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ENVIRONMENTAL REVIEW OF THE B.C. TIMBER (CELGAR PULP DIVISION) PULPMILL AT CASTLEGAR, B.C.

Regional Program Report No. 81-20

by

G. Derksen and M. Lashmar

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ABSTRACT

The Environmental Protection Service (EPS) initiated a program to compile and review environmental information on the pulp and paper mills in British Columbia. With the cooperation of various other government agencies and the pulp and paper industry, EPS compiled relevant resource and receiving environment monitoring information. After reviewing and evaluating the existing information, the environmental quality of each area was assessed and the need for additional monitoring studies determined. This report represents an assessment of the B.C. Timber pulpmill at Castlegar, B.C.

RESUME

Le Service de la protection de l'environnement a entrepris de compiler et d'étudier les renseignements recueillis sur l'environnement et concernant les usines de pâte à papier de la Colombie- Britannique. Grâce à la collaboration de plusieurs autres agences gouvernementales et de l'industrie de la pâte à papier, le Service de la protection de l'environnement a compilé les données pertinentes et les résultats de l'effet de la pollution sur l'environnement. Après avoir étudié et évalué les données obtenues, on a pu établir la qualité de l'environnement de chaque zone et déterminer dans quelle mesure on avait besoin de nouvelles études susceptibles de fournir d'autres données. Le présent rapport consiste en une évaluation portant sur l'usine de pâte à papier B.C. Timber (Castelgar, C.-B.).

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SUMMARY AND CONCLUSIONS

The B.C. Timber Ltd. (Canadian Cellulose Company Ltd. prior to June 1, 1981) pulpmill at Castlegar is the only kraft operation in British Columbia without some form of secondary treatment and discharging to freshwater. Effluent is discharged into the Columbia River approximately 3.2 km downstream of the Hugh Keenleyside dam. For the period 1976 to 1979, the yearly average loading of BOD_5 from the final effluent (combined pulpmill and woodroom discharges) ranged from 18 636 kg/day in 1978 to 23 728 kg/day in 1979. For TSS, the average ranged from 11 336 kg/day in 1978 to 18 382 kg/day in 1979. Specific loadings in terms of kg/day (total load concept) are not indicated on effluent permit PE-1272, issued September 1973 in the name of Canadian Cellulose Company Limited. For comparative purposes and using a mill production rating of 504 ADt/day (4-year average for Celgar) and a 17.5 kg/ADt TSS objective, the daily loading allowance would be in the order of 8 800 kg/day. It has been estimated that approximately 75% of the combined final effluent TSS loading originates from the pulpmill and with remainder originating from the woodroom. Suspended solids discharged in the final effluent include a considerable amount of settleable solids.

An August 1977 application was made to amend permit PE-1272 on behalf of Canadian Cellulose Ltd. The application included a request that the compliance date for reaching level B for TSS discharged from the pulpmill be altered to March 31, 1978, and an objective of 17.5 kg/ADt be used. To date the mill has been concentrating on in-plant control measures to reduce TSS loadings. The requirement for biological treatment at the Castlegar pulpmill was deferred in 1974 by the Pollution Control Branch (now the Waste Management Branch) until after completion of Phase II of the Water Investigations Branch (WIB) study on the water quality of the lower Columbia River and which was completed in April, 1979.

Canadian Cellulose Ltd. had announced a proposal to expand the Castlegar operation to a production of between 1 000 and 1 300 ADt/ day.

Although those proposed expansion plans have since been cancelled, a 400 ADt/day incremental expansion at the present mill is still an option being considered by B.C. Timber. The company has also reached an agreement with the British Columbia government on a plan to improve effluent quality at the Castelgar operation with a bio-basin treatment system. An amendment application dated August 21, 1981 has been made to the Waste Management Branch and calls for a name change to B.C. Timber Ltd. and completion of a biological treatment lagoon to meet level A objectives by December 31, 1984.

Observations by divers in June 1975 indicated that the Columbia River bottom near the diffuser was covered by a blanket of fibre up to one meter thick, extending over one-half the river width and to one kilometer downstream. The Water Investigations Branch indicated a need to assess the importance of this habitat loss.

Based on results of the Environmental Protection Service (EPS) pulpmill effluent toxicity program, the Celgar pulpmill final effluent fails to meet either federal or provincial toxicity requirements. The Water Investigation Branch reported that an analysis of effluent toxicity and dilution indicated that there are probably sub-lethal effects on aquatic organisms in the Columbia River between the pulpmill and the Kootenay River at lower flows. Based on an application factor of 0.05 of the 96-h LC_{50}, they estimated that a 96-h LC_{50} of 40% on the combined final effluent would be necessary to avoid sub-lethal stress outside the initial dilution zone during low flows. The potential for a sublethal effect was felt to be due to the pulpmill effluent and to the high dissolved gas levels resulting from the Hugh Keenleyside Dam. WIB recommended a study to assess sub-lethal stress if the effluent 96-h LC_{50} is not generally greater than 40%.

The effect of the Hugh Keenleyside Dam on the Columbia River at Castlegar is to even out the flow by reducing spring flood peaks and increasing the volume of low winter flows, thereby generally providing better winter dilution potential. However, flow regulation can increase the duration over which continuous very low flows occur, usually for periods between February and June. The normal minimum flow in the Columbia River at the pulpmill is 142 m^3/s and provides about a 50:1 dilution at the end of the 100 m dilution zone.

The stretch of river downstream of the Hugh Keenleyside Dam to the Castlegar ferry supports a significant recreational fishery for kokanee, rainbow trout, Dolly Varden and whitefish. Complaints of tainted fish (primarily whitefish, some rainbow trout) have been reported by the Fish and Wildlife Branch. Although a B.C. Research taste panel testing fish caught downstream from the pulpmill diffuser generally did not associate tainting (very slight to moderate for the trout, moderate to strong for the whitefish) with kraft mill effluent, the trout deemed to have a moderate degree of tainting were described by some tasters as having "a pulpmill taste". The test fish were caught during flows of approximately the average annual discharge (1 140 m^3/s) and gave a relatively high dilution of about 700:1. In addition, the fish were caught in a year with relatively few days of minimum flows. WIB reported that tainting may be possible at very low river flows.

Water quality parameters from a station 6 km downstream from the pulpmill diffuser that have shown an increase above background levels include colour, phenol, tannin/lignin and dissolved sodium. The minimum-maximum range for pH was much larger for the downstream samples (6.6-9.9) than for the control samples (7.3-8.7). WIB reported that the Columbia River is capable of buffering an acidic discharge but has only limited capacity to buffer an alkaline discharge. On two occasions the pH at the station 6 km downstream of the outfall exceeded 9.0. A pH of 9.1 and 9.9 was recorded during relatively high flows of 858 and 572 m^3/s, respectively. Levels were likely greater in the mixing zone. WIB identified a need to maintain the river pH at background levels beyond the initial dilution zone of 100 meters and recommended that highly alkaline effluent discharges be avoided. WIB reported that there has been no significant reduction in dissolved oxygen downstream of the pulpmill but should BOD_5

loadings increase, the assimilative capacity of the river should be assessed. In addition, they reported that any aesthetic degradation due to colour or foam was not severe and occurred for short periods at low river flows. A taste panel was able to distinguish between effluent-free and effluent-containing Columbia River water with at least 95% confidence at dilutions as high as 1 000:1. The greater part of the water quality data that has been collected respective to the Castlegar pulpmill has been collected during moderate to high flows. In a year with extended periods of low flows, such as 1974 and 1975, the impact of the pulpmill might be more pronounced.

There is no information presently available on the levels of the toxic organic chemical constituents of bleached kraftmill effluents in the sediment or the biota of the area downstream of the pulpmill diffuser. Research into this field may be warranted. Programs outlined by WIB for intensive water quality monitoring during low flows, a re-evaluation of the size and impact of the fibre bed downstream of the diffuser and an assessment of the possibility of sub-lethal stress should be made. A fish tainting study in a year with extended periods of low flows should be considered.

1 INTRODUCTION

B.C. Timber Limited (Canadian Cellulose Company prior to June 1, 1981) operate a bleached kraft pulpmill (Celgar Pulp Division) at Castlegar, B.C. (Figure 1). The pulpmill began operating in 1960 and is situated on the south side of the Columbia River and the diffuser is located approximately 7.2 km upstream of the confluence of the Kootenay and Columbia Rivers (Figure 2). The Hugh Keenleyside Dam is located approximately 3.3 km upstream from the pulpmill diffuser.

The Celgar pulpmill is the only interior British Columbia pulpmill discharging effluent into freshwater without prior biological treatment. The woodroom effluent receives primary treatment before being discharged into the Columbia River.

The Columbia River between the Hugh Keenleyside Dam and the Kootenay River supports an important recreational fishery for kokanee, rainbow trout, Dolly Varden and whitefish. A Phase I evaluation of environmental knowledge on the Lower Columbia River Basin up to the end of 1975 has been completed by the provincial Water Investigations Branch (WIB) (1) and, more recently, a Phase II evaluation has been completed on data collected in 1976 and 1977 (2).

This review has been restricted to effluent quality for the period 1976 to 1979 as it relates to BOD_5 and total suspended solids (TSS), the period 1973 to 1977 for effluent toxicity, the fishery resources in the vicinity of the pulpmill and the findings of receiving water studies conducted to assess the aquatic impact of the pulpmill discharge. Effluent quality data has been derived primarily from mill monitoring results submitted to the Environmental Protection Service (EPS). The WIB Phase I and Phase II reports have been the primary source of environmental information for this review.

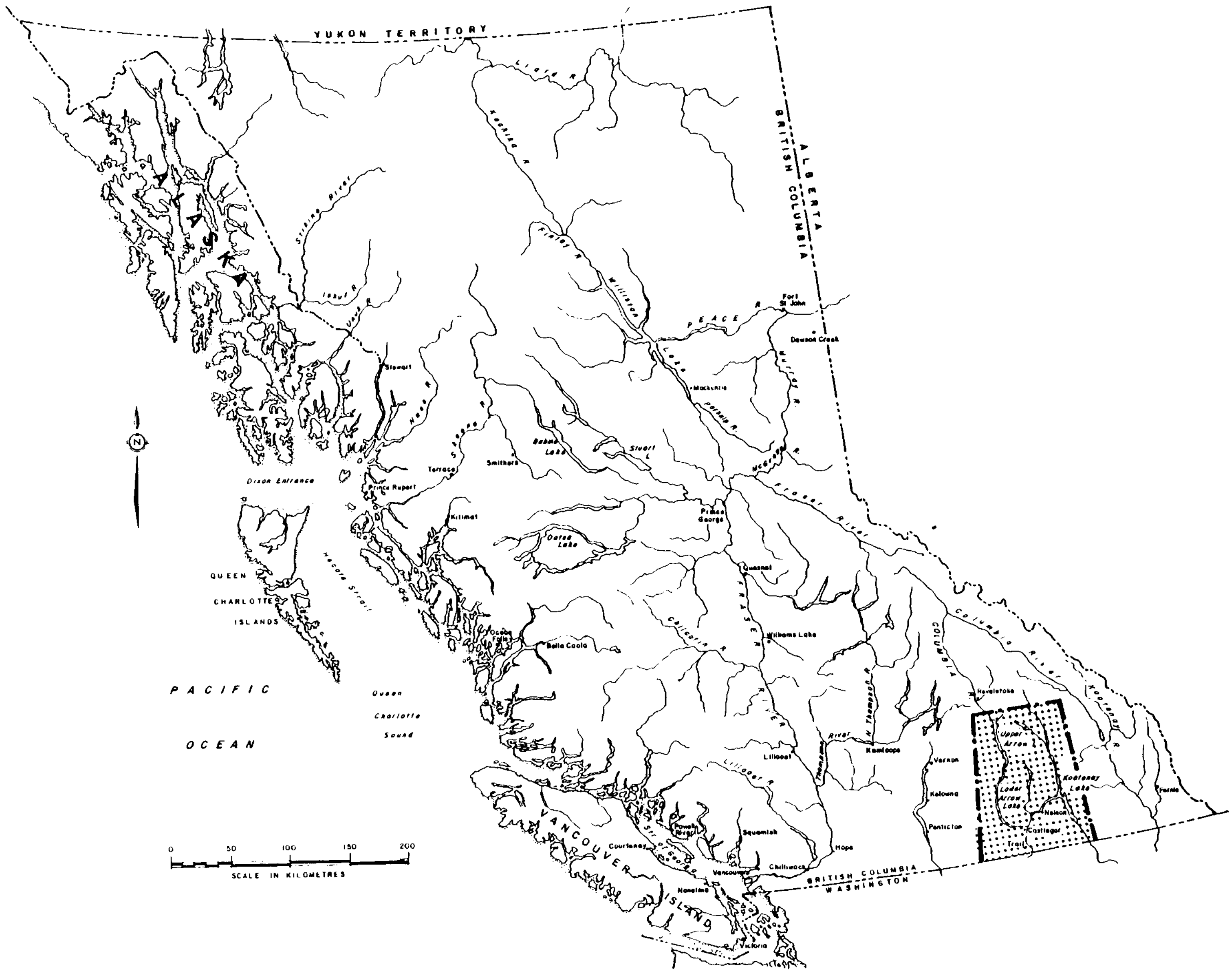

FIGURE I LOCATION MAP OF THE LOWER COLUMBIA RIVER BASIN

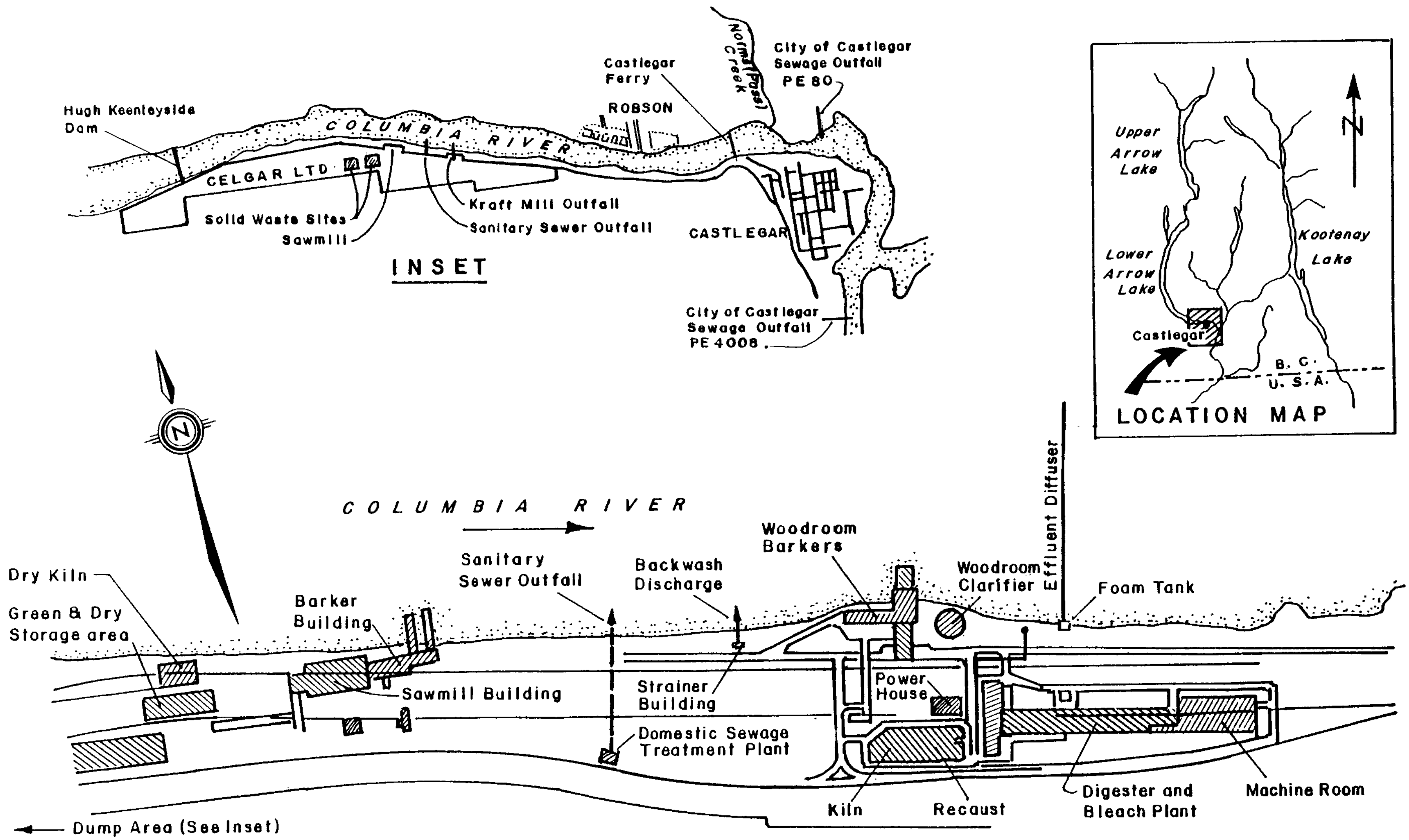

FIGURE 2 LOCATION MAP OF B.C. TIMBER (CELGAR) PULPMILL

2 PULP MILL OPERATIONS

2.1 Operational History

The Celgar pulpmill at Castlegar is an integrated wood and bleached kraft mill operation and started production in November 1960. Pulp production has gradually increased to the present level of approximately 500 ADt/day as a result of in-plant modifications (Table 1). The company had announced proposed expansion plans for the existing mill to a production of between 1 000 and 1 300 ADt/day and the possibility of building a new thermo-mechanical pulpmill was also being examined (3). The proposed expansion plans have since been cancelled but a 400 ADT/day incremental expansion is still an option being considered by B.C. Timber (29).

2.2 Effluent Treatment and Disposal

The pulpmill effluent originates from three main sources: the acid and alkaline sewers which are combined in a foam mixing tank, an overflow from the unbleached white water tank and the general sewer containing effluent from the woodroom clarifier and the recovery and the pulping processes. Effluent treatment facilities are exclusively in-plant controls and are designed to reduce the suspended solids load (Figure 3). Effluent from the digester and bleach plant is diverted over a set of fibre recovery screens prior to being released. An additional clarifier in the recausticizing area was added in 1978. Effluent from the woodroom receives filtration and primary clarification prior to being mixed in the foam tank. Beak Consultants (4) have evaluated various secondary treatment options for the Celgar operation.

TABLE 1 MILL DESCRIPTION

Mill Type	Average Production (ADt/day)	Average Annual Flow (m^3/s)	Wood Furnish
Integrated kraft and wood mill producing semi-bleached and bleached kraft market pulp	1976 - 494 1977 - 520 1978 - 500 1979 - 504	1976 - 1.41 1977 - 1.34 1978 - 1.35 1979 - 1.44	Spruce-balsam..25-30% Pine............5-10% Hemlock...........25% Cedar-fir-larch...55%

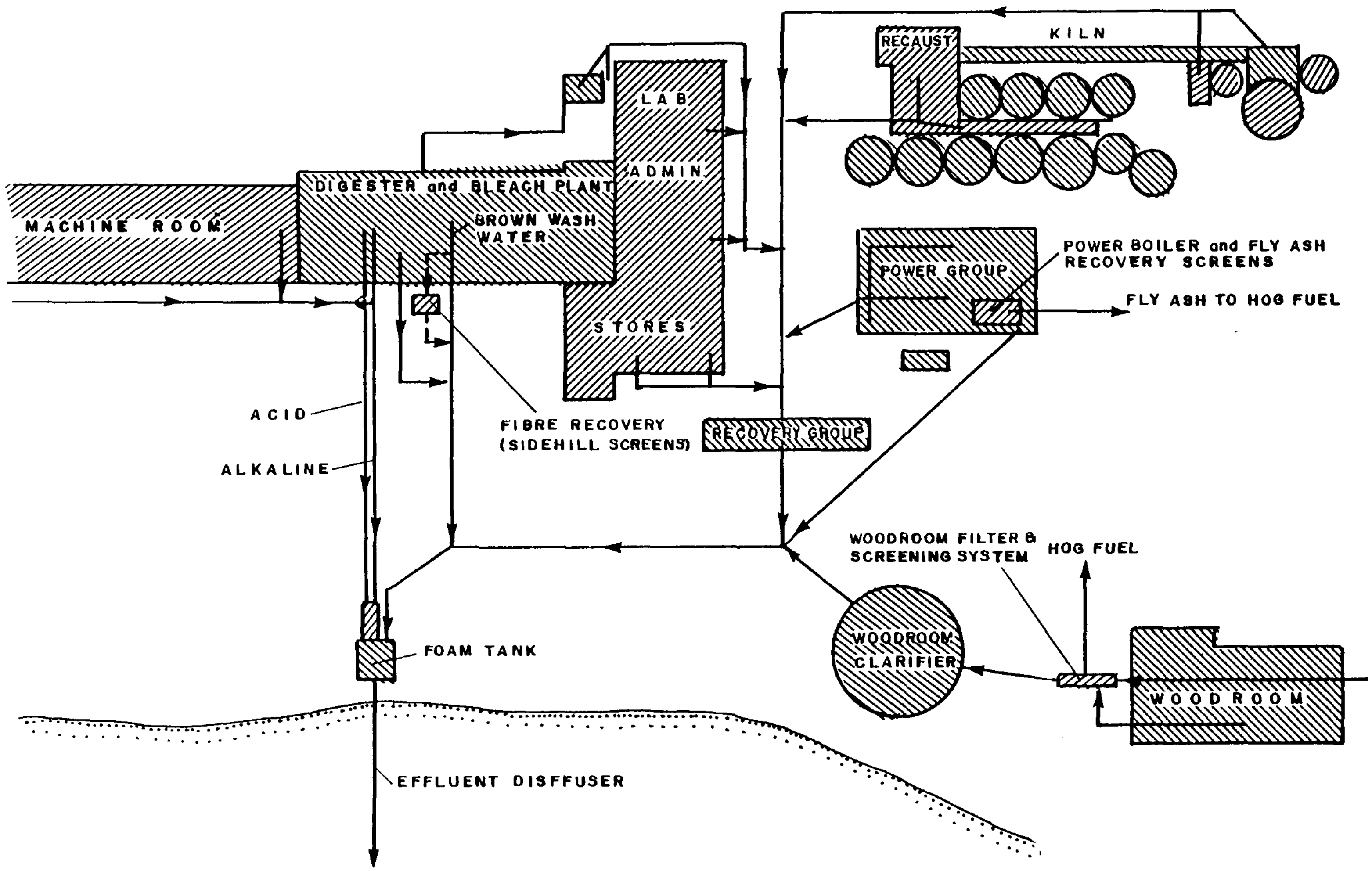

FIGURE 3 CELGAR PULP MILL TREATMENT SYSTEM FACILITIES

3 FEDERAL AND PROVINCIAL ABATEMENT REQUIREMENTS

Federal Pulp and Paper Effluent Regulations (5, 6) were introduced in 1971. The provincial Pollution Control Objectives for the Forest Products Industry of B.C. were first introduced in 1971 (7) and revised in 1977 (8).

3.1 Federal Requirements for Effluent

Under federal regulations, total suspended solids (TSS), biochemical oxygen demand (BOD_5) and toxic wastes are prescribed as deleterious under the Fisheries Act. To date, the federal approach to regulation implementation has been to achieve compliance via the provincial Waste Management Branch permit system. This approach has generally been workable, especially for mills discharging to freshwater where provincial requirements have paralleled federal regulations. The parameters of TSS, BOD_5 and toxicity have been assessed in Section 4 on that basis.

3.2 Provincial Requirements for Effluent and Solid Wastes

Canadian Cellulose first applied for a Pollution Control Permit to discharge effluent in July 1970. Permit PE-1272 was issued September 17, 1973, and required that Celgar meet provincial level B objectives for BOD_5, TSS and toxicity by December 1975. The woodroom effluent was to meet level B objectives by the same date. An amendment application was made by the company in August 1977 to defer the compliance date for the pulpmill TSS level to March 31, 1978, and that a level of 17.5 kg/ADt be used. The requirement to meet level B for BOD_5 and toxicity was deferred by the Waste Management Branch (formerly Pollution Control Branch) in 1974 pending completion of Phase II of the WIB evaluation on the water quality of the lower Columbia River and which was expected to establish if a further reduction in these parameters was required.

The effluent quality requirements as presently outlined in Permit PE-1272 do reflect level B of the 1971 Objectives. The permit allows for a discharge of 111 400 m^3/day from the pulpmill and 25 000 m^3/day from the woodroom to the Columbia River. Effluent limits prescribed on Permit PE-1272 for TSS, BOD_5 and toxicity are listed in Appendix I. Daily loadings for BOD_5 and TSS are not reflected on the permit and values reported in Appendix I have been calculated by the author for demonstrative purposes.

Canadian Cellulose Ltd. has reached an agreement with the British Columbia government on a plan to improve effluent quality at the Castlegar operation with a bio-basin treatment system (28). An amendment application dated August 21, 1981 has been made to the Waste Management Branch and calls for a name change to B.C. Timber Ltd., primary treatment, pH control facilities and a biological treatment lagoon to meet level A objectives by December 31, 1984.

Solid wastes from the pulpmill and lumber operations are landfilled at a site approximately 300 m southwest of the sawmill. Solid waste disposal conditions are stipulated in Permit PR-1760, which was last amended on January 4, 1979. The quantity of refuse which may be discharged is 67 m^3/day. Solid wastes will be made up of lime mud, slaker grits, bark and scrap lumber, waste pulp and paper, and scrap metal.

Domestic sewage at the Celgar operation receives secondary treatment and is chlorinated prior to being discharged to the Columbia River upstream of the process effluent discharge. Permit PE-1273 allows for an average annual sewage discharge of 114 m^3/day.

4 EFFLUENT ASSESSMENT

4.1 TSS and BOD_5 for 1976 to 1979

Loadings of TSS and BOD_5 for the Celgar pulpmill have been calculated for 1976 to 1979 (Table 2). The values reported reflect an approximate daily loading for a given month calculated from a representative number of individual daily production and final effluent quality results for that month.

While specific loadings in terms of kg/day are not indicated on Permit PE-1272, the usual procedure is to calculate them from the mill's production rating and a limit per tonne of production as specified in the Pollution Control Objectives. Just for demonstrative purposes, the final effluent loadings in Table 2 have been assessed in relation to an average 4-year production (1976 to 1979) of 504 ADt/day and the 1971 level B objectives reported on Permit PE-1272 (Appendix I). Based on the averages for the 4 years reviewed, the BOD_5 and TSS loadings can be about double that which the 1971 level B objectives would call for, based on a production of 504 ADt/day. The company indicated in their August 1977 amendment application that the pulpmill meet a 1977 level B objective of 17.5 kg/t for TSS. At a production of 504 ADt/day this would correspond to a loading of 8 820 kg/day. WIB (2) reported that approximately 75% of the final combined effluent (pulpmill and woodroom) TSS loading comes from the pulpmill. Based on the yearly averages in Table 2 and taking 75% of the final effluent loadings, TSS levels can still exceed the 1977 level B objective. WIB (2) reported that the suspended solids discharged from the mill included a considerable amount of settleable solids. WIB (2) reported that approximately 88% of the final effluent combined (pulpmill and woodroom) BOD_5 loading was from the pulpmill.

TABLE 2 CELGAR PULPMILL FINAL EFFLUENT TSS AND BOD_5 LOADINGS (kg/day) FOR 1976 TO 1979

	1976		1977		1978		1979	
	BOD_5	TSS	BOD_5	TSS	BOD_5	TSS	BOD_5	TSS
January	21 682	24 000	19 091	9 327	16 100	13 082	25 200	43 773
February	25 254	16 282	21 209	6 800	20 164	17 509	20 109	16 418
March	20 664	24 673	25 682	16 645	20 336	11 527	23 482	18 900
April	15 618	21 282	22 245	17 000	29 654	10 364	28 182	10 845
May	16 118	13 973	18 900	10 736	16 773	6 591	23 709	9 382
June	23 273	21 554	17 873	7 336	20 009	6 009	25 382	9 527
July	16 182	6 564	20 454	12 245	16 745	4 291	28 636	18 327
August	21 845	19 964	20 773	22 854	20 236	10 073	17 000	7 854
September	18 009	15 345	19 909	12 209	16 827	7 264	23 500	30 582
October	19 609	14 973	25 345	7 273	19 736	11 945	25 091	19 254
November	19 691	8 636	26 682	16 354	19 036	7 254	26 145	13 036
December	17 791	9 827	-	-	17 054	30 091	18 264	22 709
AVERAGE	19 645	14 927	22 018	12 554	18 636	11 336	23 728	18 382
ESTIMATED TSS AND BOD_5 LOADINGS (kg/day) CONRIBUTED FROM PULPMILL EFFLUENTS*								
	17 288	11 195	19 346	9 415	16 400	8 502	20 881	13 786

*Based on WIB (2) estimates of final combined effluent (pulpmill plus woodroom), that 75% of TSS loading and 88% of BOD_5 loading is from the pulpmill.

4.2 Toxicity for 1973 to 1977

The 1971 provincial objectives (7), in force until 1977, specified a static bioassay test in which 50% of the test fish survive a 96-hour exposure to a specific effluent concentration. A 90% effluent concentration was to be used where the final effluent dilution was greater than 20:1 (Celgar Pulpmill) and a 100% concentration where the dilution was less than 20:1 in the receiving water. Effluent testing was required quarterly, with a provision for weekly testing in the event of failure to meet the specified toxicity level. The 1977 objectives (8) specify 50% survival during a 96-hour static bioassay test of 100% effluent irrespective of dilution potential. A monthly monitoring frequency is suggested in the 1977 objectives and if a failure is detected, the frequency should be every two weeks until the objective is met.

Walden et al. (9) reported that the provincial objective of 50% survival in a 90% effluent concentration over 96 hours exposure (static test) was slightly more stringent than the federal routine monitoring bioassay of 80% survival in a 65% effluent concentration of 96 hours exposure (static test).

In December 1975 the Environmental Protection Service (EPS) initiated an effluent monitoring program to determine the extent of compliance with present toxicity standards. Under the program mills sent effluent samples to the EPS laboratory for bioassay. The effluent concentrations tested at 90% and 100% directly related to provincial objectives and those at 65% with federal routine monitoring requirements.

A listing of all bioassays conducted on the Celgar pulpmill over the period 1973 to 1977 is provided in Table 3. Toxicity testing for the Celgar operation differed from the normal procedure used in the monitoring program in that 96-h LC_{50} values were determined on all the samples and only in 1976 was an actual 65% v/v concentration (federal toxicity test concentration) ever used.

TABLE 3 CELGAR PULPMILL FINAL EFFLUENT BIOASSAY RESULTS, 1973 TO 1977

Year	Sample Date*	Species	Loading Density (gm/l)	96 h LC_{50}
1973	November 22**	Coho Salmon	1.80	13.5
	November 27	(*Oncorhynchus*	1.80	18.0
	December 3**	*kisutch*)	1.62	24.0
	December 9		1.84	13.5
	December 16		2.10	24.0
1974	November 13		0.66	22.5
	November 19		1.22	24.0
	November 25		1.02	24.0
	December 1		0.95	45.5
	December 9		0.95	24.0
	December 15		1.10	39.3
1975	December 16	Rainbow Trout	0.44	4.2
1976	February 17	(*Salmo gairdneri*	0.42	20.0
	April 28		0.22	18.2
	June 16		0.46	20.0
	August 18		0.73	8.4
	October 27		1.60	25.0
1977	January 18		0.47	27.5
	March 8		0.93	7.5
	June 21		0.47	26.5
	August 24		0.45	9.8
	November 9		0.40	28.0

* no results after 1977

** sample neutralized

Over the five years, none of the 22 samples tested passed either the provincial or federal toxicity requirement (Table 3). The 96-h LC_{50} for the final effluent averaged 21.2% and ranged between 4.2% and 45.5%.

WIB (2) reported that phenols, resin acids, tannin and lignin-like compounds, sulphides, mercaptans and chlorine residual were at levels that could make the effluent toxic to aquatic life. It was also reported that contaminated condensates from the black liquor evaporators and digesters, which contain volatile reduced sulphur compounds that are a major source of toxicity, are sewered without treatment at Celgar. In addition, spills of highly alkaline and toxic materials were reported to presumably occur at Celgar as evidenced by rapid shifts in effluent pH. Eighty percent of the pH measurements on the final effluent were outside the range of 6.5 - 8.5 specified in the permit. Seventy-five percent of the measurements were less than pH 6.5 but 4% were greater than 8.5. "pH" could shift rapidly from acid to alkaline during the day (2). WIB (2) reported that, from chlorination, a residual could be left in the effluent that would be toxic to aquatic life and that organic compounds could be formed that are known to be toxic to aquatic life.

WIB (2) reported that the analysis of effluent toxicity and dilution indicated that there are probably sub-lethal effects on aquatic organisms in the Columbia River between the pulpmill and the Kootenay River at lower flows.

Should the reader wish to review information on acute toxicity bioassay monitoring and the toxic fractions in pulpmill effluents he is referred elsewhere (10, 11, 12 13, 14, 15, 16).

5 RECEIVING WATER FEATURES

5.1 Lower Columbia River Drainage Basin

The drainage area for the Columbia River at Castlegar is 36 519 km^2. The Columbia River drains the western slope of the Selkirk Mountains and the eastern slope of the Monashee Mountains. The Columbia River north of the United States' border drains a total area of 154 623 km^2. The Columbia River-Arrow Lakes valley forms the boundary between the Selkirks and the Monashees. It is a narrow, longitudinal valley which is generally less than 3.2 km wide and lies at an elevation of 427 to 457 meters (1).

The outlet of the Lower Arrow Lake is located at the Hugh Keenleyside Dam which has no hydro-electric capability but since 1968 it has been used to control the level of the Arrow Lakes for flood control and downstream power generation in the United States.

5.1.1 Hydrology. The mean annual discharge for the Columbia River at Castlegar is 1 140 m^3/s. WIB (1) reported that the Kootenay River inflow into the Columbia River at Castlegar increases the flow in the Columbia by about 75%. Stream-flow data from Water Survey of Canada records for 1972 to 1976 (17) at Station 08NE002, located 3 km upstream of the Kootenay River confluence, are shown in Figure 4. The streamflows shown in Figure 4 deviate somewhat from a normal expected flow cycle as a result of the Hugh Keenleyside Dam. WIB (1) reported that the effect of the dam is to even out the flow by reducing spring flood peaks and generally increasing the volume of low winter flows.

The WIB (1) included a figure on the predicted effect of flow regulation on the Columbia River. That figure has been included as Figure 5 of this report.

WIB (1) reported that the natural flood peaks of May through July are substantially reduced as water is stored in the reservoirs but that the August through October flows approximated natural flow conditions (Figure 5). Flows during November through February are greatly

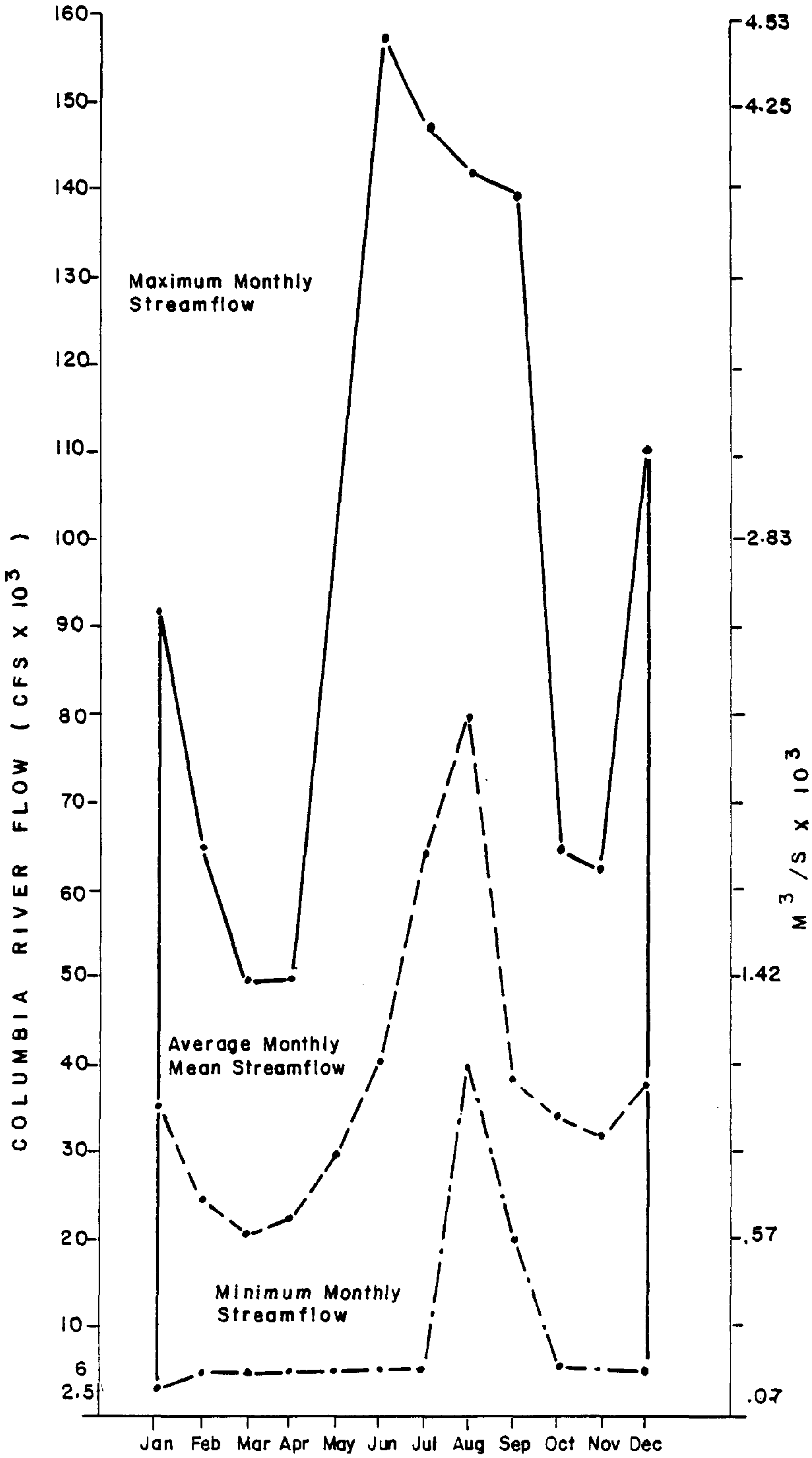

FIGURE 4 AVERAGE MONTHLY MEAN, MAXIMUM AND MINIMUM MONTHLY FLOWS FOR THE COLUMBIA AT CASTLEGAR FROM 1972 TO 1976

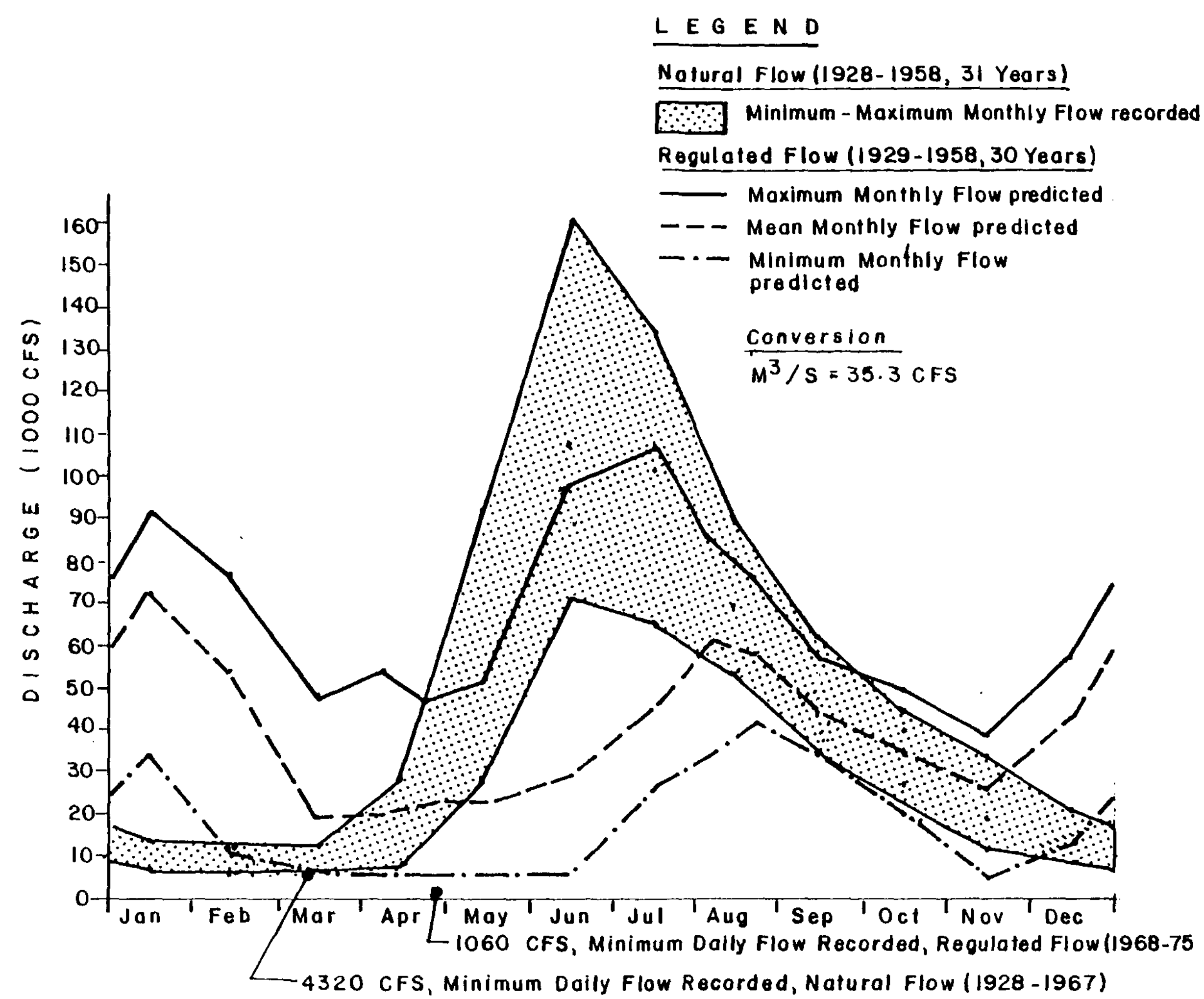

FIGURE 5 PREDICTED EFFECT OF FLOW CONTROLS ON THE COLUMBIA RIVER AT CASTLEGAR (After WIB (1))

increased as water is released for downstream uses and spring flood control (1). The increased volume of winter low flows generally provides more dilution for discharges to the Columbia River (1). WIB (2) reported that the normal minimum flow in the Columbia River above the Kootenay River is 142 m^3/s and that the average weekly discharge from the Hugh Keenleyside Dam cannot be less than 142 m^3/s unless agreed upon by B.C. Hydro, the Bonne ville Power Administration and the U.S. Army Corps of Engineers. They also reported that, on average, flows around 142 m^3/s are expected to occur about 3.5% of the time (13 days/year) and flows significantly less than 142 m^3/s are not normally expected to occur. Daily flows of less than 128 m^3/s have occurred on 15 days over the period 1968 to 1977 (2).

Water Survey of Canada data for the period 1970 to 1979 shows that the number of days of minimum flows less than 142 m^3/s is highly variable (Table 4). In certain years the number of days with flows less than 142 m^3/s is quite significant (1974 = 51 days). This is even more important when the low flows extend over a continuous period, usually for periods between February and June. There are a substantial number of days where the flows fall between the 142-156 m^3/s range (Table 4).

WIB (2) reported the dilution ratio, at an effluent flow rate of 1.4 m^3/s, during minimum flows to be about 100:1 once mixing is complete. The exact distance required to achieve complete mixing is not known but the maximum distance is probably about 4 km as mixing should be complete once the water enters Castlegar Narrows (2). WIB (2) reported that aerial photographs taken during a flow of 149 m^3/s showed that a 60 m wide effluent plume surfaced within 40 m of the diffuser, spread to 100 m wide at 100 m downstream and 120 m wide at 300 m downstream. The plume impinged on the south side of the river 450-600 m downstream from the diffuser. The minimum dilution available within the initial dilution zone (100 m) has been estimated to be about 50:1.

TABLE 4 SUMMARY OF THE NUMBER OF LOW FLOW DAYS FOR THE COLUMBIA RIVER AT CASTLEGAR OVER 1970 TO 1979

Year	Flow (m^3/s)				
	≤ 142	≥ 142, ≤ 156	>156, ≤ 170	≤170 total	≤350 total
1970	0	3	0	3	82
1971	0	0	0	0	66
1972	0	0	0	0	0
1973	14	48	1	63	99
1974	51	33	2	86	109
1975	9	72	3	84	93
1976	0	11	0	11	15
1977	3	12	0	15	27
1978	0	38	0	38	51
1979	0	0	0	0	7

Water Survey of Canada Data

5.2 Fisheries Resource

The Fish and Game Branch (18), now Fish and Wildlife Branch, conducted some preliminary investigations in 1962 and 1963 to determine the probable effects of the Hugh Keenleyside Dam. In that report it was reported that there is an extensive sport fishery in the Columbia River between the damsite and the United States' border approximately 29 km downstream. Rainbow trout up to 2.3 kg and Dolly Varden char up to 12.7 kg are taken, as well as Rocky Mountain whitefish (18).

Robinson (19) reported that the stretch of the Columbia River between the Hugh Keenleyside Dam and the Castlegar ferry supports an important winter fishery. He reported that a 1976 creel census during the months of January to March determined that 1 200 fish were caught with 2 400 angler hours of effort. Of these fish more than 75% were kokanee weighing up to 1.8 kg, while the rest were rainbow trout. Angler use was reported to be normally greater and the 1976 results may be of an atypical year. WIB (1) reported that from a creel census in 1969, over July to September, that 2 400 fish were caught by 530 anglers between the dam and the Kootenay River confluence. In addition to rainbow trout and kokanee, the stretch of river below the dam supports populations of Dolly Varden and whitefish (19). Dolly Varden are more heavily fished during May and June, while whitefish are caught year round.

P. Stent (per. comm., Fish and Wildlife Branch, Trail) reported that kokanee up to 45 cm are caught in the stretch of Columbia River downstream of the dam to Castlegar and that kokanee spawn in Norns Creek (local name is Pass Creek), a tributary located just upstream of the Kootenay confluence (Figure 3). L. Fleck (per. comm., Fish and Wildlife Branch, Nelson) reported that Norns Creek also supports spawning populations of rainbow trout and Dolly Varden and likely whitefish. Maher (20) reported that no migratory runs of fish would be significantly affected by the Hugh Keenleyside Dam therefore fish ladders would not be required at the dam.

6 ENVIRONMENTAL IMPACT AND ASSESSMENT STUDIES

6.1 River Studies

Very little detailed work has been done on the Columbia River with respect to the Celgar operation. Robinson (19) reported that the Celgar operation has never implemented a receiving environment monitoring program as stipulated in their permit. Environmental data up to the end of 1975 has been reviewed by the WIB (1) in their Phase I report and data collected over 1976 and 1977 was reviewed in their Phase II report (2). The information presented in this section is based mainly on the findings reported in the two WIB reports.

6.1.1 River Study Assessments.

6.1.1.1 Water quality. The Ministry of the Environment has a water quality station located immediately downstream of the Hugh Keenleyside Dam (0200183). A monitoring station downstream of the mill outfall and upstream of the Kootenay River confluence did not exist at the time of the WIB Phase I study (1). Since that report, Station 0200200 was established on the west shore 6 km downstream of the pulpmill outfall (1.2 km upstream of the Kootenay River confluence). Water quality data from Stations 0200183 and 0200200 for June 1975 to June 1978 have been supplied for this review by Pommen (21) of the Water Investigations Branch, Victoria.

Data collected between 1956 and 1971 and reviewed in the Phase I report was reported to show no detectable changes in the parameters measured. Data collected from June 1975 to June 1978 has been summarized in Table 5. The data have been presented only as an average of all samples and without seasonal variability or dilution being considered. Parameters that show some increase 6 km downstream include colour, phenol, tannin/lignin and dissolved sodium. While the average pH for each station was comparable, the minimum-maximum range for the downstream station (6.6 - 9.9) was much broader than for the upstream site (7.3 - 8.7). In their Phase II report WIB reviewed the same data, but for the period June 1975 to July 1977, as well as additional surveys on pH and dissolved oxygen levels and on a fish tainting study.

TABLE 5 WATER QUALITY DATA FOR THE COLUMBIA RIVER AT CASTELGAR (JUNE 1975 TO JUNE 1978), DATA SUPPLIED BY WATER INVESTIGATIONS BRANCH, VICTORIA

Parameter	Station (0200183) 3 km upstream of diffuser					Station (0200200) 6 km downstream of diffuser				
	Average	Maximum	Minimum	S.D.	No. of values	Average	Maximum	Minimum	S.D.	No. of values
True colour (Rel units)	5.3	10.0	L5.0	1.2	17	7.0	20.0	L5.0	4.9	17
Colour (TAC)	2.4	6.0	L1.0	1.4	26	4.7	19.0	L1.0	3.8	25
pH	7.9	8.7	7.3	0.2	89	7.9	9.9	6.6	0.4	88
Total residue (mg/l)	76.0	106.0	54.0	9.9	42	77.0	100.0	54.0	8.7	42
FR* (mg/l)	72.3	88.0	52.0	7.9	34	76.0	98.0	52.0	8.9	33
NFR** (mg/l)	4.0	28.0	L1.0	5.7	25					
Spec. cond. (umhos/cm)	109.0	150.0	72.0	22.4	68	110.0	149.0	75.0	22.0	62
Diss. oxygen (mg/l)	12.1	15.8	8.1	1.5	42	11.9	15.8	8.2	1.7	31
Turbidity (JTU)	1.0	4.0	0.4	0.8	19	0.8	2.1	0.1	0.5	20
Total alkalinity (mg/l)	50.3	61.0	23.0	9.0	32	49.9	62.0	29.5	8.9	31
Organic carbon (mg/l)	1.6	5.0	L1.0	1.0	32	1.8	4.0	L1.0	1.1	32
Hardness (mg/l)	55.1	63.2	41.4	6.8	32	54.9	62.9	39.4	6.9	31
NH_3 (mg/l)	0.006	0.010	L0.005	0.001	28	0.006	0.010	L0.005	0.002	27
NO_2 - NO_3 (mg/l)	0.12	0.18	0.08	0.02	30	0.11	0.15	0.06	0.02	29
NO_3 (mg/l)	0.11	0.15	0.07	0.03	14	0.10	0.15	0.04	0.04	14
TKN (mg/l)	0.07	0.17	L0.01	0.04	42	0.09	0.23	L0.01	0.06	41
Total N (mg/l)	0.19	0.31	0.09	0.05	20	0.22	0.32	0.08	0.07	20
Phenol (mg/l)	0.003	0.007	L0.002	0.001	32	0.004	0.019	L0.002	0.003	32
ortho-phosphorus (mg/l)	0.003	0.003	L0.003	0.0	34	0.003	L0.003	L0.003	0.0	34
Total phosphorus (mg/l)	0.006	0.026	L0.003	0.005	47	0.007	0.023	L0.003	0.003	46
Silica (mg/l)	3.8	4.6	3.2	0.4	17	3.8	4.6	3.2	0.4	17
Sulphate (mg/l)	7.7	8.9	6.4	0.9	9	8.0	9.2	5.9	1.1	8
Tannin/lignin (mg/l)	0.13	0.2	L0.1	0.04	43	0.36	1.2	L0.1	0.23	42
Diss. Na (mg/l)	0.8	1.1	0.6	0.15	10	1.1	1.4	0.7	0.23	9
Fecal coliform (MPN)	3	33	L2	6	26	3	20	L2	4	25
Total Coliform (MPN)	28	540	L2	103	26	16	79	L2	16	25

L = less than
* FR = Filterable Residue
**NFR = Non-filterable Residues

With respect to the location of station 0200200, it should be emphasized that the station was 6 km downstream from the Celgar outfall, well beyond the 4 km distance WIB (2) estimated complete mixing would be achieved. In addition, it should be noted that 1976 and 1977 had very few days of minimum low flows (Table 4). Of the approximate 30 data points used in the WIB (2) report to summarize colour, phenol, tannin and lignin, dissolved oxygen and pH, only 5 of the samples were collected at flows less than 224 m^3/s, all others were at flows greater than 500 m^3/s. More in-depth sampling was conducted with respect to dissolved oxygen and pH but only one of the seven dissolved oxygen surveys was conducted during minimum flows (146 m^3/s), all others exceeded flows of 870 m^3/s and on some of the surveys upstream and downstream samples were not collected for comparative purposes. Of the two pH surveys, one was conducted during a flow of 146 m^3/s and the other at a flow of 1 500 m^3/s.

The greater part of the water quality data has been collected during moderate to high flows. In a year such as 1974 or 1975 (Table 4) which had extended periods of low flows less than 156 m^3/s, an effect due to the Celgar operation would likely be more pronounced.

The following discussion on water quality is based on information reported in the WIB, Phase II, report. WIB (2) reported a minimum dissolved oxygen level of 8.2 mg/l at a flow of 154 m^3/s and concluded that no significant reduction in dissolved oxygen occurs downstream of the pulpmill. They also reported that if the BOD_5 loadings are increased, the assimilative capacity of the river should be determined.

For pH, WIB (2) reported that water quality monitoring indicates that the acidic effluent has had little effect on the pH of the Columbia River but that alkaline effluent has caused occasional high pH values in the river. They reported the capacity of the river to buffer an acidic effluent was substantial but that the river had only a limited capacity to buffer an alkaline effluent. They concluded that the discharge of a highly alkaline effluent should be avoided. On two occasions the pH of the river was significantly increased 6 km downstream of the outfall, i.e., from 8.6 to 9.9 and 8.4 to 9.1. These increases were at relatively high flows of 572 m^3/s and 858 m^3/s respectively. On the one occasion the mill's continuous pH chart indicated an alkaline effluent discharge of pH 11 for about 5.5 hours. This worked out be be 4 to 10 hours before the downstream sample was collected and a time-of-travel of about 6 hours (2). WIB (2) reported that the pH was likely higher in the mixing zone and that these high pH values are near the upper lethal limit of pH 10 for coho salmon and rainbow trout. The natural pH range (7.3 - 8.7) of the river is high and the river probably has little capacity to buffer an alkaline discharge (2). The effluent is normally acidic but the river is able to buffer this. WIB (2) concluded that effluent pH control is needed to maintain the pH of the river between 7 and 8.5 at 100 m downstream, i.e., no pH increase above normal levels. A program to investigate and control the effect of pulpmill effluent pH at low flows was appended in the Phase II report.

Visual observations and an aerial survey during minimum flow conditions indicated that the river was higly coloured and showed the river to be discoloured between the diffuser and the Kootenay River confluence (2). WIB (2) reported that there is some aesthetic degradation of the river downstream of the pulpmill due to discoloration and foaming. The degradation was reported not to be severe and occurred for short periods at low flows.

WIB (2) reported that turbidity and suspended solids levels of the Columbia River were not affected by the pulpmill effluent. However, they reported that a diver survey in June 1975, during a flow of 144 m^3/s, showed that the settleable solids fraction of the effluent had created a blanket of fibre to about 1 km downstream of the outfall and had seriously affected bottom life in the area.

WIB (2) reported that taste and odour tests using Columbia River water and Celgar effluent indicated that the water downstream of the diffuser would not be suitable for domestic purposes. The taste panel was able to distinguish between effluent-free and effluent-containing water with at least 95% confidence at dilutions as high as 1000:1. The dilution in the river downstream of the pulpmill to the Kootenay River confluence is expected to be less that 1000:1 seventy-four percent of the time (2). The panelists could detect an odour in effluent-containing Columbia River water at a dilution of 8200:1. The maximum dilution for the pulpmill effluent is 1800:1 upstream of the Kootenay River confluence.

6.1.1.2 Benthic Invertebrates. Macroinvertebrate collections made for the pulpmill over July to October, 1972, at stations upstream and downstream of the diffuser were reported as inconclusive by WIB (1). Some of the trays were exposed due to changes in water level and differences in substrate were not allowed for (1). WIB (1) reported on the findings of a diver survey made in June 1975 near the mill outfall. They reported that near the diffuser the bottom was covered by a blanket of fibre up to one meter thick, extending halfway across the river and approximately one kilometer downstream along the south side. Opposite the outfall on the north side there was a heavy growth of aquatic plants harbouring invertebrates and fish. Similar habitats were reported upstream of the outfall and on the south side of the river downstream of the fibre blanket. The suspended matter discharged by the mill was reported to have affected bottom life in a localized area (1). WIB (2) identified a need to assess the importance of this habitat loss and concluded that once Level B is achieved the river bottom should be resurveyed and its effect on the aquatic community assessed.

6.1.2 Fish Tainting. Robinson (19) reported that there have been occasional complaints regarding tainted fish from that section of the Columbia River downstream of the Hugh Keenleyside Dam to the Castlegar Ferry. The complaints most often involved whitefish but tainting in rainbow trout has also been reported. B.C. Research (22), on behalf of WIB, performed organo-leptic tests to evaluate fish tainting in wild fish collected from the Columbia River. The B.C. Research report findings are summarized in Table 6. From the spring 1976 catch, control (lower Arrow Lakes) and downstream-of-the-pulpmill samples of rainbow trout, kokanee, large-scale suckers and whitefish were tested and from the summer 1976

TABLE 6 B.C. RESEARCH FISH TAINTING STUDY SUMMARY

Species	Period Caught (1976)	Degree of Tainting and Level of Significance	Comments
Spring Catch			
Rainbow Trout	Test Fish - May Control Fish - June	4 of 5 tests ranged from very slight to moderate and the panel were able to differentiate between the test and control samples with at least a 95% level of confidence in all but one test which was not significant.	Some panel members described moderate tainted sample as being "a pulp mill taste" and 100% of the correct tasters identified the test sample as being the tainted sample.
Kokanee	Test Fish - May Control Fish - June	4 of 6 tests identified as very slight to slight and 2 of 6 not significant. Of the 4 positive tests, on 2 occasions tasters were evenly split as to whether the control or test sample was tainted.	None of the panel made any comment that the tainting was associated with pulp mill effluent.
Sucker	Test Fish - May Control Fish - June	5 of 6 tests identified as moderate to strong and 1 of 6 not significant. Panel had difficulty in distinguishing whether the control or test sample was tainted.	Tainting described as strong, earthy, musty, or muddy taste rather than pulp mill flavour
Whitefish	Test Fish - May Control Fish - June	2 tests both identified as moderate to strong. Panel were able to differentiate between samples with at least a 99% degree of confidence.	In both cases, test fish tainting was described as an earthy, swampy, or muddy taste.
Summer Catch			
Kokanee	Test Fish - July Control Fish - July	2 of 6 tests described as very slight to slight and 4 tests as not significant. Panel had difficulty in distinguishing whether the control or test sample was tainted.	

catch, only kokanee were tested. B.C. Research (22) summarized that a taste panel could differentiate between rainbow trout and whitefish caught downstream of the Celgar outfall and those caught in areas not influenced by pulpmill effluent. Although the panel generally did not associate tainting (very slight to moderate for the trout, moderate to strong for the whitefish) with kraft mill effluent, the rainbow trout deemed to have a moderate degree of tainting were described by some of the tasters as having "a pulp mill taste" (22). The panel could not differentiate between kokanee or suckers influenced by the outfall and those caught elsewhere.

During the period the fish were caught, Columbia River flows at Castlegar were in the order of 1080 m^3/s for May 1976 and 1090 m^3/s for July 1976 (2). These flows were approximately equal to the average annual flow (1110 m^3/s) and gave a relatively high dilution ratio of 700:1 (2). WIB (2) summarized that tests on fish caught near the pulpmill indicated that the effluent did not affect their flavour, although tainting may be possible at very low flows. Referring back to Table 4, 1976 had relatively few low flow days (11 days between 142 and 156 m^3/s) and they were all in April. WIB (2) reported that should tainting prove to be a problem in the future another study should be conducted at low river flows. Ideally, a study should be made after a period of continuous minimum flows.

6.1.3 Sub-lethal Toxicity. WIB (2) reported that there is a potential for a sub-lethal effect on aquatic life in the Columbia River between the Hugh Keenleyside Dam and the Kootenay River. This was felt to be due to the pulp mill effluent and to the high dissolved gas levels resulting from the dam. They reported that of the 40 adult fish caught between the dam and the Castlegar ferry during July and August, 1976, when total dissolved gas levels were approximately 140% saturation, only one exhibited minor symptoms of gas bubble disease. WIB (2) reported that a 96-h LC_{50} of 40% on the combined final effluent from the pulpmill would appear to be necessary to avoid sub-lethal stress outside the initial dilution zone during low flows. The basis for the 40% concentration is an adoption of an application factor of 0.05 of the 96 hr LC_{50}, that is, lowest 96-h LC_{50} of 7.5% x 0.05 = 0.4% effluent in water or a 250:1 dilution. At a low flow of 142 m^3/s the dilution of effluent in the river at the end of the initial dilution zone is about 50:1 or 2% effluent in water, thus, 2% ÷ 0.05 = 40% (2). Davis (23) suggested that for neutralized whole bleached kraftmill effluent some sub-lethal effects will be present at a discharge dilution of 0.1 of the 96-h LC_{50}, few at 0.05 of the 96-h LC_{50} and only rarely at 0.02 of the 96-h LC_{50}. He also indicated that even at a dilution of 0.02 of the 96-h LC_{50}, flesh tainting or colour effects on the food chain may remain. He considered that the criteria are tentative, subject to revision and that they do not necessarily ensure protection of aquatic communities or sensitive food-chain organisms. At a protection criterion of 0.02 of the 96-h LC_{50}, the 96-h LC_{50} of the combined effluent would be 100%.

Based on laboratory experiments on the stress and chronic effects of untreated and treated bleached kraft pulpmilll effluent on coho salmon, McLeay and Brown (24) indicated their findings showed that the effluent constituents and/or the site of toxic effect resulting in the observed changes due to chronic exposure are, in fact, different from those that result in acute lethal (and conceivably sub-lethal) effects. They reported their data suggests that conventional treatment methods used by pulpmills that are successful in detoxifying their wastes according to conventional standards do not necessarily ensure protection and that the use of application factors for predicting safe discharge limits is not valid if based on acute lethal and sub-lethal data alone. McLeay and Brown (24) indicated further examination of the chronic effects of pulpmill effluent, including life-cycle studies, on the well-being of fish is warranted.

WIB (2) recommended that a study to assess sub-lethal stress due to the combined effect of gas supersaturation and pulpmill toxicity be considered if the 96-h LC_{50} for the pulpmill effluent is not generally greater than 40%.

6.1.4 Organic Pollutants. WIB (2) reported that chlorine residual levels in the Celgar final effluent were at levels that could make the effluent toxic to aquatic life. They also reported that chlorination will form organic compounds that are known to be toxic to aquatic life. There is no data available on the levels of the toxic organic chemical constituents of the Celgar kraft mill effluent (resin acids, chlorinated organics) or in the sediments and resident biota feeding on the benthos of the Columbia River. Research into documenting such constituents is recommended.

Holmbom (25) reported that although resin acids and chlorinated phenolics constitute key groups of compounds in pulpmill effluents which are acutely toxic to fish, little is still known about the fate of those fish-toxic compounds in effluent treatment systems and in the receiving waters. Lander et al (27) reported that a few chlorinated phenols that are present in sulphate pulpmill bleachery effluents were also found in fish caught in the vicinity of a pulpmill producing full bleach kraft pulp. They indicated that this in itself didn't tell anything about their possible detrimental effects on fish or other parts of the aquatic ecosystem. Holmbom (25) sampled fish caged in a lake system receiving biologically treated bleached kraft pulpmill effluent. He reported that significant bioaccumulation of resin acids in fish (plasma and bile) was found to occur in water containing only 20 ug/l of resin acids and that there appeared to be a threshold level for bioaccumulation of resin acids between 5 ug/l and 20 ug/l. This concentration range in water might also constitute a threshold for physiological stress in the fish (25). Holmbom (25) reported that there was no indication of any threshold for bioaccumulation of tetrachloroquaiacol down to the 0.5 ug/l level. Holmbom (25) reported that the study results indicated that resin acids did not have any appreciable effects 3.5 km from the pulpmill whereas chlorinated phenols still had noticeable effects 6 km from the pulpmill. Study of fish bioaccumulation may be one possible approach for determination of how far, in distance, from a pulpmill that the "stress on fish" of toxicants is extended (25). Kruzynski (26) reported on the uptake of dehydroabietic acid (DHA) in laboratory exposed sockeye salmon smolts, mature rainbow trout and the marine amphipod Anisogammarous. Kruzynski (26) reported that laboratory exposure experiments established that salmon can rapidly accumulated DHA in major organs such as the brain, liver and kidney and that these high residual levels are probably related to the observed physiological dysfunctions in the test fish.

REFERENCES

1. Water Investigations Branch, Kootenay Air and Water Quality Study - Phase I. Water Quality in Region 8, The Lower Columbia River Basin. Ministry of the Environment (1977).

2. Water Investigations Branch, Kootenay Air and Water Quality Study - Phase II. Water Quality in the Lower Columbia River Basin. Ministry of the Environment (1979).

3. Canadian Pulp and Paper Industry, A MacLean Hunter Production Vol. 33, No. 6, (1980).

4. Beak Consultants Ltd., Evaluation of Secondary Treatment Alternatives. A report for Canadian Cellulose Company Limited, Castlegar, B.C., File K4178 (February, 1975).

5. Pulp and Paper Effluent Regulations, Report No. EPS 1-WP-72-1, Water Pollution Control Directorate, Ottawa (1971).

6. Guidelines for the Pulp and Paper Regulations. Report No. EPS 1-WP-72-2, Water Pollution Control Directorate, Ottawa (1972).

7. Pollution Control Objectives for the Forest Products Industry of British Columbia, Department of Lands, Forests and Water Resources, Victoria, B.C. (1971).

8. Pollution Control Objectives for the Forest Products Industry of British Columbia, Ministry of the Environment, Victoria, B.C. (1977).

9. Walden, C.C., D. McLeay and D. Monteith, Comparing Bioassay Procedures for Pulp and Paper Effluents, Pulp and Paper Canada,

10. Walden, C.C., and D. McLeay. Interrelationships of Various Bioassay Procedures for Pulp and Paper Mill Effluents. CPAR Project Report 165-1, Canadian Forestry Service, Department of Environment, Ottawa (1974).

11. Walden, C.C., "The Toxicity of Pulp and Paper Mill Effluents and Corresponding Measurement Procedures," Water Research, 10, pp. 639-664 (1976).

12. McLeay, D.J., C.C. Walden and J.R. Munro, "Effect of pH on Toxicity of Kraft Pulp and Paper Mill Effluent to Salmonid Fish in Fresh and Seawater," Water Research, 13, pp. 249-254 (1979).

13. ________________________ "Influence of Dilution Water on the Toxicity of Kraft Pulp and Paper Mill Effluent Including the Mechanisms of Effect," Water Research, 13, pp. 151-158 (1979).

14. McLeay, D.J., and M.R. Gordon, "Effect of Seasonal Photoperiod on Acute Toxic Responses of Juvenile Rainbow Trout (Salmo gairnderi) to Pulpmill Effluent," J. Fish. Res. Board Can., 35, pp. 1388-1392 (1978).

15. Leach, J.M., and A.N. Thakore, "Identification of the Constituents of Kraft Pulping Effluent that are Toxic to Juvenile Coho Salmon (Oncorynchus kisutch)," J. Fish. Res. Board Can., 30, pp. 479-484 (1973).

16. Rogers, I.H., "Isolation and Chemical Identification of Toxic Components of Kraft Mill Wastes," Pulp and Paper Mag. Can., 74, T303-T308 (1973).

17. Water Survey of Canada, Surface Water Data (1972 to 1976), Inland Waters Directorate, Ottawa (1973-1977).

18. Fish and Game Branch, Effects on Fish and Game Species of Development of Arrow Lakes Dam for Hydro-Electric Purposes. Fish and Game Branch, Department of Recreation and Conservation (March, 1965).

19. Robinson, D.J., Fish and Wildlife Branch memorandum, (October 26, 1977).

20. Maher, F.P., A Preliminary Report on the Effects on Fisheries of Four Dams Proposed for the Columbia and Kootenay Rivers in British Columbia. Fish and Game Branch (August 1961).

21. Pommen, L.W., Water Investigations Branch memorandum, (July 4, 1978).

22. B.C. Research, Evaluation of Fish Tainting in Wild Fish Exposed to Industrial Effluents, prepared for Water Investigations Branch, Project 1-09-763 (March, 1977).

23. Davis, J.C., Progress in Sublethal Effect Studies with Kraft Pulpmill Effluent and Salmonids. J. Fish. Res. Board Can., 33, pp. 2031-2039 (1976).

24. McLeay, D.J., and D.A. Brown, Stress and Chronic Effects of Untreated and Treated Bleached Kraft Pulpmill Effluent on the Biochemistry and Stamina of Juvenile Coho Salmon (Oncorhynchus kisutch). J. Fish. Res. Board Can., 36, 1049-1059 (1979).

25. Holmbom, B.R., Studies on Resin Acids and Chlorinated Phenolics in Finnish Pulp Mill Effluents and on Their Bioacumulation in Fish. Paper presented at the 89th National AICLE Meeting, Portland, Oregon, August 17-20 (1980).

26. Kruzynski, G.M., Some Effects of Dehydroabietic Acid (DHA) on Hydromineral Balance and Other Physiological Parameters in Juvenile Sockeye Salmon (Oncoryynchus nerke). A Thesis Submitted in Partial Fulfilment of the Degree of Doctor of Philosophy, Department of Zoology, University of B.C. (1979).

27. Landner, L., K. Lindstrom, M. Karlsson, J. Nordin and L. Sorensen. Bioaccumulation in Fish of Chlorinated Phenols from Kraft Pulp Mill Bleachery Effluents. Bulletin of Environmental Contamination and Toxicology, 18 (6), pp. 663-673 (1977).

28. Pulp and Paper, Miller Freeman Publications. Vol. 55, No.6 (1981).

29. Pulp and Paper, Miller Freeman Publications. Vol. 55, No.11 (1981).

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APPENDIX I

PROVINCIAL POLLUTION ABATEMENT REQUIREMENTS

APPENDIX I PROVINCIAL POLLUTION ABATEMENT REQUIREMENTS

Production Rating (4-year average 1976 to 1979)	BOD_5 (kg/d)	TSS (kg/d)	Toxicity
1. 504 ADt/day	10 080	7 560	50% survival in 90% effluent concentration over 96 hour exposure time
2. 504 ADt/day	3 780	3 780	same as 1
3. 504 ADt/day	3 780	5 040	50% survival in 100% effluent concentration over 96 hour exposure time

1. Based on level B of the 1971 objectives for the Forest Products Industry of B.C. of 15 kg/ADt (30 lb/ADT) TSS and 20 kg/ADt (40 lb/ADT) for BOD_5.

2. Based on level A of the 1971 Objectives for the Forest Products Industry of B.C. of 7.5 kg/ADt (15 lb/ADT) for BOD_5 and TSS.

3. Based on level A of the 1977 Objectives for the Forest Products Industry of B.C. of 10 kg/ADt for TSS and 7.5 kg/ADt for BOD_5.