FRASER RIVER
ACTION PLAN

Guide For Best Management Practices For Process Water Management At Fish Processing Plants in British Columbia

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Guide for Best Management Practices for Process Water Management at Fish Processing Plants in British Columbia

NovaTec Consultants Inc.
Environmental Engineers and Scientists

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DISCLAIMER

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TABLE OF CONTENTS

LIST OF FIGURES

page #

LIST OF TABLES

GLOSSARY OF ABBREVIATIONS

B.C.	British Columbia
BOD	Biochemical Oxygen Demand (five day)
COD	Chemical Oxygen Demand
DAF	Dissolved Air Flotation
FCBC	Fisheries Council of British Columbia
GVRD	Greater Vancouver Regional District
GVS&DD	Greater Vancouver Sewerage and Drainage District
IPC	Inert Particulate Carrier
LW	Low Water
MLW	Mean Low Water
MAFF	Ministry of Agriculture, Fisheries and Food
MOELP	Ministry of Environment, Lands and Parks
NH3-N	Ammonia nitrogen
P	Phosphorus
O&G	Oil and Grease
RBC	Rotating Biological Contactor
TKN	Total Kjeldahl Nitrogen
TS	Total Solids
TSS	Total Suspended Solids

1 INTRODUCTION

1.1 Terms of Reference

In September 1993 Environment Canada - Supply and Services Canada, Pacific Directorate retained NovaTec Consultants Inc. (NovaTec) to carry out a study and to prepare a Guide for Best Management Practices for process water management at fish processing plants in British Columbia.

Fish processing is a major industry in British Columbia and the liquid wastes from such production constitute a significant load to either the municipal sewage collection and treatment systems or the surface waters into which the plants discharge their wastes. A document was needed to provide a reference source and technical guidance to minimize potential environmental impacts cost-effectively.

The scope of the study as defined in the Terms of Reference is to:

- collect and summarize available literature and case information in the area of fish processing technology, wastewater treatment, and waste disposal practices at fish processing facilities throughout the world, and specifically in British Columbia;

- summarize the available information on wastewater treatment technology in the context of best available technology appropriate to fish processing;

- summarize and analyze the present practices used within the Lower Fraser Basin including an assessment of the applicability of different components at other facilities within the Basin and elsewhere in the province;

- summarize the size, economic value, diversity, profitability, and trends within the British Columbia fish processing industry, and assess the probable impact of various investments, and present case studies.

- provide a guidance document for regulatory bodies, and for use throughout the industry, and others concerned with the building of new facilities or the upgrading of existing ones.

1.2 Project Objectives

The objectives of the Guide for Best Management Practices - Process Water Management at Fish Processing Plants in B.C. are:

- to give a comprehensive review of the best processing technologies, treatment technologies and wastewater management options;

- to outline the feasibility of process improvements, water conservation, byproduct recovery and wastewater treatment in a comprehensive manner.

2 BACKGROUND INFORMATION

2.1 General

The fish and shellfish processing industry is faced with increasing problems of waste handling and disposal, plant sanitation, raw material availability and cost, production efficiency, increased competition (from other countries as well as other protein sources), and increasing labour and energy costs. At the same time regulations protecting the environment from pollution are becoming more stringent. If waste handling and operating costs significantly increase at fish processing plants, some plants may no longer find it profitable to stay in business.

If pollution is viewed as an indication of an inefficient manufacturing process where both product and energy are wasted, then it maybe more cost effective to reduce pollution by improving the process rather than by adding expensive treatment facilities at the end of discharge pipes, which in turn produce sludge for later disposal. The ideal food processing plant takes in raw materials and generates products. Water and energy are efficiently recycled and byproducts are recovered for internal use or for external markets (Gates, 1991).

2.2 Seafood and Marine Products in Canada and the West Coast

The Canadian seafood and marine products industry is comprised of firms engaged primarily in the processing and marketing of fish, shellfish and marine plants and animals as well as by-products such as fish meal and fish oil (Ind. Sci. and Tech. Canada, 1991 b). Canadian fish products are harvested from oceans off Canada's Atlantic and Pacific coasts as well as from inland freshwater lakes. These three fisheries are based chiefly on groundfish, pelagics, salmonides, molluscs, crustaceans and freshwater fish.

The Canadian seafood and marine products industry is a major world exporter of such products. It provides hundreds of small communities with an important source of jobs and resources. Statistic Canada estimates that in 1990 there were 460 fish processing establishments in Canada employing 27,617 people, with 57 establishments (not including small enterprises) in B.C. employing 4,366 people (Table 2.1). Other estimates include smaller companies, and put the number of fish processing plants in B.C. in 1990 at 160

(Ind.Sci. and Tech. Canada, 1991 b), compared to 173 facilities licensed by the British Columbia Ministry of Agriculture, Fisheries and Food in 1993 (see Section 2.3).

Table 2.1 Economic Summary of Fisheries Resources

Canada Total	1984	1985	1986	1987	1988	1989	1990
Number of Facilities	397	390	404	414	453	472	460
Employment	24372	26964	28934	31 171	31086	30498	27617
Shipments ($ millions) (10^3 tonnes)	1980 699	2476 792	2956 804	3146 860	3340 881	3225 899	3303 957
Landed value ($ millions)	902	1131	1358	1648	1628	1496	1509
Landings (103 tonnes)	1284	1446	1513	1568	1653	1606	1647
West Coast							
Number of Facilities	49	47	47	48	59	62	57
Employment	2972	3695	3788	4156	4447	3620	4388
Shipments ($ millions) (10^3 tonnes)	467 126	728 158	767 174	798 219	956 207	946 224	952 244
Landed value ($ millions)	243	378	402	442	534	454	478
Landings (10^3 tonnes)	169	214	222	251	266	283	305

Source: Industry, Science and Technology Canada, 1991 b

B.C. fish processing in 1990 accounted for 12 % of the total number of Canadian fish processing plants, 16 % of total industry employment, and 32 % of the landed value, making it the largest fishing province in Canada (Ind. Sci. and Tech. Canada, 1991 b).

Commercial fishing is the fourth largest primary industry in British Columbia after forestry, mining and agriculture. The fish processing sector accounts for over 25 % of all food manufacturing activity in the province (B.C. Ministry of Agriculture, Fisheries and Food, 1992a). In 1990, approximately 70 % of the total value of fish products originated from the Lower Mainland region, and 18 % in the Prince Rupert area with the Vancouver Island and the Sunshine Coast regions contributing 9 and 3 % respectively (B.C. Ministry of Agriculture, Fisheries and Food, 1992a).

The British Columbia fishing fleet was comprised of 5,773 and 5,915 vessels in 1990 and 1992, respectively (pers. comm. with Ms. Maureen Kostner of Department of Fisheries and Oceans, 1993). The west coast seafood and marine products industry process primarily pelagic fish or'mid-water dwellers such as salmon and herring. Groundfish or bottom-feeding fish such as halibut, redfish and hake, and shellfish including clams, oysters, shrimps and crabs make up most of the balance. Fish processing is concentrated in the Lower Mainland of B. C., Vancouver Island, and around Prince Rupert.

Fish processing is highly seasonal, as fish are only caught when they are in prime harvest condition. In addition, some species such as salmon are migratory. The harvest of most coast salmon species occurs from late June until October - November. Pacific salmon includes six commercial species: sockeye, chinook, chum, coho and pink which form the basis of the west coast salmon fishery, and cherry salmon which is harvested only in the vicinity of Japan. There is also a growing farm salmon harvest occurring year round based on chinook (spring) and Atlantic salmon.

The roe herring harvest takes place principally in March, just before the herring are about to spawn.

In 1993, the pelagic subsector, mainly salmon and herring, accounted for 35 % and 17 % (respectively) of fishery landings by weight and 46% and 17 % (respectively) of the landed value in B.C. (Figures 2.1 and 2.2). Groundfish accounted for 30 % of landings by weight in the same year, but only 20 % of the landed value. Shellfish accounted for only 8 % of landings by weight and 17 % of the landed value.

The west coast fish processing is highly export-oriented. More than 50 % of salmon products and all herring roe are exported. About two-thirds of the groundfish and most of the shellfish products are exported as well (Ind. Sci. and Tech Canada, 1991 b). The United States is the principal market for groundfish and shellfish. The United Kingdom accounts for half of the canned salmon exports, and Japan accounts for about 40 % of the frozen salmon exports and virtually all of the herring roe production (Ind. Sci. and Tech. Canada, 1991a).

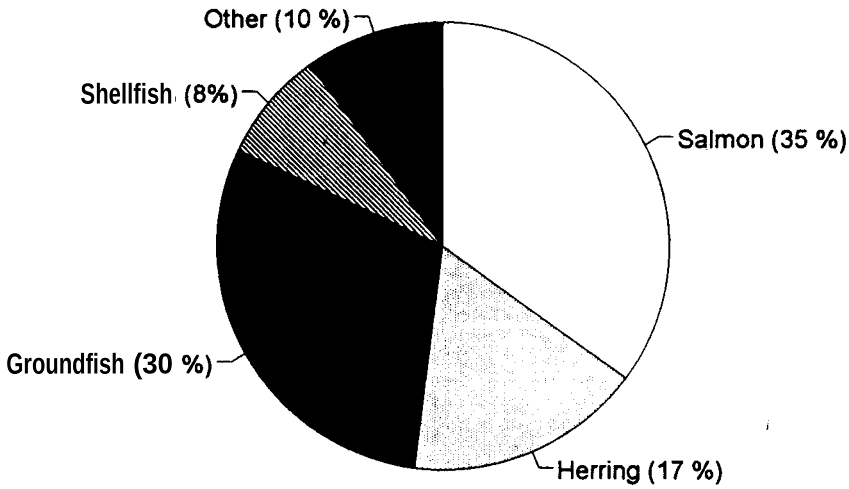


FIGURE 2.1
1993 WEST COAST SEAFOOD HARVEST
(SOURCE: DEPARTMENT OF FISHERIES AND OCEANS, 1993)

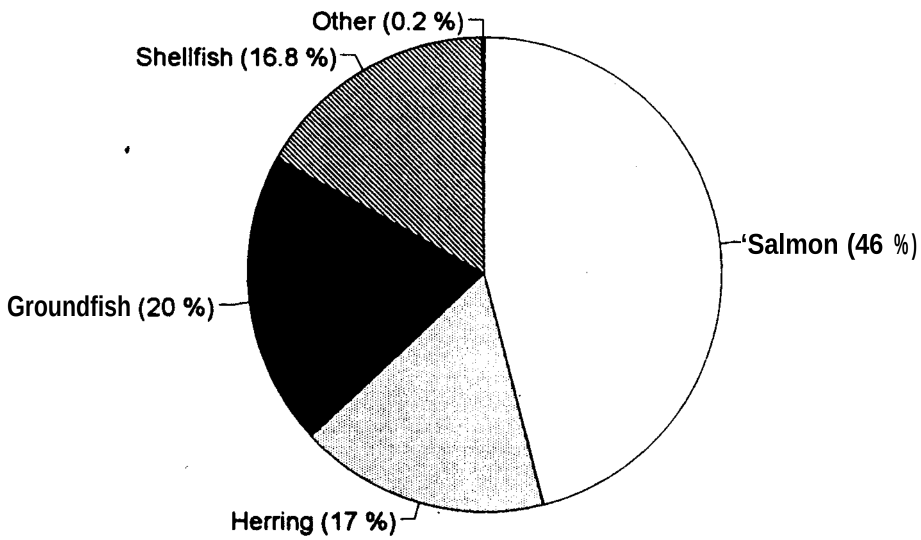


FIGURE 2.2
1993 WEST COAST SEAFOOD PRODUCTS BY VALUE
(SOURCE: DEPARTMENT OF FISHERIES AND OCEANS, 1993)

Development of aquiculture (husbandry of aquatic animals) in recent years in Canada may lead to a year-around operation in the fish processing industry. Aquiculture is a relatively new industry in Canada and is confined principally to four species groups: salmon, trout, oysters and mussels. Canadian aquiculture output of all species is about 10 % of the volume from the wild fishery and is growing rapidly (Ind., Sci. and Tech. Canada, 1991 c). Of the Canadian aquiculture industry subsectors, salmon farming is the largest and fastest growing.

In British Columbia salmon aquiculture has grown rapidly from 4 sites in 1981 to 135 in 1989. At the beginning of the 1990 season, the farm salmon industry in B.C. consisted of 72 producers operating 135 sites and employing 1,400 people (Ind., Sci. and Tech. Canada, 1991 c). Farmed salmon production in B.C. was 24,200 tonnes in 1992 (Table 2.2). In 1993, 105 salmon farms were licensed in B. C., approximately 75 of which were actually operating (pers. comm. with Mr. Richard Deegan of B.C. Ministry of Agriculture, Fisheries and Food). Salmon farms were first established along the Sunshine Coast in the Sechelt area, but are now concentrated around Campbell River and Port Hardy (Ind., Sci. and Tech. Canada, 1991 c).

Table 2.2 **Aquiculture Farm Gate Production in British Columbia**

Year	Production [tonnes]			
	Salmonids	Freshwater Trout	Oysters	Clams
1981	176	71	1,415	
1982	273	74	1,579	
1983	128	77	2,453	
1984	107	71	2,897	
1985	120	83	3,420	4 ,
1986	400	101	2,864	7
1987	1,931	90	3,482	25
1988	6,590	113	3,702	30
1989	11,883	86	3,721	31
1990	15,486	109	4,547	39
1991	23,780	116	4,482	169
1992	24,200	115	5,000	200

Source: B.C. Ministry of Agriculture, Fisheries and’ Food, 1993b)

In 1988, some 74 % of the farmed salmon was sold fresh, 25 % frozen and about 1% smoked (Ind., Sci. and Tech. Canada, 1991 c).

Shellfish aquiculture is now well established on both the Atlantic and Pacific coasts. Oysters are the principal shellfish product in British Columbia (Ind., Sci. and Tech. Canada, 1991 c).

New commercial fisheries are now under way or being explored for products such as purple urchins, venus clams, squid and snow shark. With this new focus on previously underutilized species, new processing facilities are being built in coastal communities further diversifying the nature of the industry (B.C. Ministry of Agriculture, Fisheries and Food, 1992b).

2.3 Fish Processing Plants in British Columbia

In 1993, 173 fish processing facilities were in possession of a licence (Licensed Facilities) issued by the B.C. Ministry of Agriculture, Fisheries and Food (MAFF) to process fish for human consumption (i.e. licensed facilities excluding fish offal processing and cold-storage-only facilities). This figure included large fish processing facilities such as salmon canneries as well as small stores serving the fresh fish market. Almost half of all licensed facilities are located in the B.C. Lower Mainland. Other major processing areas are along the east coast of Vancouver Island between Nanaimo and Campbell River, the Tofino and Ucluelet area, and Prince Rupert. Figure 2.3 shows the approximate location of all Licensed Facilities, with the area of the circles indicating the number of facilities located in a specific area. Also shown are reduction plants and fish offal comporting sites which were in operation in 1993. Information about plant capacities could not be obtained due to the confidential nature of such data. However, maximum permitted discharge flows may be considered as an estimate of the plants capacities, and are shown in Figure 2.4 for plants operating with a permit to discharge to the environment or to the Greater Vancouver Sewerage and Drainage District (GVS&DD).

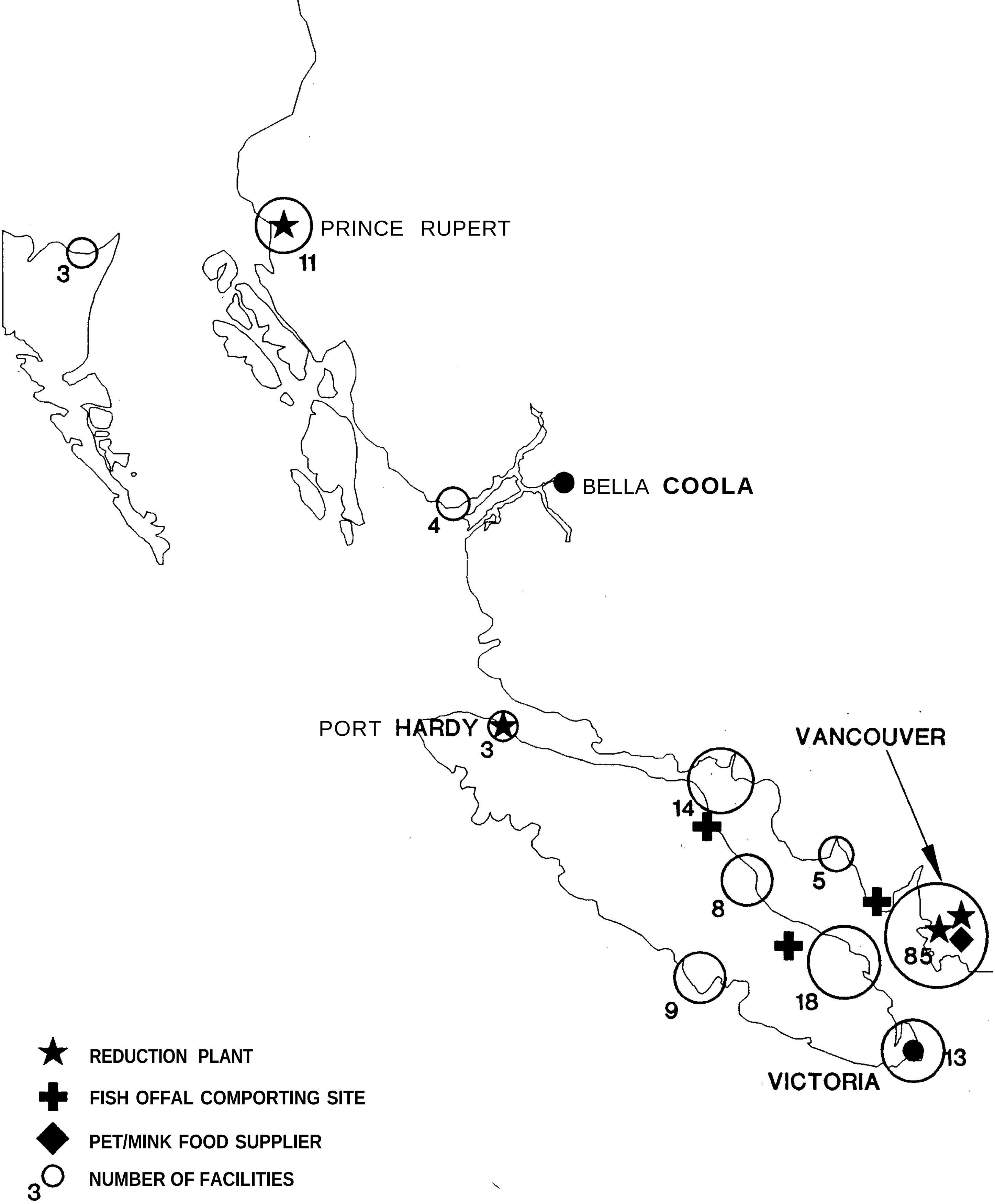


FIGURE 2.3
FISH PROCESSING PLANTS IN BC - LOCATION

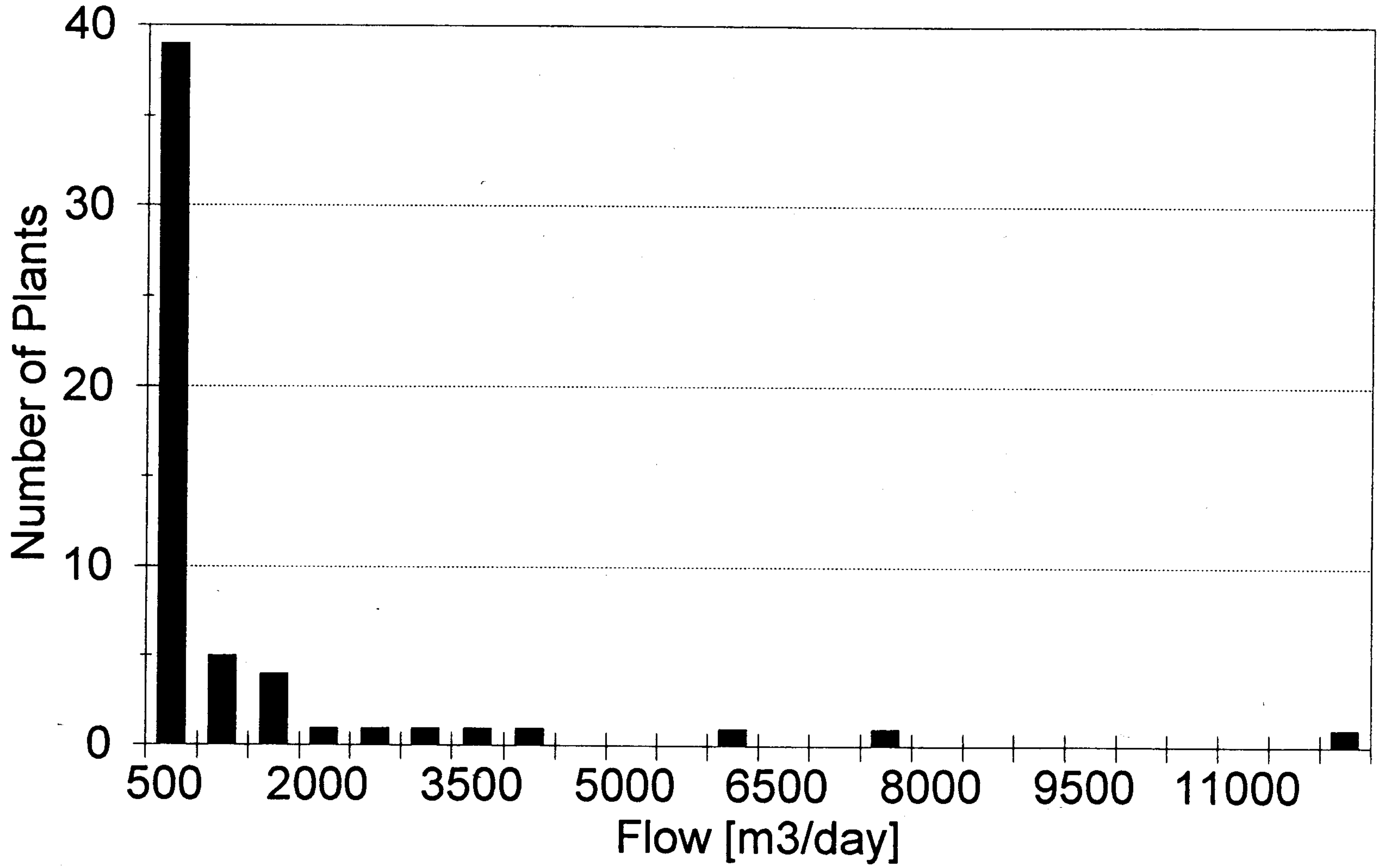


FIGURE 2.4
BC FISH PROCESSING PLANTS PERMITTED DISCHARGE FLOWS

2.4 Review of Current Regulations

2.4.1 Federal Acts and Regulations

The Fisheries Act regulates the discharge and disposal of deleterious substances in Canadian fisheries waters on the federal level. Under Section 36 (3) of this Act, “no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish . ...”. A deleterious substance is defined as:

> ... any substance that, if added to any ‘water, would degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water, or any water that contains a substance in such quantity or concentration, or that has been so treated, processed or changed, by heat or other means, from a natural state that it would, if added to any other water, degrade or alter form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water...

The Fisheries Act does not set up limits for any of the possible pollutants that fall under the definition of a deleterious substance.

Fish Processing Operations Liquid Effluent Guidelines is available under the Fisheries Act. The intent of the Guidelines is to indicate the level of effluent controls considered necessary to the federal government. Generally, screening and discharging through an outfall below low tide is acceptable. Good housekeeping is recommended.

2.4.2 Provincial Acts and Regulations

The “Pollution Control Objectives for Food-processing, Agriculturally Oriented,. and Other Miscellaneous Industries of British Columbia” (1975) (Objectives) establishes objectives for wastewater discharge and waste disposal within B.C. The Objectives apply to effluents discharged to fresh and marine waters other than groundwater, and are expressed as a weight of contaminant per unit weight of production. Different limits, monitoring requirements and monitoring frequency are set for salmon processing (cannery and reduction plant), fresh and frozen fish dressing, fresh and frozen fish filleting and reduction plant, and herring processing. Pollution control objectives for discharges from fish processing plants are shown in Table 2.3. However, more stringent limits may be put in place if receiving waters are affected detrimentally.

The B.C. Ministry of Environment, Lands and Parks (MOELP) considers the Objectives as not stringent enough and is in the process of revising the document (pers. comm. with Richard Laird of MOELP).

Table 2.3 Objectives for the Discharge of Effluent to Marine Waters From Fish Processing Plants

Operation	Level / Parameter [kg/tonne product]	A	B	c	Monitoring Frequency
Salmon cannery and reduction plant	BOD	7.0	32.0	40.0	weekly
	TSS	2.6	13.0	22.0	weekly
	Ether soluble oils	0.8	10.0	10.0	monthly
Fresh and frozen fish (dressing only)	BOD	1.4	1.4	1.8	twice/month
	TSS	1.0	1.0	1.6	twice/month
Fresh and frozen fish filleting and reduction plant	BOD	4.0	10.0	30.0	weekly
	TSS	1.5	6.0	15.0	weekly
	Ether soluble oils	0.8	4.0	20.0	monthly
Herring processing	BOD	1.2	4.0	14.0	weekly
	TSS	0.9	3.5	10.0	weekly
	Ether soluble oils	0.5	3.5	3.5	weekly

Source: Pollution Control Objectives for Food-processing, Agriculturally Oriented, and Other Miscellaneous Industries of British Columbia, 1975)

Note:
All new or proposed discharges should meet Level A objectives. All existing discharges should meet Level C either immediately or within the shortest possible time technically feasible to do so. Existing discharges should be upgraded to interim Level B and ultimately to Level A by a staged program of improvement.

2.4.3 Municipal and Regional Bylaws

The discharge of wastewater from fish processing plants to municipal sewer systems is generally regulated by municipal or regional sewer use bylaws. Typically, these bylaws do not refer to such effluents specifically, but include general restrictions such as particle-size, total suspended solids (TSS), oil and grease (O&G), and biochemical oxygen demand (BOD) limits which must be met by all discharges.

In the Greater Vancouver area, discharges to sewer are regulated by the GVS&DD Sewer Use Bylaw No. 164. Fish processing effluents fall under the category of "non-domestic waste" and their discharge requires a permit if more than 300 cubic metres of effluent are discharged from a facility over any consecutive 30 day period. Effluent concentration limits in effect for discharge to sewer are shown in Table 2.4. At the time of the preparation of this report, the GVS&DD was in the process of developing a fee structure for the discharge of non-domestic waste. The 1992 rate structure proposal called for a surcharge of $0.27 per kilogram of TSS and $0.13 per kilogram of BOD discharged (GVRD, 1992). The fees are only proposed for TSS concentrations and BOD exceeding 200 mg/L which is typical of domestic sanitary waste.

Table 2.4 **GVS&DD Effluent Discharge Limits for Parameters Applicable to the Fish Processing Industry**

Parameter	One-OperatIng-Day Composite Sample	Two-Hour Composite Sample	Grab Sample
BOD	500	1000	2000
TSS	600	1200	2400
O&G	150	300	600

Source: GVS&DD Sewer Use Bylaw No. 164

Notes:

1. All concentrations are in mg/L.
2. One-operating-day Composite Sample': A composite sample of the discharge consisting of equal portions of grab samples collected at consecutive one-hour intervals over the duration of the operating day.
3. Two-hour Composite Sample: A composite sample consisting of equal portions of 8 grab samples collected at consecutive 15-minute intervals.

3 WATER CONSUMPTION AND WASTEWATER CHARACTERISTICS

3.1 Water Consumption

Water consumption depends upon a number of factors, including the species processed, applied water conservation techniques, processing technology and type of finished product. High water consumption was generally encouraged in the past to control plant sanitation. Recently, successful efforts have been made to decrease water consumption without compromising the plant sanitation (Sections 5.2.2 and 6.2).

A review of water consumption rates reported in literature is presented in Table 3.1.

Stone et al. (1981) reported that the amount of water used for each unit of production decreases as daily production increases. The same was observed and reported by NovaTec Consultants Inc. and EVS Environment Consultants (1994). A very high water consumption per unit of production that occurs on low production days is believed to be due to a high base line water consumption related to activities like equipment and plant cleanup.

Water conservation techniques and modifications in processing technology can reduce water consumption significantly (see Sections 5.2). Implementation of water conservation techniques at fish processing facilities in Northern Europe resulted in up to 50% reduction of the water consumption (NovaTec Consultants Inc., 1993a).

Water consumption is also a function of the type of species processed. The highest water consumption is reported for groundfish processing. It can amount to 154 L/kg (Table 3.1). The lowest water consumption is reported for oyster and clam processing, only 0.2 and 0.6 L/kg respectively (Table 3.1).

Typical water consumption rates at fish processing facilities in B.C. are presented in Table 3.2.

Water consumption at B.C. fish processing facilities generally fall in the range reported in literature (Table 3.1). However, when typical water consumption rates are compared with rates reported at facilities which implemented water conservation techniques, it can be seen that there is still considerable room for improvement. For example, water consumption at salmon processing facilities in Northern Europe that have implemented

Table 3.1 Water Consumption Rates - Literature Data

Type	Water Consumption[(1)] [L/kg]	Remarks	Reference
Salmon (hand butchered)	9.0		Tilsworth & Morgan, 1983
Salmon (mech. butchered)	19		Tilsworth & Morgan, 1983
Salmon cannery	7.5-30	per processed fish	Villamere, 1974
Salmon slaughterhouse	6		NovaTec, 1 993a
Salmon canning	7.5-66	per canned fish	Riddle and Shikaze, 1973
Salmon	20		Tavel Ltd., 1991
Groundfish (dry line)	12.5-139	per fish filleted	Riddle & Shikaze, 1973
Groundfish (wet line)	38.4-154.2	per fish filleted	Riddle & Shikaze, 1973
Groundfish	15		Tavel Ltd., 1991
Bottom fish	62-31	per live weight	Brinsfield et al., 1978
Fat fish	2.5-7.0		NovaTec, 1993a
Herring	2.5-4.3		NovaTec, 1993a
Mackarel, tuna, herring	5		NovaTec, 1993a
Surimi	10-20	per deboned meat	Lee, 1984
Shrimp	73.4		Tilsworth & Morgan, 1983
Shrimp	55	per peeled shrimp	Nielsen, 1983
Shrimp	26		Tavel Ltd., 1991
Blue Crab	1.4-5	per live weight	Brinsfield et al., 1978
Crab and Crab sections	18.6		Tilsworth & Morgan, 1983
Crab meat	3.6		Tilsworth & Morgan, 1983
Clams	0.55-1.4	per live weight	Brinsfield et al., 1978
Clams	14.5		Tavel Ltd., 1991
Oysters	0.2-28	per finished product	Brinsfield et al., 1978

(1) Unless specifically stated in the Remarks column, the' authors did not clarify whether water consumption is per live or processed weight.

water conservation programs is only 6 L/kg, whereas typical water consumption for salmon processing plants in B.C. is 10 to 30 L/kg (Table 3.2). A B.C. fish processing facility that recently replaced manual salmon gutting lines with semi-automatic vacuum suction lines (see Section 4.3. 1) experienced a reduction of its water consumption by almost 90 to 95 %. “Water consumption at this facility decreased from 28-75 L/kg to only about 3.5 L/kg (NovaTec and EVS, 1994).

Water consumption for groundfish and groundfish/salmon processing at Lower Mainland fish processing plants is lower than the water consumption reported in the literature for groundfish processing plants (Table 3.1). Measures to further reduce water consumption are discussed in Sections 5.2.2 and 6.2.

Table 3.2 Water Consumption Rates - B.C. Lower Mainland Fish Processing Plants

Type	BC Water Consumption - Range [L-/kg]	Typicai industry Water Consumption - Range[L/kg]	Reference
Salmon (hand butchered)	7-32	10-15	NovaTec and EVS, 1994
Salmon (mech. butchered)	3-326	10-30	NovaTec and EVS, 1994; NovaTec, 1993c
Salmon, groundfish	2-163	7-27	NovaTec and EVS, 1994
Groundfish, halibut	5-35	6-20	NovaTec and EVS, 1994
Herring	1.5-50	5-30	NovaTec and EVS, 1994; NovaTec, 1993c
Surimi	14*		Aquametrix, 1993a
Surimi	13- 14* 45-52 **		Aquametrix, 1993b

* Per kg of round fish
** Per kg of product

3.2 Wastewater Characteristics

3.2.1 General

A summary of contaminant concentrations in effluent from different seafood processing plants, as reported in the literature, are presented in Tables 3.3 and 3.4.

Wastewater characteristics vary substantially with the type of species processed, applied processing technology and type of finished product. Overall, high BOD, oil and grease, and nitrogen content can be expected in effluents from fish processing facilities (Table 3.3). Most of the BOD and TSS and up to 60 % of oil and grease originates from the butchering process (NovaTec Consultants Inc., 1993c). The high nitrogen content is due to high blood and slime content in the wastewater streams. Generally, lower BOD and nitrogen concentrations can be expected from shellfish processing (Table 3.4).

Table 3.5 is a presentation of the amount of contaminants discharged per unit weight of fish processed (contaminant mass loadings). This type of data allows a more accurate evaluation of plant performance with respect to generating wastewater, as low contaminant concentrations are not necessarily due to “clean” processing but maybe the result of high water use. High water consumption would dilute the contaminant concentration, thereby obscuring the fact that such a plant may actually generate more contaminants on a per-fish weight basis than another plant which discharges higher strength wastewater but requires less water for processing the same amount of fish. The latter plant would discharge fewer contaminants than the former.

Variations in daily production, water use, and waste concentration values make it difficult to calculate precisely the amount of waste discharged for each unit of production. A wide range of contaminant loadings per tonne of processed fish/shellfish indicates that loading also depends upon the species processed and applied processing technology. Less BOD, TSS, and oil and grease per unit of production on high production days was reported by Stone et al. (1981) and NovaTec Consultants Inc. and EVS Environment Consultants (1994) than on low production days.

Table 3.3 Contaminant Concentrations of Fish Processing Plant Effluents - Literature Data

Specie Processed	BOD [mg/L]	COD [mg/L]	TS [mg/L]	TSS [mg/L]	Oil & Grease [mg/L]	TKN [mg/L]	Other	Reference
Fish	1200	460			160			Sasaki et al., 1980a
Fish cannery		2560		1360	603			Shifrin et al., 1972
Fish salting, smoking and cannery	1600-2000 (total)	500-5000		200-2000			(1)	Pesenon et al., 1974
Fish processing	3500	326-1432	4721	918-1000	1000	117		del Valle & Aguilera, 1990
Fish canning	1400	2900		1900	1200	62		Ziminska, 1985
Fish salting	2300	5400		6000	150	257		Ziminska, 1985
Fish smoking	1700			400	200	77		Ziminska, 1985
Oil rendering	11500	91000		25900	25000	268		Ziminska, 1985
Salmon cannery	2500	4000					(2)	Clagget, 1972
Salmon cannery	2490-2682	4462-5348		1330-1575	648-687	388-417	(3)	Stone et al., 1981
Salmon	397-3082		88-3422	40-1824				Riddle & Shikaze, 1973
Bottom fish	192-1726			300				Riddle & Shikaze, 1973
Halibut	64-150			66110				Riddle & Shikaze, 1973
Halibut	145-420			95-245				Riddle & Shikaze, 1973
Redfish	40-114			14-101				Riddle & Shikaze, 1973
Groundfish (dry line)	27-1775			7-1006	0-526			Riddle & Shikaze, 1973
Groundfish (wet line)	146-1205			30-1550	200-1500			Riddle & Shikaze, 1973
Herring (filleting)	3200-5800	6258	6986	1150-5310	200-3000			Riddle & Shikaze, 1973
Herring (pumpout wat.)	33500			7955	500			Riddle & Shikaze, 1973
Tuna	895		17900	1091	500			Riddle & Shikaze, 1973
Surimi		6400-18000	5120-7790			740-1100		Green et al., 1984

Table 3.3 (cent'd)

Type	BOD [mg/L]	COD [mg/L]	TS [mg/L]	TSS [mg/L]	Oil & Grease [mg/L]	TKN [mg/L]	Other	Reference
Surimi	5000-5500	1600-2200		1500-2000				Okumura & Uetana, 1992'
Surimi	6350-11600		3920-10800	.	106-1530			Oregon Dept. of Env. Quality, 1993
Fish meal	66400	191000		19000	12500	6400		Ziminska, 1965
Fish meal: bailwater	4600	35200						del Vane & Aguilera, 1990
Fish meal: bloodwater		93000						del Vane & Aguilera, 1990

(l): Phenols = 50-500 mg/L
(2): Protein = 1600 mg/L
(3): Total residue = 3196-3607 mg/L
(4): Ammonia Nitrogen = 0.7-69,7 mg/L

Table 3.4 Contaminant Concentrations of Shellfish Processing Plant Effluents - Literature Data

Specie Processed	BOD [mg/L]	COD [mg/L]	TS [mg/L]	TSS [mg/L]	TKN [mg/L]	NH_3-N [mg/L]	Reference
Shellfish	290-380 (filt), 280-1075(tot)	250-738 (filt) 485-1623 (tot)	776-2000	125-825 120-81 8(VSS)	36-45	6-15	Hudson et al., 1976
Shrimp				2900			Tilsworth & Morgan, 1983
Shrimp canning	1070			550			del Vane & Aguilera, 1990
Shrimp		3400-6500	1 900-2808				del Vane & Aguilera, 1990
Shrimp packing	112-340	131-360	50-900	22-200	22.4-59.4	1.8-13.8	Horn & Pohland, 1973
Shrimp precessing	416-857			115-357			Horn & Pohland, 1973
Shrimp precessing	530-1240 (tot.), 330-530 (sol.)			240-660			NovaTec, 1993b
Crab processing	181-1281	320-2940	1040-1814	80-815, 11429(VSS)	23-166	6-13.6	Horn & Pohland, 1973
Crab	4100	29000		95			Gates, 1991
Crab & crab sections				210			Tilsworth & Morgan, 1963
Crab meat				170			Tilsworth & Morgan, 1983
Blue crab	10000-14000	20000-25000	18000-25000	700-1000		200-250	Chao et al., 1960
scallop	560-1250	544-3184		31-1905		15.5-37,5	Krofta et al., 1988
Scallop shucking		1965	9 8 6 7	350	420		del Vane & Aguilera, 1990
Scallop shucking		1965	9887		420		Welsh & Zall, 1979
Clam washwater		637-3590	2528-3590		113-260		del Vane & Aguilera, 1990
oyster	164-576	164-1000	240-400	50-284	22.4-91	2-10	Horn & Pohland, 1973
Oyster canning	510			2280			del Vane & Aguilera, 1990
oyster	31 0(tot), 282(filt)	407(tot), 357(filt)		12-11 (VSS)			Hudson et al.,1978

filt.: filtered, tot: total, sol: soluble, VSS: Volatile suspended Solids

Table 3.5 Production-based Contaminant Discharge - Literature Data

Specie Processed	BOD [kg/1000kg of product]	TSS [kg/1000 kg of product]	Oil & Grease [kg/1000 kg product]	Remarks	Reference
Salmon	1.8-29	1.2-23	0.2-7.4	per raw fish	Riddle & Shikaze, 1973
Salmon	20-50	16	3.5-7.4		Tavel Ltd., 1991
Salmon (hand butchered)		1.6	0.2		Tilsworth & Morgan, 1983
Salmon (mech hutch.)		26	11		Tilsworth & Morgan, 1983
Groundfish (dry line)	1.3-8	1-22.5		per raw fish	Riddle & Shikaze, 1973
Groundfish (wet line)	15-20	7-34		per raw fish	Riddle & Shikaze, 1973
Groundfish	12-18	9-15	2.5		Tavel Ltd., 1991
Halibut (dry line)	2.6-4	1.6-7		per raw fish	Riddle & Shikaze, 1973
Redfish (dry line)	0.7	1.3	0.2	per raw fish	Riddle & Shikaze, 1973
Herring	22	21			Tavel Ltd., 1991
Shrimp (mechanical)	8	5			Horn & Pohland, 1973
Shrimp (hand)	4	2			Horn & Pohland, 1973
Shrimp	68	39			Mauldin & Szabo, 1974
Shrimp	84-130	54-210	17-42		Tavel Ltd., 1991
Crab	1.7-14	,1.39-11		per raw crab	Horn & Pohland, 1973
Crab	4-92	13-73		per processed crab	Horn & Pohland, 1973
Crab	40	20			Tavel Ltd., 1991
Clam	19	6	0.5		Tavel Ltd., 1991
Fish meal	3	1	0.6		Tavel Ltd., 1991

Note: Unless specifically stated 'in the Remarks column, the authors did not clarify whether loading is per live or processed weight.

3.2.2 Fish Processing Facilities in British Columbia

Wastewater characteristics from fish processing facilities in B. C., with respect to conventional contaminant concentrations and loadings are summarized in Tables 3.6 and 3.7, respectively. The tables are a summary of monitoring data of fish processing plant effluents obtained from MOELP, the Greater Vancouver Regional District (GVRD),, City of Vancouver, and NovaTec and EVS, 1994.

BOD, COD, and TSS effluent concentrations from salmon processing at B.C. fish processing facilities are typically in the range reported in the literature for these contaminants (Table 3.3). Oil and grease concentrations are generally lower than' concentrations reported in the literature. Wastewaters from herring, groundfish, and salmon/groundfish processing plants in B.C. generally have lower BOD, COD, TSS, and oil and grease concentrations than reported in the literature (Table 3.3). However, European experience shows that contaminant loading can be significantly reduced if measures discussed in Sections 5.2.4 and 6.3 are applied. Significantly lower levels of BOD and TSS are recorded at B.C. herring processing facilities in comparison with levels reported in the literature (Table 3.3). Wide range of fecal coliform concentrations in fish processing effluent was reported by NovaTec and EVS (1994) and Environment Canada (1993) (Table 3.6). High fecal coliform counts maybe partly due to bird droppings and/or scavenging animals (NovaTec and EVS, 1994 and Environment Canada, 1993).

Limited data is available for effluent toxicity, heavy metals and ammonia concentrations, as these parameters are generally not determined as part of regular effluent monitoring. A detailed study of effluent from fish processing plants discharging into the Fraser River was conducted during the salmon season of 1993 (NovaTec Consultants and EVS Environment Consultants, 1994). For this study the metals and ammonia concentrations in effluents from four plants (see Table 3.8) and the toxicity of the effluent samples of three plants were determined (see Table 3.9). The metals were analyzed by atomic emission spectroscopy using an inductively coupled plasma as excitation source, With the exception of copper and zinc (concentration ranges 0.013-0.159 mg/L and 0.072-0.433 mg/L, respectively) no other heavy metals were detected by this method. These two metals are believed to be present in tap water in the concentration ranges measured in the effluents due to the low pH of drinking water in the Greater Vancouver area which causes copper and zinc to dissolve in copper piping.

Table 3.6 Contaminant Concentrations of Fish Processing Plant Effluents - B.C. Lower Mainland Plants

Specie Processed	BOD [mg/L]	COD [mg/L]	TS [mg/L]	TSS [mg/L]	Oil & Grease [mg/L]	Fecal Coliform [MPN/100 mL]
Salmon	20-2680	30-3500	220-3640	11-2180	1.5-490	50-1,700,000
Salmon/Groundfish	150-1000	80-1340		20-290	2-180	
Groundfish	35-370	165-790		45-1”95	18-80	
Groundfish/Halibut	165-1670	185-2460		28-960	8-100	
Herring	20-1745	25-4864		25-400	6-75	
Surimi	160-3400 (1)		5500 (2)	330-5300 (1)		<2-33,00 (3)
Surimi	2100-5000 (total) 990-2800 (soluble)			1160-3560	41-200	

Source: NovaTec, 1990, 1993b; NovaTec and EVS, 1994;
(1) Aquametrix, 1993a
(2) Aquametrix, 1993b
(3) Environment Canada, 1993

Table 3.7 Production-based Contaminant Discharge - B.C. Lower Mainland Fish Processing Plants

Specie Processed	BOD [kg/1000 kg of product]	COD [kg/1000 kg of product]	TSS [kg/1000 kg of product]
Salmon	1-66	3-44	1-167
Salmon/Groundfish	1-16	2-25	1-8
Groundfish/Halibut*	1-18	1-7	0.2-3
Herring	0.2-10	0.3-12	1-3

Source: NovaTec and EVS, 1994

* Derived from limited data base

Table 3.8 Selected Heavy Metal Concentrations in Effluent from Four Fish Processing Plants

Metal	Concentration [mg/L]
Cadmium	< 0.02
Chromium	< 0.015
Copper	0.013-0.159
Nickel	< 0.04
Lead	< 0.1
Zinc	0.072-0.433

Source: NovaTec and EVS, 1994

Note: < Not detected at the detection limit indicated.

A battery of four different toxicity tests were carried out including acute and chronic toxicity tests, such as the 96hr LC50 test using rainbow trout, and the seven day Ceriodaphnia dubia. A summary of the test results is shown in Table 3.9. Several effluent samples failed some or all of the toxicity tests, which was attributed to high effluent ammonia concentrations and/or BOD. Unlike persistent toxins, which present the possibility for harm at some future time and place even when regulated to non-toxic levels, ammonia exerts immediate toxicity (Lewis, 1988). Ammonia toxicity to aquatic species is well documented. It is also widely recognized that ammonia toxicity is a function of pH, temperature and concentration of degradable organic material in the effluent (most often reported as BOD). Difficulties encountered in toxicity determination include dissolved oxygen depletion during the test as a result of high BOD in the effluent, and synergistic/antagonistic effects of ammonia and pH, temperature and BOD, as discussed elsewhere (Lewis, 1988; Aquametrix, 1993a; NovaTec and EVS Environment Consultants, 1994; NovaTec, 1994) and is beyond the scope of this report. Toxicity tests are normally carried out without pH adjustment unless the pH of the test solution is outside the range 5.5 to 8.5, and aeration is restricted to a minimal rate of 7.5 mL/minL-’ (Environment Canada, 1990).

Table 3.9 Toxicity of Effluents from Three Fish Processing Plants

Test Type	Test	Samples Failing Toxicity Test	Range
Acute	Rainbow Trout (LC50)	5 of 9	37- **>100%**
Acute	***Ceriodaphnia Dubia*** (LC50)	8 of 10	**0.5->** 100%
Chronic	***Ceriodaphnia Dubia*** **(IC50)**	5 of 5	5- 60 %

Source: NovaTec and EVS, 1994

3.2.3 BOD Loading Estimate

Based on available BOD data, an attempt was made to estimate an order of magnitude BOD loading associated with effluents discharged from all fish processing plants in B.C. in 1993. To establish this estimate, BOD mass loadings (kg BOD/tonne of fish landed) were calculated using monitoring data obtained from MOELP, the GVRD, the City of Vancouver, and a previous NovaTec study (NovaTec and EVS, 1994). The data was examined and determined to be logarithmically distributed. Consequently, the geometric mean was selected as the most appropriate statistic upon which to estimate contaminant loading. This estimate excludes the BOD contribution of wastewater from three plants which are permitted to grind and discharge their waste (see Section 5.1.1), as no BOD data is available for this waste stream. Subgroups within this total were also calculated. The subgroups considered were:

- direct discharge to marine waters;
- direct discharge to the Fraser River;
- direct discharge to municipal sewers.

The BOD loading estimate for effluents discharged to marine waters was calculated in the following way: The largest processors discharging to marine waters (accounting for approximately 95 % of the sum of the permitted daily discharge flows) were contacted to obtain the total amount of fish handled by these processors in 1993. (Production data were provided by the plants on a voluntary basis.) This amount was then multiplied by the mass loading estimate, and added to the BOD loading due to surimi processing. The latter was estimated separately based on effluent concentration and flow data, as surimi processing typically results in effluent with higher BOD than other fish processing.

The loading estimates for discharges to the Fraser River and discharges from all B.C. fish processing facilities were determined in an analogous manner, whereas the loading froml plants discharging to a sewer system was assumed to account for the balance of the total estimated 1993 loading. The breakdown of the estimated 1993 BOD load is shown in Table 3.10.

The estimated 1993 BOD loads were compared to population equivalents based on a per-person-per-day BOD equivalent of 100 grams BOD (see Table 3.10). Based on these assumptions, the estimated 1993 BOD load from all fish processing plants in BC excluding surimi processing had a population equivalent of approximately 30,000 people. If surimi processing is included in the calculation (including a BOD loading estimate for Ucluelet Seafood Processors, a surimi processing plant which did not process surimi in 1993) the population equivalent is approximately 50,000 people. It should be pointed out that the comparison was carried out assuming an even landing through the year. In reality, the monthly population equivalent loading would be considerably higher during the peak processing months (peak loading) and lower during the off-peak period. Although only peak loadings are of environmental concern at a specific site, assessment of environmental impacts on receiving environment was beyond the scope of this report. Annual loading averages were selected for use for comparative purposes.

Table 3.10 Estimated BOD Load and Population Equivalents

Source	Excluding Surimi Processing			Including Surimi Processing*		
	1993 BOD Load Estimate [tonne/year]	Population Equivalent	Fraction of Total [%]	BOD Load Estimate* [tonne/year]	Population Equivalent	Fraction of Total [%]
Effluent to Municipal Sewers	350	9600	32	750	20500	42
Effluent to the Fraser River	180	5000	17	180	5000	10
Effluent to Marine Environment	560	15200	51	860	23600	48
Total from all Fish Processing Facilities	1090	29800	100	1790	49100	100

* Includes BOD loading estimate for Ucluelet Seafood Processors (a surimi processing plant).
The estimate is based on 1992 data, as Ucluelet Seafood Processors did not process surimi in 1993.

4 PROCESSING TECHNOLOGY

The five major types of fish processing on Canada's West Coast are:

- Groundfish processing;
- Salmon processing;
- Herring processing;
- Shellfish processing;
- Surimi processing.

Each group has a unique production process. Variation in processing procedures are found from plant to plant, but the major features of each type of production are quite consistent and are discussed below.

4.1 Vessel Unloading

Vessel unloading is common to all fish processing. It can be done with wet (siphon) or dry (vacuum) pumps, or with buckets or baskets. Dry pumps result in rough handling of , the fish and are generally only used for ground fish due to the relatively low commercial value of the fish. Wet pumps are much gentler and are used for freshly caught herring and salmon which are kept in water inside the holds of fishing boats and fish packer vessels during transport. The pumps use large diameter hoses to pump water and whole fish out of the vessels' holds. Water and fish are then discharged onto grating to allow the separation of fish and water. A certain amount of water is recirculated to the vessels to ensure sufficient water for the operation of the pumps and to be able to remove all fish. The water level in the vessel is continually lowered during the unloading operation and the vessel, generally, is almost completely empty when all fish have been unloaded.

Conveyors pick up the fish after their separation from the vessel hold water and transport them to grading stations, where the fish are manually sorted according to their species. After sorting, fish are kept in chilled water or ice for intermediat'e storage until they can be further processed. Grading is not required for herring.

Baskets or buckets can also be used to unload vessels but are, generally, only used if small quantities of fish need to be unloaded, or to offload frozen fish. In these cases baskets are lowered into the vessels holds by a crane and filled with frozen fish.

4.2 Groundfish Processing .

With the exception of halibut, groundfish species preprocessed in somewhat the same manner (Riddle and Shikaze, 1973). The fish are either stored whole on the ship or are eviscerated prior to storage, the viscera and blood being washed overboard.

Most groundfish require no pretreatment prior to filleting (Riddle and Shikaze, 1973). In small plants, the fish are processed by hand. The fillets are cut on a board, washed and immediately iced in boxes for distribution.

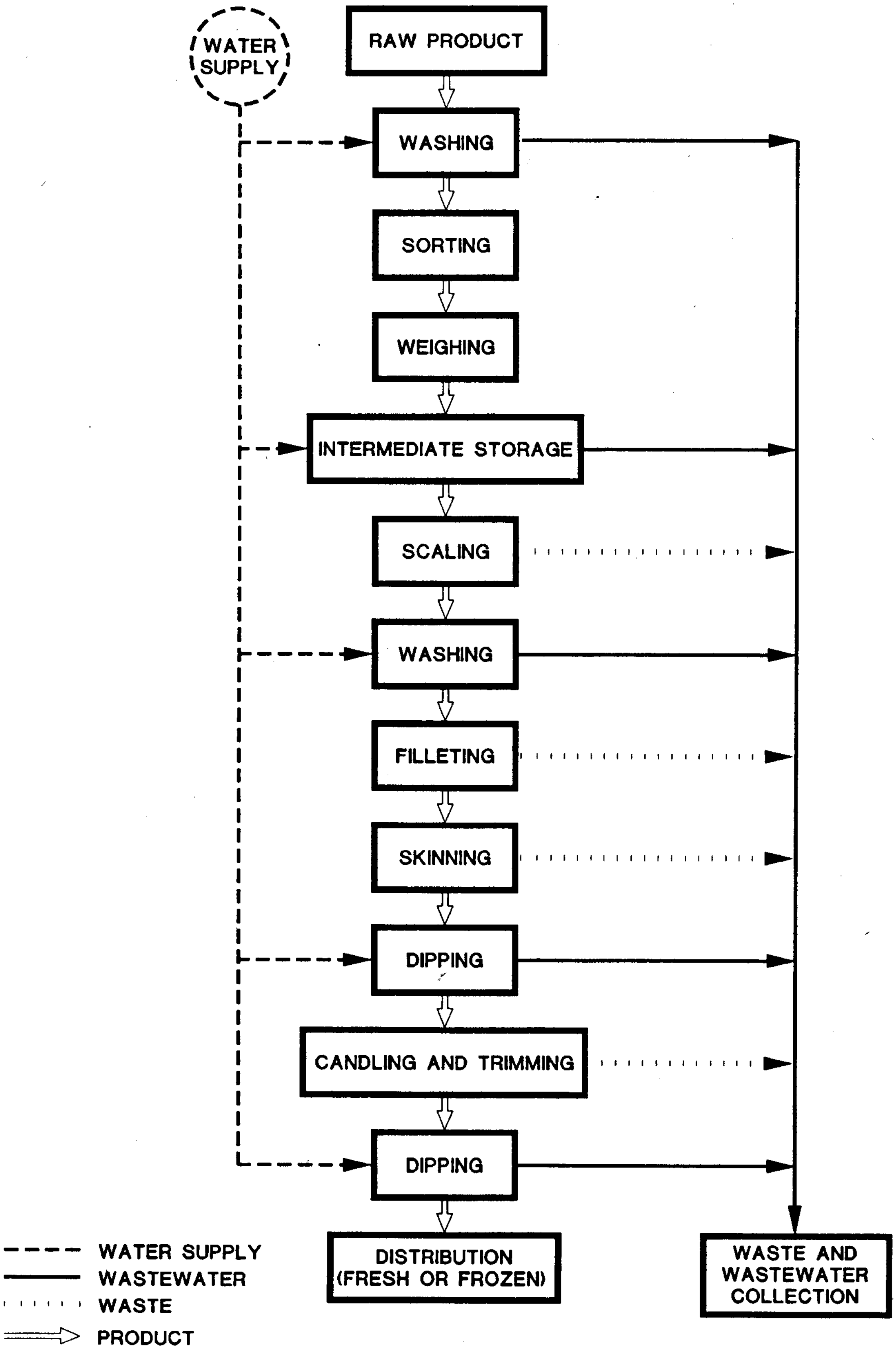
Most plants processing fillets use mechanized equipment (Riddle and Shikaze, 1973). The fish are first washed in large wash tanks or by water sprays. Next, the fish pass to filleting machines or hand filleting tables. The skin is removed from fillet by hand or machines. The solid wastes from filleting, skinning and candling operations (inspection by shining light through fillets to detect and subsequently remove parasites) are usually rendered for pet food or animal meal (Riddle and Shikaze, 1973). Figure 4.1 outlines a typical groundfish filleting operation.

The skinned fillets are transported by conveyor belt through a washing tank and, in some cases, a dip tank. After inspection the fillets are packed into containers by hand or are frozen and then packed.

Halibut processing involves dressing by removing the viscera and cutting away the gills. The halibut are then packed in ice in the holds. If the fish are not processed immediately, they are re-iced in the fish processing plants. The majority of halibut are filleted and marketed frozen. Some halibut are frozen whole or sold fresh. Prior to whole freezing, a continuous belt washer sprays the fish. The fish are frozen with a glaze protection at approximately -250 C (Riddle and Shikaze, 1973). Halibut can be cut in fletches (boneless and skinless pieces). The fletches are either glazed or packaged in moisture-proof wrapping.

4.3 Salmon Processing

Spring, coho and some pink and sockeye salmon are caught using trolling techniques, whereas the remaining species of salmon are netted. Troll caught salmon are gutted at sea and stored on ice, or frozen at sea.



(ADAPTED FROM: FCBC, 1993)

FIGURE 4.1
TYPICAL GROUNDFISH FILLETING OPERATION

4.3.1 Butchering for Freezing

A typical flow diagram depicting freezer - dressing of salmon and associated processes is shown in Figure 4.2. The equipment used for salmon butchering (also referred to as "dressing") depends on the requirements for further processing. Dressing fish for freezing involves the removal of the head and gutting of the fish. The tails, fins and the collar bone immediately behind the head are not cut off. The eggs (or roe) of the female fish are removed for further processing, and the milt of the male is removed at this stage.

Butchering for freezing is done manually or with semiautomatic dressing lines. The manual dressing lines consist of a large table and fish cleaning station, where workers are responsible only for specific tasks, such as:

- head removal
- belly slitting
- removal of viscera and separation of milt and/or roe
- removal of the kidney
- cleaning of fish

The final cleaning of the fish is done with a spoon which is directly attached to a small water hose to both scrape and flush remaining viscera and blood away.

Offal from dressing tables may be dropped' on the floor, into totes for collection, or chutes which discharge to a flume or dedicated offal conveyance system.

On the semi-automatic processing lines, fish are placed belly up in a pocket conveyor after their heads have been removed. Head removal can be achieved manually or automatically. The bellies are then slit manually; guts, and roe or milt are removed by hand and separated for waste disposal, or further processing, followed by the cutting of the kidney. The fish are then cleaned with nozzles attached to suction hoses which remove remaining guts and blood by vacuum, and with spoons attached to small water hoses as in the case of manual cleaning. The dressed fish are then washed, graded, and frozen.

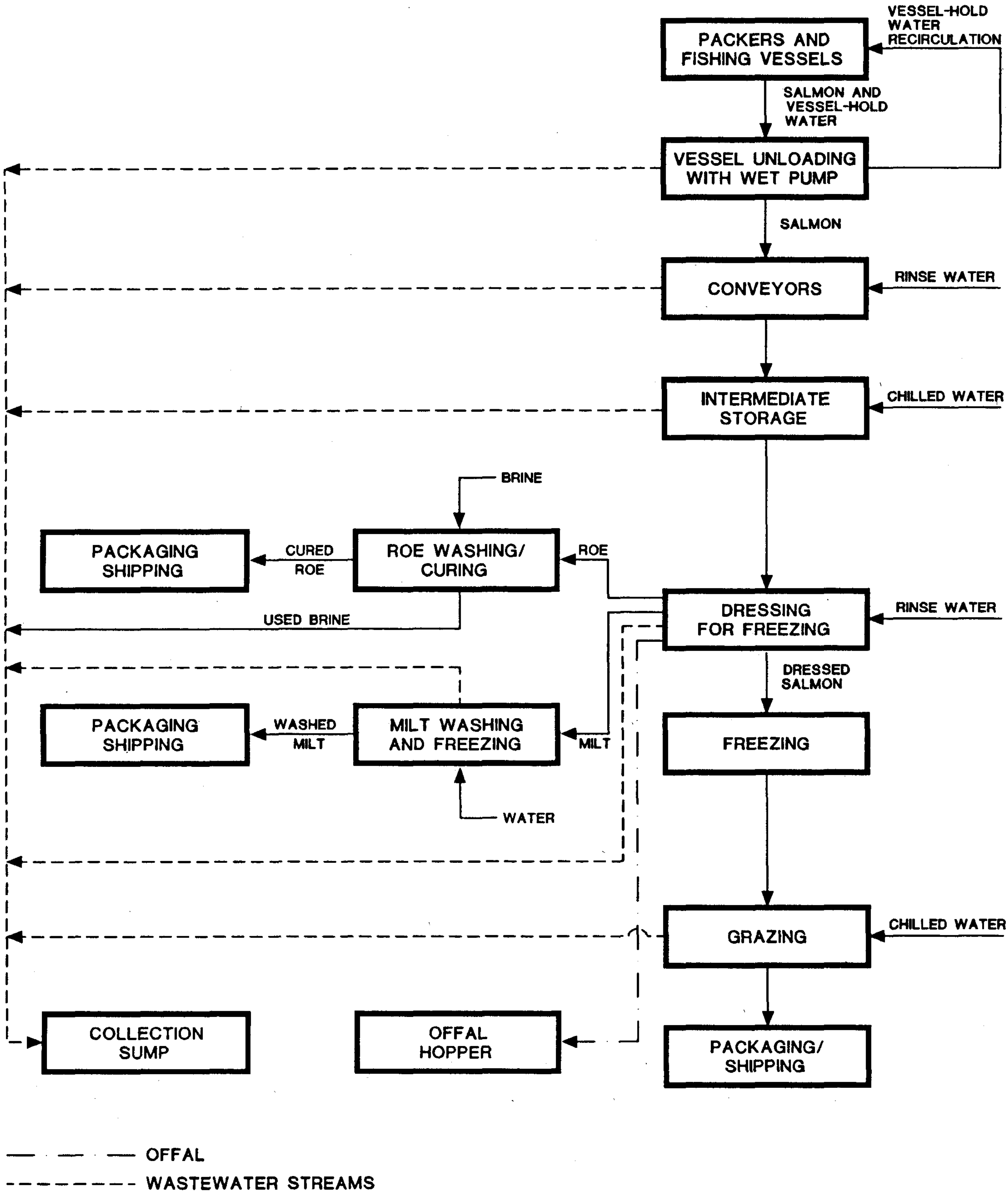


FIGURE 4.2
TYPICAL SALMON DRESSING FOR FREEZING

4.3.2 Butchering for Canning

A typical flow diagram for salmon canning is shown in Figure 4.3. Dressing for canning is generally done with an iron butcher which cuts off heads (including the collar bone), tails and fins. Although the iron butcher can be used to slit and remove the viscera, this is usually done by gutting and washing machines which results in better cleaning. Entrails are removed with rotating wheels and brushes. Final cleaning is with water sprays.

The wash water, mixed with guts and blood, drains out at the bottom of the gutting machines.

The fish are inspected after the gutting process and are further manually cleaned if necessary. During this cleaning step, workers scrape and cut off remaining entrails and fins, and remove bruises and blood clots. Typically, each manual cleaning station is equipped with a small, constantly running, water hose to rinse off any offal and/or blood.

4.3.3 Salmon Canning

Salmon, butchered as described in Section 4.3.2, is fed into filling machines which cut the fish into sections of appropriate size for the cans to be used in the canning machines. Canning machines then press the salmon sections into cans which are subsequently inspected by workers who rearrange the material in the cans for aesthetic purposes and add additional material to under-weight cans (patching), if necessary. Lids are then lightly clinched onto the cans, and the cans are sealed in the seamers which operate under vacuum.,

Following the sealing, the cans are washed and placed in busses (slatted metal baskets with movable bottoms) and pressure cooked in large retorts. After the cooking process the cans are cooled with water, which must be chlorinated to a concentration of at least 2 mg/L for a minimum of 20 minutes to ensure disinfection.

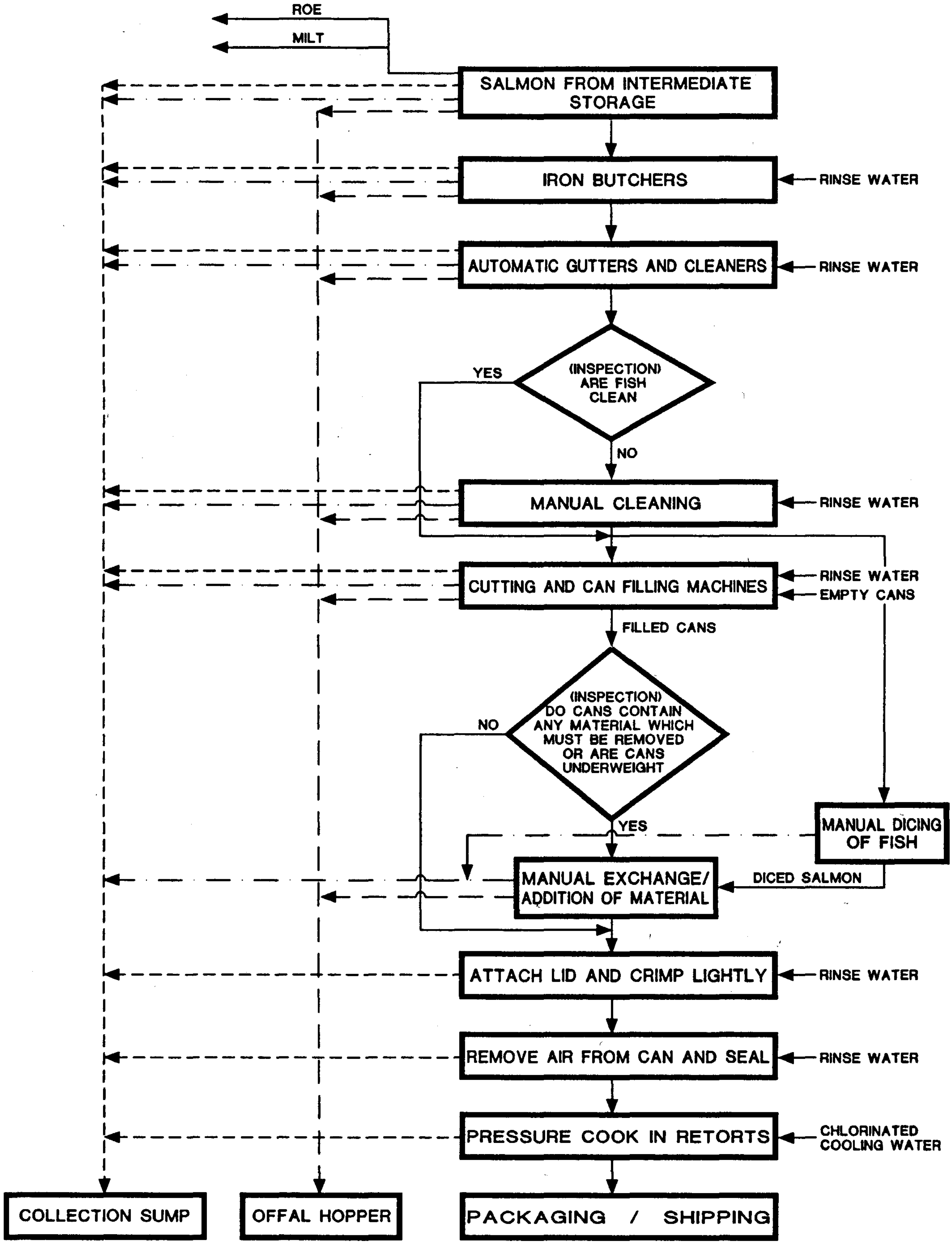


FIGURE 4.3
TYPICAL SALMON CANNING

4.3.4 Salmon Roe Processing

The roe collected during the fish dressing (butchering for freezing or canning) is further processed by washing and curing in a concentrated brine solution for 20 minutes. Washing and curing takes place in agitated, circular tubs. The brine is replaced after each five batches of roe processed.

4.3.5 Salmon Milt Processing

Milt processing only involves washing the milt in water and freezing prior to shipping.

4.3.6 Glazing

Frozen salmon generally receive a smooth coating of clear ice glaze prior to final packing and shipping. This glazing is accomplished by either spraying already frozen fish with a fine water spray, or by dipping the frozen fish into chilled water. After glazing the frozen fish are packed in plastic bags and placed in boxes for shipment.

4.3.7 Farm Salmon Processing

Farm salmon processing differs from wild salmon processing because farm salmon can be transported live to processing facilities. This allows bleeding-out of the fish prior to processing which improves shelf life, appearance and quality. Farm salmon are mainly processed for the fresh fish market.

After live-hauling to a processing facility, the fish are removed from the water with a wet pump, cut behind the gill arch on one side of the head and placed in water-filled totes for bleeding. Further processing consists of eviscerating, cleaning and washing which may be done manually or with vacuum suction as described in Section 4.3.1. Fins and tails are not removed and even the heads are generally not cut off.

4.4 Herring Processing

4.4.1 General

The main product of herring processing in the B.C. Lower Mainland is cured herring roe. However some processing of herring caught in the fall does occur. Due to the relatively short fishing season and the necessity for freezing herring to preserve fish shape and quality of the roe, herring processing is divided into two distinct phases:

- Vessel unloading and freezing, and,
- Thawing, roe “popping”, and roe processing.

These phases take place at different times. The fish processing operations that occur during the individual phases are described in detail in the following sections.

4.4.2 Freezing

Herring are delivered to the fish processors suspended in chilled seawater in the holds of fishing boats and fish packer vessels. Vessel unloading is done with wet pumps, as described in Section 4.1. Intermediate storage of the herring may be required, as the capacity of the vessel unloading pumps may exceed the throughput of subsequent handling steps.

Freezing generally takes place in brine freezing channels which contain a saturated sodium chloride solution at -180 C followed by tunnel” freezing to rapidly freeze the individual fish.

Herring sex sorters are available to separate male from female herring. The use of such sorters results in reduced water consumption and wastewater contaminant loadings, and reduces labour requirements for subsequent handling steps, as all male fish would be sent to a reduction plant rather than undergo additional handling (washing, freezing, and belly slitting - see Section 4.4.3). Ideally, sex sorting of herring should take place immediately after vessel unloading.

4.4.3 Thawing and Roe Popping

Herring may be thawed in water or in air. Air thawing is substantially more Iabour intensive than water thawing and requires placing the frozen herring on racks for thawing. Air thawing also generates wastewater, as the thawed herring are generally stored in water until roe popping takes place.

When the thawing process is complete, the fish are separated from the tote water using tote dumpers. Conveyors then transport the fish to popping stations for roe removal. At manual popping stations the fish are broken open, and the roe removed and collected. The fish carcasses are collected separately.

Automatic roe popping machines which only require the fish to be manually placed on an infeed belt are also available. These machines also separate the roe from the milt of the male herring, although this separation is not without errors, and further manual separation of milt from roe and vice versa is required. The milt is collected with the carcasses and generally is directly transported to offal hoppers.

The roe from manual and/or automatic popping is rinsed with water, and washed and cured in diluted brine, followed by the curing of the roe in concentrated brine for four to seven days.

After curing, the roe is manually graded, packed in pails to which concentrated brine and salt is added, and shipped.

Carcasses, milt and other offal may be used for pet food production, or production of fish meal and oil.

4.5 **Shellfish Processing**

4.5.1 Shrimp Processing

The simplest of the shrimp processing operations is that of the packing plant which receives the shrimp either whole or deheaded, deheads them if necessary, weighs the catch and packs it in ice for shipment to another processor for breading, freezing or canning.

Raw shrimp are held on ice for about 2 days after catching to allow proteolytic enzymes and microorganisms the time to break down connective tissue between meat and shell to improve peelabilty. This deterioration also increases water-holding capacity and the holding period results in an increased bacterial load on the raw shrimp (Nielsen et al., 1983).

Iced shrimp are dumped into a melt/feed tank where potable water is continuously introduced to melt the ice and distribute the shrimp on the precooker conveyor. In the precooker, live steam is injected to provide optimum peeling and recovery of meat. In the precooker, the microbial load is reduced. The precooked shrimp fall onto the oscillating rollers of the peeler which pull extraneous parts from the meat. Water sprays loosen and wash away waste. Waste and the sprayed water are flumed away to a waste sump.

From the peeler the shrimp fall into the first of several flumes which lead to cleaning and separating steps. Mesh belt conveyors and elevators permit the flume water to pass through the mesh belt and onto the floor, from where it is discharged. After mechanical cleaning operations, the shrimp are flumed onto a table or “picking belt” where workers hand sort and clean the shrimp. Shrimp meat is salted by spraying with a salt solution or immersing it in a salt tank. Shrimps are often hand-packed into cans, vacuum sealed, and refrigerated or frozen. A typical flow diagram of shrimp processing is illustrated in Figure 4.4 (Horn and Pohland, 1973).

4.5.2 Crab Processing

Crabs are harvested from shallow water and transported to a processing plant. The crabs are loaded into baskets, briefly rinsed with tap water and then loaded into cookers. After the crabs are loaded and the cooker closed, steam is applied. The baskets are then removed from the cooker and stored overnight in a walk-in refrigerator. The backs and claws are then removed and the remaining viscera washed free. The crab meat is then either manually or mechanically picked and placed in plastic containers for shipment to market. A typical crab processing flow diagram is presented in Figure 4.5 (Horn and Pohland, 1973). Claws may be canned whole or the meat extracted and canned. The edible meat produced from the crab is only 10 to 15 % of the total live weight before cooking.

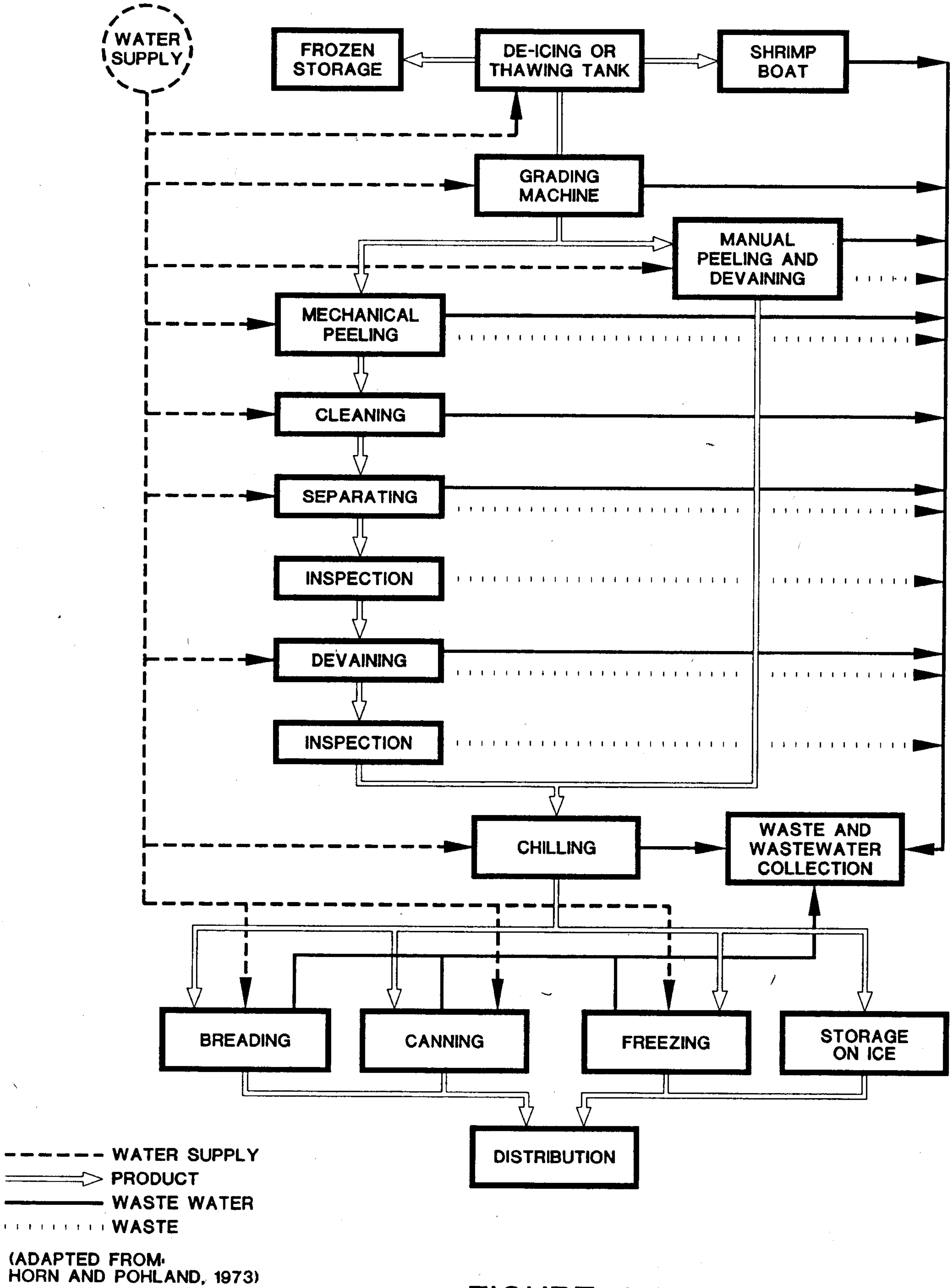


FIGURE 4.4
TYPICAL SHRIMP PROCESSING

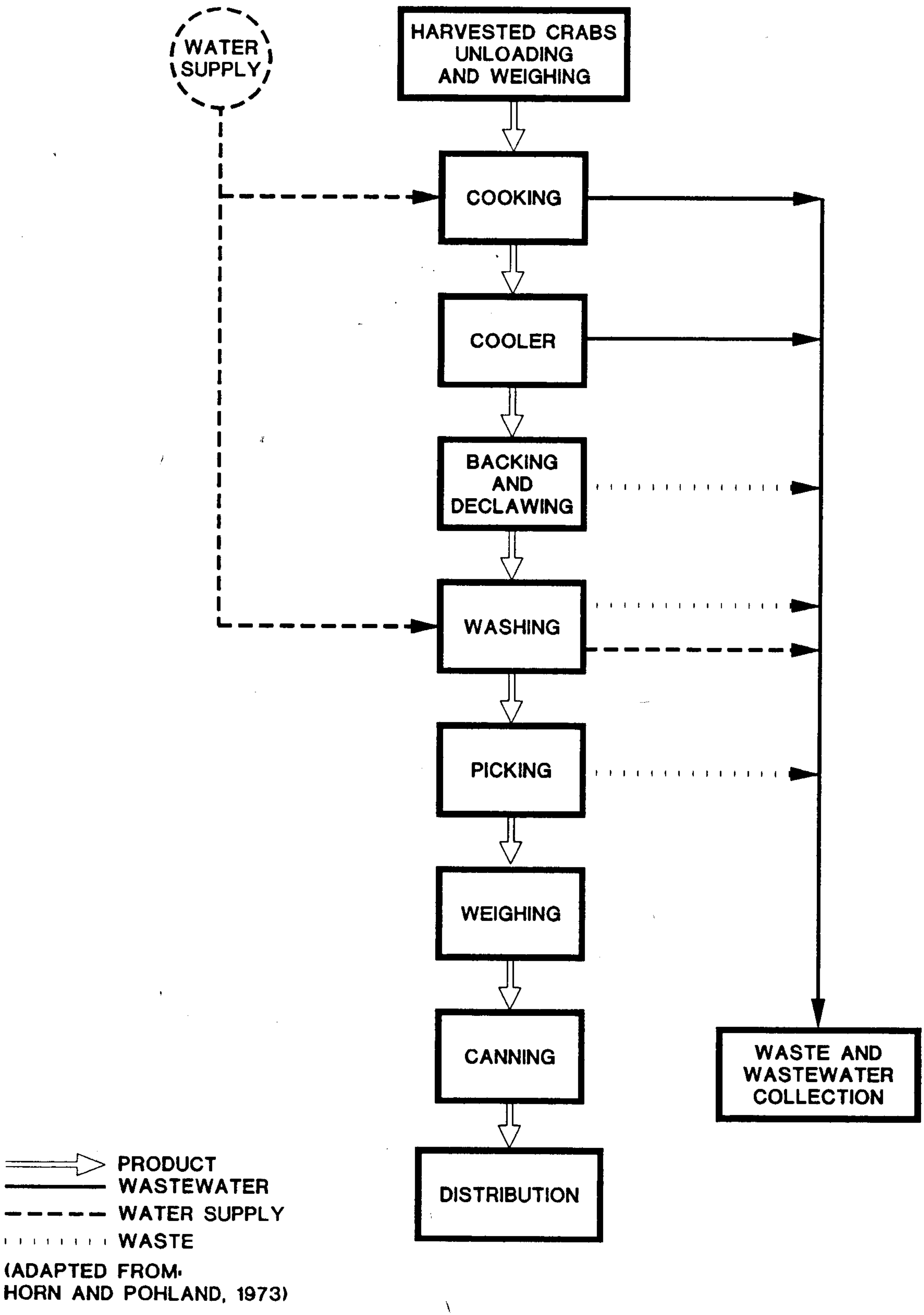


FIGURE 4.5
TYPICAL CRAB PROCESSING

4.5.3 Oyster Processing

Oyster processing involves cutting the muscles, which keep the shells closed, with a knife. Following this, the meat is taken out of the shells and washed in cold water. Oyster meat may then be stored on ice for sale on the fresh seafood market, or further processed.

4.5.4 Clam Processing

After the clams are shucked, the meat is washed, minced and packaged for distribution. A typical clam processing operation is shown in Figure 4.6 (Hood and Zall, 1979).

4.6 **Surimi Processing**

The frozen surimi process was first developed by the Japanese in the late 1950’s as a means of increasing the supply of high quality fish meat required to produce traditional dishes. Surimi is a highly refined form of fish muscle protein whose primary quality attribute is the ability to form strong, heat-induced gels which possess a high capacity for immobilizing water (Green et aI., 1984). Other desirable product attributes include whiteness of colour and the absence of fishy odours and flavour.

The overall process of modern surimi production is summarized in Figure 4.7 (Ohshima et al., 1993). The fish should be handled carefully since fish freshness affects the quality of the surimi; fresher fish results in higher quality products. The head, viscera and a major part of the backbone are removed with a header/gutter, followed by filleting with a mechanical filleter. During subsequent processing, the muscle tissues are separated and removed from the skin. The crude muscle tissues thus obtained are then extruded over a rotating stainless steel drum with small pores to obtain the minced meat. Usually three or four separate ‘tanks each filled with cold fresh water are used in washing the minced meat. This step removes most of the water soluble protein (Ohshima, 1993). The washed meat is then passed through a refiner to remove any remaining small bones, skin, dark muscle tissues and scales. Excess water being held in the washed meat is then removed using a screw press. Preservatives are added to the product which is packed in a freezing pan and frozen quickly to below -25 ^{o}C using a contact freezer. The only two surimi processing facilities in B.C are the Ucluelet Seafood Processors and Pacific Coast Processors, both located in the village of Ucluelet on Vancouver island.

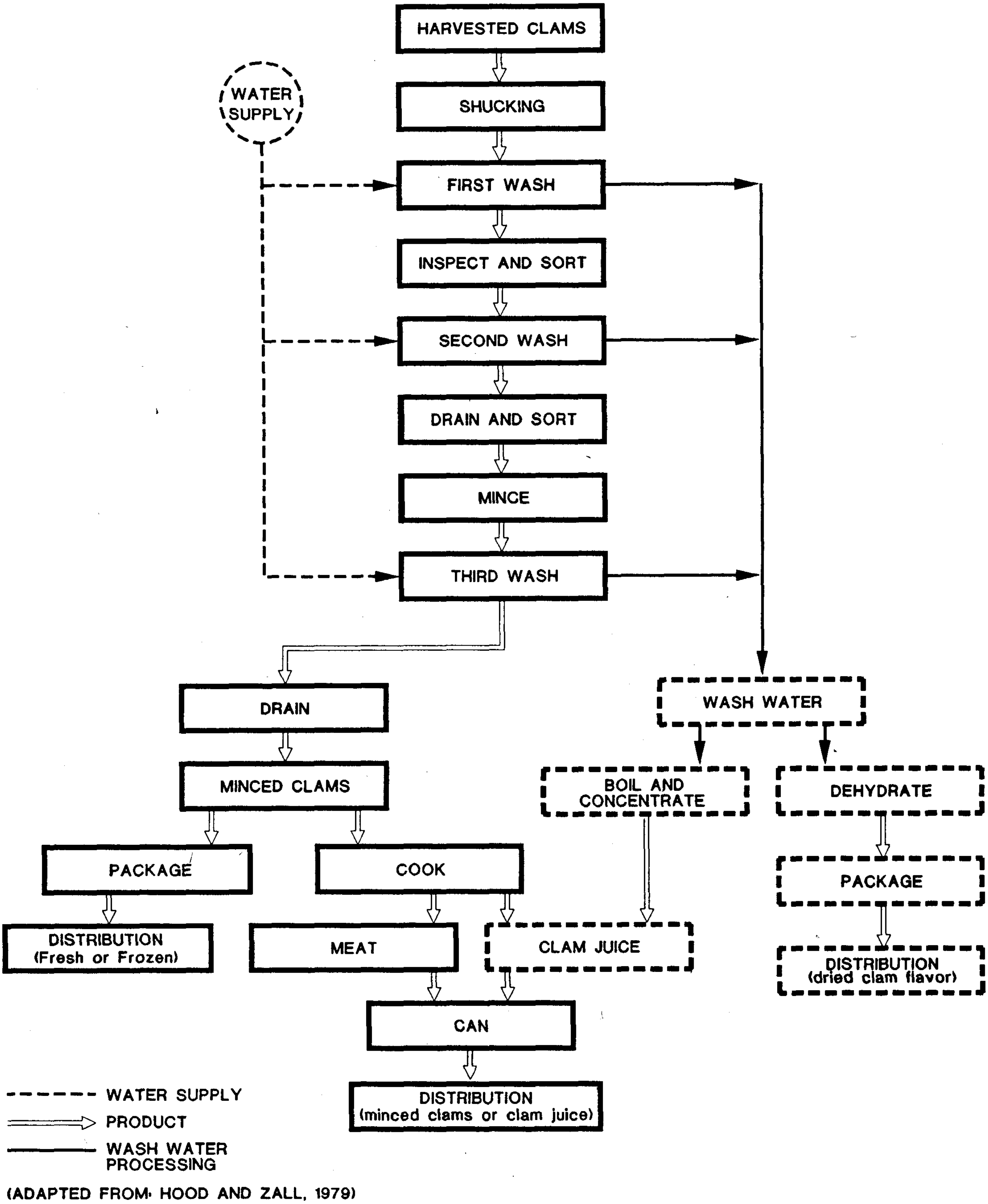


FIGURE 4.6
TYPICAL CLAM PROCESSING

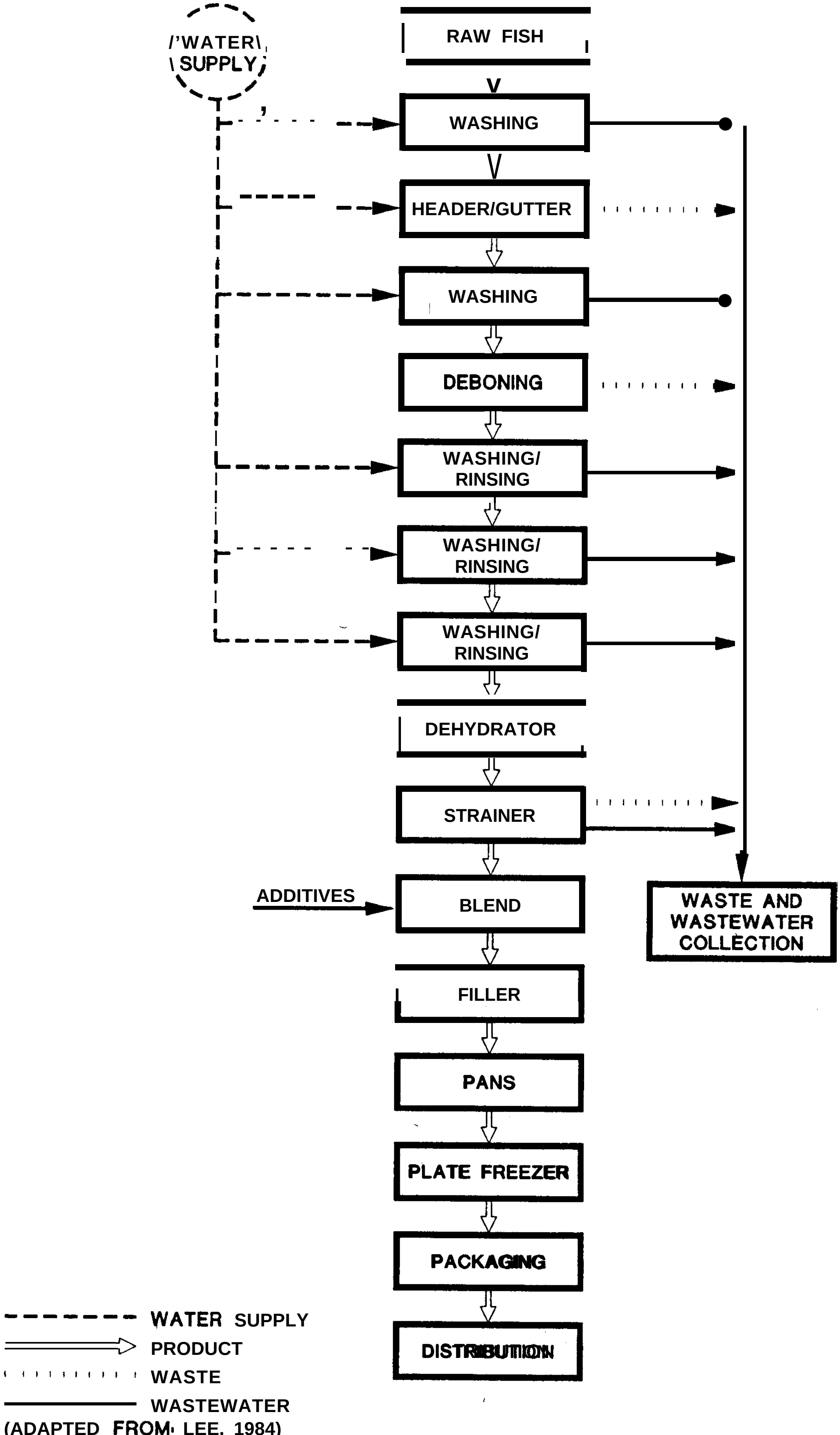


FIGURE 4.7
TYPICAL COMMERCIAL SURIMI PROCESSING

5 WATER AND WASTE MANAGEMENT

5.1 Current Practices in British Columbia

5.1.1 General

Fish processing plants in B.C. discharge either to municipal or regional sewer systems, or directly to the environment (mainly the Fraser River, Pacific Ocean, and Straight of Georgia). To determine the number of processing plants discharging to the environment, copies or summaries of Waste Management Branch discharge permits were obtained from the appropriate local MOELP offices. Comparing the number of permits to the total number of Licensed Facilities (173, see Section 2.3) shows that the majority of all facilities do not discharge directly to the environment, but are connected to sewer systems. However, several of the largest processing plants in B.C. discharge to the environment (i.e. British Columbia Packers Limited, Ocean Fisheries Ltd.), Compared by region, the majority of the fish processing facilities located in the Lower Mainland (85 %) and on Vancouver Island (83 %) were found to discharge to the sewer, whereas the majority of the facilities located in other areas of B.C. discharge directly to the environment (Figure 5.1). Based, on water consumption rates (Table 3.2) and landing in 1993 (Table 5.4), total discharge volume from all fish processing plants in B. C., except shellfish processing plants, was 1.5 to 5.5 million cubic meters.

MOELP discharge permits were also reviewed to determine the status of treatment in place for effluents discharging to the environment (Figure 5.2). Effluent treatment at fish processing plants discharging into the environment generally involve screening (73 %, or 27 plants). However, three plants (8 %) ‘located in remote areas and discharging into a well flushed environment, are permitted to grind and discharge fish offal. To the knowledge of the authors, B.C. fish processors currently do not implement any further treatment of the effluent besides screening.

Approximately 38 % of the plants discharging to the environment use 25 mesh (0.6 mm) screens, but smaller mesh screens are also in use (at least at four facilities). Four (1%) of the processing facilities use basket strainers in drains, screen-covered floor drains, and other screens with mesh sizes larger than 1 mm. For the remainder of the facilities no information was obtained, or the size of the screens used is not specified in the discharge permits. All these facilities have minor discharge flows only.

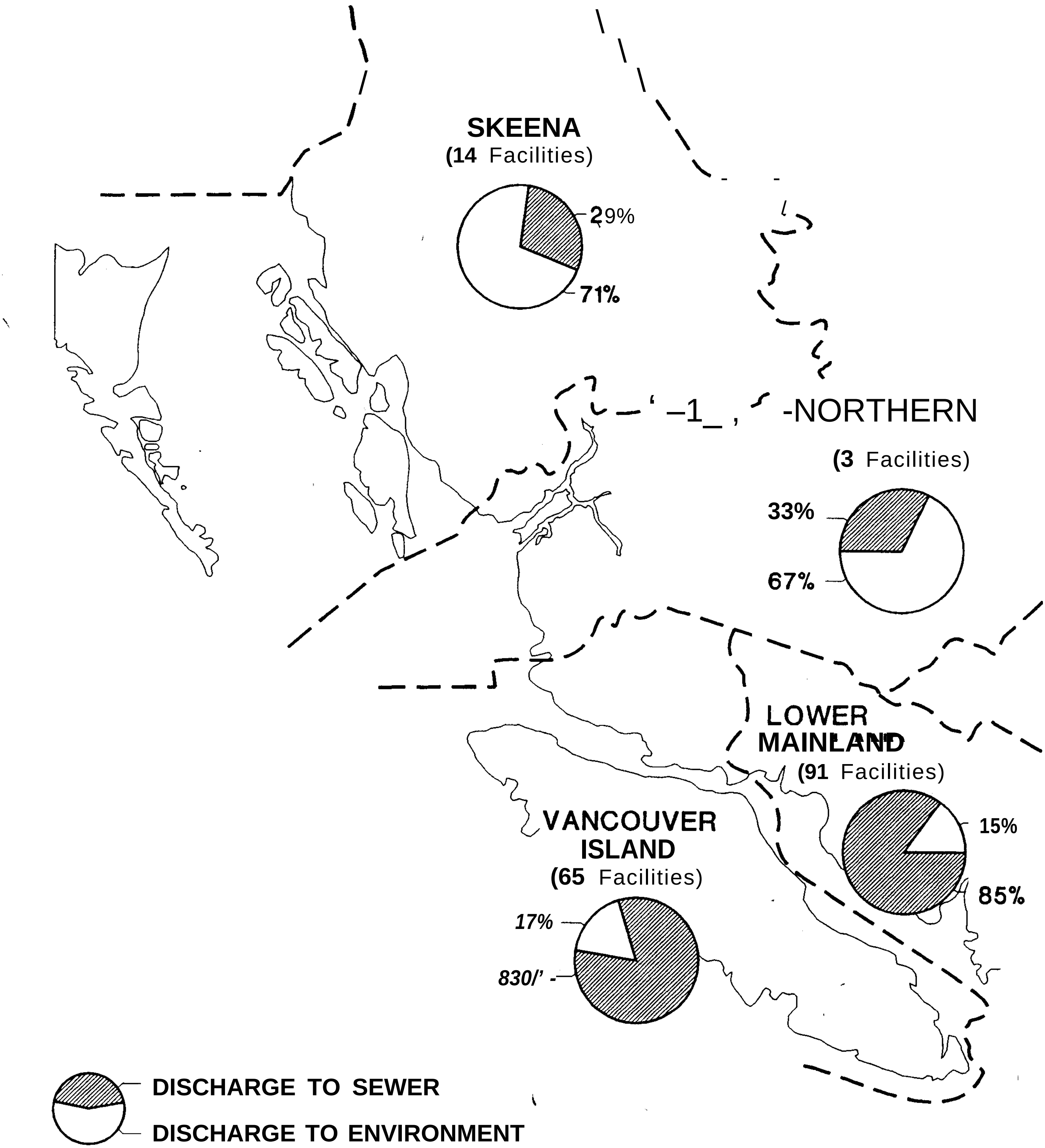


FIGURE 5.1
DISTRIBUTION OF FACILITIES DISCHARGING TO SEWER OR THE ENVIRONMENT - BY REGION

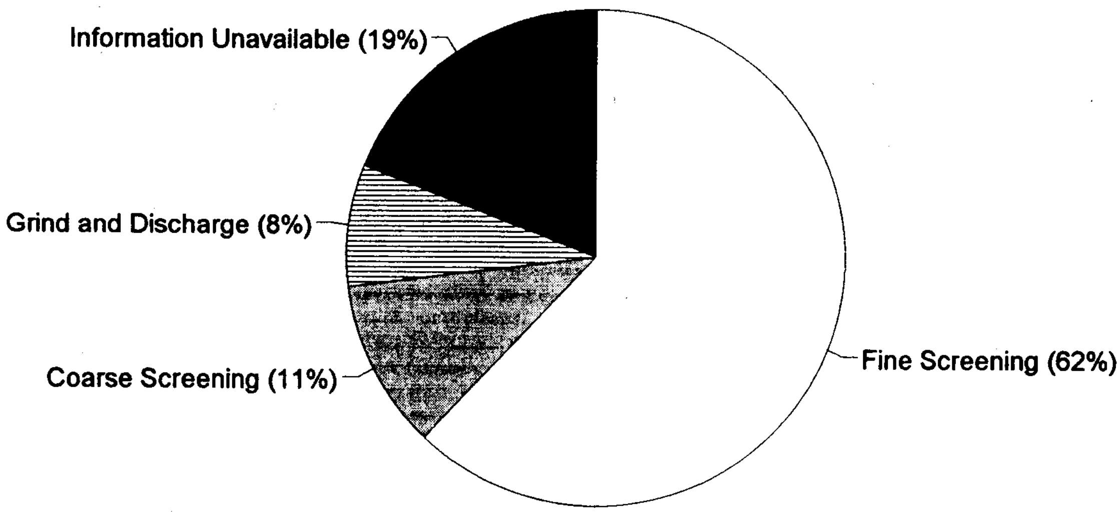


FIGURE 5.2
STATUS OF TREATMENT - DISCHARGE TO ENVIRONMENT

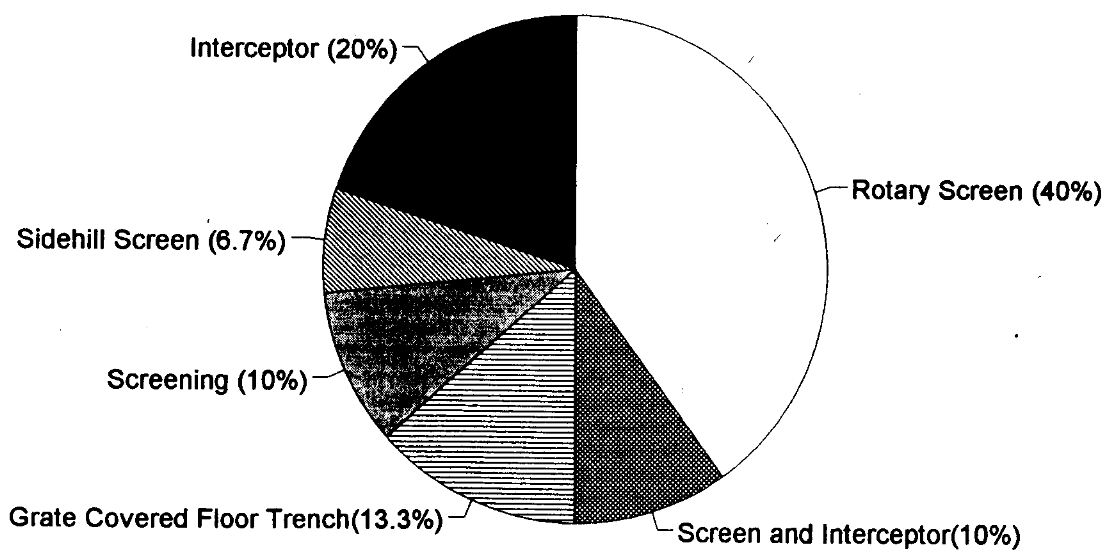


FIGURE 5.3
STATUS OF TREATMENT - DISCHARGE TO GVS & DD

The status of treatment for plants discharging to sewer was reviewed for those located in the GVS&DD (Figure 5.3). The individual discharge permits require treatment of the effluent prior to discharge to sewer. The level of treatment ranges from the use of grease and sand interceptors to screening (30 % and 80 % of all plants, respectively). Approximately 10 % of these facilities use a combination of the two forms of treatment. The screen sizes used in plants discharging to the GVS&DD is not specified in the permit.

A summary of MOELP, GVRD or City of Vancouver discharge permit requirements is presented in Table 5.1. Contaminant discharge concentration limits are generally 600 mg/L for TSS and 1000 mg/L for BOD for plants discharging to the GVRD, but to date have not been enforced. MOELP permits for the discharge of process water from fish processing plants generally do not contain BOD or TSS limits, and contain statements such as the requirement that the effluent quality should be equivalent to or better than typical fish processing plant effluent. For the purpose of calculating permit fees (which are based on the TSS and BOD loading of the effluent), effluents are assumed to exhibit a TSS concentration and BOD of 70 mg/L and 100 mg/L, respectively. Effluent concentrations generally exceed these assumed values. However, permit fees are determined by multiplying the assumed concentrations by the product of the maximum permitted daily discharge flow, by the number of days per year, by the unit fee for each parameter. Therefore, permit fees are also to be paid for days during which no processing takes place. It is probable that permit fees would be in the same order of magnitude should they be paid on actual concentrations (i.e. organic load, hydraulic load and days of operation per year).

A summary of fish processing effluent discharge regulations in selected European jurisdictions is presented in Table 5.2. Experts from the Danish Institute for Fisheries Technology and Aquiculture, however, expressed the opinion that the lowest BOD level that industry could achieve is 100 -150 mg/L. They also recognized that the set limit of 15 mg/L BOD is not economically achievable by fish processors using currently available technology (NovaTec, 1993a).

5.1.2 Water Consumption and Wastewater Management

Wastewater management practices in place at fish processing facilities in the Pacific Northwest' (B. C., Alaska, Washington, and Oregon) range from grinding and discharging

Table 5.1 Permit Summary

Name	Permit No.	Flows		Effluent Quality			Authorized Works	Discharge
		process	cooling	BOD mg/L	TSS mg/L	O&G mg/L		
		(m3/day)						
Vancouver Island Region								
Cape Scott Seafoods Ltd.	PE-8370	14					25 mesh screens	Outfall (100 m long; 12 m below MLW)
Seafood Products Ltd.	PE-2499	730					Fine screening; Stickwater evaporation	Outfall (106 m long; 20 m below MLW)
J.W. Timber Co. Ltd.	PE-8124	28					Rotostrainer (0.5 mm apertures)	Outfall (30 m long; 15 m below MLW)
Lions' Gate Fisheries Ltd.	PE-5255	2.5					none	Outfall (65 m long; 13 m below MLW)
Lions' Gate Fisheries Ltd.	PE-7952	150					Min 25 mesh screen	Outfall (5 m below MLW)
Mari Fish Ltd.	PE-8151	11					25 mesh screens	Two outfalls (90 m long;10 m below MLW)
Nimpkish Development Corporation	PE-8000	100					Coarse screens (12.5 mm), settling basin	Outfall (150 m long; 8.5 m below MLW)
Quartz Bay Sea Farms Ltd.	PE-7562	6					Fine screening	Outfall (70 m long; 14 m below MLW)
Rippingale Mariculture Ltd.	PE-8120	29					Screens (0.71 mm openings)	Outfall (10 m below MLW)
Tyrer Enterprises Ltd.	PE-3301	264/1200		300	120		60 mesh screen	
Walcan Seafood Ltd.	PE-5661	116					Fine screening	Outfall (20 m long; 6 m below MLW)
Northern Sub-Region								
Bella Bella Fisheries Ltd.	PE-8085	200					Mechanical grinder, coarse screen	Outfall
Pacific Canadian Fisheries/Booth Inc.	PE-4580	320					Fine grinding	Outfall
Skeena Region								
Aero Trading Company Ltd.	PE-07866	110					25 mesh screen	*
British Columbia Packers Ltd.	PE-01812	6000					25 mesh screen	*
British Columbia Packers Ltd.	PE-01816	75					25 mesh screen	*
British Columbia Packers Ltd.	PE-01829	500					25 mesh screen	Outfall
Canadian Fishing Co.	PE-08220	2400					25 mesh screen	*
Great Glacier Salmon Ltd.	PE-6776	184					none	Outfall
J.S. McMillan Fisheries Ltd.	PE-04748	1400					25 mesh screen	*
Prince Rupert Fishermen's Co-Op	PE-02498	3270					25 mesh screen	*
Ocean Fisheries Ltd.	PE-01862	600					25 mesh screen	*
Tenerife Packing Co. Ltd.	PE-07982	65					25 mesh screen	*

* Information not available
LW - low water
MLW - minimum low water

Note: The compiled list may be incomplete

Table 5.1 Permit Summary (cont'd)

Name	Permit No.	Flows		Effluent Quality			Authorized Works	Discharge
		process	cooling	BOD mg/L	TSS mg/L	O&G mg/L		
		(m3/day)						
.ower Mainland Region								
3ella Coola Fisheries Ltd.	PE-5400	1400	340				Rotary screen	Two outfalls (45 m long;6 m below LW)
3ritish Columbia Packers Ltd.	PE-1830	11800					Screening	Outfall (5m long; 3 m below LW)
:gmont Fish Plant	PE-7581	60					*	*
:inn Bay Seaproducts Ltd.	PE-7117	10					*	*
3reat Northern Packing Ltd.	PE-7810	3960					Rotary secreen (25 mesh size)	Outfall (80 m long at LW)
.ions' Gate Fisheries Ltd.	PE-3139	800	20				Rotary screen	Outfall (7 m long; 1 m below LW)
lew West Net Co. Ltd.	PE-8167	22.7					Coarse mesh	Outfall (15 m long; 4.5 m below LW)
)cean Fisheries Ltd.	PE-1975	7240					Sidehill and rotary screens	Outfall (24 m long; 6 m below LW)
'ender Harbour Fishing Co. Ltd,	PE-7555	3					*	*
;.M. Properties Ltd.	PE-8430	23					Strainers in the floor drains	Outfall (1m long; 1m below LW)
;canmar Sefood Ltd.	PE-7702	45					*	*
;hearer Seafood Products Ltd.	PE-7785	4.6					Wire mesh	Outfall (15 m long; 3.6 m below LW)
Vestview Fisheries Ltd.	PE-5299	0.6					*	*
Vood Bay Salmon Farm	PE-7552	40					*	*
3illingsgate Fish Ltd.	SC-1031						Screen covered floor trench	GVRD sewer system
:jord Pacific Marine Ltd.	SC-1045						Grate covered floor drains	GVRD sewer system
3reat Northern Packing Ltd.	SC-1025						Rotary screen and settling tank	GVRD sewer system
ling Lee Seafoods	SC-1052						Grate covered floor drains	GVRD sewer system
lokkai Marine Ltd.	SC-1033						Screening	GVRD sewer system
)rca Seafoods Ltd	SC-1034						Screening	GVRD sewer system
;canner Enterprises Ltd.	SC-1019						Rotary screen	GVRD sewer system
;ealand Foods International	SC-1080						Rotary screen	GVRD sewer system
;even Seas Fish Co. Ltd.	SC-1032						Screening	GVRD sewer system
;ir Richards Seafoods Inc.	SC-1028						Rotary screen	GVRD sewer system
'amazaki Enterprises	SC-1105						Grate covered floor drain	GVRD sewer system
;ero Trading Co. Ltd	SC910013	800			600	150	Rotary Screen	Vancouver City sewer system
,lbion Fisheries Ltd	SC910015	500			600	150	Rotary Screen, Interceptor	Vancouver City sewer system
,stra Industries Inc	SC910017	400			600	150	Rotary Screen	Vancouver City sewer system
ornstein Seafood Canada	SC910014	550			600	150	Rotary screen	Vancouver City sewer system
;anadian Fishing Company	SC910010	2,900					Rotary Screen, 3 DORR Oliver Inclined screens	Vancouver City sewer system
vergreen Foods Int - 1944 Franklin	SC920077	140			600	150	Interceptor, sand trap, concrete pad	Vancouver City sewer system
vergreen Foods Int - 323 Semlin	SC920078	100			600	150	Interceptor	Vancouver City sewer system
i-To Fisheries Ltd	SC910016	400			600	150	Rotary Screen	Vancouver City sewer system
.S. McMillan Fisheries Ltd	SC910012	1,500		1000	600	150	Rotary Screen	Vancouver City sewer system
iku Fisheries Ltd	SC920053	100			600	150	Interceptor	Vancouver City sewer system
eader Marine	SC930101	150			600	150	Rotary Screen	Vancouver City sewer system
orth Sea Products Ltd	SC910019	250			600	150	Rotary Screen	Vancouver City sewer system
)ceanfood Industries Ltd	SC920064	100			600	150	Interceptors	Vancouver City sewer system
rince Rupert	SC910011	1,900		1000	600	150	Rotary Screen	Vancouver City sewer system
ea World Fisheries Ltd	SC920056	150			600	150	Interceptor	Vancouver City sewer system
eafood Products Co.	SC910018	300			600	150	Drum Screen	Vancouver City sewer system
ung Fish Co. - 1722 Franklin	SC920051	150			600	150	Concrete offal pad, Interceptor	Vancouver City sewer system
ung Fish Co. - 1795 Pandora	SC920080	100			600	150	Interceptor	Vancouver City sewer system
ersacold Canada Corp (Ocean Fisheries)	SC910009	1,400		1000	600	150	Inclined Screen	Vancouver City sewer system

Information not available
W - low water
ILW - minimum low water

ote: The compiled list may be incomplete

Table 5.2 Effluent Discharge Regulations in Selected European Jurisdictions

Country	COD mglL	BOD mglL	Tot-N mglL	NH4-N mglL	Tot-P mglL	Remarks
Denmark	none none	15 none	8 none	none none	1.5 none .	For all discharges except fish processors Special dispensation to 1995 for direct discharge from fish processing plant
	BEST TECHNOLOGY ECONOMICALLY ACHIEVABLE					For fish processing plants
Norway	none	none	none	none	none	Screening and disinfection only to prevent fish disease transmission Fat separation for processors of over 1,000 t/y of fat fish
Germany	75 110	15 25	18 25	10 10	1 2	Where industrial discharge is below 67 % of total discharge Where industrial discharge exceeds 67 % of total discharge
EEC*	TO BE DETERMINED BY YEAR 2000					To be set in each member state by 31/12/1993 and comparison 10 be completed by EEC Commission by 31/12/94

Source: NovaTec, 1993c

*European Economic Community

offal with wastewater, which is the predominant offal disposal method in ‘Alaska, to fine screening, and the use of dissolved air flotation in one plant in Newport, Oregon (see Section 5.3.3). The level of treatment implemented depends to a large extent on the location of the plant. The level of treatment at B.C. fish processing plants is generally superior to that practised in Alaska and equal to that practised in Washington and Oregon. Only three processing plants grind and discharge their offal in B. C.. A flow diagram of a typical waste treatment scenario is shown in Figure 5.4.

Most fish processing plants in Northern Europe screen their effluent prior to discharge to . the municipal sewer or to a receiving water body. Screen mesh sizes vary from 40 to 5000 μm. The end of pipe treatment is not widely implemented and it appears to be generally preceded by completion of an in-plant water reduction program which lasts several years. End of pipe treatment typically involves a dissolved air flotation unit with or without chemical addition. Only one facility has biological treatment (NovaTec, 1993a).

Generally, wastewater is generated at fish processing facilities from a variety of processes, such as:

- Intermediate fish storage;
- Fish cleaning;
- Fish transport (for example in wet pumps and fluming);
- Fish freezing;
- Fish thawing;
- Preparation of brines;
- Equipment sprays;
- Offal transport;
- Cooling water;
- Steam generation; and
- Equipment and floor cleaning.

Most of these uses have been addressed in Section 4 and are inherently connected to the particular type of fish processing taking place at individual facilities, such as the use of cooling water for salmon canning. In addition to these applications, water is also used to flush offal and blood from equipment and floors, and to transport or flume the **offal** to floor drains and collections sumps. Department of Fisheries and Oceans Fish Inspection Regulations require that all conveyor belts be equipped with water sprays, and automated processing equipment generally have permanently installed water sprays to keep the

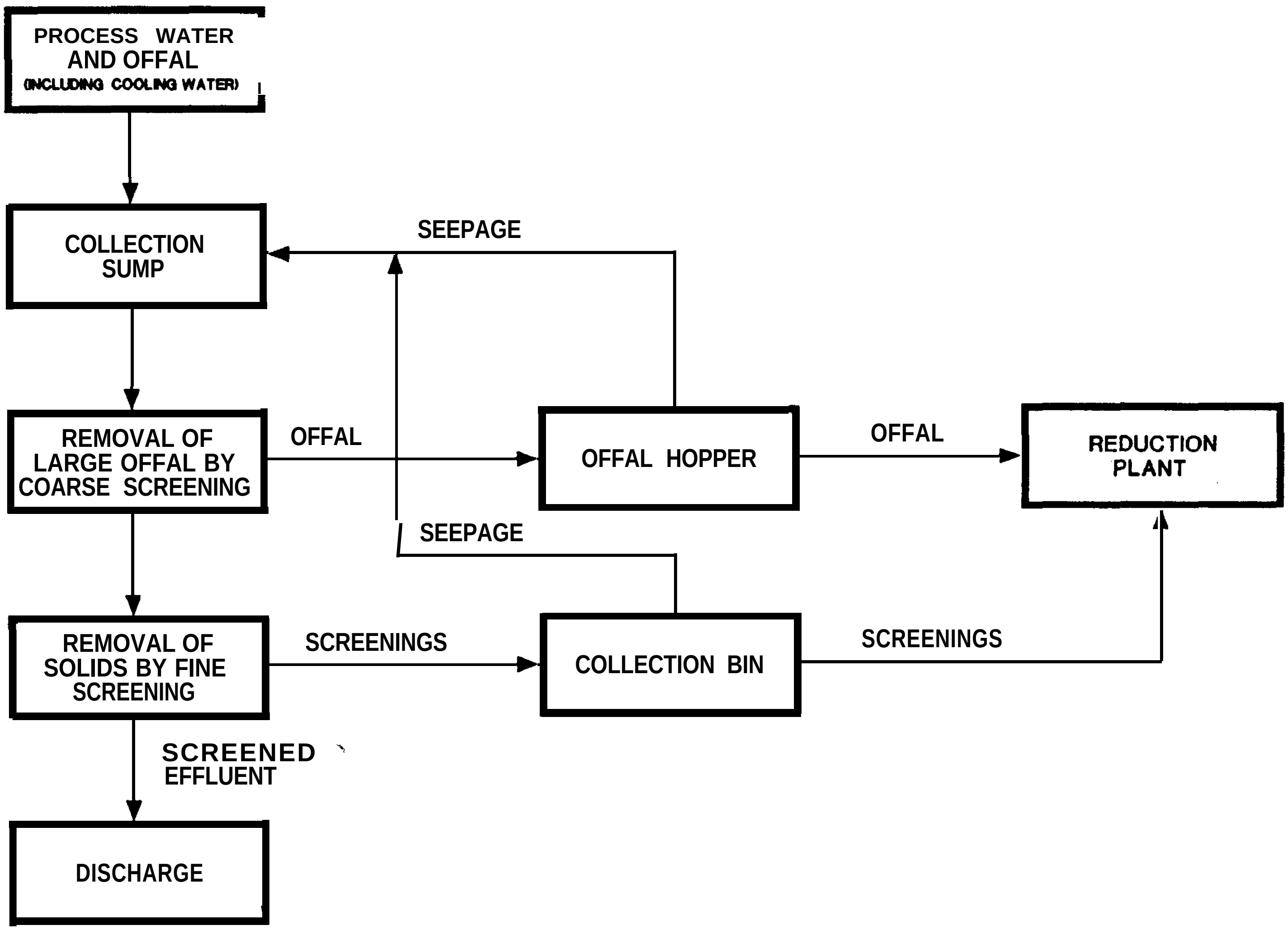


FIGURE 5.4
TYPICAL WASTE TREATMENT SCENARIO

equipment clean and to flush offal away. Typically, large chunks of offal (heads, tails, fins, etc.) fall into chutes which direct the offal to flumes, or are washed into flumes, which transport the offal to a collection sump. However, a certain amount of offal generally falls onto the floor where it accumulates and must be removed manually. This is typically done by hosing the offal into a nearby drain or flume.

Apart from resulting in high water consumption, this method of equipment cleaning and offal transport causes the mixing of the rinse water with offal and blood, which has two main disadvantages:

1) Any soluble BOD components (i.e. blood) will be dissolved in the water. Dissolved BOD cannot be removed by physical treatment such as screening.

2) The wastewater pumping action is rough on offal chunks resulting in an increase of smaller particles which may pass through the following screen. In addition, pumping is believed to increase the dissolved BOD content by solubilizing suspended organic material.

5.1.3 Solid Waste Generation

Solid waste generation rates at B.C. fish processing plants are summarized in Table 5.3 (based on values reported by B.C. Ministry of Agriculture, Fisheries and Food, 1992a).

Waste generation from filleting operation varies significantly with species processed. While salmon filleting generates only 60 to 65 % waste, groundfish filleting generates up to 75 % waste. Waste generation from halibut filleting in B.C. falls into the range reported by Green and Mattick (1977). Very high waste generation is reported for herring roe processing because the balance of the fish is normally disposed of (in addition to all male fish which are disposed of without processing). Waste generation from shrimp and crab processing is within the waste generation range reported in the literature (Green and Mattick, 1977).

The amount of offal generated in B.C. is estimated at 109,000 tons/year (wet weight) based on 1988 statistics (Aegis Management Services Ltd., 1991) (compared to 587,000 tons generated in 1991 in all of Canada - Canadian Fishery Consultants Ltd., 1991.) The geographic split is estimated to be 81,000 tonnes from the Lower Mainland, 17,000 tonnes from the Central and North Coast, 11,000 tonnes from Vancouver Island, and less than 1,000 tonnes from the Sunshine Coast. The species split is estimated to be groundfish 41 %, roe herring carcass 27 %, salmon offal 19% and others 13% (Aegis Management Services Ltd., 1991).

Table 5.3 Offal Generation Rates for Fish Processing in B.C.

Production Type	Generated Waste [%]
Salmon filleting	60- 65*
Salmon dressing	15-25
Herring roe	85
Halibut	40-60
Groundfish	30-75
Shrimp	75
Crab	130

Source: BC Ministry of Agriculture, Fisheries and Food, 1992a.

* Based on observations at British Columbia Packers Limited, the amount of waste generated for salmon filleting was adjusted from 20-35 % to 60-65 %.)

A summary of solid waste generation from fish processing plants in B.C. for the year 1993 is presented in Table 5.4. The estimate is based on the preliminary data of fish landings by species in 1993 and estimated recovery rates (percentage of the total final product recovery in relation to round fish weight) reported by B.C. Ministry of Agriculture, Fisheries and Food (1992a). Estimated volumes of offal for the year 1988 reported by Ming-Lesage Development Inc. '(1991) are also presented in Table 5.4.

Table 5.4 Solid Waste Generation at British Columbia Fish Processing Plants

Type	Landing [tonne]	Offal [tonne]	Offal [%]
Salmon	84,100	16,820	20
Herring	40,880	34,748	85
Halibut	4,230	2.115	50
Groundfish	68,840	35,796	52
Shellfish	20,950	15,715	75
Year 1993 total	**219,000**	**105,194**	**48**
Year 1988 total*	**266,000**	**112,500**	**42**

* Reported by Ming-Lesage Development Inc., 1991

5.1.4 Waste Disposal and By-product Recovery

Most of the fish offal generated in B.C. is sent to reduction plants, of which there are four in B.C. (in Prince Rupert, Port Hardy, Vancouver, and Richmond). A pet/mink food supplier located in Langley also utilizes fish offal. A comparison of fish offal generated in B. C., based on landing estimates obtained from the Department of Fisheries and Oceans, to the amount of offal handled by reduction plants, comporting facilities and used for pet/mink food, shows that approximately 85-90 % of all offal is used for value added products (compared to a waste utilization rate of 51 % for all of Canada - Canadian

Fishery Consultants Ltd., 1991). (Fish offal processing data was provided voluntarily by all companies operating reduction plants, comporting facilities, or supplying pet/mink food in BC). In 1993, a small fraction of offal (1.5%) was cpmposted at one of the three offal comporting sites in B.C. (at Oyster River, Port Alberni, and Schelt). Screenings from shrimp processing are also picked up by farmers as fertilizers. An unknown quantity of offal is landfilled, or ground and discharged. Permits or approvals are required both for operating a fish waste comporting facility and for the disposal of fish processing wastes on land, including use as fertilizer.

The City of Vancouver only accepts fish offal for landfilling which is odour-free and handleable by front-end loader, which generally requires offal to be frozen. Records are not kept by the City as to the amount of offal being landfilled. The City is currently reviewing its policy with respect to accepting this type of waste.

5.2 Wastewater Minimization

5.2.1 General

Seafood waste management options and practices are changing. End-of-pipe treatment systems enforced by regulatory agencies are no longer viewed as the only options for environmental protection. High costs of end-of-pipe treatment systems and increasing costs of waste disposal' have shifted the attention to conservation, recycling and byproduct recovery practices.

Instead of the expensive end-of-pipe treatment, the fish processing industry has taken the initiative and is moving towards water conservation and in-house modifications to improve the quality of the process effluent. For example, representatives from several fish processing companies participated in a wastewater technology mission to learn about pollution control measures implemented at several North European fish processing facilities. The mission was co-sponsored by the Fisheries Council of B.C. (FCBC), who also co-sponsored a conference in Vancouver in February 1994 on dealing with waste handling in the fish processing industry. To the knowledge of the authors of this study, two major fish processors in the Lower Mainland are already implementing water conservation techniques and equipment modification/modernization similar to the ones described later in this section. However, there is still considerable room for further improvements.

With regard to wastewater minimization, the following different aspects can be identified:

- reduction of the wastewater volume, and
- reduction of the contaminant loads.

Although water conservation measures would at first glance seem not to affect the contaminant loading, observations in fish processing plants which have implemented extensive water saving measures, indicate that substantial reductions in the contaminant loadings are possible. Certain water conservation measures result in a reduction of the contaminant loadings in the process effluent due to segregation of offal and blood from process water. However, different reduction rates for contaminants and water consumption have the net effect of increasing the contaminant concentration in the discharged effluent. For example, fish processors in northern Europe who have implemented extensive water conservation measures have found that, as a rule of thumb, a reduction of 50 % in water consumption results in an increase of BOD concentration of 10-20 % although the total BOD load discharged is reduced considerably (NovaTec, 1993a).

Water conservation also allows the use of smaller and therefore, less costly equipment for wastewater treatment.

5.2.2 Water Conservation

Water conservation measures are primarily designed to reduce water consumption at fish processing plants, although some reductions of contaminant loads can also be achieved as well. Employee education and training to diligently implement water conservation measures has been identified as a major factor for reducing water consumption. Drops in water consumption of 25 to 50 % due to employee education and training have been reported in the literature (Gates, 1991). Water conservation practices, however, should not compromise plant sanitation, and must be in agreement with regulatory requirements.

Modifications to existing equipment and ‘plants, or installation of new equipment and construction of new plants should include the following:

- installation of equipment designed for easy, cleaning;
- construction of floors and walls of easily cleaned surfaces;

to assure easy implementation of water conservation. In addition, flow meters should be installed to allow the monitoring of water consumption of various processes and operations.

Processing plants in northwestern Europe which have implemented some of the above water conservation techniques reported up to 50 % reductions in water usage (NovaTec Consultants Inc., 1993a).

A major step toward water conservation is dry clean-up. It is also an important factor in achieving a reduction of the contaminant loads (see Sections 5.2.4 and 6.3).

As with water conservation methods, dry clean-up practices should not compromise plant sanitation, and must be in agreement with regulatory requirements.

5.2.3 Water Recycling

Similar to the water conservation measures recycling can reduce water use, reduce discharge volume, thus requiring smaller treatment facilities, and can concentrate pollutants, facilitating treatment or byproduct recovery.

Research to assure product safety and regulatory guidelines are needed to fully implement water recycling. Possible problems include (Gates, 1991):

- bacterial and chemical contamination;
- reclaimed water with a high organic content treated with chlorine producing possible toxic, mutagenic or carcinogenic compounds;
- no available on-line monitoring equipment to determine real-time water quality;
- possible disease pathways.

Khosid et al. (1983) reported that water from mechanical or hand washing of wood and metal containers for fish canning in Leningrad could be used to transport mechanical impurities or wastes from fish processing. They also concluded that bacterial counts of the coolant water from the autoclaves for sterilization of canned products were within standard limits and that the water can be directly recycled to defrost fish. Water recycling at the Leningrad fish plant decreased consumption of potable water by 30 % Standard limits were not identified in the report, and it is not clear, if this kind of water recycling would meet regulatory requirements in Canada.

Nielsen et al. (1983) conducted a study of water reuse in processing of Pacific shrimp. A counter current flow configuration of shrimp peelers achieved water reduction of 41 % The total annual savings as a result of the recycle modifications was estimated to be between $3 and $10 per 1000 kg of shrimp.

5.2.4 Contaminant Reduction

Several of the measures recommended for water conservation will also lead to a reduction of the contaminant loadings. The guiding principle for achieving contaminant reduction is dry clean-up (segregation of offal and blood from process water).

Overall, the segregation of offal and blood from process water can reduce the organic loading from a fish processing facility by about 50 to 60 % and even more, depending on the extent of measures adopted.

5.3 Wastewater Treatment

5.3..1 General

Wastewater treatment options for fish processing plants can be divided into physical, chemical and biological treatment. Physical treatment options make use of differences in physical properties between water and contaminants for their separation. Chemical treatment is generally required to improve removal efficiencies. With the exception of ultrafiltration (see Section 5.3.6. 1) physical treatment methods cannot remove BOD which is associated with dissolved substances. This fraction of the overall BOD can be substantial and can only be removed by chemical and/or biological treatment.

5.3.2 Physical Treatment

Screening is the most prevalent method of physical treatment in the fish processing industry. Most fish processing plants screen their effluent prior to discharge to a receiving environment or municipal sewer. The types of screens used include:

- tangential screens (sidehill screens);
- rotary drum screens with spray water and, in some cases, counter flow helical brushes for cleaning of screen;
- filter belt screens;
- wheel filters with solids scrappers and warm water spray.

Tangential and rotary screens have received wide acceptance due to their simplicity. The mesh sizes of the screens installed in North American fish processing plants range from 0.15 to 1.52 mm, with 0.5 mm being the most widely used (pers. comm. with suppliers: Mr. David Botwright of Sanitherm Engineering Ltd. and representative of Hycor and Mr. Brian Graham of IPEC Industries, and review of MOELP Permits).

Typical solids removal rates achieved with tangential screens are presented in Table 5.5. Aquametrix (1993a) reported 75 to 80 % solids removal efficiencies with 0.42 mm internally fed rotoshear screen.

Wheel filter screens, in use mostly in Norway, can have mesh sizes as small as 10 μm (NovaTec, 1993a).

Table 5.5 Solids Removal by 25 mesh (0.6 mm) Tangential Screens

Wastewater Source	Flow rate [m^3/m^2]	Solids Removal [%]
Salmon canning	2.3	43
Groundfish	2.7	**10**
Herring	1.1	**50**

Source: Riddle and Shikaze, 1973

Solids removal is an important step in wastewater treatment, as solids of organic origin contribute to the BOD and TSS of “a wastewater. However, a substantial fraction of the BOD of wastewater is due to dissolved substances (such as blood and soluble proteins) which, together with particles smaller than the screen openings cannot be removed by screening.

Screens used in fish processing can be divided into three categories according to mesh size:

1. coarse screens with mesh sizes above 600 μm;
2. fine screens with mesh sizes from 150 to 600 μm;
3. very fine screens with mesh sizes from 10 to 150 μm.

Fine screening is generally used as pretreatment ahead of more advanced physical, chemical and biological methods. Fish processing plants in which offal is flumed generally employ coarse screening prior to fine screening. In these facilities the flumes discharge onto wire mesh conveyors which allow process water to drain to a collection sump, but retain large offal pieces for transport to an offal hopper.

5.3.3 Flotation

Flotation is a wastewater treatment process in which minute air bubbles are generated in a reactor vessel. As these bubbles rise to the surface they carry particulate matter and emulsified oil with them. A skimmer removes the resulting scum to a separate channel while the treated liquid moves on for further treatment or discharge. The most widely used flotation technique for food processing wastes is dissolved air flotation (DAF). In DAFs the liquid effluent is saturated with air inside a pressurized chamber and then released to a reactor vessel under atmospheric pressure. The resulting pressure drop causes the wastewater to become supersaturated with air, which consequently causes the formation of minute bubbles.

The operation of a DAF unit usually requires pretreatment of the process water by screening. Generally, flotation is effective in removing fats and to a lesser extent suspended solids, but less effective in reducing BOD, especially soluble BOD. The addition of coagulant and flocculants is needed for improved BOD and TSS reduction. Graham and Yacob (1978) reported low protein and total solids removal with DAF without coagulant addition. Krofta et al. (1988) reported BOD removal of only 35 % and suspended solids removal of only 26 **%** for DAF without coagulant addition (on-site field testing). Existing DAF units located in Europe and operating without chemical addition also showed low efficiencies in removal of BOD (Table 5.6).

DAF is generally not suited for the treatment of fish processing plant effluents in B.C. due primarily to the large fluctuations in effluent flow and composition, both within and between seasons, generally experienced by these plants which would reduce the efficiency of this type of treatment. In addition, a substantial amount of time is generally required to optimize the operation of flotation plants, particularly when combined with chemical treatment (see Section 5.3.4). Flotation plants may, therefore, not be optimized during the relatively short processing seasons such as for herring and salmon. Use of

‘ DAF in fish processing plants in Europe is generally restricted to plants operating on a year-round basis (NovaTec, 1993a).

5.3.4 Chemical Treatment

Chemical treatment generally refers to the addition of chemicals to screened effluent. This is required as emulsified oil and particulate matter suspended in wastewater are generally negatively charged. The resulting repulsion substantially impedes certain particle removal processes such as gravity settling, flotation and hydrocyclone separation. Consequently, coagulant which reduce or eliminate the repulsive forces between particles are often added to wastewaters prior to employing these processes. Coagulant are generally used in conjunction with flocculants which are long chain synthetic or natural polymers and cause the agglomeration of the now neutral particles.

Both coagulant and flocculants require rapid mixing with the wastewater in order to be effective. Metal salts are the most common coagulant and flocculants in use at full scale facilities practicing chemical aided treatment. The most widely used coagulant and coagulant combinations are: ferric chloride and ferric sulphate, aluminum chloride and aluminum sulphate, sodium hexametaphosphate, anionic polyelectrolyte, and calcium chloride. Accurate pH control is generally required, as the efficiency of coagulant and flocculants is pH dependent.

A disadvantage of using iron or aluminum salts as coagulant is the increase in sludge volume, contamination of the resulting sludge with metals which may make the product unsuitable for reuse, reduce its value, or cause the sludge not to be accepted at landfills. Water soluble organic polyelectrolytes avoid these problems and have the added advantages of requiring concentrations of only a few milligrams per litre and not generating extra quantities of waste for disposal (Steiner and Gee, 1992). Nonetheless, there are very few full scale installations using only organic polyelectrolytes. The major detriment appears to be lower removal efficiencies (NovaTec, 1993a).

Results of selected jar-test and bench scale studies are reported below. The economics, however, are unknown.

Numerous processes using coagulation for treating fish processing wastewater have been reported. Ohhashi (1974) described a process involving heating effluent to 70-100 “C to coagulate proteins, cooling and adjusting the pH to 3.5 -4.5 by acid addition, adding polyacrylate and removing the floe by flotation. COD and suspended solids were reduced by 92 % and 99 %, respectively. Hozumi (1988) reported that, in a jar-test, organic components of diameter less than 0.1 μm were completely removed by flocculation and the components of diameter greater than 0.1 μm were partially removed after pH adjustment to 5.5 and alum addition or pH adjustment to 5.0 for sodium polyacrylate addition. According to Izumi et al. (1982) calcium chloride was superior to ferric chloride, sulphate and sulphite in forming floes. Oshima et al. (1973) reported a 85-90 % BOD and COD reduction after using ferric chloride, calcium sulphate and polyacrylamide. A study on protein recovery from fish canning plant effluents in Poland (Ziminska, 1985) examined the effectiveness of ferric chloride and ferric stulphate, aluminum chloride and aluminum sulphate and sodium hexametaphosphate. The conclusion was that ferric chloride recovered the most solids and gave the greatest COD reduction.

The use of edible additives such as chitosan, alginate, organo sulphonates instead of chemicals has been investigated over the past twenty years. In the USA anionic and cationic polyacryiamide flocculants are generally recognized as safe aids for food processing waste destined for recycling as animal feed, and are already in use (e.g. Arctic Alaska Fisheries Corporation, Newport Facility). However, they have not been approved for this purpose in Canada. The advantage of edible additives is that the resulting sludge can be recovered by fish meal processors. Takei (1978) reported sea weed coagulant efficiency in fish washing waste to be superior to aluminum sulphate. Jar-test results showed that COD removal after 5 minutes of 400 mg/L of sea weed coagulant addition was 97 % versus O % with 150 mg/L of aluminum sulphate and 10 mg/L of polymer addition. The Norwegian Research Institute is planning bench scale studies on the use of edible additives for fish processing waste treatment (NovaTec, 1993a).

A recently developed proprietary flocculent (EnviroFloc, marketed by Epsilon Chemicals Ltd.) causes suspended particles and emulsified oil to form a floe, which is reported to be heavy enough to settle within 15 to 30 minutes. As of the completion date of this report, there have been no full-scale installations of this type of treatment. However, pilot tests in fish processing plants have resulted in 60-80 % reduction of BOD, and 90-95 % reductions of TSS and oil and grease (O&G) (pers. comm. with Mr. Colm O'Carroll of Epsilon Chemicals, Ltd.). This process is currently being tested by a Lower Mainland processor.

Chemical treatment is normally used in conjunction with flotation, although some vendors combine it with gravity settling. These two forms of chemically-assisted treatment are discussed in the following sections.

5.3.4.1 Chemically-Assisted Flotation

Chemical addition greatly improves the performance of DAF systems. The BOD reduction efficiency of DAF systems without chemical addition range from 10 % to maximum of 50 % However, with pH adjustment and chemical addition efficiency of BOD removal increases to up to 99 % European experience suggests that DAF with chemical addition can be successfully used to treat fish processing plant effluents. The most widely used operating scheme is pH adjustment to 4.2 -5.5 followed by ferric chloride and polymer addition, BOD removal efficiency may reach 97 % (NovaTec, 1993a).

A summary of reported coagulant and DAF efficiencies in seafood effluent treatment is presented in Table 5.6.

Only one fish processing facility in the Pacific Northwest, situated in Newport, Oregon (USA), employs dissolved air flotation for effluent treatment. This plant has very high contaminant loads (BOD, TSS and oil and grease) in the wastewater stream due to surimi processing. The achieved BOD reduction varies from 45 to 80 % (Table 5.6). However, effluent BOD concentrations can still be very high (e.g. 2,200 mg/L after 80 % reduction). This is due to the inability of the DAF process to effectively remove dissolved organics. The only treatment process that would be able to remove dissolved organics from the wastewater streams to low levels is biological treatment (see Section 5.3.5). However, biological treatment is generally not feasible in the fish processing industry due to the industry's seasonal nature and high capital and operating costs of biological treatment.

The sludge generated by the DAF system at the Newport facility is used in the facilities' own reduction plant. However, reduction plants generally do not accept this type of sludge, as its water content is very high and the material is of low quality which may compromise the quality of the product. Also, chemicals used with DAF may result in sludges containing unacceptably high levels of metals (i.e. iron or aluminum, see Section 5.3.4).

Table 5.6 Summary of Fish Processing Waste Treatment Using Coagulation/Flotation

Type	Treatment System	% Removal					Reference
		BOD	COD	TSS	O&G	Protein	
Salmon	pH 5.4, aluminum sulphate, anionic polyelectrolyte and DAF	84		92	90	61	Riddle and Shikaze, 1973
Salmon	pH 4.0-6.05, ferric chloride, polymer and DAF		68				NovaTec, 1993a
Salmon/ Groundfish	alum (24 mg/L), polymer (1 mg/L) and DAF	20	50	60-86	90		NovaTec, 1990
Herring	pH=5.2, alum and DAF		84	92	94	61	Clagget, 1972
Herring	pH=5.4, aluminum sulphate, anionic polyelectorlyte and DAF	72		74	85		Riddle and Shikaze, 1973
Herring filleting	DAF. no chemical addition	29					NovaTec, 1993a
Mackarel/ tuna/ herring	pH=4.2-5.5, ferric chloride, polymer and DAF	97	95		100		NovaTec, 1993a
Mackarel/ tuna/ herring	DAF, no chemical addition	50					NovaTec, 1993a
Groundfish	pH= 5.4, aluminum sulphate, anionic polyelectrolyte and DAF	77		86			Riddle and Shikaze, 1973
Fish and whale	heating to 70-100 °C, pH=3.5-4.5, polyacrylate and DAF		92	99			Ohhashi, 1974
Whitefish	alum, polymer and DAF	75					NovaTec, 1993a
Fish	ferric chloride (100 mg/L) and polymer (4-10 mg/L)		73	86			del Valle and Aguilera, 1990
Fish	pH adjustment, polyacrylamide and DAF	99	96	79	100		del Valle and Aguilera, 1990
Surimi	pH adjustment, polyacrylamide and DAF	45-80		70-98	40-99		Oregon Dept. of Env. Quality, 1993
Crab, salmon and shrimp	pH=4.1-6.1, ferric sulphate (500 mg/L) and settling			93-98			del Valle and Aguilera, 1990
Shrimp	pH=5.2, alum, polymer and DAF	65	59	65.5		52.5	Krofta et al., 1988
Shrimp	pH=6.2, chitosan 10 (mg/L), synthetic polymer (5 mg/L), settling		75	93			del Valle and Aguilera, 1990
Shrimp canning	DAF, no chemical addition	11		4	69		del Valle and Aguilera, 1990
Shrimp canning	pH=4.5-5.0, alum (219 mg/L), synthetic polymer (4 mg/L) and DAF	87		49	63		del Valle and Aguilera, 1990
Shrimp canning	pH=4.5-5.0, polyelectrolyte (300 mg/L), synthetic polymer (5 mg/L) and DAF	71		64	57		del Valle and Aguilera, 1990
Clam washwater	alum (140 mg/L), centrifugation		19-25				del Valle and Aguilera, 1990
Clam washwater	ferric chloride (80 mg/L), centrifugation		19-25				del Valle and Aguilera, 1990
Clam washwater	chitosan (10 mg/L), centrifugation		47				del Valle and Aguilera, 1990
Oyster canning	alum, synthetic polymer and DAF	56		43	89		del Valle and Aguilera, 1990

Various types of flotation devices are available. A unit manufactured locally (known as Aerosep) was recently pilot tested at the Ucluelet Seafood Processors facility which processes surimi. The wastewater from the surimi process was first preconditioned with coagulant and then fed to the Aerosep at a flow rate of approximately 4 m^3/hr. It was demonstrated that Aerosep, under optimum conditions, achieved a TSS reduction of 80-95 % and consistently achieved TSS levels of less than 200 mg/L (International Water Solutions, 1993). Dosing levels of chemicals have not been reported.

5.3.4.2 Other Bubble Generation Systems

Other forms of bubble generation systems have been investigated. Among these, the most common is dispersed (or induced) air flotation which makes use of an impeller and draft tube assembly to supply air to the bottom of a reactor vessel, and to generate and disperse the bubbles. To the knowledge of the authors, there are no full scale installations of this kind of flotation cell for treating effluent from fish processing plants.

Other alternative bubble generation methods include in situ electrolysis of water (electroflotation), and use of hydrogen peroxide to chemically generate oxygen bubbles.

Shifrin et al. (1972) reported high removal efficiencies of fats, suspended matter and COD (99.8 %, 86.5% and 59.8% respectively) when fish cannery wastewater was treated with dispersed air flotation.

Electroflotation may yield skimmings with a higher total solids content (9-12%) than DAF (3-5%) (del Vane and Aguilera, 1990). Recovery of 85 % of protein from fish processing wastewater was achieved using electroflotation after pH adjustment (del Vane and Aguilera, 1990). It should be pointed out that no full scale installation exists.

The use of hydrogen peroxide instead of air in DAF units proved to be more effective in fat, oil and grease recovery and BOD removal when poultry and meat processing effluents were treated in DAF units (pers. comm. with Mr. Robert Gec of Degussa). Testing of hydrogen peroxide in the fish processing industry is still to be done.

5.3.4.3 Enhanced Gravity Settling

To the knowledge of the authors no full scale installations of this type exist in fish processing plants.

The recently developed process of enhanced gravity settling (Microsep) is described by its manufacturer (International Water Solutions Corporation) as a combination of a chemical reactor and a clarifier within a single plant. It generally requires pH adjustment of the wastewater prior to addition of an inert particulate carrier (I PC) and flocculent. The IPC, flocculent, and contaminants (solids, and O&G) form particles of sufficient weight to settle rapidly, thus requiring substantially smaller equipment compared to conventional clarification. The settled sludge is withdrawn from the clarifier and passed through a separation device to remove the IPC for reuse in the process, while the removed contaminants may be further dewatered. The type of IPC used depends on the particular application.

The Microsep process has already been used successfully in wastewater treatment applications in a wide variety of industries. Recent preliminary testing of the bench scale Microsep process for TSS and COD removal from hold water of fishing boats showed promising results. With coagulant addition, TSS and COD removal efficiencies were 95-99 %, and 81-91 %, respectively (pers. comm. with Mr. Rob Dash and Mr. Ken Peon of International Water Solutions Corporation, 1993). Microsep generally achieves sludges with 2-7 % solids concentrations without additional dewatering.

5.3.5 Biological Treatment

Most seafood processing plants in BC are relatively small and are located along coastal areas where land is expensive and space limited (i.e. Lower Mainland, Vancouver Island, and Prince Rupert area). Land considerations alone can be an inhibitive factor in applying biological methods for pollution abatement in coastal zones (Chao et al., 1980). Further, most seafood processing operations are seasonal as they are dependent on the seafood catch. Another factor that may affect biological treatment is the low temperature of the wastewater which slows down biological activity. Wastewater temperature is a function of temperature of water used in the process, mixing of wastewater stream with water from ice melting, and inclusion of cooling water into the waste stream. Wastewater temperatures at B.C. fish processors could be as low as 40 C in winter (NovaTec pers.

files). Thus, it is difficult to maintain a trouble-free operation of a biological system for treating seafood wastewaters. The seasonal nature and intermittent processing of the industry makes almost any biological treatment system, except lagoons, impossible to use (Riddle and Shikaze, 1973). However, different types of biological treatment are successfully applied in seafood processing industries throughout Japan, as reported by Okumura and Uetana (1992) and in some European installations with year round operation and in combination with municipal sewage (NovaTec Consultants Inc., 1993a). In general, biological treatment may be used to reduce toxicity caused by high ammonia concentrations and/or BOD levels.

European experience suggests that separate biological treatment of fish processing wastewater is not a feasible solution for the fish processing industry.

However, at most Japanese fish processing facilities where production is relatively small and the volume of waste is limited, the batch type activated sludge process is the most popular treatment method (Okumura and Uetana, 1992). In cases where the pollution load of the wastewater is low, with low oil content, the “screen plus biological treatment” system is adopted. Where the pollution load is high, with high oil content, the “screen plus coagulation - pressure floating plus biological treatment” system is adopted (Okumura and Uetana, 1992). In areas where the quality of treated wastewater is severely restricted, wastewater treated using a biological method is further treated using ultrafiltration with activated carbon (tertiary treatment) (Okumura and Uetana, 1992). The authors cited above, however, do not give any indication of seasonality of fish processing in Japan.

The various types of biological treatment and their use in the treatment of fish processing wastewater are discussed briefly in the following section.

5.3.5.1 Lagoons

Both aerobic and anaerobic lagoons can be used for treating fish processing plant , effluents. Unfortunately the location of many seafood processing plants does not feasibly permit this form of treatment, since the land needed for lagoon treatment is usually not available in coastal areas.

To the knowledge of the authors, only one seafood processing facility in B.C. indirectly treats its wastewater in aerated lagoons. The Ucluelet Seafood Processors facility on Vancouver Island is connected to the municipal sewer system and the sewage is pumped to the four cell lagoon system. In 1992, an expansion of this facility was completed fo surimi processing. The start-up of surimi operation resulted in a five fold increase in BOD loading from Ucluelet Seafood Processors to the lagoons. About 50 % of the BOD loading is in the soluble form. The increase in TSS load to the lagoons is also estimated to be five fold since the surimi process was introduced. This increase in loading to the lagoons resulted in a deterioration of lagoon effluent quality and odour problems and the plant is currently discharging a portion of its surimi effluent directly to the harbour. Effluent from fish and shellfish processing, and the remainder of the surimi processing effluent is still treated through the lagoons (pers. comm. with Mr. Paul Bourke of Ucluelet Seafood Processors).

5.3.5.2 Land Disposal

A study carried out by Chawala (1971) showed promising results in nutrient removal efficiencies when an existing fish and vegetable processing lagoon effluent was applied to the land. A spray application of lagoon effluent on a sandy loam soil resulted in high removal rates of BOD, COD, soluble P and NH_3-N. Removal efficiencies were 96 % 94 'Mo, 91 % and 86 %, respectively.

5.3.5.3 Rotating Biological Contactor

The Rotating Biological Contactor (RBC) is a very compact treatment system, suitable for sites with limited area. To the knowledge of the authors no full scale facility exists at fish processing facilities.

Based on laboratory scale tests, Hudson et al. (1976) reported that BOD and COD removal efficiencies approached 95 % and 92 % respectively, for system loadings of approximately 130 L/m’ of disc area per day and less. However, the high capital cost of RBCS is an unfavorable factor (Green and Mattick, 1977). Also, it is a biological treatment process that responds poorly to the seasonal nature of fish processing.

Laboratory scale tests conducted by Riddle and Shikaze (1973) showed that BOD removal of 0.022 kg/m^2 of disc surface per day is easily attainable on a salmon canning plant effluent previously treated by DAF.

5.3.5.4 Activated Sludge

Full scale activated sludge treatment facilities are reported to be fairly common at fish processing plants in, Japan (Okumura and Uetana, 1992). However, data on the performance and economics of applied activated sludge facilities is not available.

A state-of-the-art activated sludge biological nutrient removal pilot plant facility incorporating two forms of disinfection has been operation for one year at a herring processing plant in Denmark. The performance is encouraging but the economics are not (NovaTec, 1993a).

Results of the pilot and bench scale tests of activated sludge treatment of fish processing wastewater are reported in literature (Sasaki et al., 1980 (a), (b) and 1981, and Lin et al., 1 979).

To the knowledge of the authors, no full or pilot scale activated sludge treatment plant at a fish processing facilities exist in North America.

5.3.5.5 Anaerobic treatment

Anaerobic treatment is uneconomical mainly due to the moderate to low organic strengths of the seafood processing wastewater and seasonal nature of most fish processing plant operation. These relatively low concentrations do not permit high biomass generation and retention capacity under normal hydraulic loadings and thereby limit the effectiveness of conventional anaerobic treatment applications (Hudson et al., 1978).

Bench scale research of shellfish processing wastewater treatment by anaerobic packed column by Hudson et al. (1978) showed that organic removal efficiencies near 80 % for COD and 88 % for soluble BOD can be achieved. Effluent solids concentrations observed were low, never exceeding 20 mg/L. Methane gas production was consistently greater than 80 %

To the knowledge of the authors, no full scale anaerobic treatment at fish processing facility exists.

5.3.6 Other Types of Treatment

A number of other types of treatment processes have been reported or tested on fish wastes at the bench or jar scale level. They remain largely unproven with respect to technical feasibility and costs. A highlight of selected ones are presented in this section.

5.3.6.1 Ultrafiltration

The ultrafiltration process employs a semipermeable membrane to separate macro-molecular substances from water. The membrane coats the wall of a closed space. When the solution contained in the enclosure surrounded by the membrane is pressurized, the water, inorganic salts and organic compounds of small molecular weights are forced through the membrane and collected as a permeate. Macromolecular substances such as proteins are left within the membrane enclosure as concentrate (Chao et al., 1980). To the knowledge of the authors no full scale ultrafiltration installations exist in the fish processing plants.

The flux of permeate across the membrane is the most influential factor on the capital cost and operating costs of an ultrafiltration process. It is generally felt, based on laboratory scale tests, that a flux rate in the range of 0.33-0.61 m^3/m^2~day is the needed for the ultrafiltration process to be economically feasible (Chao et al., 1980). Table 5.7 presents a summary of ultrafiltration efficiency in treatment of blue crab steam cooker discharge (laboratory scale tests).

Ohsihima et al. (1993) reported recovery of 90 % of proteins from red-meat fish , processing wastewater when ultrafiltration was applied, and Ninomiya et al. (1985) reported that proteins were concentrated from 0.1 -2 % to 0.4-18 % using ultrafiltration treatment.

Precipitation and separation of proteins in aqueous solution can also be effected by relying on electrolytic rather than chemical means. Effectiveness of direct acid precipitation, ion exchange chromatography, ultrafiltration and microgas 'dispersion -

flotation in protein recovery were evaluated by Jhaveri (1988) and are presented in Table 5.8.

Membrane separation techniques using ultrafiltration have been investigated at the pilot scale level in Europe and generally found to be unsatisfactory and uneconomical (NovaTec, 1993a).

Table 5.7 Summary of Wastewater Treatment Test Results Employing an Ultrafiltration Membrane

Parameter	Raw waste [mg/L]	Concentrate [mg/L]	Permeate [mg/L]	% Removal
COD	20000-25000	67000-74000	6000	60-66
BOD	10000-14000	50000-60000	4000	60-71
TS	16000-25000	52000-64000	15000	17-40
TSS	700-1000	10000-13000	10	98 -99
NH4-N	200-250	240	220	0-12

Source: Chao et al., 1980

Table 5.8 Protein Recovery and BOD Reduction Achieved with Various Treatment Technologies

Method	Protein Recovery [%]	BOD Reduction [%]
Direct acid precipitation	70-60	72
Ion exchange chromatography	72	62
Ultrafiltration	79	79
Ion exchange chromatography and direct acid precipitation	90	91
Ultrafiltration and direct acid precipitation	90	91
Microgas dispersion and flotation	88	87

Source: Jhaveri, 1988

5.3.6.2 Hydrocyclones

Hydrocyclones cause the rotation of a fluid, creating centrifugal forces which separate particles with specific gravities greater than the carrier fluid. The total suspended solids migrate outward toward the conical wall of the cyclone and are removed in the underflow stream. The clarified liquid leaves with the overflow (Johnson and Lindley, 1982). To the knowledge of the authors no full scale operation of hydrocyclones at fish processing facilities exist.

Based on laboratory-scale tests, Johnson and Lindley (1982) reported that hydrocyclon can efficiently remove particulate matter from seafood processing wastewaters but additional concentration of solids may be necessary if solids are to be used in a byproduct recovery operation.

Tilsworth and Morgan (1983) reported that hydrocyclons alone removed approximately 90 % of crab fragments and up to 80 % of salmon and shrimp particulate. Improved removal efficiency occurred by the use of the coagulant at dosages of about 30 mg/L chitosan and 500 mg/L ferric sulphate.

5.3.6.3 Electrolytic Treatment

To the knowledge of the authors no full scale installations of this type exist in fish processing industry.

A study of electrolytic treatment of wastewater from seafood processing was carried out by Matasuura et al. (1979). The wastewater at pH 2-6 was electrolyzed to the isoelectric point of proteins, peptides and amino acids and the floe removed. Then, calcium oxide, calcium hydroxide or calcium chloride was added to co-precipitate the remaining proteins, peptides and amino acids. Reported COD and BOD removal efficiencies were 92 and 97 % respectively.

5.3.6.4 Evaporation

Evaporation is a method to turn a dilute stream into a concentrated one. There are many different types of evaporators, ranging from open kettles to very sophisticated and expensive ones. Evaporators usually cannot concentrate beyond 60 % water and 40 % solids (Goldhor and Koppernaes, 1993). Evaporation is used in several clam plants to treat cookwater, resulting in clam broth or flavour concentrate (Goldhor and Koppernaes, 1993). Evaporation is normally considered to be far too costly for waste treatment, and is only used where a saleable product will be a result.

5.3.7 Summary of Treatment Processes in Use for Fish Processing Plant Effluents

Of the end of pipe treatment technologies reviewed in this section, only a handful are in use at fish processing plants. Table 5.9 presents a summary of the known full scale treatment technologies currently in use at fish processing plants.

Table 5.9 Full Scale End-of-Pipe Treatment Technologies for Use at Fish Processing Plants

Treatment Type	Installations
500 μm screening	Large number of installations
150 μm screening	Very few installations
Under 150 μm screening	None in North America, some in Norway
DAF without chemicals	Installations in Europe
DAF wtth chemicals	Installations in Europe, one in North America
Activated sludge (separate)	One installation in Europe, several in Japan
Activated sludge (combined)	Several installations in Europe
Lagoons (combined)	One installation in BC

5.4 Byproduct Recovery

5.4.1 General

Seafood processing operations generate a great deal of solid waste, much of it in the form of edible protein. Recovery of edible byproducts for human or animal feed is affected by the small scale and seasonality of many food processing facilities.

Solid wastes generated by seafood processing plants, with the exception of that generated by fish meal plants, represent 30 % to 85 % of landed fish weight, depending upon the operation (Green and Mattick, 1977). Shrimp processing generates from 40 to 80 % waste, filleting plants generate 30 to 60 % waste, and crab processing generates from 75 to 85 % waste (Green and Mattick, 1977). The goal of byproduct recovery is to attain maximum utilization of seafood processing wastes for food or feed thus reducing the amount of waste and decreasing the need and cost of waste treatment.

There is a variety of uses for seafood processing wastes. However, not all uses are optimal for a particular waste disposal situation. The feasibility of waste utilization and byproduct recovery are situation specific and are affected by a number of factors including:

- type and composition of waste;
- volume generated;
- waste availability (seasonality);
- location of waste sources;
- location of processing facilities;
- location of end users;
- costs;
- climatic conditions;
- existing end users of waste products;
- markets for waste products;
- local regulations.

Some approaches to byproduct utilization are described in order of importance in the following sections.

5.4.2 Fish Meal

Approximately 28.6 % of the world annual fish catch is used to produce fish meal (del Vane and Aguilera, 1990). Canada is a very minor player in the world production of fish meals, producing approximately 1 % of worldwide production (Can. Fishery Consultants Ltd, 1991).' Fish meal is an internationally recognized commercial commodity utilized in feeding farm animals such as chickens, turkeys and pigs and farmed fish. Some disadvantages of fish meal production are the high capital costs of the equipment,

requirements for a minimum tonnage of raw materials on a continuing basis and, in many locations, environmental considerations (Canadian Fisheries Consultants Ltd., 1991).

5.4.3 Pet Food

Fish offal, underutilized fish and minced meat recovered from shellfish plants can be processed into pet food. The marketing of fish waste to large pet food manufacturers seems to be limited to companies with cold storage facilities and access to the raw materials that meet company specifications.

5.4.4 Fertilizers

Shellfish shells are high in calcium content and can be used as liming agents for agricultural lands, but additional magnesium would have to ,be included (Hood and Zall, 1979). Fish offal has also been utilized as a fertilizer. Results of some of the studies carried out to evaluate fish fertilizers with inorganic chemical fertilizers are presented in Table 5.10. Fish fertilizers, once widely used, are now replaced with petrochemical fertilizers. However, they have a market in home and garden use and also organic farming. Production of liquid fish fertilizers can be done with low capital investment and low energy input (Green and Mattick, 1977).

5.4.5 Fish Silage

Fish silage is liquified fish produced by grinding and acidification of fish or fish scrap followed by autolytic digestion at room temperature. The product has little objectionable odour and serves as a nutritious animal feed (Gates, 1991). Fish silage probably offers the most promising aspect for seafood processing waste utilization (Green and Mattick, 1977). The capital cost investment is at a minimum. It can be carried out at small and large installations (as small as 200 L drum scale). However,, it is important for a plant of any size to have at least automated acid addition with a pH meter (Canadian Fishery Consultants Ltd., 1991). At present, most of the fish silage produced is fed in its liquid form to pigs, poultry, fur bearing animals, fish which demand high level of protein, sheep and cattle. However, it can be dried for long term storage and shipping (Green and Mattick, 1977).

Table 5.10 Results of Applications of Fish Fertilizers

Crop	Application rate of fish fertilizer	Control fertilizer	Yield results
Cherry tomatoes '	-8 mL/L - dipped prior to planting - sprayed every 2-3 weeks	-5:2:1 to 0:10:10 - manures	-22.7 kg/plant - several times the control
Beefsteak tomatoes	- as above	- chicken manure	-9 kg/plant -6.8 kg/plant control
Pole beans	-4 mL/L - foliage spray after staking and wiring and again after 2 weeks		-12 kg/30 m row -3 kg/30 m row (control)
Lawns,	- diluted 1:5 -3.7 mL/m^2	-13:8:4 at 46.4 mL/m^2	- much more lush lawn with fish fertilizer and longer fertilizer retention time
Cabbage	-2.8 mL/m2 at planting and 2.8 mL/m^2 foliage spray after 4 weeks		- larger, denser, 50 % heavier heads than controls
Corn	-3.7 mL/m2 at planting and 3.7 mL/m2 as foliage spray after 5 weeks		- greater than 20 % more weight of corn/plant
Apples	-1:20 dilution -93 mL/m^2 of above, foliage spray		- increase in size and weight of fish fertilized apples

Source: Canadian Fishery Consultants Ltd., 1991

5.4.6 Protein Hydrolysates

Protein hydrolysates are formed by the rapid dissolution of fish flesh away from bones, scales, and fat. Proteolytic enzymes are added to the minced fish along with mineral or organic acids. The mixture is heated to 65 “C to solubilize the protein. Potential uses of hydrolysates include milk replacers in animal feeds and peptones for microbiological media worth more than $2,500/ton (Gates, 1991). This process involves considerable capital and technical investment which might not be attractive for small and/or seasonal fish processing operations (Green and Mattick, 1977).

5.4.7 Chitin and Chitosan

Chitosan is a high molecular weight carbohydrate polymer manufactured from chitin in shrimp and crab wastes (Bough, 1976). An estimated 120,000 tons of chitin can be produced annually on a worldwide basis (Knorr, 1991). Shells are first ground, protein is extracted, and the shells are demineralized. After washing and dewatering chitin is recovered. Chitin is converted to chitosan by deacetylization. Proposed applications of chitin - chitosan include (Gates, 1991, Johnson and Peniston, 1971, Knorr, 1991, Bough, 1976):

- water treatment flocculent for: recovery of food processing byproducts (especially proteins), biosorption of heavy metals, removal of dyes and pesticides;
- surgical sutures;
- contact lenses;
- burn dressings;
- immobilization agent in cell cultures;
- agricultural nematocide;
- digestive aid;
- coatings for paper and for glass fibres to permit dyeing;
- encapsulation agent for pharmaceuticals;
- viscosity control agents for drilling muds;
- biodegradable packaging films;
- dietary supplement in fish farming;
- clarification of beverages.

A substantial investment in chemical processing equipment and technical personnel is required for chitin - chitosan production (Green and Mattick, 1977). Japanese production of chitin - chitosan currently exceeds 300 tons per year, with pilot scale production in the United States (Gates, 1991).

5.4.8 Food Flavours

Concentrated clam and oyster cook water can be converted into, marketable food products such as clam juice, dehydrated clam flavour used for soups, dips and snacks and fermented oyster sauce (Hood and Zall, 1979 and Gates, 1991).

5.4.9 Bone Meal

Experiment conducted by Johnson and Peniston (1971) showed that extraction of protein from fishery waste such as herring will leave residue of bone which could be dried, ground and marketed as bone meal.

5.4.10 Bait

One of the oldest methods of seafood waste recovery and disposal is as a bait for both sport and commercial fishermen. However, the use of this method is limited since only lobster, crab and Ionglining fishing use this type of bait (Green and Mattick, 1977 and Hood and Zall, 1979).

5.4.11 Ground Fish Scales

Fish scales constitute about 1 % of the total weight of the fish. Dried and ground fish scales can function as effectively as chitosan as a flocculating agent in the food processing industry (Hood and Zall, 1979 and Welsh and Zall, 1979).

5.5 Solid Waste Disposal

5.5.1 Ocean dispersion/disposai

Ocean dispersion/disposal of fish offal is common in the USA (pers. comm. with Mr. Brian Yin and Ms. Florence Carol of EPA Seattle Office and Mr. Tim McFetridge and Mr. Kent Ashbaker of Oregon Dept. of Env. Quality). Effluents are discharged through outfalls with or without screening prior to discharge. Solids collected from screening shellfish wastewaters are, in many cases, ground and then disposed off in the ocean. While these practices may not cause significant problems if discharge/dumping is done into the open ocean where currents are strong, discharge/dumping into bays, estuaries and areas that are not sufficiently flushed may pose environmental problems and fragile ecological systems may be damaged.

Ocean disposal in Canada is regulated by Environment Canada and refers to disposal of offal generated at a land-based facility in the ocean. To date, only one permit for ocean dumping of offal has been granted by Environment Canada (for emergency disposal), as officials of the department are of the opinion that sufficient alternatives for the beneficial use of offal exist in B.C. (pers. comm. with Ms. Dixie Sullivan of Environment Canada).

The discharge of offal with effluent is not considered ocean dumping and is regulated under permit by MOELP. Three processors in B.C. are permitted to use this form of offal disposal (see Section 5.1. 1).

Disposal of offal at sea after gutting at sea, as is the practice for troll-caught fish is not considered ocean dumping.

5.5.2 Landfilling

Sanitary Iandfilling is usually a poor choice for the disposal of fisheries waste from both an environmental and economic points of view (Green and Mattick, 1977). Large volumes of waste are required before costs, particularly hauling expenses, can be reduced.

5.5.3 Incineration and Pyrolysis

Although energy can be recovered from burning the waste, the sophisticated equipment capital costs and high operating costs of incineration and pyrolysis are beyond the means of most seafood processors. To the knowledge of the authors this process is not applied at B.C. fish processing facilities, nor is fish offal sent to municipal garbage incinerators.

5.5.4 Comporting

Direct use of fish wastes as manure by spreading on fields is uncommon due to the typical obnoxious odours of putrefying fish or shellfish. Comporting fish waste is an intermediary step to utilizing fish as a soil conditioner. The comporting process converts organic solid waste into a stable, humus like product whose chief use is as a soil conditioner and fertilizer (Canadian Fishery Consultants Ltd., 1991). Comporting is environmentally acceptable and an economically viable solution in specific instances.

The comporting operation consists of several key components such as: storage of input materials, grinding and conveyance to mixer, mixing, comporting (aeration and turning), screening and bagging, storage of finished products, odour control and wastewater collection.

Typically, the ground raw fish or silage are mixed with clean wood waste. The wood makes the pile porous and provides a source of carbon for the compost bacteria. After the initial mixing, comporting involves managing the temperature, moisture and oxygen levels.

Fish offal comporting in B.C. is discussed in Section 5.1.4.

6 BEST MANAGEMENT PRACTICES

6.1 General

Best management practices at fish processing facilities should be implemented in two stages:

- The first stage generally include less intensive and less expensive measures applicable to a wide variety of fish processing plants. These practices would be common to most facilities regardless of the type of fish processed, applied technology or site specific conditions. It includes water conservation, waste stream separation, by-product recovery, employee education and training, and some minimal wastewater treatment, generally in the form of screening.

- The second stage include more site specific actions that should be developed after the completion of a detailed site audit[1].

The scope of this document is to outline first stage best management practices that could be implemented at fish processing facilities across B.C. without undertaking detailed site audits or costly site specific actions. Additional treatment technologies are discussed in Section 5.3.

6.2 Water Conservation

Water conservation has two major beneficial effects: it is cost effective and it reduces contaminant loadings discharged with the waste stream (as outlined in Section 5.2.1), thus protecting the receiving environment.

Water conservation may be achieved through:

- dry transport of offal;
- dry cleanup of equipment, offal and blood spills;
- dry transport of product;

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[1]The B.C. Ministry of Agriculture, Fisheries and Food is in the process of preparing two handbooks to provide assistance with design and execution of such an audit.

- installation of shut-off nozzles on clean-up hoses;
- replacement of high-volume/low-pressure hoses with low-volume/high-pressure washers. High-pressure hoses should be used only after sufficient dry cleanup;
- installation of low-flow nozzles on equipment sprays;
- reduction of water pressure on equipment spray nozzles;
- shutting off all ‘water flow during breaks, with the exception of water used for cleanup;
- reuse of retort cooling water for fluming of offal, if dry transport of offal is not possible;
- prompt repair of leaking equipment and pipes;
- use of in-place-cleaning systems when possible;
- use of sex sorters (for roe herring processing only);
- implementation of water recycling;
- water metering.

As outlined in Section 5.2.2, water conservation practices should not compromise plant sanitation, and must be in agreement with regulatory requirements.

Dry clean-up includes the following:

- cleaning of dressed fish using vacuum hoses connected to a cyclone separator followed by discharge of the collected blood and offal to the offal hopper rather than into the wastewater collection system;
- cleaning of floor spills with squeegees (into pans) to prevent them from entering drains;
- use of stiff brooms to clean floor prior to wash down;
- cleaning of equipment by hand or with stiff brushes prior to wash down.

Dry transport of offal generally refers to the use of conveyors in place of flumes or wet pumps. Such modifications are generally associated with substantial reductions in the contaminant loads.

Water recycling is a component of water conservation which should only be implemented if the quality and safety of the product will not be compromised. Recycled water should move from clean operations to less clean operations. In the traditional system, water enters the plant, flows through each process step, and is discharged as waste. The reuse system collects wastewater from all processing steps, treats it, and then recycles it to all processing steps. Make-up water is added as needed. Concurrent recycling collects water at a point downstream in the processing scheme, treats it in-line, if necessary, and recycles the water upstream to a less clean portion of the operation. Modular recycling separately treats and recycles water at specific processing steps (Gates, 1991);

A major factor in implementing water conservation is employee education and training.

6.3 Waste Stream Separation

The major waste streams generated at a fish processing facility are process water, sanitary sewage, and cooling water (optional). While these two/three streams are generally separated at most existing facilities in B. C., separation of different process water waste streams is strongly recommended. Together with water conservation, separation of process water waste streams in a major factor in achieving a reduction in contaminant loadings.

The major measures in waste stream separation include:

- dry transport of offal;
- immediate separation of offal and product from process water using dewatering belts;
- avoidance of bloodwater seepage from offal hoppers, or collection of this waste stream;
- installation of pans under tables to collect dripping blood for subsequent discharge to the offal hopper;
- installation of trays under conveyor belts to catch solids before they fall on the floor;
- installation of chutes to direct offal to the offal handling system and to avoid the accumulation of offal on the floor;
- collection of offal in non-leaking containers;
- use of pumps designed to reduce break-up and, therefore, solubilization of solids;
- screening process wastewater prior to pumping;
- use of vacuum suction for gurry collection;
- use of sex sorters in roe herring processing;

- use of finer mesh screens (down to 0.15 mm) to separate solids form the wastewater liquid stream.

The above measures can reduce the organic loading from a fish processing facility by approximately 50 to 60 %

6.4 By-Product Recovery

By-product recovery is a cost effective way to reduce the amount of waste that would, otherwise, be disposed of. There are numerous ways for by-product recovery in the fish processing industry (as outlined in Section 5.4), such as production of:

- fish meal;
- pet food;
- fertilizers;
- fish silage;
- protein hydrolysates;
- chitin and chitosan;
- food flavours;
- bone meal;
- bait;
- fish scales.

The predominant commercial use of fisheries waste in Canada is fish meal production. On the West Coast, fish meal is manufactured primarily in the Lower Mainland followed by Prince Rupert and Port Hardy.

6.5 Wastewater Treatment

Although there is a wide variety of wastewater treatment technologies (Section 5.3), the only type currently economical for the fish processing industry is fine screening (mesh size 0.5 mm or less) followed by a deep water discharge. The most widely used screens in the fish industry include tangential and rotary screens.

Screening of the effluent should be carried out, when practical and economical, prior to any effluent pumping as pumping increases the concentration of very fine particles in the effluent. These particles will pass through the screens and thus increase the organic loading to the receiving environment.

7 ECONOMIC ANALYSIS

7.1 Review of the Economic State of the B.C. Fish Processing Industry

This section provides a general overview of the economic state of the B.C. fish processing industry based mainly on information obtained from the Ministry of Agriculture, Fisheries and Food (MAFF). A detailed economic analysis of the status of the industry can not be presented, as this would require a review of the profits and losses of individual processing companies. Such information is not readily available and companies are reluctant to provide this kind of data. The analysis below is, therefore, restricted to information about the wholesale and landed value of B.C. seafood.

Figure 7.1 shows the historic landed and wholesale value of all B.C. seafood for the years 1978 to 1992 (MAFF, 1992). The wholesale value experienced a sizable increase in the period from 1984 to 1990, after which time the industry experienced a downturn which, according to the 1992 data (latest year for which data is available) seems to have levelled off. The changes in the wholesale value generally follow those in the landed value, although fluctuation of the latter are not as pronounced as the changes of the former. The wholesale values generally were 170 % to 200$40 of the landed value of seafood, and reached $879 million in 1992, down from a high of $1033 million in 1990.

A breakdown of wholesale values according to contribution by species is presented in Table 7.1 for the years 1990-1992. In this time period, salmon products accounted for 57 to 63 % of all seafood, with the contribution of farm salmon increasing steadily from 8.2 to 16.5 % This increase in the contribution of farm salmon to the total wholesale value of B.C. seafood is due to the drop in landings of wild salmon and an increase in the farm salmon production.

Herring and groundfish contributed approximately equally to the total wholesale value (average for the years 1990 -1992:15.9 % and 13.3%, respectively). The remainder was ‘ made up by shellfish, halibut, farmed trout and other fish.

Table 7.2 shows the average per-tonne wholesale and landed value, and their ratios for each species for the years 1990 to 1992. in general, the highest wholesale and landed values/tonne were obtained for halibut and farmed trout, followed by salmon (both wild and farmed), herring and shellfish. The lowest values were obtained for groundfish (approximately $800 per tonne). However, comparing the ratios of the per-tonne

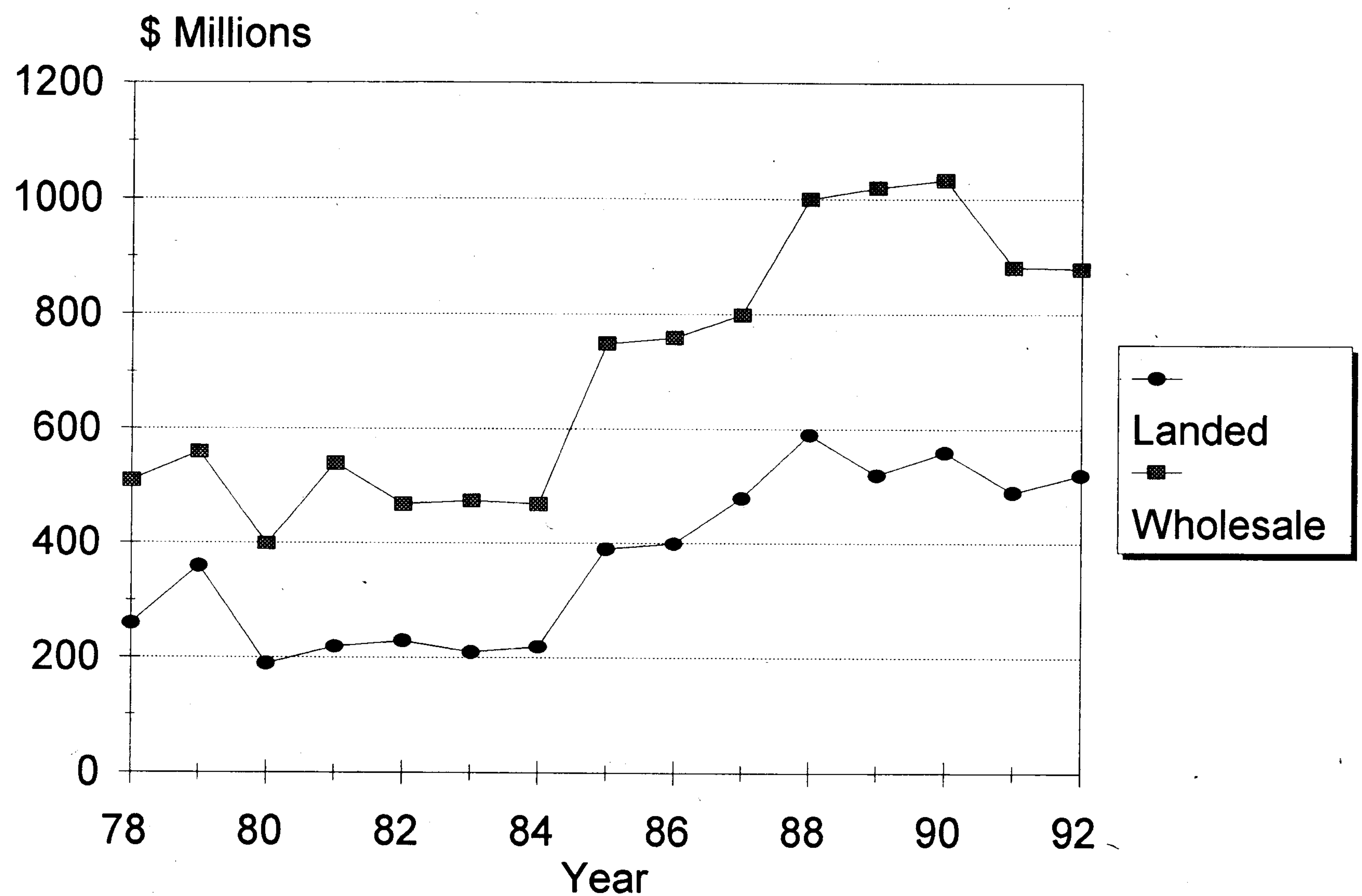

FIGURE 7.1
LANDED AND WHOLESALE VALUE OF ALL BC SEAFOOD

wholesale and landed values as a measure of the extent of value-added processing carried out, it can be seen that herring processing (mainly roe herring) contributed to the highest increase in value, followed by salmon and groundfish processing.

While a detailed review of the economic state of the B.C. fish processing industry is not available, an unaudited survey of four of the largest fish processors in the province provides an indication of the overall economic well-being of the industry. The survey was conducted by Price Waterhouse on behalf of the Fisheries Council of British Columbia, and included the following companies:

- British Columbia Packers Limited
- J.S. McMillan Fisheries Ltd.
- Canadian Fishing Company
- Ocean Fisheries Ltd.

Table 7.1 Wholesale Value of B.C. Seafood by Species 1990-1992

Specie	Wholesale Value [$ Millions]			Contribution to Total Value [%]			
	1992	1991	1990	1992	1091	1990	Avg
Salmon	359.0	371.7	564.3	40.8	42.2	54.6	45.9
Farmed Salmon	145.0	135.8	85.1	16.5	15.4	8.2	13.4
Farmed Trout	0.7	0.6	0.5	0.1	0.1	0.0	0.1
Herring	129.7	146.2	169.3	14.8	16.6	16.4	15.9
Halibut	25.0	28.7	27.8	2.8	3.3	2.7	2.9
Groundfish	125.0	128.2	116.0	14.2	14.5	11.2	13.3
Shellfish	93.0	69.3	68.7	10.6	7.9	6.6	8.4
Other	1.5	1.3	1.4	0.2	0.1	0.1	0.2
Total	878.9	881.8	1033.1	100.0	100.0	100.0	100.0

Source: B.C. Ministry of Agriculture, Fisheries and Food, 1992.
Notes: 1991 values are preliminary.
1992 values are estimates.

Table 7.2 Average per-tonne Wholesale and Landed Value (1990 - 1992) by Species

Specie	Average Value* Wholesale ($/tonne)	Average Value* Landed ($/tonne)	Ratio
Salmon	5,227	2,545	2.05
Farmed Salmon	5,729	4,786	1.20
Farmed Trout	6,000	6,000	1.00
Herring	3,827	1,673	2.29
Halibut	7,953	6,182	1.29
Groundfish	807	487	1.66
Shellfish	3,031	2,012	1.51
Other	2,072	1,433	1.45
Total	**2,873**	**1,611**	**1.78**

Source: B.C. Ministry of Agriculture, Fisheries and Food, 1992.

Notes:
: Average of the years 1990-1992.
1991 wholesale values and 1992 landed values are preliminary.
1992 wholesale values are estimates.

The four companies reported an average net after tax loss of $10 million per annum for the four years from 1990 to 1993 (1993 data was estimated). The poor performance during these years lowered the average net after tax profits for the period of 1980 to 1993 to $540,000 per annum.

7.2 Processing Technology Improvements, Water Conservation and Wastewater Treatment

7.2.1 General

The following section is a general discussion of some of the factors which have or may have an impact on the cost of implementing changes to reduce the contaminant load being discharged from fish processing plants (i.e. in-house modifications as well as end-of-pipe treatment). The discussion is presented in general form, as a wide range of conditions exist. In general, the factors that need to be considered are as follows:

- plant profitability
- type of process
- labour costs;
- water rates;
- discharge fees;
- waste disposal requirements and options.

7.2.2 Plant Profitability

As outlined in Section 7.1, plant profitability cannot be addressed in this document on a plant-specific basis. The discussion presented in Section 7.1 should be reviewed to determine the overall profitability of the B.C. fish processing industry.

7.2.3 Type of Process

The species of fish handled, and the type of processing taking place at a fish processing plant, greatly affect the nature and quality of the wastewater generated. For example, herring processing generally results in wastewater with a higher dissolved BOD fraction than salmon canning, with the result that employing finer screens would not be as beneficial for herring processing as for salmon canning wastewaters. Similarly, bleeding farm salmon is believed to result in a higher dissolved BOD fraction than salmon canning due to the high dissolved BOD of blood. The species and process specific wastewater characteristics can not be changed unless new operating methods can be developed which result in comparable or superior product quality.

Operating methods which belong to this category include the use of vacuum suction to remove entrails when dressing salmon (mainly for the fresh/frozen market), and sex sorters used for roe herring processing (see Section 4.4.2). New developments which would allow the removal of entrails from salmon gutting machines by vacuum suction (i.e. without the entrails coming into contact with water) are being or will be marketed in the near future (communications with Coastline Equipment Inc. and Ryco Incorporated of Seattle, WA).

As discussed in Section 4.4.2, the use of herring sex sorters results in reduced water consumption and wastewater contaminant loading. These sorters have a high capital cost and are labour intensive, as they require manual placement and alignment of the fish, although they reduce the labour requirements for freezing, frozen storage, thawing, and breaking. Also, sex sorters are not 100 % accurate, and a certain loss of roe due to miss-identification of females as male herring must be taken into account in an economic analysis. However, the economics of sex sorting might further improve if the sorters are used in conjunction with automatic feeders, which could also be used to supply automatic popping machines (see Section 4.4.3). As the same machine could be used for two different purposes (feeding of sex sorters, and automatic popping machines), the savings of the labour cost would accelerate the amortization of the feeders.

The type of processing carried out at a plant also substantially affects how seasonal the operation is, which directly affects the time required for amortizing equipment purchased for in-house modifications or wastewater treatment. For example, some facilities processing farmed salmon operate year round, compared to wild salmon which is processed mainly from July through August. Processing plants handling farmed salmon can make use of, and amortize, their equipment year-round, whereas ,plants processing wild salmon are restricted to a few months. Because of the seasonal nature of wild salmon processing, most plants involved in this type of operation also process roe herring to make use of unused capacities during the spring. In additidn, to adequately treat all wastewater generated at a fish processing plant, any wastewater treatment system would have to be designed for a relatively large flow which the processing plant may only discharge on few days during the year. This is caused by the tremendous fluctuations in throughput during the processing seasons. To illustrate this point, Figure 7.2 shows the monthly landings at three plants as a fraction of the maximum monthly landings at each facility in 1993. The plants had the following characteristics:

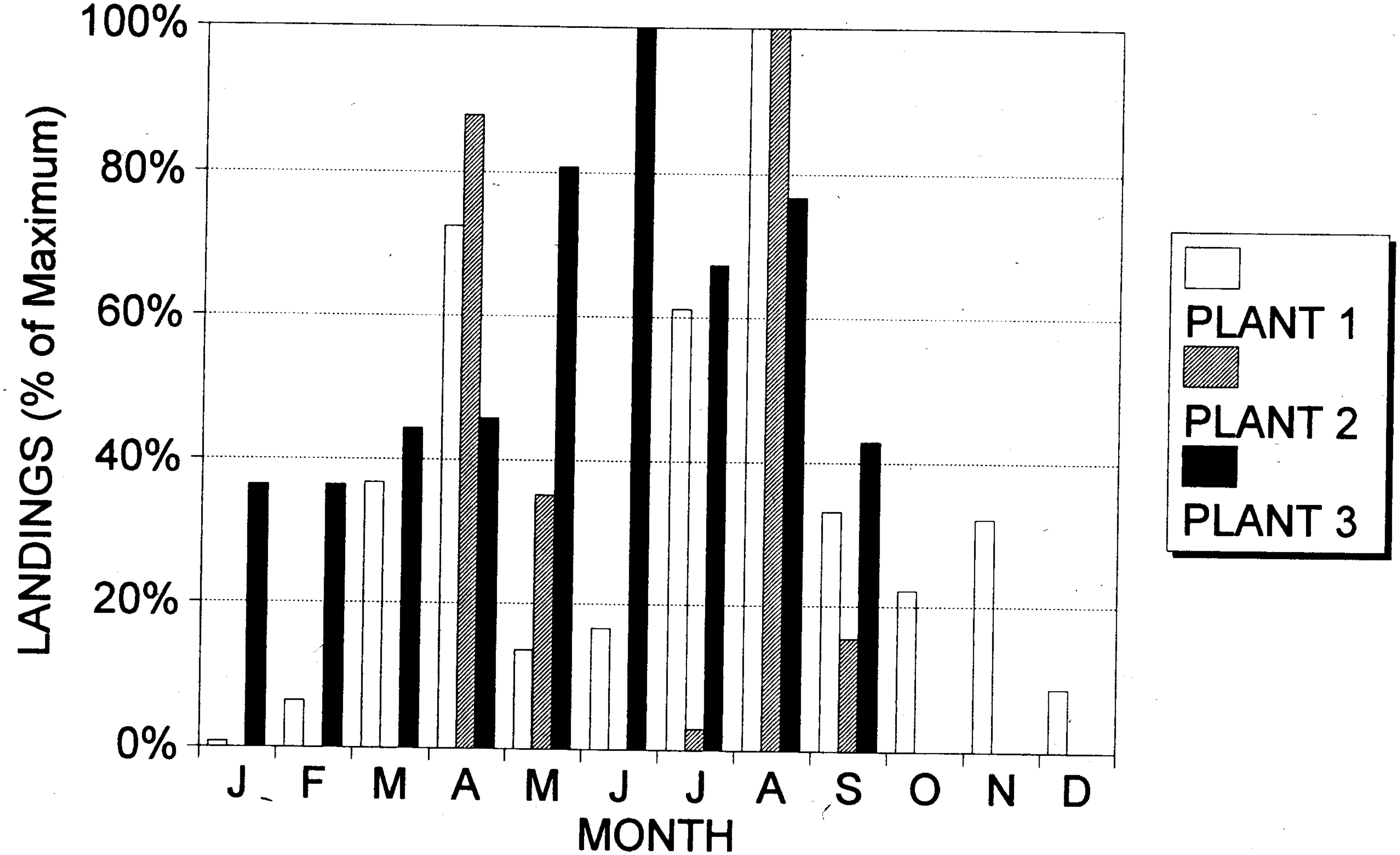

FIGURE 7.2
MONTHLY LANDINGS (1993) AT THREE SELECTED PLANTS

Plant 1: Roe herring, salmon (both for the frozen market, and canning), and groundfish processing;
Plant 2: Roe herring and salmon (fresh and frozen) processing;
Plant 3: Salmon (fresh and frozen) and groundfish processing.

Of the three plants, only Plant 1 operated each month in 1993, however, the amount of processing varied tremendously in all three plants. The fact that groundfish was processed (which generally can be processed year-round, depending on fisheries openings) did not result in a more steady production than occurred with salmon canning and roe herring processing plants.

7.2.4 Labour Costs

Labour costs are a substantial contributing factor to the overall production cost. At least one process modification in fresh/frozen salmon processing which has been implemented in a number of B.C. processing facilities to reduce Iabour costs has resulted in a substantial decrease in water consumption and may also be used to improve the quality of the generated wastewater. The process modification involves the installation of vacuum lines for cleaning salmon following manual gutting, as described in Section 4.3.1. These systems cost between $70,000 and $140,000, depending on the configuration selected. According to observations made in a processing plant, the system increased the throughput from 300 to 385 pounds of fish ,per worker to 520 to 630 pounds per worker. In addition, the system used less water. Transporting the entrails and collected blood directly to an offal hopper rather than discharging this waste stream into the wastewater collection system would also improve the quality of the process water, as contaminants would be prevented from mixing and solubilizing in water. In order to use these systems, the fish being processed must be of relatively uniform size. Manual butchering and cleaning may still be necessary for fish which do not meet this requirement.

7.2.5 Water Rates

Water usage can result in large costs to processing plants. Even plants which pay a nominal fee for the water they consume are expected to benefit from a reduction in water consumption, as this would be associated with a reduction in discharge permit fees. Declining-block rate structures in place in a number of jurisdictions do not promote water conservation and the implementation of conservation measures. However, in the GVRD, declining block rates are expected to be phased out in addition to a substantial increase in the water rate, providing a powerful incentive for conserving water.

Reducing water consumption also has the added benefit of reducing the cost of any end-of-pipe treatment, as treatment systems can be designed for smaller flows which generally reduces the capital and operating costs. In addition, many water conservation measures also result in a reduction of the contaminant load. For example, European experience has shown, that a 50% reduction in the BOD load due to measures which also conserve water is possible. The implementation of water conservation and other in-house water and wastewater minimization measures is therefore strongly recommended as a first step towards reducing the contaminant load discharged from fish processing facilities.

7.2.6 Discharge Fees

According to the B.C. Permit Fee Regulation fish processing facilities have to pay $13.90 and $9.20 per tonne of BOD and TSS discharged, respectively. The fees are generally based on an assumed BOD and TSS effluent concentration of 100 mg/L and 70 mg/L respectively, regardless of the actual effluent quality. The assumed BOD and TSS effluent concentrations are multiplied by the maximum permitted daily discharge flow and the number of days per year. If the permit lists the average permitted daily discharge flow and/or is for an operating period of less than one year, the average flow multiplied by the operating days listed in the permit are used for the calculations. The maximum and average permitted daily flows could be reduced by implementing in-house modifications as outlined in Sections 5.2 and 6.

As an example of fees applicable to plants discharging to sewer, the rate structure proposed by the GVRD in 1992 was reviewed (GVRD, 1992). According to this structure, companies would be required to pay a surcharge for effluent exceeding 200 mg/L BOD or TSS. The proposed surcharge would be $0.27 per kilogram BOD and $0.13 per kilogram TSS. This rate structure was based on operating costs for primary treatment only, and that the GVRD is in the process of revising the originally proposed fee structure to include operating costs and debt service for secondary treatment as well. As a consequence, substantially higher rates (up to five times - pers. comm. with Ms. Christina Jacob of the GVRD) may be set.

7.2.7 Waste Disposal

Waste ‘disposal options are an important consideration when selecting wastewater treatment options. As shown in Section 5.1.4, most offal generated in B.C. is presently sent to reduction or is used for pet/mink food. These uses would not be available for sludge generated by DAF, particularly if chemicals are used in the treatment. The only options left for this kind of waste would be landfilling, or comporting. As cost for both these waste disposal options is on a per-weight basis, sludge dewatering would probably be required to keep disposal costs low. However, this would further increase the capital and operating costs of wastewater treatment by DAF. Comporting facilities charge between $30 and $80 per tonne of offal. At the landfill of the City of Vancouver, normal tipping fees ($69/tonne) apply to fish waste with the added requirement that it must be possible to handle the waste with a front-end loader, and that the waste must be odour free, which generally requires the waste to be frozen.

The problems of dealing with waste generated by wastewater treatment would be minimized by using in-house waste reduction measures. Also, screening is preferable to DAF, as the solids collected by screens are generally disposed of with other fish offal and may be sent to reduction plants.

7.2.8 In-house Modifications

In-house modification to implement the methods outlined in Sections 5.2 and 6 for water conservation and wastewater minimization are considered the first step towards lowering the contaminant load discharged from fish processing plants. Plants can make use of a large number of low tech modifications to achieve these goals. Ideally, to make the most efficient use of money spent for new equipment or equipment modifications, **a** water and wastewater audit should be conducted first to determine the areas with the greatest potential for water conservation and wastewater minimization. As outlined above, these modifications may be associated with savings due to the following:

- lower water consumption;
- smaller contaminant load;
- smaller wastewater treatment systems (if required); and
- more efficient production methods.

In-house modifications can result in a reduction of the contaminant load discharged from a plant but may not result in a reduction of the contaminant concentrations of the effluent. This is due to the fact that contaminant loadings and effluent flows may be reduced by similar margins. Therefore, effluents may continue to exceed discharge limitations or may exceed the limits above which surcharges have to be paid.

7.2.9 Wastewater Treatment

Suppliers and manufacturers of wastewater treatment equipment were requested to provide cost estimates for equipment required to treat a range of flows. The type of treatment processes selected included fine screening using 600 mm, 500 mm, and 150 mm screens, and dissolved air flotation (DAF). The cost estimates were used to calculate the range of treatment costs per discharge flow (see Figure 7.3)

A rule-of-thumb markup of 50% of the original cost estimates to account for taxes and installation was assumed for the calculations. The results are shown for the flow range of 100 m^3/day to 6000 m3/day. Cost estimates for DAF do not include any sludge dewatering equipment, or the cost of waste disposal. Costs also exclude in-plant modifications to piping, yard work, power supply, and equipment housing which are site specific which can easily double the total capital cost.

The efficiencies expected for each individual treatment option, shown in Table 7.3, are based on file data and literature values, as detailed process evaluations could not be obtained from the manufacturers/suppliers. The, efficiency of a particular wastewater treatment system is dependent on the nature of the wastewater to be treated. For example, with respect to screening, the treatment efficiency is dependent on the size distribution of the particles in the wastewater. If all particles (suspended solids) present in the wastewater are larger than the openings of the screen to be used, all particles and the BOD associated with them can be removed. Conversely, suspended solids removal may not increase much after the installation of finer screens, if the majority of the solids are too small to be retained by the screen. In addition, screens will not affect dissolved substances and the BOD which is associated with them. This dissolved BOD may, however, be removed by chemically assisted DAF.

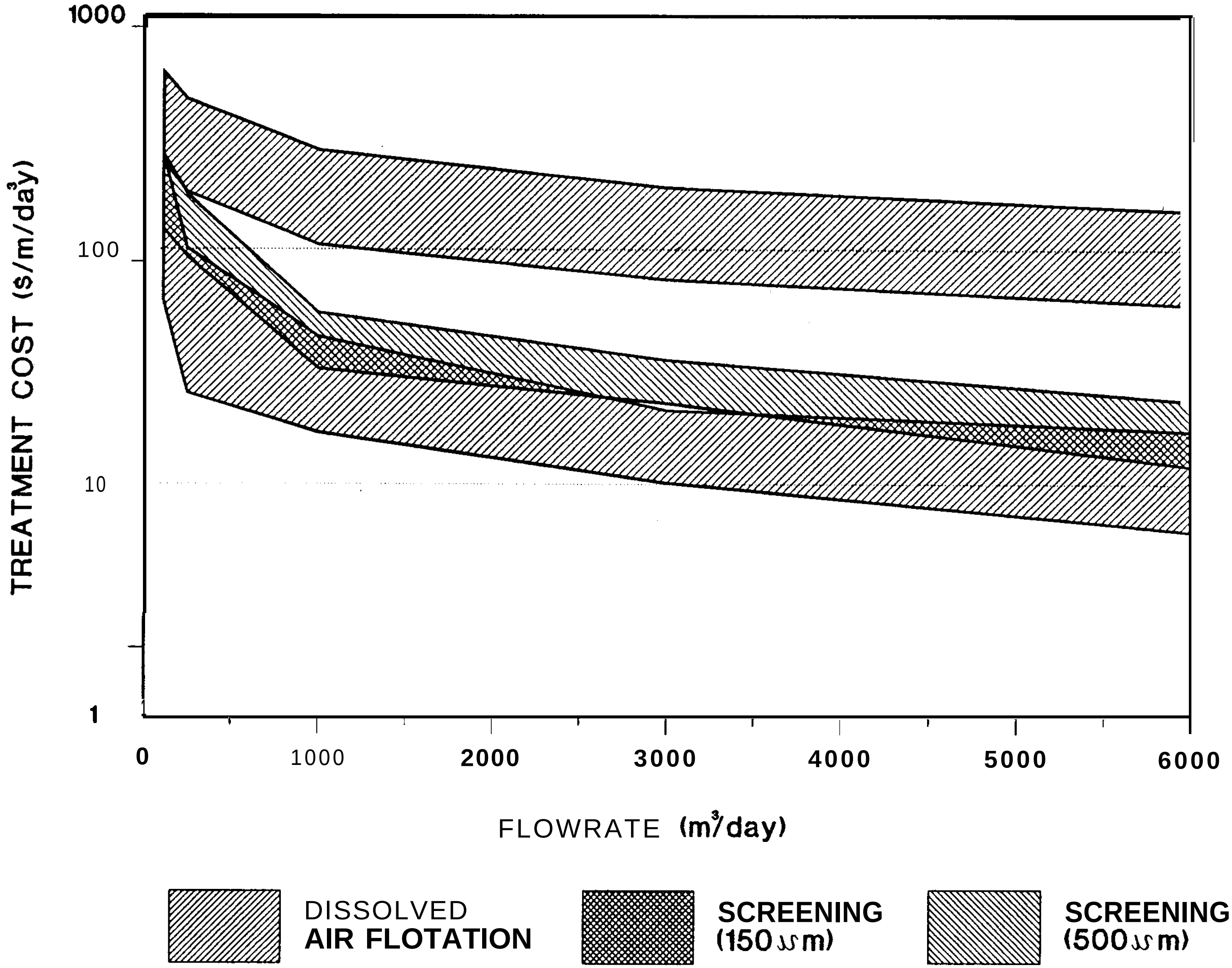

FIGURE 7.3
TREATMENT COST PER DISCHARGE FLOW

Table 7.3 Expected Efficiency of Wastewater Treatment Methods

Treatment	Range of expected BOD removal efficiency [%]	
	Low	High
Screening 600 μm Screens	5	10
500 μm Screens	7.5	15
150 μm Screens	15	30
DAF	80	90

7.3 Case Study

7.3.1 General

Based on available file data, and information obtained from equipment suppliers, equipment costs for various modifications were calculated for a hypothetical fish processing plant.

7.3.2 Assumptions and Background Information

The hypothetical fish processing plant is assumed to be a salmon cannery which also processes roe herring in spring. The plant is assumed to have 600 μm screens, which are the most common form of effluent treatment in B.C. for large processing plants. Further, it was assumed that extensive in-house modifications would result in a 50% reduction of the water consumption and the BOD loading. Although it has not yet been demonstrated that these levels of reduction can be achieved in North American fish processing plants, these assumptions seem reasonable based on the results obtained by European processors who have implemented modifications according to the principles described in Section 5.2. The replacement of 600 μm screens with 500 and 150 μm screens was assumed to result in a reduction of the effluent BOD of 5% and 20 %, respectively. Installation of DAF was assumed to reduce the effluent BOD by an additional 80 % when compared to the existing level of treatment.

Two lischarge scenarios were considered:

1. Discharge to a municipal sewer (assumed to be the GVS&DD)
2. Direct discharge to the environment

For discharge to the GVS&DD, the fee structure presently proposed by the GVRD, $0.27/kg TSS and $0.13/kg BOD for TSS concentrations and BOD exceeding 200 mg/L, is used. The fee to be paid for discharge to the environment was calculated based on the method described in the Provincial Permit Fee Regulation. According to this regulation, the maximum permitted daily discharge flow is multiplied by the TSS concentration and BOD of the effluent. Each is then multiplied by the number of days per year. The effluent TSS concentration and BOD are assumed to be 70 mg/L and 100 mg/L, respectively, as is the current practice for calculating permit fees if limits on these parameters are not set in the discharge permit itself.

As operating costs of finer screens were assumed to be comparable to the costs of the existing 600 μm screens, and the implementation of in-house modification is not expected to result in additional operating costs, these added operational costs were assumed to be zero. The operating costs for DAF were assumed to be $0.50/m3 based on experience obtained from pilot plant tests. The volume of process water discharged, was assumed to be 90% of the water consumption. Equipment costs were assumed to be amortized in 5 years at an interest rate of 8 %

The assumptions used in the economic analysis are summarized in Table 7.4. The result of the evaluations are shown in Tables 7.5 and 7.6 which, for comparison purposes, also present the cost accrued if no modifications are carried out.

7.3.3 Results and Discussion

7.3.3.1 Discharge to GVS&DD

During the relatively short amortization period of five years, each of the evaluated modifications would result in a larger annual expenditure than maintaining the status quo. Of all modifications, the installation of 150 μm screens would result in the lowest expenditures followed by the installation of 500 μm screens, and in-house modifications. The annual expenditures for these three modifications are fairly close, ranging from

Table 7.4 Assumptions used for Economic Analysis

PLANT TYPE	Salmon cannery (also processing roe herring in spring)	
EXISTING EFFLUENT TREATMENT	Fine screening (600 μm)	
DISCHARGE TYPE	1. Discharge to GVS&DD 2. Discharge to the environment	
DISCHARGE FEES	1. Discharge to GVS&DD $0.27/kg TSS, for TSS >200 mg/L $0.13/kg BOD, for BOD >200 mg/L 2. Discharge to the environment $9.20/tonne TSS (assumed effluent TSS: 70 mg/L) $13.90/tonne BOD (assumed effluent BOD: 100 mg/L)	
Annual water consumption	m^3/year	235,000
Annual wastewater discharge	m3/year	211,500
Water cost	\$/m^3	0.25
Existing maximum daily effluent discharge	m3/day	5000
Maximum daily effluent discharge after in-house modifications	m^3/day	2500
Annual interest rate (for amortization of equipment)	%	8
Amortization period	years	5
Operating costs of DAF	\$/m^3	**0.50**
Operating cost of screens	\$/m’	0

Table 7.4 Assumptions used for Economic Analysis (continued)

EVALUATED MODIFICATIONS		
Modification	Assumed Reduction of	
	Effluent Contaminant Concentration [%]	Water Consumption [%]
Replacement of the 600 um screens with 500 μm screens;	5	0
Replacement of the 600 μm screens with 150 μm screens;	**20**	**0**
Installation of DAF (without improved screening);	80	0
In-house modifications without upgrading of the treatment system;	0	**50**
In-house modifications and replacement of the **600 μm** screens with 500 μm screens;	5	**50**
In-house modifications and replacement of the **600 μm** screens with 150 μm screens; and	**20**	**50**
In-house modifications and installation of DAF (without improved screening).	80	**50**

$156,000 to $169,000. Installation of DAF without prior in-house modifications would result in more than twice the annual expenditures of any of the previously discussed changes. Due to the smaller equipment requirements, the annual expenditures for DAF during the amortization period is reduced if in-house modifications are carried out first.

After the amortization period the lowest annual expenditures would be expected for in-house modifications and installation of finer screens, followed by in-house modifications alone. These modifications would result in a reduction of the annual expenditures by a factor of at least two, compared to the expenditures which would be required if the status' quo had been maintained. For each treatment option the implementation of in-house modifications always cuts the annual expenditures in half because water consumption would be reduced by 50 %

The results obtained for the evaluation show that implementing extensive in-house modifications as described in Sections 5.2 and 6 should be carried out as a first step to both reduce water consumption and minimize contaminant loadings. Following these modifications, the replacement of relative coarse screens (opening sizes of 600 μm or more) with finer screens (opening size as low as 150 μm) may be installed to further reduce the amount of contaminants discharged.

7.3.3.2 Discharge to the Environment

The overall results for the above hypothetical plant discharging to the environment are similar to the results obtained for a plant discharging to GVS&DD. For example, the installation of DAF would still result in the highest annual expenditures during and after the amortization period (with or without in-house modifications). Also, not-implementation of any changes would result In the lowest annual expenditures during the amortization period. Due to the lower permit fees relative to GVS&DD fees, in-house modifications would result in substantially higher expenditure than installing finer screens, or making no changes at all.

With the exception of the DAF options, annual expenditures after the amortization period relate mostly to water consumption and permit fees. As a result, annual expenditures for scenarios without water reduction are similar to each, as are those with water reduction. The use of assumed effluent contaminant concentrations to calculate permit fees **as** currently practised by MOELP shows that processing plants derive no financial benefit from discharging fewer contaminants. Any fee reduction would be solely associated with a reduced permitted maximum daily discharge flow resulting from water conservation.

As in the previous case, fish processing plants discharging to the environment are expected to benefit from implementing extensive in-house modifications. To further lower contaminant loadings, finer screening may be employed, although with the present practice of calculating permit fees no financial benefit could be realized for the processing companies.

Table 6.5 Cost Comparison of Various Modifications - Discharge to the GVS&DD

Modifications		Capital Costs [$]	Amortization Costs [$/yr]	Aditional Operating Costs [$/yr]	Water Costs [$/yr]	Discharge Fees [$/yr]	Annual Expenditures During Amortization Period [$/yr]	Annual Expenditures After Amortization Period [$/yr]
No Modifications		0	0	0	58,750	87,264	146,014	146,014
500µm Screens		87,500	21,915	0	58,750	81,975	162,640	140,725
150µm Screens		123,250	30,869	0	58,750	66,108	155,727	124,858
DAF		754,700	189,019	105,750	58,750	6,341	359,860	170,841
In-House Modifications only		382,500	95,800	0	29,375	43,632	168,807	73,007
In-House	- 500µm Screens	437,500	109,575	0	29,375	40,988	179,937	70,363
Modification	- 150µm Screens	478,250	119,781	0	29,375	33,054	182,210	62,429
plus installation of:	- DAF	875,200	219,199	52,875	29,375	3,170	304,620	85,420

Table 6.6 Cost Comparison of Various Modifications - Discharge to the Environment

Modifications		Capital Costs [$]	Amortization Costs [$/yr]	Aditional Operating Costs [$/yr]	Water Costs [$/yr]	Discharge Fees [$/yr]	Annual Expenditures During Amortization Period [$/yr]	Annual Expenditures After Amortization Period [$/yr]
No Modifications		0	0	0	58,750	3,712	62,462	62,462
500µm Screens		87,500	21,915	0	58,750	3,712	84,377	62,462
150µm Screens		123,250	30,869	0	58,750	3,712	93,331	62,462
DAF		754,700	189,019	105,750	58,750	3,712	357,232	168,212
In-House Modifications only		382,500	95,800	0	29,375	1,856	127,031	31,231
In-House	- 500µm Screens	437,500	109,575	0	29,375	1,856	140,806	31,231
Modification	- 150µm Screens	478,250	119,781	0	29,375	1,856	151,012	31,231
plus installation of:	- DAF	875,200	219,199	52,875	29,375	1,856	303,306	84,106

See text for explanation. Assumed reductions of effluent contaminant concentrations and water consumption are listed in Table 6.4.

All cost estimates involving DAF units do not include costs for sludge dewatering and disposal. Therefore, the total costs for this treatment option would be even higher than shown. Also, rises in water costs, discharge fees and/or permit fees will further increase the gap in favour of the in-house modifications options.

8 CONCLUSIONS AND RECOMMENDATIONS

Fish processing is a major industry in British Columbia, employing more than 4,000 people, with an estimated wholesale value of processed seafood in 1993 of $750)000,000. The environmental performance of the industry as a whole was reviewed and generally found to be equivalent to or better to that reported in the literature with respect to water consumption and amount of contaminants discharged. However, a comparison of the industry with some advanced operations **in northern Europe showed that there is still considerable** room for improvement in these areas. This is further confirmed by results of audits conducted at selected B.C. plants in the past years.

The industry makes good use of the offal generated during processing, with an estimated 80- 85% of all offal being used for value-added products. Three processing plants located in remote areas and discharging into well-flushed environments are permitted to grind and discharge offal. Ocean dumping as a means of disposal of fish offal does not take place in British Columbia.

A review of Ministry of Environment, Lands and Parks discharge permits revealed that most fish processing facilities licensed by the Ministry of Agriculture, Fisheries and Food are connected to regional or municipal sewers (78%. However, some of the largest plants in British Columbia discharge their effluent directly into the environment. These plants also process the majority of all landed fish, accounting for an estimated 68% of the contaminant discharge from all fish processing. The industry's wastewater treatment standard is screening, typically using 600 μm screens, with finer screens employed by some large facilities. Coarser screens are used by only a few, small facilities,

The contaminant contribution to local sewer systems and receiving waters can be high, particularly during the peak processing months. On an annual basis, the contaminant load discharged from processing plants, estimated to have a population equivalent of 50,000 people, is believed to be minor compared to the discharge of municipal sewage in British Columbia.

The limited data available with respect to toxicity of fish processing plant effluent suggest that effluents may fail toxicity tests because of elevated ammonia concentrations and/or BOD. Of the treatment options discussed in this report, only biological treatment can remove ammonia and lower the BOD sufficiently to allow fish processing wastewater to meet toxicity limits. However, biological treatment is generally not recommended as a treatment option for the following reasons:

- seasonal nature of fish processing;
- generally low temperature of wastewater which is detrimental to biological treatment, especially biological vitrification of ammonia;
- high cost of biological treatment, especially with seasonal production.

Biological treatment may be considered in individual cases, due to site-specific constraints.

Water and wastewater minimization procedures should be implemented prior to upgrading existing wastewater treatment facilities. This is expected to be the most economical way to reduce the contaminant loadings discharged to the environment from fish processing facilities. It also results in a payback due to decreased water consumption costs. However, as these modifications reduce the water consumption and contaminant loadings to the same extent, effluent contaminant concentrations may not be reduced substantially although the mass loading would be.

Best management practices for fish processing plant effluents include dry processing and transport, and prevention of mixing of solid waste material with water. Implementation of in-house modifications to ‘achieve these practices is expected to decrease the water consumption and contaminant load by as much as 50 % In addition, it will allow the installation of smaller and, therefore, less expensive treatment equipment. This is of particular importance because of the seasonal nature of the fish processing industry which increases the time required to amortize equipment.

A detailed water and wastewater audit should be carried out prior to implementing major process modifications in order to identify the areas where the greatest improvements can be achieved. It is important for regulatory agencies to realize that a substantial amount of time may be required to audit a plant, develop and implement recommendations, and evaluate the impact of the changes made, due to the generally relatively short processing seasons.

At the present time, fine screening is generally considered to be the best economically achievable technology for treating fish processing effluents. More advanced forms of treatment, such as dissolved air flotation and enhanced gravity settling, should only be considered based on specific receiving environment considerations, type and frequency of operation, and after acceptable options for disposing of the solid waste generated by the treatment processes have been developed. Also, additional treatment (including finer screens) should generally be considered only after in-house modifications are completed.

Based on an unaudited survey of four of the largest fish processors in British Columbia, it appears that the industry has experienced a dramatic downturn in the last several years. The four companies combined averaged an estimated net after tax loss of $10 million per annum for the years 1990 to 1993.

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