228. *Pooecetes gramineus* (Vesper sparrow)
229. *Junco hyemalis* (dark-eyed junco)
230. *Spizella arborea* (tree sparrow)
231. *S. passerina* (chipping sparrow)
232. *Zonotrichia querula* (Harris' sparrow)

Appendix 9.1 (cont'd).

233. *Zonotrichia leucophrys* (white-crowned sparrow)
234. *Z. atricapilla* (golden-crowned sparrow)
235. *Z. albicollis* (white-throated sparrow)
236. *Passerella iliaca* (fox sparrow)
237. *Melospiza lincolnii* (Lincoln's sparrow)
238. *M. melodia* (song sparrow)
239. *Calcarius lapponicus* (lapland longspur)
240. *Plectrophenax nivalis* (snow bunting)

(ii) MAMMALS *

Order Insectivora (shrews)
- *Sorex palustris* (American water shrew)
- *S. vagrans* (wandering shrew)

Order Chiroptera (bats)
- *Plecotus townsendi* (Townsends big-eared bat)
- *Eptesicus fuscus* (big brown bat)
- *Myotis californicus* (California bat)
- *M. evotis* (long-eared bat)
- *M. keeni* (Keen's bat)
- *M. lucifugus* (little brown bat)
- *M. yumanensis* (Yuma bat)

Order Rodentia

Family Sciuridae (squirrels, chipmunks, marmots)
- *Marmota vancouverensis* (Vancouver Island marmot)
- *Tamiasciurus hudsonicus* (American red squirrel)

Family Castoridae (beavers)
- *Castor canadensis* (American beaver)

Family Muridae (new world rats and mice)
- *Microtus townsendi* (Townsend vole)
- *Mus musculus* (house mouse)
- *Ondatra zibethica* (muskrat)
- *Peromyscus maniculatus* (deer or white-footed mouse)
- *Rattus norvegicus* (Norway rat)

* nomenclature based on Banfield (1974).

Appendix 9.1 (cont'd).

Rattus rattus (roof rat)
Family Capromyidae
Myocaster coypus (nutria or coypu)
Order Cetacea (whales and dolphins)
Balaenoptera acutorostrata (pike or Minke whale)
B. physalus (fin or finback whale)
Delphinus delphii bairdii (Baird dolphin)
Eschrichtius robustus (gray whale)
Lagenorhynchus obliquidens (Pacific white-sided dolphin)
Megaptera novaeangliae (humpback whale)
Orcinus orca (Pacific killer whale)
Phocoena phocoena (harbour porpoise)
Phocoenoides dalli (Dall porpoise)
Order Carnivora
Family Canidae (dog-like flesh-eaters)
Canis lupus crassodon (Vancouver Island wolf)
Family Ursidae (bears)
Ursus americanus (Black bear)
Family Procyonidae (raccoons)
Procyon lotor (raccoon)
Family Mustelidae (weasel-like flesh-eaters)
Gulo gulo luscus (wolverine)
Luntra canadensis (Canadian river otter)
Martes americana (marten)
Mustela erminea (ermine or short-tailed weasel)
M. vison (mink)
Family Felidae (cat-like flesh-eaters)
Felis concolor (cougar)
Order Pinnipedia (seals, sea-lions, walruses)
Callorhinus ursinus (northern fur seal)
Eumetopias jubata (northern or Steller sea-lion)
Phoca vitulina richardi (harbour or hair seal)
Zalophus californianus (California sea lion)

Appendix 9.1 (cont'd).

Order Artiodactyla (cloven-hoofed ungulates)

Cervus elaphus roosevelti (Roosevelt elk)

Odocoileus hemionus columbianus (blacktail deer)

(iii) AMPHIBIANS AND REPTILES *

Ambystoma gracile (northwestern salamander)
A. macrodactylum (long-toed salamander)
Aneides ferreus (clouded salamander)
Bufo boreas (northwestern taod)
Chrysemys picta (painted turtle)
Contia tenius (sharp-tailed snake)
Dermochelys coriacea (leatherback)
Ensatina eschscholtzi (red salamander)
Gerrhonotus coeruleus (northern alligator lizard)
Hyla regilla (Pacific tree toad)
Pituophis catenifer (Pacific gopher snake)
Plethodon vehiculum (red-backed salamander)
Rana aurora aurora (red-legged frog)
R. clamitans (green frog)
Taricha granulosa (Pacific coast newt)
Thamnophis elegans (coast garter snake)
T. ordinoides (Puget garter snake)
T. sirtalis (striped garter snake)

* from the records of the B.C. Provincial Museum, Victoria.

Appendix 10.1.

The Cowichan Estuary Task Force (1974)

Provincial

B.R. Gates	Environment and Land Use Committee Secretariat (Chairman)
W.W. Wiebe	Agriculture
G.N. Worsley	Economic Development
R.S. Hooton	Fish and Wildlife Branch
Lehel Porpaczy	Forest Service (Replaced in October by Frank Nyers)
Richard Readshaw	Highways (John Blackey, alternate)
J.A. Esler	Lands
Tom Maftechuk	Municipal Affairs
Jack Wester	Water Resources (Aubrey Brown, alternate)
K.J. Chauncey	B.C. Development Corporation (withdrew October 15)

Federal

D.E.C. Trethewey	Canadian Wildlife Service
Robert Kohlert	Department of Regional Economic Expansion
Thomas Bird	Fisheries and Marine Service (A. Lill and F. Boyd, alternate)

Regional

Kenneth Stinson	Cowichan Valley Regional District

Appendix 10.2. Maps, charts and aerial photographs of the Cowichan-Chemainus Region.

TOPOGRAPHIC MAPS:

	Sheet No.	Scale
Victoria, B.C.	92 B-C	1:250,000
Victoria, Canada-U.S.A.	92B	1:250,000
Shawnigan Lake	92B/12	1:50,000
Duncan	92B/13 (east half)	1:50,000
Duncan	92B/13 (west half)	1:50,000
Cowichan Lake	92C/16 (east half)	1:50,000
Cowichan Lake	92C/16 (west half)	1:50,000
Nanaimo	92G/4 (east half)	1:50,000
Nanaimo	92G/4 (west half)	1:50,000

Obtainable from: Department of Energy, Mines and Resources Ottawa, Ontario, or Geographic Division, Surveys and Mapping Branch, Department of Lands, Forests and Water Resources, Victoria, B.C.

GEOLOGICAL MAPS:

	G.S.C. Map No.	Scale
Nanaimo, Comox coalfields (Richardson, 1871)	87	1 in = 10 mi.
Cowichan Basin, Nanaimo coal-fields (Dowling, 1915)	1415	1 in = 9 mi.
Southern Vancouver Island	1314	1 in = 6 mi.
Duncan Sheet (Clapp (1918) (Ladysmith Harbour to Saanich Inlet)	42A	1 in = 2 mi.
Surficial geology Duncan,B.C. (G.S.C. Paper 65-24)	14-1965	1 in = 1 mi.
Surficial geology Shawnigan, B.C.	15-1965	1 in = 1 mi.
Geology of Nanaimo Group Vancouver Island and Gulf Islands (J.E. Muller, 1963-66)	G.S.C. Paper 69-25	1:250,000

Appendix 10.2 (cont'd).

		Scale
Vancouver Island, Mineral Inventory Maps (December, 1971) B.C. Dept. Mines and Petroleum Resources	Same sheet numbers as National Topographic maps	1:250,000
Soil map of Vancouver Island Duncan-Nanaimo Sheet (J.H. Day, L. Farstad and D.G. Laird)	Report No. 6 B.C. Soil Survey, 1959	1 in = 1 mi. 1:63,360

Obtainable from: Geological Survey of Canada, Department of Energy, Mines and Resources, Ottawa, or 100 West Pender, Vancouver, B.C.

MISCELLANEOUS MAPS (Environmental land use):

	Scale
Generalized land use Strait of Georgia - Puget Sound Basin	1:500,000
Water Use Strait of Georgia - Puget Sound Basin	1:500,000

Obtainable from: Lands Directorate, Environmental Management Services, Environment Canada, Ottawa.

Georgia Strait Urban Region Map ELD-4, showing Land use pattern, Population density, Transport movements - Vancouver and Vancouver Island (Nanaimo to Victoria).

Obtainable from Canada Map Office, Department of Energy Mines and Resources, Ottawa, or Information Canada Bookstores.

British Columbia Road Map, Campground and Fishing Guide, Department of Travel Industry, Victoria, B.C.

Appendix 10.2 (cont'd).

Provincial Parks on Vancouver Island, Department of Recreation and Conservation, Victoria, B.C.

Vancouver Island Touring Map. Vancouver Island Publicity Bureau, 786 Government St., Victoria, B.C.

Road Map of Cowichan Valley and the City of Duncan. Printed by the Cowichan Leader, Duncan, B.C.

Cowichan River Foot Path and Map (revised 1974), Cowichan Fish and Game Association, Duncan, B.C.

HYDROGRAPHIC CHARTS

	Chart No.	Scale
Gulf Islands, Victoria Harbour to Nanaimo Harbour	3310 (sheet 2 of 4)	1:40,000
East Point to Sand Heads (Ladysmith Harbour to Cowichan Bay)	3450	1:80,000
Haro Strait to Stuart Channel (Cowichan Bay)	3452	1:40,000
Trincomali and Stuart Channels (Chemainus and Ladysmith Harbour)	3453	1:40,000
Plans in the vicinity of Salt-spring Island (Cowichan Bay)	3470	1:18,000
Plans in Stuart Channel (Ladysmith Harbour, Chemainus Bay and Osborn Bay)	3471	1:12,000 1:15,000

Obtainable from: Canadian Hydrographic Service, Ocean and Aquatic Sciences, Fisheries and Marine Service, Department of the Environment, Ottawa or local agents.

Appendix 10.2 (cont'd).

AERIAL PHOTOGRAPHS

	Flight line	Photo No.	Scale
Cowichan Bay	BC 7399	94-97	1 in = 1/4 mi.
Lower Cowichan-Duncan (Special Project OP 1/74) December 7,1973	BC 7565	1-24	1 in = 500 ft.
Cowichan River (Special Project OP 107/74) October 7, 1974)	BC 7697	21-148	1 in = 1000 ft.
Cowichan River (Lockwood Survey Corp. Ltd.) March 22, 1973	--	67053B to 67105B	1 in = 400 ft.
Chemainus Delta	BC 7408	118-124	1 in = 1/4 mi.
Chemainus Delta	BC 5047	117-120	1 in = 1/2 mi.
Chemainus Delta	BC 5628	2-4	1 in = 1 mi.
Chemainus Delta (Lockwood Survey Corp. Ltd.) March 22, 1973	--	67110B to 67122B	1 in = 400 ft.
Ladysmith Harbour	BC 7408	130-133	1 in = 1/4 mi.
Ladysmith Harbour	BC 5047	113-115	1 in = 1/2 mi.
Ladysmith Harbour	BC 5628	5-8	1 in = 1 mi.
Ladysmith Harbour (Special Project 276/74) October 4, 1974	BC (c) 105 BC (c) 106	130-135 61-65	1 in = 400 ft.
Ladysmith Harbour (Lockwood Survey Corp. Ltd.) March 22, 1973	--	67140B to 67148B	1 in = 400 ft.

Appendix 10.2 (cont'd).

Federal Government aerial photographs and prices may be obtained from: National Air Photo Library, Department of Energy Mines and Resources, Ottawa, Ontario.

The Surveys and Mapping Branch maintains a library of air photographs taken by the Provincial Government. Prints are available for reference and sale at Map and Air Photo Sales, Dept. Lands, Forests and Water Resources, 553 Superior, Victoria, B.C.

Appendix 11.1. Water Pollution Sources Within the Present Study Area (Can. Dept. Environ., 1975).

1. SEWAGE

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	cu. m/Day (I Gal/Day)	PRESENT EFFLUENT QUALITY	COMMENTS
PE-0232	The Corporation of the District of North Cowichan	Cowichan River	1,955 (430,000)	BOD_5 - 45 mg/l SS - 60 mg/l Chlorine Residue - <0.2 ppm	Domestic sewage treated by a two cell facultative lagoon with chlorine contact pond. Storm drainage during flood periods can create treatment problems.
PE-1497	The Corporation of the City of Duncan	Cowichan River	3,637 (800,000)	Domestic Sewage: BOD_5 - 45 mg/l SS - 60 mg/l Chlorine Residue - between 0.1-1.0 ppm	Domestic wastes are treated biologically and chlorinated.
PE-1538	Regional District of Cowichan Valley	Cowichan Bay	273 (60,000)	BOD - 30 mg/l TSS - 30 mg/l Chlorine Residue - 0.1-1.0 ppm	Extended aeration package treatment plant, chlorination facilities and outfall.
PE-247	The Corporation of the Village of Lake Cowichan	Cowichan Bay	1,637 (360,000)	BOD - 45 mg/l TSS - 60 mg/l Chlorine Residue - 0.2 mg/l	Domestic waste treated in aeration lagoon and polishing lagoon: Chlorinated and dechlorinated.

Appendix 11.1 (cont'd).

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	cu. m/Day (I Gal/Day)	PRESENT EFFLUENT QUALITY	COMMENTS
AE-3893	Lambourn Holdings Limited Subdivision	Satellite Channel	105 (23,000)	Applicant has applied for permit to discharge effluent with post-treatment: BOD_5 - 45 mg/l TSS - 60 mg/l	Domestic waste treatment via package treatment plant. A deep-sea outfall has been recommended by EPS.
PE-00082	Corporation of the District of North Cowichan (Crofton)	Osborn Bay	227 50,000	Typical of chlorinated domestic waste.	
PE-00142	Corporation of the District of North Cowichan (Chemainus)	Stuart Channel	659 (145,000)	Typical raw domestic waste.	
PE-2220	B.C. Forest Products Limited Crofton.	Osborn Bay			
	Pulp & Paper Plant				
-01	Lunchroom Dock #3	30m(100') from low tide water in BCFP docking area	4.5 (1,000)	Typical septic tank effluent.	Treatment is via a two chamber 4,546 l (1,000 I. gal.) septic tank.
-02	Lunchroom - Woodroom	30m(100') from low tide water in Osborn Bay	4.5 (1,000)	Typical septic tank effluent.	Treatment via 4,546 l (1,000 I. gal.) septic tank.

Appendix 11.1 (cont'd).

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	cu. m/Day (I Gal/Day)	PRESENT EFFLUENT QUALITY	COMMENTS
-03	Lunchroom adjoining No. 1 Dock	30m (100') from low tide water in Osborn Bay	4.5 (1,000)	Typical septic tank effluent	Treatment via a proposed two chamber 4,546 (1,000 I. gal.) septic tank
-04	Lunchroom adjoining No. 2 Dock	30m (100') from low tide water in Osborn Bay	4.5 (1,000)	Typical septic tank effluent	Treatment via a proposed two chamber 4,546 (1,000 I. gal.) septic tank
AE-1790	Island Processing Limited Reduction Plant	Bonsall Creek which drains to Chemainus Estuary	873 (192,000)max. over an operating period of 16 hr/day	As per application BOD - 70 mg/1 TSS - 20 mg/1 TS -150 mg/1 PH - 5.5 - 80 Temp.- $15^{\circ}C$	Treatment via aerator and fat skimmer. This discharge can create problems during low flow - particularly BOD loading and thermal problems
AE-2961	Island Wharves Ltd.	Chemainus Bay	0.09 (20)	Typical untreated domestic sewage	
PE-120	Town of Ladysmith	Ladysmith Harbour	6,819 (1,500,000)	SS - 150 mg/1 BOD_5 - 135 mg/1 Until Dec. 31/76 SS - 60 mg/1 BOD_5 - 45 mg/1 Thereafter	Chlorine contact chamber and chlorinator is to be completed by December 31, 1976

Appendix 11.1. Water Pollution Sources Within the Present Study Area (Can. Dept. Environ., 1975).

2. FOREST INDUSTRY

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	cu. m/Day (I Gal/Day)	PRESENT EFFLUENT QUALITY	COMMENTS
AE 1871-1	B.C. Forest Products	Youbou (Cowichan Lake)	6,546 (1,440,000)	Hydraulic debarker effluent BOD_5 - 4.0 mg/l TSS - 4.0 mg/l pH - 6.5 - 8.0	Settling pond for hydraulic debarker effluent.
AE 1871-2 AE 1871-3 AE 1871-4	B.C. Forest Products	Youbou (Cowichan Lake)	112,740 (24,800,000)	Condenser cooling water and turbine cooling water. Dissolved solids 13.0 mg/l pH - 7.05 Temp - 68°C	Combined outfall for all turbine cooling water and boiler blowdown.
AE 1871-5	B.C. Forest Products	Youbou (Cowichan Lake)	113 (24,840)	Boiler blowdown Total solids - 206 mg/l TSS - 9 mg/l pH - 10.95 Temp. - 40.5°C Phosphate - 9.2 mg/l	To be combined with condenser cooling water and turbine cooling water.
AE 1871-8	B.C. Forest Products	Youbou (Cowichan Lake)	1.8 (400)	Veneer dryer washdown BOD_5 - 61 mg/l TSS - 12 mg/l Total Solids - 162 mg/l pH - 6.5	Fine screening on vibratory screen.

Appendix 11.1 (cont'd).

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	cu. m/Day (I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
AE 1871-9	B.C. Forest Products	Youbou (Cowichan Lake)	4,364 (960,000)	Block Saw sawdust recovery. TSS - 180 mg/1	Fine screening on vibratory screen.
PE-114	B.C. Forest Products Crofton Division Kraft and Newsprint Production	Stuart Channel	163,656 (36,000,000)	S.S.-25.35 kg/metric ton (50 lb/ton) of product BOD_5 - 31.97 kg/metric ton (65 lb/ton) of product Toxicity - 42-65% Mercaptans - 2.0 mg/1 Sulphides - 1.0 mg/1 Residue Chlorine - 0.1 mg/1 pH - 6.5 - 8.5 6m(20') from diffuser.	Two effluent lines equipped with diffuser, convery effluent and past foreshore area into Stuart Channel. Expired Mar. 1970. Application for new permit asks for 227,300 cu.m/day (50,000,000 IGD), including newsmill as well as Kraft.
PE-1905	B.C. Forest Products Woodroom	Stuart Channel	15,911 (3,500,000)	Toxicity - Non toxic Suspended Solids - 0.64 kg/cu.m* (4.0 lb/cunit). Total Solids - 3.2 kg/cu.m* (20 lbs/cunit). Settleable Solids - 2.5 ml/1 BOD - 0.64 kg/cu.m* (4 lbs/cunit) pH - 6.5 - 8.5 Temp. - 4.5 - 26°C	Treatment via two - 12 hr. settling ponds. Expired Mar. 1970.

* Solid wood

Appendix 11.1 (cont'd)

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	cu. m/Day (I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
PE-362	MacMillan Bloedel Limited Chemainus Saw-mill Division	Chemainus Bay			
-01	Hydraulic Barker Steam Condensate		12,115 (2,665,000)	TSS - 0.24 kg/cu.m* (1.5 lbs/cunit) SS - 0.5 ml/1 BOD_5 - 0.4 kg/cu.m* (2.5 lbs/cunit) Floatable solids - negligible pH - 6.5 - 8.5 (within 3.3 m (15') of the outfall).	Treatment is via 2 settling ponds and a submerged outfall.
-02	Boiler Blowdown Condenser		68,249 (15,013,000)	Temp. - max. $35^{o}C$	Treatment via outfall.

* Solid wood

Appendix 11.2. Industrial Air Pollution Sources Within the Present Study Area (Can. Dept. Environ., 1975).

PCB I.D.#	DISCHARGER & TYPE OF OPERATION	LOCATION OF EMISSION	TOTAL FLOW RATE moles/sec (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
PA-3011	Armour and Saunders Limited Ready Mix Concrete Operation	3.22 km(2 mi.) south of Duncan on banks of Koksilah River			
-01	Cement Silo		600 (500) for an operating period of 1 hour per day, twice per week.	Particulate matter: 0.219 g/cu.m (0.100 grains/SCF)	Stack height: 30m(100')
-02	Boiler Stack		720-960(600-800) for an operating period of 8 hrs.	Particulate matter: 0.219 g/cu.m 0.100 grains/SCF Temp: - 229°C	Stack height: 7.6m(30')
PA-2677	Duncan Paving Company Ltd. Bituminous Ashphalt Plant	Drinkwater Rd Lake Cowichan Highway, Duncan	Present permit is for 42,000 (35,000) for normal operation period of 8 hours. Application for amendment to increase this to 97,680(81,400) over a normal operation period of 10 hrs/day has been filed.	Particulate matter: 0.219 g/cu.m (0.100 grain/SCF) is specified in permit application has been filed to increase this to 0.547 g/cu.m(0.250 grains/SCF) Temp. - 38°C	Treatment via dry cyclone, wet scrubber and 12m(40') 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
PA-3822	Cowichan Co-Operative Services Animal Feed Plant	Duncan			
-01	Hammer Mill		3,600(3,000) over and 9½ hr/day	Particulate matter: 0.219 g/cu.m (0.100 grains/SCF)	Treatment via cyclone.
-02	Pellet Mill		18,000(15,000) over operating period of 9½ hr. day.	Particulate matter: 0.219 g/cu.m (0.100 grains/SCF)	Treatment via cyclone.
-03	Grain Crusher		2,520(2,100) over operation period of 9¼ hr/day	Particulate matter: 0.219 g/cu.m (0.100 grains/ SCF)	Treatment via cyclone.
-04	Seed Cleaner		4,920(4,100) over normal operation period of 9½ hr/day	Particulate matter: 0.219 g/cu.m (0.100 grains/SCF)	Treatment via cyclone.
-05	Package Boiler		738(615) over normal operation period of 9½ hr/day	SO_2 - 200 ppm	Treatment via stack.
PA-2844 -01	Regional District Cowichan Valley A Municipal Refuse Incinerator	4 km(2.5 mi.) west of the village of Lake Cowichan	12,000(10,000)	Capacity - Ringelman No. 1 to 2	

Appendix 11.2 (cont'd).

PCB I.D.#	DISCHARGER & TYPE OF OPERATION	LOCATION OF EMISSION	TOTAL FLOW RATE moles/sec (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
PA-3086	Osborn Contracting Limited	Island Highway north of Duncan			
	Concrete products manufacturing plant				
-01	Boiler Stack		-360(-300),8 hrs/day	Products of combustion of No. 2 fuel oil	Discharge via stack.
-02	Cement Silo		840(700) for 1 hour, once a week.	Particulate: 0.219 g/cu.m (0.100 grains/SCF)	Treatment via bag filter.
-03	Four concrete block curing kilns		Not specified	Not specified	No treatment.
PA-02200	Buckerfield's Limited	Duncan	-552(-460),24 hrs/day	Particulate: 0.219 g/cu.m (0.100 grains/SCF)	
	2 package boilers			SO_2 - 200 ppm NO_2 - 600 ppm	
AA-4063	MacMillan Bloedel Industries Limited Chemainus Sawmill Civision Multiple Chamber Incinerator	Chemainus	9,600(8,000) - 24 hr/day 5 days per week	Products of combustion tion from 2,000 per hour type 1 & 2 waste. CO_2 - 6% Total Particulates: <0.219 g/cu.m (0.100 grains/SCF)	

Appendix 11.2 (cont'd).

PCB I.D.#	DISCHARGER & TYPE OF OPERATION	LOCATION OF EMISSION	TOTAL FLOW RATE moles/sec (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
AA-2055	MacMillan Bloedel Industries Limited Chemainus Sawmill Division Sawmill Planer Mill Dry Kilns & Power House	Chemainus	618,000(515,000) ½ hr/day 3 times/day 5 days per week	Total Particulate: 0.1013 g/cu.m (0.463 grains/SCF) Wood Dust: 0.1882 g/cu.m (0.086 grains/SCF) Fly Ash: 0.3282 g/cu.m (0.150 grains/SCF)	Proposed treatment: Phase 1 - Purchase of extra power to reduce turbine load and thus flyash emissions. Phase 2 - a) Hog fuel preparation or b) Wet type scrubber system c) Air pretreaters or a combination of a, b and c.
AA-1902	British Columbia Forest Products Limited Crofton Pulp & Paper Kraft, Groundwood Newsprint mills & Woodrooms	Crofton	1,957,764 (1,631,470) 24 hr/day	Recovery Boiler: H_2S - 20 ppm SO_2 - 250 ppm Particulate: 5.0 kg/ADmetric T (10 lbs/ADT) Other Sources: Bivalent Sulphur Compounds: 1.25 kg/AD metric T (2.5 lbs/ADT) Particulate: 1.00 kg/ADmetric T (2.0 lbs/ADT)	Proposed treatment to install 3rd Recovery Boiler and Strong Black Liquor Oxidation in 1975.

Appendix 11.2 (cont'd).

PCB I.D.#	DISCHARGER & TYPE OF OPERATION	LOCATION OF	TOTAL FLOW RATE moles/sec (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
AA-1902	BCFP (cont'd)	Crofton		Chlorine & Chlorine Dioxide: 0.1 ppm Wood Buring Power: Boiler Particulate - 0.547 g/cu.m (0.250 grains/SCF) (12% CO_2) Power Boiler: SO_2 Emissions: #1 and #2 - 300 ppm #3 - 1000 ppm Water Vapour = 16.5% of Total Volume	
AA-4166	Nanoose Forest Products Limited Planer Mill Cyclone	Chemainus	24,000(20,000) - 16 hr/day 5 days per week	0.219 g/cu.m (0.100 grains/SCF)	Treatment via cyclone.
PA-1872	British Columbia Forest Products Limited	Youbou	0.100 g/scf 16 hrs./day 5 days/week	Particulates	

Appendix 11.3. Landfill Operations Within the Present Study Area (Can. Dept. Environ., 1975).

PCB I.D.#	DISCHARGER	LOCATION OF LANDFILL	VOLUME	WASTE CHARACTERISTICS	COMMENTS
AR 3839	Western Forest Industries Ltd. Lumber and Shingle Mill	610 m(2000') east of Ashburnham Creek which drains to Lake Cowichan	38 cu.m (50 cu. yds.) per day	Industrial Wood wastes such as bark sawdust, surplus hog spalts, trims, boiler ash and particulate matter from an emission collection system. 90% bark, sawdust, hog and waste wood. 10% boiler ash and fly ash.	
AR 3882	MacMillan Bloedel Industries Limited Shawnigan Division Dryland Log Sorting Operation	0.8 km(0.5 mi) west of the end of Rowe Road, Sahtlam Land District	15 cu.m (20 cu. yds.) per day	Wood bark - 70% Aggregate - 30%	Debris is that material which gathers on an asphalt surface yard where logs are off-loaded, sorted, up-graded and reloaded. This material includes branches, knots, bark, slivers, lily pads, mud and gravel
PR 506	British Columbia Forest Products Limited Groundwood Mill	On B.C.F.P. millsite in an old borrow pit	153 cu.m (200 cu. yds.) per day	Industrial by-products, hog fuel, cinders, fly ash, lime kiln bricks, grits, sawdust and earth spoil.	

Appendix 11.3. (cont'd).

PCB I.D.#	DISCHARGER	LOCATION OF LANDFILL	VOLUME	WASTE CHARACTERISTICS	COMMENTS
PR 507	British Columbia Forest Products Limited Newsprint Mill	On B.C.F.P. millsite nr. Osborn Bay	229 cu.m (300 cu. yds.) per day	Industrial wastes consisting of newsprint wrapper, newsprint, paper cores, wood plugs cinders, fly ash, lime kiln bricks, grits and earth spoils.	Surface waters drain through refuse site into the ocean.
PR 1805	The Corporation of the City of Duncan Municipal Refuse Disposal Operation.	4 km(2.5 mi.) south of Duncan city centre	17 cu.m (22 cu. yds.) per day	Ordinary domestic refuse, no contributing industry of consequence.	Refuse is to be covered weekly with a gravel overburden. Site life has been estimated at 20 years.
PR 3639	MacMillan Bloedel Limited Chemainus Sawmill Division	on millsite near Chemainus Bay	17,585 cu.m (23,000 cu. yds.) per year. 3,058 cu.m (4,000 cu.yd.)	Debarker lagoon dredgings and harbour dredgings. Fly ash, grate ash and hog fuel.	100 % survival of fish after 96 hours in 100% concentration.
PA 2844-02	Regional District of Cowichan Valley Municipal Refuse Incinerator	4 km(2.5 mi.) west of village of Lake Cowichan	2.3 cu.m (3 cu.yds.) per day	Ash and incombustibles resulting from the incineration of typical municipal solid waste.	

Appendix 13.1. Statistical data available from Government Agencies.

Environment Canada, Atmospheric Environment, 4905 Dufferin Street, Downsview, Ontario.

- British Columbia, Temperature and Precipitation, 1941-1970.
- Monthly record meteorological observations in Canada.
- Canadian Normals Vol. III, wind 1955-1972.

British Columbia Department of Agriculture, Parliament Buildings, Victoria, B.C.

- Climate of British Columbia. Tables of temperature precipitation and sunshine, 1973. (Based on data compiled by Environment Canada.)
- Climate of British Columbia. Tables of temperature and precipitation. Climatic normals 1941-1970, extremes of record.

Environment Canada, Inland Waters Directorate, Ottawa.

- Surface water data, reference index Canada, 1972 (Water Survey of Canada).
- Historical streamflow summary,British Columbia, to 1973 (Water Resources Branch).
- Sediment data for Canadian Rivers, 1969 (Water Survey of Canada).
- Water quality data, British Columbia, 1961-1971 (Water Quality Branch).

Environment Canada, Fisheries and Marine Service, Fisheries Management, Fisheries Research Board of Canada, Pacific Environment Institute, 4160 Marine Drive, West Vancouver, B.C.

- Manuscript Report Series No. 989 - Physical and Chemical Oceanographic Data for the East Coast of Vancouver Island, 1954-1966 (including Stuart Channel - Osborn Bay), by M. Waldichuk, J.H. Meikle and J.R. Markert.

Appendix 13.1 (cont'd).

Statistics Canada, User Inquiry Service, Census Field, Ottawa, or Statistics Canada Information, 16 E. Hastings, Vancouver, B.C.

- Statistics Canada Catalogue 11-204 E (up-dated to June 30, 1974).

  Part I - Publications.

  Part II - Data Files and Unpublished Information.

- 1971 Census Catalogue 11-506 Population, Agriculture, Housing, Employment.

- 1971 Census of Canada, Population Census divisions and subdivisions (western provinces) Catalogue 92-707.

- 1971 Census of Canada, Special Bulletin-Geography, Land areas and densities of statistical units, Catalogue 98-701 (SG-1).

- 1971 Census of Canada-Agriculture, British Columbia, Catalogue 96-711.

- 1973 Shipping Report Part II. International seaborne shipping (by port) Catalogue 54-203.

15. GLOSSARY

GLOSSARY INDEX

GLOSSARY OF SELECTED TERMS

(i) GENERAL TERMS

aquatic: growing or living in, or frequenting water, as opposed to terrestial.

biota: the flora and fauna of an area; or, the living part of a system.

coastal zone: the coastal waters and adjacent shorelands influenced by each other, including transitional and intertidal areas, salt marshes, wetlands, and beaches. The coastal zone extends seaward to the outer limit of the territorial sea, and extends inland from the shoreline to the extent necessary to control land uses which may have a direct and significant impact on the coastal waters.

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.

Cowichan: a native Indian word from the Cowichan dialect meaning, "land warmed by the sun".

delta: the low, nearly flat, alluvial tract of land deposited at or near the mouth of a river, commonly forming a triangular or fan-shaped plain of considerable size, enclosed and crossed by many distributaries of the main river, perhaps extending beyond the general trend of the coast, and resulting from the accumulation (in a wider body of water) of sediment supplied by the river in such quantities that it is not removed by tides, waves, or currents.

detritus: an accumulation of decaying debris, both organic and inorganic.

ecology: the study of the interrelationships between organisms and their environment.

ecosystem: an ecological unit consisting of both the biotic and abiotic (i.e. non-living) environment, interacting to produce a stable system.

environment: a collective term for the condition in which an organism lives (e.g. temperature, light, water, other organisms, etc.).

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.

flood plain: the area of land, adjacent to a river channel, subjected to flooding, when floodwater levels reach a predetermined height.

freshet: a sudden increase or rise in river flow or level because of melting snow and/or heavy rain.

headwaters: the streams and creeks that are the sources of a river or other water body.

intertidal zone: that area of shore bounded by the levels of high and low tide.

littoral: of or pertaining to a shore especially of the sea.

morphology: the observation of the form of lands; or the study of the form and structure of organisms.

nutrient: a substance necessary to maintain life and promote growth.

sublittoral: the benthic region extending from mean low water level to a depth of about 200 metres (100 fathoms), or the edge of the continental shelf.

subtidal: below the lowest low tide.

topography: the physical features of a district or region, such as are represented on maps taken collectively; especially the relief and contour of the land.

turbid: muddy or cloudy from suspended particles.

(ii) GEOLOGICAL AND SOIL TERMS

algal mat: layer of algae covering sediments usually found in the lower to intermediate tidal zone.

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

clastic: consisting of fragments of rocks or of organics that have been moved individually from their places of origin.

conglomerate: rounded waterworn fragments of rocks or pebbles, cemented together by another mineral substance.

cordillera: the great mountain region of western North America between the Interior Plains and the Pacific Ocean.

eustatic: pertaining to simultaneous, world-wide changes in sea-level.

flutings: smooth gutter-like channels or deep smooth furrows worn in the surface of rock by glacial action.

fluvial: of or pertaining to, rivers; produced by river action.

fluvioglacial: pertaining to streams flowing from glaciers or to the deposits made by such streams.

isostatic: being in hydrostatic equilibrium.

lineation: in rock the parallel orientation of structural features that are lines rather than planes. It may be expressed by the parallel orientation of the long dimensions of minerals or of pebbles, cleavage - bedding intersections, or fold axes.

loam: a soil composed of a mixture of clay, silt, sand, and organic matter.

metamorphism: process by which consolidated rocks are altered in composition, texture or internal structure by pressure, heat and the introduction of new chemical substances.

pyroclastic rocks: any rocks consisting of unreworked solid material of whatever size, explosively or aerially ejected from a volcanic vent.

radiocarbon dating: the determination of the age of a material by measuring the proportion of the isotope C^{14} (radiocarbon) in the carbon it contains. The method is suitable for the determination of ages up to a maximum of about 30,000 years.

range: a chain of mountains or hills.

shell-hash: a sediment layer composed of loosely cemented sand, silt, clay and shell fragments or fossil debris generally larger than 2 mm.

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.

stoss-and-lee topography: topography having gentle upstream (stoss) and steep downstream (lee) slopes as a result of glacial erosion.

tidal flat: a marshy or muddy land area which is covered and uncovered by the rise and fall of the tide.

till: unsorted and unstratified sediment generally unconsolidated, deposited by the melting of a glacier, and consisting of a mixture of clay, sand, gravel, and boulders.

volcanic rocks: the class of igneous rocks (formed by solidification from a molten or partially molten state), that have been formed at or near the earth's surface.

wave-cut bench: a bench extending seaward from the base of a sea cliff produced by wave erosion.

(iii) CLIMATOLOGICAL TERMS

anemometer: an instrument by which the velocity and often the direction of the wind is measured, usually in miles per hour or metres per second.

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

evaporation: the physical process by which a liquid is transformed to a gas, or in general, the amount of water evaporated.

humidity: a measure of the water vapour present in the air; may be given in terms of relative humidity, or the absolute humidity.

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.

modified maritime climate: a maritime climate that has attained a degree of continentality owing, for example, to occasional intrusions of cold arctic air.

radiation: the process by which a body emits radiant energy, e.g. in the form of heat; it causes a loss of heat, and therefore, cooling.

relative humidity: the ratio of the actual amount of water vapour in a given volume of air to the amount which would be present if the air were saturated at the same temperature, usually expressed as a percentage.

temperature inversion: an increase in air temperature with an increase in altitude (also, the layer through which this condition prevails), which results in stable stratification and prevents the vertical mixing normally associated with conditions of decreasing temperature with increasing height.

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.

(iv) HYDROLOGICAL TERMS

drainage area: the region which drains all the rain water 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.

hydrograph: a graph showing changes in water flow over a period of time.

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.

watershed: the elevated boundary line separating the head-streams which are tributary to different river systems or basins. It often has an extremely irregular course, and does not necessarily follow the ridge of a range of hills or mountains.

(v) OCEANOGRAPHICAL TERMS

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

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

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

ebb tide: outgoing or falling tide.

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

entrainment: the transfer of fluid, by friction, from one water mass to another, usually between opposing currents; turbulence results in mixing.

fetch: in wave forecasting, the continuous area of water over which the wind blows in essentially a constant direction.

flood tide: rising or incoming tide.

humic substances: substances of organic origin that are fairly but not entirely resistant to further bacterial decay.

hydrography: the study, description, and mapping of oceans, lakes, and rivers, especially with reference to their navigational and commercial uses.

insolation: in general, the solar radiation received at the earth's surface.

mixed tide: type of tide in which a diurnal wave produces large inequalities in heights and/or durations of successive high and/or low waters.

physiography: the description of the features and phenomena of nature; or, the science which deals with the nature and origin of the earth's topographic features.

salinity: a measure of the quantity of dissolved salts in sea water; the total amount of dissolved solids in sea water in parts per thousand ($^0/_{00}$) by weight, when all the carbonate has been converted to oxide, the bromide and iodide to chloride, and all organic matter is completely oxidized.

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.

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.

vernal: relating to, or appearing, or occurring in, the spring.

windrow: a row of materials that has been swept together by the wind.

(vi) BIOLOGICAL TERMS

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.

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.

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

aquaculture: the regulation and cultivation of ocean plants and animals for human use or consumption.

autotroph: green plants, some protozoa, etc., capable of making organic matter from carbon dioxide and water, in the presence of chlorophyll, using sunlight as an energy source.

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 sediment 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).

biogeoclimatic zone: a zone which is named either by its most characteristic plants or by their geographic (latitudinal or longitudinal) distribution, in relation to the areas macroclimatic and zonal-soil features.

biomass: the total weight of organisms per unit area.

bivalve: a mollusc having a shell which consists of two hinged plates or valves.

bloom: an unusually large number of organisms per unit volume of water, usually algae, made up of one or a few species.

blueback: Strait of Georgia coho salmon in the beginning of their third year characterized by a deep blue colour on the back and bright red flesh.

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.

consumptive wildlife: wild animals which are destroyed by man; refers to game animals hunted for sport or food.

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

detritus: an accumulation of decaying debris, both organic and inorganic.

diatom: any of a number of related microscopic algae, one-celled or in colonies, whose cell walls consist of two box-like parts or valves, and contain silica.

dinoflagellates: any of an order of single-celled organisms, mainly marine and often with a cellulose shell, and having one or more flagellae carried in "grooves" in the shell.

dipteran: pertaining to an order of insects comprised of the true flies; characterized by having one pair of functional membranous wings, and a vestigial or modified hind pair.

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

ecology: the study of the interrelationships between organisms and their environment.

entomology: that branch of zoology that deals with insects.

epifaunal: benthic organisms which live on the surface of the substrate.

eutrophic: referring to a water body rich in plant nutrient minerals and organisms but often deficient in oxygen in midsummer.

fauna: animal life of a specific region or time.

feral: wild or untamed.

flora: plant life of a specific region or time.

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.

grilse: immature sea-going chinook or coho salmon.

habitat: the place where an organism, or a population, lives.

halophyte: a plant that can grow in salty or alkaline soil.

heterotroph: all animals and fungi, most bacteria and a few flowering plants; requiring organic food substances to produce their own organic material.

infaunal: benthic organisms which live buried in, or beneath, the surface of the sediment.

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.

intertidal zone: that area of shore bounded by the levels of high and low tide.

jacks: male chinook salmon returning to spawn in their second or third year.

kokanee: a sockeye salmon (*Oncorhynchus nerka*) which does not migrate to the sea, but spends its entire life in fresh water.

littoral: that zone of shore having light penetration to the bottom and experiencing wave action; in the case of oceans, usually above 200 m.

non-consumptive wildlife: wild animals which are not destroyed by man's use of them, examples being bird-watching, nature photography, etc.

periphyton: a more or less dense coating on submerged or intertidal surfaces chiefly consisting of filamentous algae and diatoms.

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.

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 is stored by photosynthesizing organisms (mainly green plants) in the form of organic substances.

raptorial bird: a bird of prey, usually having a strong notched beak and sharp talons (e.g. eagles, hawks, owls, vultures).

riparian: of, adjacent to, or living on, the bank of a river or other water body.

salmonid: any fish of the family Salmonidae (e.g. salmon or trout).

saprophyte: an organism which obtains organic matter in solution from dead and decaying tissues of plants or animals.

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.

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.)

smolt: usually, a yearling salmonid (that is, older than a fry), when it first leaves fresh water and descends to the ocean.

spat: the spawn of a bivalve mollusc, such as that of an oyster.

sublittoral: below that zone of shore having light penetration to the bottom and experiencing wave action; in the case of the oceans, usually below 200 m.

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.

waterfowl: birds that live on, or near, water, especially swimming game birds like geese and ducks.

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.

(vii) POLLUTION TERMS

anoxic: anaerobic, without oxygen.

bioaccumulation: the concentration of a substance or substances by living organisms.

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.

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 dilutions. It is often used as an indicator of fecal contamination of water supplies.

effluent: the waste outflow from something, such as from a sewer, pulp mill, etc.

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

hinterland: the land or district behind that bordering on a coast or river.

isoline: a line that represents a constant or equal value of a given quantity.

leachate: the solution resulting from the slow passage of a liquid through a medium, during which substances are dissolved, in the liquid.

mercaptan: a substance containing the monovalent radical SH.

pathogenic: causing disease.

pH: the negative logarithm of the hydrogen-ion concentration (in moles per litre) of a solution, which thus provides a measure of acidity or alkalinity, based on a scale of 0 to 14 where 7 is neutral, less than 7 is acidic, and greater than 7 is alkaline.

suspended solids: substances, the particles of which are dispersed through a fluid but not dissolved in it, and which will separate out on standing.

toxic: poisonous.

turbidity: reduced water clarity resulting from the presence of suspended matter.

16. BIBLIOGRAPHY

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