ENVIRONMENT CANADA
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC REGION

ENVIRONMENTAL REVIEW OF THE FINLAY AND MACKENZIE PULPMILLS AT MACKENZIE, B.C.

Regional Program Report No. 80-7

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ABSTRACT

In October 1976, the Environmental Protection Service 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 data and receiving environment monitoring information. After reviewing and evaluating the existing information, the environmental quality of each area was assessed and the need for additional monitoring studies determined. This report represents an assessment of the Finlay Forest Industries and B.C. Forest Products (Mackenzie Division) pulpmills at Mackenzie, B.C.

RESUME

En octobre 1976, 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 les usines de pâte à papier Finlay Forest Industries et B.C. Forest Products (Mackenzie Division), Mackenzie, C.-B.).

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SUMMARY AND CONCLUSIONS

The Finlay pulpmill has been consistently meeting the provincial BOD_5 and total suspended solids (TSS) requirements of its pollution control permit. A significant reduction in suspended solids output was achieved at the Mackenzie pulpmill with the installation of a new brown stock washer in 1976. The Mackenzie pulpmill has experienced a notable increase in BOD_5 and TSS loadings and pulp production over 1978 and 1979 compared to 1977. The Mackenzie pulpmill presently has an amendment application before the Waste Management Branch to establish loading requirements.

Based on the results of the Environmental Protection Service (EPS) pulpmill effluent toxicity program (1976 to 1979) the percentage of bioassays passing the provincial 90% effluent toxicity standard at the Finlay pulpmill has ranged between 31% to 50% annually. For the Mackenzie pulpmill the percentage passing has ranged from a low of 44% in 1976 to 100% in 1977. The 1978 and 1979 results indicate the Mackenzie pulpmill is not consistently meeting the 100% effluent toxicity standard or the 90% effluent toxicity standard.

The Williston reservoir undergoes an annual oscillation resulting from a combination of the drawdown at the Bennett Hydroelectric Dam and the annual recharge during freshet. Full pool occurs in August, after which time the water level decreases reaching a minimum just prior to spring runoff. As such, dilution potential is least during the winter period. B.C. Research (3) determined that for the Mackenzie pulpmill, with a single critical low flow expected once in every 15 years, a minimum dilution in the range of 50:1 to 100:1 would occur during the low flow months of January to April.

The Williston Lake reservoir whitefish population has increased in response to the new reservoir environment and possibly could support a commercial fishery. However, fish production is expected to decrease because the relative abundance of various species is expected to change as

the reservoir ages and stabilizes. The impact of the mills on the fishery resource has not been studied. Fish tainting has not been reported from the Williston Lake area and the only reported fish migration is of Lake whitefish moving from the Peace and Finlay basins and passing Mackenzie enroute to spawning grounds in the Parsnip and tributary rivers. The migration occurs in the autumn; however, its size has not been determined.

The mills jointly conduct a water quality monitoring program in the lower half of the Parsnip Basin and a cursory evaluation by the author of the few parameters monitored did not appear to indicate an appreciable overall change in water quality at certain times of the year. Changes in water quality were noted primarily at the outfall locations but values appeared to return to background levels within relatively short distances. The survey data summarized was collected at full pool conditions, when highest dilution potential would be expected.

Biological monitoring data specific to the pulp mills does not exist and the only biological data found is from a B.C. Research station some 16 km north of the mills. The lake was reported to be oligotrophic at that station with low chlorophyll-a values and a phytoplankton population made up primarily of diatoms.

The Provincial Environmental Land Use Secretariat is presently compiling information on a full range of resource studies implemented by that group. These studies included the fishery resources and limnology of Williston Lake.

Detailed assessments on the water quality and limnology of the Williston Lake reservoir do not exist. Due to the nature of the system (winter drawdown and freshet recharge) comprehensive limnological studies would have to be conducted to fully assess pulpmill effluent dispersion and its potential impact. This report has not consolidated all of the water quality data collected by the pulpills. It is felt that all available water quality data on Williston Lake, with respect to the pulpmills, should be compiled as one report, reviewed to determine if any water quality trends exist and assessed to determine if the existing program is effectively delineating the zone of influence of the pulpmills.

Considering that a potential exists for a commercial lake whitefish fishery, as assessment of fish tainting potential in the Parsnip Arm might be warranted. The continued monitoring of dissolved oxygen levels is necessary and nutrients should be added to the list of parameters monitored in the present water quality program. An annual summary report of mill monitoring findings would be a benefit to any pulpmill review process. In addition, an annual summary report should also be made available on specific loadings from the pulpmills as they relate to the receiving water program and the report should outline any significant improvements in effluent treatment. A sediment and fish collection survey of Parsnip Arm in the vicinity of the pulpmills for analysis for dehydroabietic acid as well as chlorinated organics might be a method to assess the areal influence of the pulpmill discharges.

1 INTRODUCTION

Finlay Forest Industries Limited (Finlay Pulp Mill) and British Columbia Forest Products Limited (Mackenzie Pulp Mill) operate pulpmills located at Mackenzie, British Columbia, approximately 193 km north of Prince George (Figure 1). The two pulpmills, situated within 4.8 km of each other, are located on the southern end of the Parsnip Basin of Williston Lake which is a hydroelectric reservoir (Figure 2).

This review has been restricted to the effluent quality of the pulpmill discharges for the period 1976 to 1979 as it relates to BOD_5, total suspended solids (TSS) and toxicity, to the fishery resources of Williston Lake and to the aquatic impact of the discharges. Effluent quality data have been derived primarily from mill monitoring results submitted to the Environmental Protection Service (EPS). Resource information on the Williston Lake fishery was obtained primarily from two B.C. Fish and Wildlife studies (1, 2). There has been little aquatic impact work done on Williston Lake respective to the pulpmill discharges and information on the lake's environmental quality has been derived from mill water quality monitoring data and three B.C. Research studies (3, 4, 5).

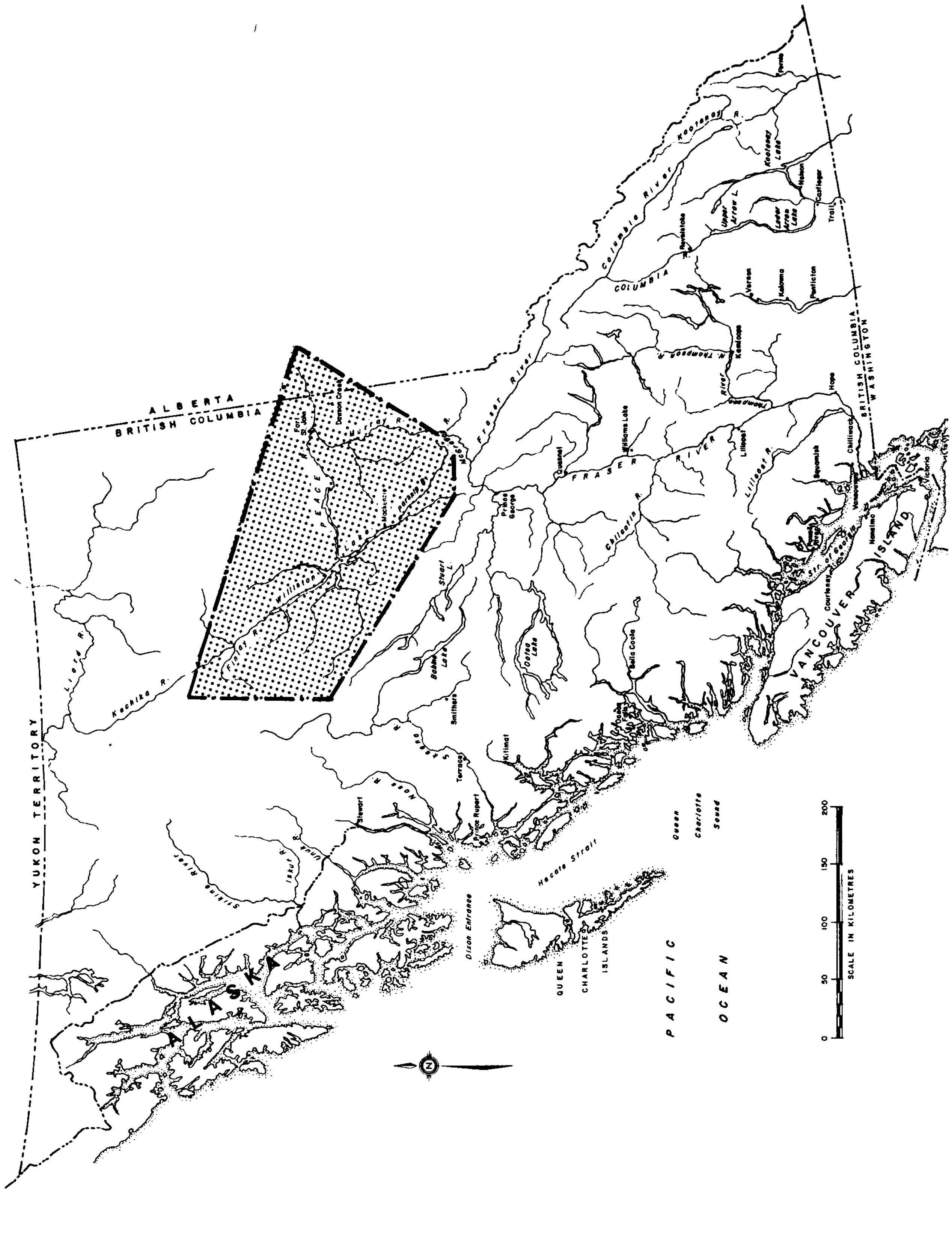

FIGURE I LOCATION MAP

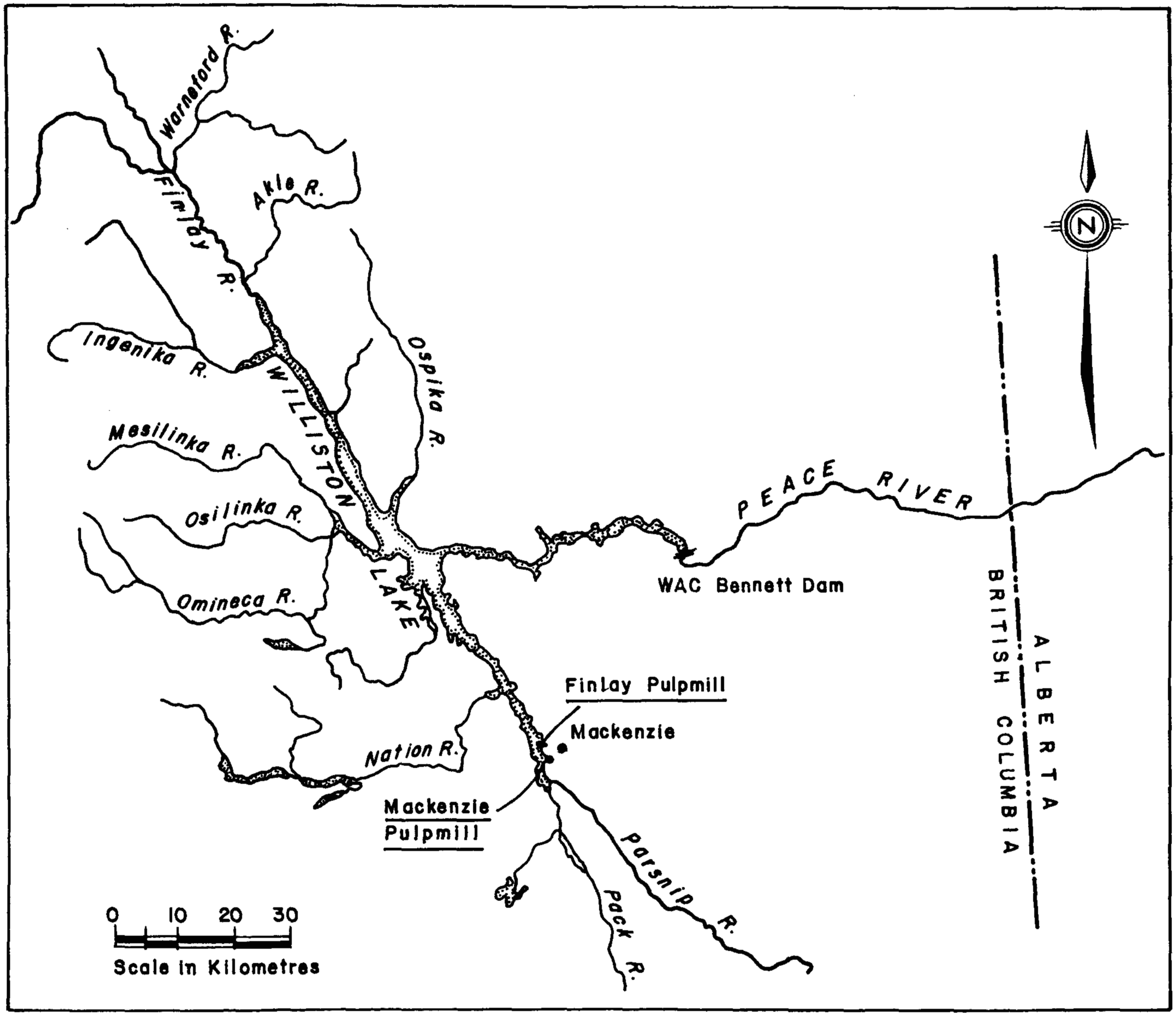

FIGURE 2 WILLISTON LAKE AND SURROUNDING AREA

2 PULP MILL OPERATIONS

2.1 Operational History

2.1.1 Finlay Pulp Mill. Finlay Forest Industries began its refiner groundwood operation in early 1971 at 136 Air Dried Tonne per day (ADt/day) and completed an expansion to 272 ADt/day in February 1975 (Table 1).

Outplant operational changes have included the upgrading of effluent treatment facilities to their present level in December 1973 (Table 2). In 1974 the mill began adding heat to the effluent entering the biobasin during winter to enhance biological activity, mainly for toxicity removal but also for BOD_5 removal.

2.1.2 Mackenzie Pulp Mill. British Columbia Forest Products began its Mackenzie Division bleached kraft mill operation in January 1973 at 454 ADt/day (Table 1). This operation has not apparently undergone any notable outplant effluent treatment system changes. A new brown stock washer installed in 1976 resulted in reduced suspended solids generation in the aeration lagoon.

2.2 Effluent Treatment and Disposal

2.2.1 Finlay Pulp Mill. The Finlay pulpmill treatment facilities are designed to treat the total mill effluent (Table 2). Effluent treatment facilities are shown in Figure 3. After treatment, the final effluent is discharged through a diffusion system to Williston Lake.

2.2.2 Mackenzie Pulp Mill. The Mackenzie pulpmill treatment facilities are designed to treat the total bleach plant and general mill effluent (Table 2). Effluent treatment facilities are shown in Figure 4. Neutralized effluent is pumped from a mix tank to the clarifier, where ammonia is added. The effluent is then directed from the clarifier outlet to the aeration lagoon and finally through a forcemain and diffuser to Williston Lake (old Parsnip River channel). In addition to the lake discharge, there is a discharge of power boiler ash to a sluicing line impoundment near a swamp (Figure 4).

TABLE 1 PULP MILL DESCRIPTIONS

Mill Type	Average Production (ADt/day)	Wood Furnish
Finlay Pulp Mill		
Refiner groundwood mill	1976 - 219	white spruce........75-85%
producing groundwood	1977 - 258	lodgepole pine......15-25%
market pulp	1978 - 268	alpine fir.......... 5%
	1979 - 261	
Mackenzie Pulp Mill		
Kraft mill producing		
bleached	1976 - 497	spruce.............. 45%
kraft and market pulp	1977 - 463	pine................ 45%
	1978 - 528	balsam fir.......... 10%
	1979 - 559	

TABLE 2 EFFLUENT TREATMENT FACILITIES

FINLAY PULP MILL		
Settling Pond	Aeration Lagoon	Aeration Settling Pond and Polishing Pond
Two, used alternately, each with a volume of 10 636 m^3	- Approx. 2-day retention	- Two aeration settling ponds, used alternatively, each with a volume of of 14 770 m^3.
	- 3 aerators of 60 hp each	- Approx. 3 1/4 day retention and 3 aerators of 30 hp each.
	- volume - 9 090 m^3	- Polishing pond volume of 9 455 m^3 and with 2 aerators of 25 hp each.

MACKENZIE PULP MILL			
Spill Pond	Primary Clarifier	Settling Pond	Aeration Lagoon
Volume - 56 875 m^3	67 m diameter	none	- Approx. 4.8 days retention - 12 stationary aerators (combined hp of 900)

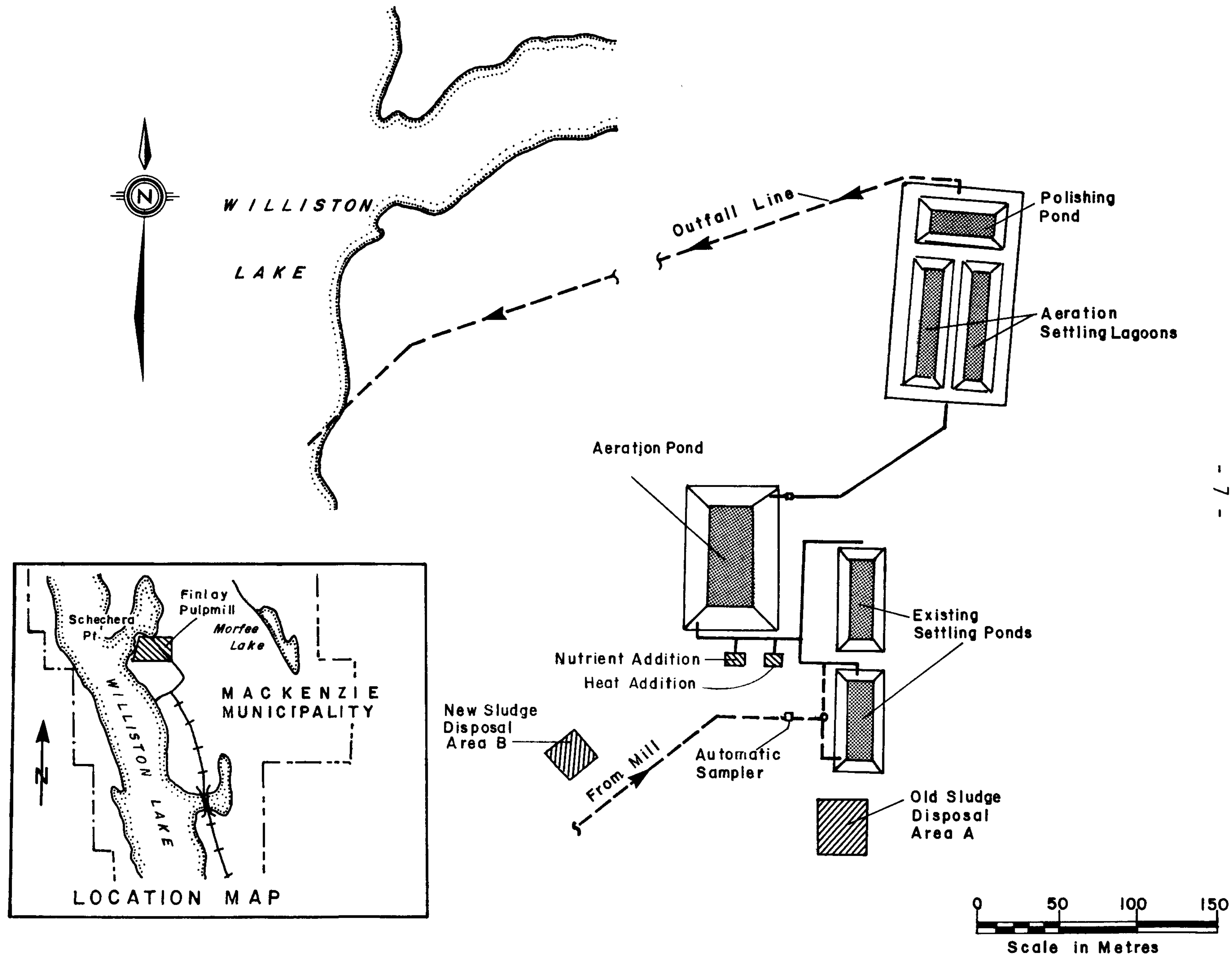

FIGURE 3 SCHEMATIC DIAGRAM OF THE FINLAY PULPMILL TREATMENT FACILITIES

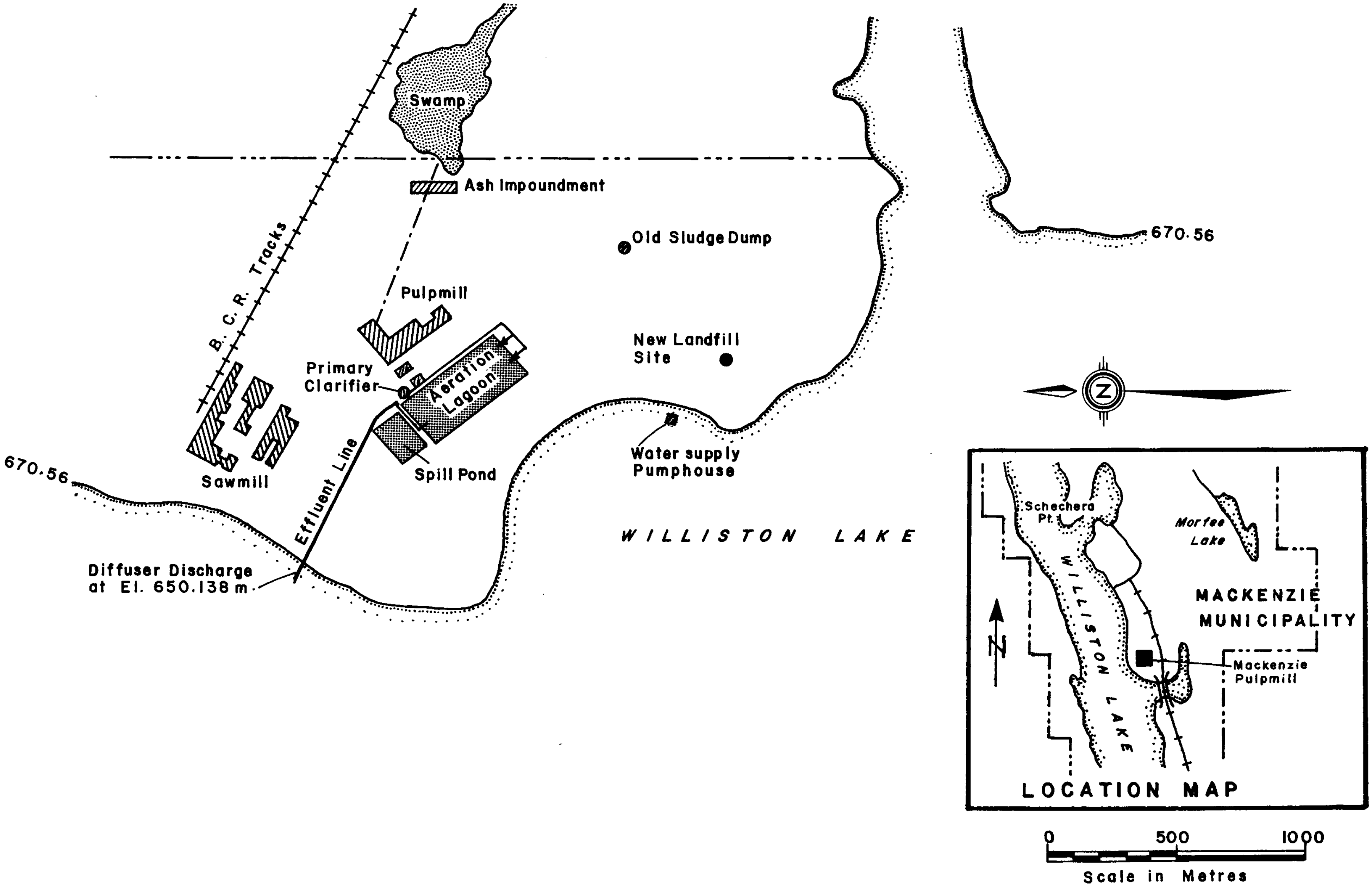

FIGURE 4 SCHEMATIC DIAGRAM OF THE MACKENZIE PULPMILL TREATMENT FACILITIES

3 FEDERAL AND PROVINCIAL ABATEMENT REQUIREMENTS

Federal Pulp and Paper Effluent Regulations (8, 9) were introduced in 1971. The provincial Pollution Control Objectives for the Forest Products Industry of B.C. were first introduced in 1971 (10) and revised in 1977 (11).

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 been workable for mills discharging to fresh water where provincial and federal requirements are comparable. 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

3.2.1 Finlay Pulp Mill. The Finlay pulpmill is required to meet effluent quality requirements as outlined in permit PE-1174, which was last amended February 15, 1977, and still reflects the 1971 objectives. The permit allows for a weekly average discharge of 4 700 m^3/d and a maximum of 6 800 m^3/d of effluent to Williston Lake (Figure 3). Effluent limits prescribed on permit PE-1174 for TSS, BOD_5 and toxicity are listed in Appendix I.

Solid waste disposal conditions for the refiner groundwood pulpmill are stipulated in permit PR-4133, which was last amended August 21, 1978. The quantity of refuse which may be discharged is 3 800 m^3 every two months and an additional 8 400 m^3 once per year. Solid wastes will be made up of sludge from the primary and secondary treatment facilities and dredged material (Figure 3). Treatment works will consist of sludge dewatering fields.

3.2.2 Mackenzie Pulp Mill. The Mackenzie pulpmill is required to meet effluent quality requirements as outlined in permit PE-1138 issued on February 4, 1972. The permit allows for a discharge of 68 000 m^3/d to Williston Lake (Figure 4). Effluent limits prescribed on permit PE-1138 for TSS, BOD_5 and toxicity are listed in Appendix I. Daily loading for BOD_5 and TSS are not reflected on the permit and values reported in Appendix I have been calculated by the author. The pulpmill has a second discharge of 1 370 m^3/d from the boiler ash sluicing line to an impoundment located near a swamp located east of the mill (Figure 4). At the time of this review the Mackenzie pulpmill had an amendment application before the Waste Management Branch to amend their permit to reflect both a total load concept and the 1977 Provincial objectives.

Solid waste disposal conditions for the pulpmill are stipulated in permit PR-1421, last amended June 30, 1977. Solid wastes consist of clarifier sludge dregs, limestone grit as well as scrap metal, wood and paper wastes.

4 EFFLUENT ASSESSMENT

4.1 TSS and BOD_5 for 1976 to 1979

Loadings of TSS and BOD_5 for the Finlay and Mackenzie pulpmills have been calculated for 1976 to 1979 (Table 3). The values reported reflect an approximate daily loading for a given month calculated from a representative number of individual daily production and effluent quality results for that month.

For the Finlay pulpmill, the yearly average loading for BOD_5 ranged between 927 kg/day in 1976 to 1573 kg/day in 1977. For TSS the yearly average ranged between 1 454 kg/day in 1976 to 2 191 kg/day in 1977. With the exception of TSS in 1977, the averages reported in Table 3 are below the allowable load of 2040 kg/day for BOD_5 and TSS reported in Permit PE-1174.

A new brown stock washer was installed in June 1976 at the Mackenzie pulpmill. This resulted in a substantial reduction in TSS formation (calcium-lignin complex) in the aeration lagoon (19). While specific loadings in terms of kg/day are not indicated on Permit 1138 (February 4, 1972), the usual procedure is to calculate them from the mills production rating and a limit per tonne of production. For a production of 454 ADt/day and 6.15 kg/ADt this would amount to 2 795 kg/day of BOD_5 and TSS. With the exception of BOD_5 in 1977, the averages reported in Table 3 exceed this limit. There has been a noticeable increase in BOD_5 and TSS loadings over 1978 and 1979 compared to 1977 and this likely reflects the increasing production over the same period. As indicated previously, the Mackenzie operation has an amendment application before the Waste Management Branch to establish new loading requirements.

4.2 Toxicity for 1973 to 1979

The old 1971 Provincial objectives (10) in force until 1977 specified a static 96 hour LC_{50} with a 90% effluent concentration where

TABLE 3a FINLAY PULP MILL 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	836	1254	5936	2736	2618	1609	1918	1673
February	1336	1745	1591	1745	1854	2282	2782	2764
March	1545	2945	2027	2173	1864	1800	1418	2145
April	564	827	1618	2473	1282	1927	1409	3654
May	609	909	1227	1464	1264	1682	1618	1791
June	373	682	1009	1691	1573	1782	1536	3173
July	518	909	1373	3264	1036	1945	600	1009
August	564	773	1036	1391	1318	1445	1082	1364
September	991	564	1200	1418	1364	1518	1264	1173
October	282	445	1282	2691	1045	1627	936	1964
November	1164	4527	1936	2036	1409	1409	1473	2364
December	2318	1936	1491	3218	2227	2082	791	1336
AVERAGE	927	1454	1809	2191	1573	1764	1400	2036

TABLE 3b MACKENZIE PULP MILL 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	4418	15945	2073	4900	4764	10135	3218	5745
February	5554	22182	1954	4336	2500	8473	3273	5418
March	5764	20973	2145	6482	3327	9982	5454	4582
April	5273	17464	2545	4282	2818	8954	2545	4818
May	5036	15600	3391	5773	3945	9845	3436	6727
June*	3618	14736	4082	6300	2991	7036	5273	7764
July	1818	8882	1909	4636	6027	6291	8109	6218
August	1200	5782	1391	3873	3273	6400	3982	6164
September	1954	9191	1254	2336	3073	6345	3664	8709
October	1754	7964	5909	8709	2754	6127	3664	5782
November	1909	9691	2154	3900	3800	9082	4854	9082
December	1909	11154	2136	3991	3682	7682	7945	15927
AVERAGE	3354	13300	2582	4964	3582	8027	4618	7245

* new brown stock washer installed in June 1976.

the dilution was greater than 20:1 (Finlay Pulpmill and Mackenzie Pulpmill) and a 100% concentration where the dilution was less than 20:1 in the receiving waters. 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 (11) specify 50% survival during a 96 hr bioassay of 100% effluent, irrespective of dilution potential.

Walden et al. (18) report that the provincial objective of 50% survival in 90% effluent concentration over 96 hours exposure (static test) to be slightly more stringent than the federal monitoring bioassay of 80% survival in a 65% effluent concentration over 96 hours exposure (static test).

In December of 1975, the 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 Environmental Protection Service Laboratory for bioassay. The effluent concentrations tested at 90% and 100% coincided with provincial objectives and those at 65% with federal monitoring requirements.

A listing of all bioassays conducted on the Finlay and Mackenzie mills over 1973 to 1979 are included in Appendix II and a summary of those results is provided in Table 4.

The results show that the Finlay pulpmill has difficulty meeting the provincial 90% effluent toxicity standard with only 31% to 50% of the samples passing annually over 1976 to 1979. In 1978 and 1979 some of the samples required oxygenation prior to running the assay to bring the dissolved oxygen level up to an acceptable level. This indicates the effluent has a high oxygen demand.

For the Mackenzie pulpmill, the percent pass at the 90% effluent toxicity standard ranged between 73% in 1979 and 100% in 1977. This is an improvement over 44% in 1976 and is likely related to the improvements in brown-stock washing. The 1978 and 1979 results indicate the pulpmill does not continually meet the 100% effluent toxicity standard or 90% standard. Factors affecting toxicity control at the Mackenzie operation have been reported by Chandrasekran *et al*. (6). Brown-stock washing was indicated to be the most important process in the mill for toxicity removal (6). The higher production rate in 1978 and 1979 may be a factor influencing toxicity performance.

It was beyond the scope of this review to discuss acute toxicity bioassay monitoring in detail or to review the toxic fractions in pulpmill effluents and the reader is referred elsewhere (12, 13, 14, 15, 16, 17).

4.3 Monitoring and Miscellaneous Studies

On a monthly basis, the Finlay and Mackenzie pulpmills submit daily effluent results to the Waste Management Branch and EPS.

The Finlay and Mackenzie pulpmills have been involved in Cooperative Pollution Abatement Research (CPAR) projects. The Finlay pulpmill was involved in a study on the identification and treatment of toxic materials in mechanical pulping effluents (7). The Mackenzie pulpmill was involved in a study on the origin and removal of precipitated suspended solids in bleached kraft pulp mill effluent (19).

TABLE 4 ANNUAL PERCENT PASS TO FEDERAL (65% effluent - 80% survival) AND PROVINCIAL (90% and 100% effluent - 50% survival) TOXICITY REQUIREMENTS FROM 1973 TO 1979

	Number of Bioassays Completed			Annual Percent Passing		
				Provincial Standard		Federal Standard
Year	65% Effluent	90% Effluent	100% Effluent	90%	100%	65%
Finlay Pulpmill						
1973	5	-	-	-	-	20
1974	25	-	-	-	-	56
1975	20	-	-	-	-	100
1976	10	9	10	56	60	90
1977	9	13	14	31	29	45
1978[1]	5	10	10	50	30	80
1979[2]	5	9	7	44	43	40
Mackenzie Pulp Mill						
1973	6	-	-	-	-	100
1974	19	-	-	-	-	89
1975	9	-	-	-	-	100
1976	8	9	11	44	45	75
1977	-	6	6	100	100	-
1978	3	12	12	75	67	100
1979	5	11	9	73	56	80

1. October 16, 1978, sample oxygenated, otherwise it would have been toxic. Reported as a pass.

2. January 29, April 17, August 7, November 13, 1979, samples required oxygenation to bring DO level up. All but January 29, 1979, sample reported as a pass.

5 RECEIVING WATER FEATURES

5.1 Williston Lake (Williston Reservoir)

Williston Lake (reservoir) was formed in 1969 behind the W.A.C. Bennett Dam which is situated in the canyon of the Peace River downstream of the confluence of the Finlay and Pack-Parsnip drainage systems (Figure 2). The lake is made up of the Pack-Parsnip Reach where the water moves northward, the Finlay Reach where water movement is to the south and the Peace Reach where the combined flows move eastward.

The area of the lake is in the order of 173 588 hectares with a length of 233 km and a mean depth of 43.3 m. The Parsnip Reach on which the pulpmills are located is in the order of 63 606 hectares with a mean depth of 38 m.

The reservoir undergoes yearly seasonal oscillations resulting from drawdown at the dam and an annual recharge during freshet. Low water occurs just prior to spring runoff beginning in April and rises steadily to high-water in August and then declines steadily. The mean annual discharge from the lake is 1 020 m^3/s and the estimated flushing rate is 2.2 years (8). At full pool (first reached in summer of 1972) the reservoir elevation above sea level is 672 m and the normal low level in spring is approximately 655 m (1). The average annual drawdown is 16.8 m.

The main tributaries draining into the Parsnip Reach include the Pack and Parsnip rivers at the south, the Nation River mid-reach and the Manson River which enters near the north end (Figure 2).

B.C. Research (3) calculated that based on a 83 562 m^3/d discharge for the Mackenzie pulpmill and with complete mixing, in the immediate area a minimum dilution of 103:1 would occur in a typical year. Considerably greater dilution would be expected when the Parsnip and Pack rivers peak freshet flows occur in May and June. They calculated further that, based on a single critical low-flow year in every 15, a minimum dilution in the range of 50:1 to 100:1 would occur during the low flow months of January to April (3).

B.C. Research (3) report that preparation of the Williston reservoir site prior to flooding was extremely poor as only merchantable timber was removed. Non-merchantable timber was initially windrowed after falling and the bulk of that left without burning. As a consequence of this, a maximum amount of organic material was left for decomposition, resulting in a high oxygen demand.

5.2 Fishery Resources

Halsey and Barrett (1) and Bruce and Starr (2) have conducted assessments on the fisheries resource and its potential in the Williston Reservoir and on its tributary streams, respectively. Aitken et al.(24) conducted a creel survey of Williston Lake in 1977. A sport fishery on the reservoir is well estabished but no commercial fishery takes place.

5.2.1 Williston Lake. Halsey and Barrett (1) collected 15 species of fish from the reservoir and all of which were reported in the Parsnip Basin (Table 5). Lake whitefish (Coregonus clupeaformis) were the dominant species in the reservoir and estimates of the carrying capacity suggested that the reservoir is capable of sustaining a commercial fishery. Lake whitefish populations which occurred in the system prior to flooding have probably greatly expanded in response to the new reservoir environment which that species was able to exploit.

Halsey and Barrett (1) reported that few kokanee (Oncorhynchus nerka), a newly introduced species, were found in each basin and, as they establish, the relative abundance of other fish will change. No northern pike (Esox lucius) was taken in the reservoir during 1974 and 1975.

Halsey and Barrett (1) further report that:

"Lake trout (Salvelinus namaycush) which was reported from the southern Parsnip drainage (Withler, 1959) would now have access to the new reservoir but was not collected there during 1974-1975. Fluctuating water levels during the winter incubation period would certainly eliminate any lake trout eggs deposited in the required shore spawning habitat, this probably explains the absence of the species from the reservoir which is otherwise a suitable habitat. Withler (1959) predicted

TABLE 5 SPECIES LIST OF FISH TAKEN FROM WILLISTON RESERVOIR AND TRIBUTARY STREAMS (1974 and 1975)

RESERVOIR*

Family	Common Name	Scientific Name
Whitefish (Coregonidae)	Lake Whitefish	*Coregonus clupeaformis*
	Mountain Whitefish	*Prosopium williamsoni*
Grayling (Thymallidae)	Arctic Grayling	*Thymallus arcticus*
Trout, char, and salmon (Salmonidae)	Dolly Varden	*Salvelinus malma*
	Rainbow Trout	*Salmo gairdneri*
	Kokanee	*Oncorhynchus nerka*
Minnows (Cyprinidae)	Redside Shiner	*Richardsonius balteatus*
	Northern Squawfish	*Ptychocheilus oregonensis*
	Peamouth Chub	*Mylocheilus caurinus*
	Lake Chub	*Couesius plumbeus*
Suckers (Catostomidae)	Largescale Sucker	*Catostomus macrocheilus*
	White Sucker	*Catostomus commersoni*
	Longnose Sucker	*Catostomus catostomus*
Codfish (Gadidae)	Burbot	*Lota lota*
Sculpin (Cottidae)	Prickly Sculpin	*Cottus asper*

* Halsey and Barrett (1)

TRIBUTARY STREAMS**

Common Name	Scientific Name
Rainbow trout	*Salmo gairdneri*
Mountain whitefish	*Prosopium williamsoni*
Dolly Varden	*Salvelinus malma*
Arctic grayling	*Thymallus arcticus*
Lake whitefish	*Goregonus clupeaformis*
Longnose sucker	*Catostomus catostomus*
Largescale sucker	*Catostomus macrocheilus*
Redside shiner	*Richardsonius balteatus*
Slimy sculpin	*Cottus cognatus*
Prickly sculpin	*Cottus asper*
Peamouth chub	*Mylocheilus caurinus*
Northern squawfish	*Ptychocheilus oregonensis*
Lake chub	*Couesius plumbeus*
Burbot	*Lota lota*

** Bruce and Starr (2)

that lake trout would become widely distributed in the reservoir and would provide the basis for a major portion of the sports fishery. This may yet occur but the evidence to date appears to preclude the possibility. Lake trout are known to spawn in fluvial habitat in rare instances (Scott and Crossman, 1973); if lake trout within the watershed (i.e., Morfee and Arctic lakes) adapt to fluvial spawning, the reservoir may yet support a population."

In addition, Halsey and Barrett (1) reported that:

"In both the Peace and Finlay basins about twice as many fish were taken in the spring sampling period as were collected in the autumn whereas about 20 percent more fish were taken in the Parsnip Basin in the autumn; this is probably a result of large numbers of lake whitefish from the Peace and Finlay basins (where little reproductive habitat exists) migrating through the Parsnip Basin enroute to spawning ground in the Parsnip and tributary rivers."

"As large numbers of forage fish (whitefishes, kokanee, chub, etc.) become more readily available, piscivorous species such as Dolly Varden, burbot and rainbow trout may make up greater proportion of the total than those species do now."

"Both the Finlay and Peace basins offer better opportunities for recreational angling because the percent composition of sports fish is about 3 times (30%) greater than in the Parsnip basin, where sports fish represent only about 10 percent of the total catch. The relatively low numbers of sports fish in the Parsnip Basin compared to others may be the result of comparatively high numbers of coarse fish (minnows and suckers) which compete with them. Support for this suggestion was evident in the Peace Basin where central basin catches of coarse fish represented only about 5% and sports fish made up about 33% of the total catch."

They also reported that the relative abundance of species will undoubtedly change with time and with progressive stabilization of the reservoir environment and that the relatively high estimates of fish production are probably in part a reflection of the newness of the reservoir. As the system stabilizes and the additon of inorganic and organic nutrients decreases, fish production will probably decrease. The magnitude of the lake whitefish migration through the Parsnip Basin past the mills to the Parsnip River is not known.

5.2.2 Tributary Streams of Williston Lake. Streams studied by Bruce and Starr (2) in relation to the pulpmills are shown in Figure 5. They reported that in all of the larger rivers adult over-wintering, spawning and fry-rearing habitats were abundant, indicating excellent potential for the production for all age classes and species of fish (Table 5).

Bruce and Starr (2) reported that Arctic grayling, rainbow trout, mountain whitefish, and Dolly Varden were captured in each of the larger rivers and are resident in these rivers. Lake whitefish from the reservoir spawn in the Parsnip and Pack Rivers south of the pulpmills and in the Manson River and probably Nation and Omineca Rivers north of the mills. The only lake whitefish that were identified as resident fish in the tributary streams were found in the upper Pack River system.

Resident populations of fish were not found in the smaller streams on either side of the Parsnip Basin, nor did these streams have extensive fry, juvenile rearing or overwintering habitat. Adult fish apparently migrate up these streams to spawn and then return to the reservoir. Spawning times for individual species as observed by Bruce and Starr (2) are reported in Table 6. The primary importance of the smaller streams in the basin are as spawning grounds for Arctic grayling, rainbow trout and mountain whitefish. Their importance to Dolly Varden spawning is probably marginal and it is unlikely that lake whitefish utilize these streams.

Bruce and Starr (2) reported that fishing pressure in the Parsnip Basin is probably greater than the rest of the reservoir simply because it is most accessible to relatively large population centres. Aitken et al. (24) in their creel census report found the four major game fish to be rainbow trout, Arctic grayling, Dolly Varden and whitefish. Aitken et al. (24) also reported that for the Parsnip Reach area the areas of greater percentage fishing usage were the Pack River, Nation River and Nation Arm, and the Manson River and Manson Arm. B.C. Research (4) reported that Williston Lake is not suitable for the average family boater as floating and standing timber is an ever-present hazard.

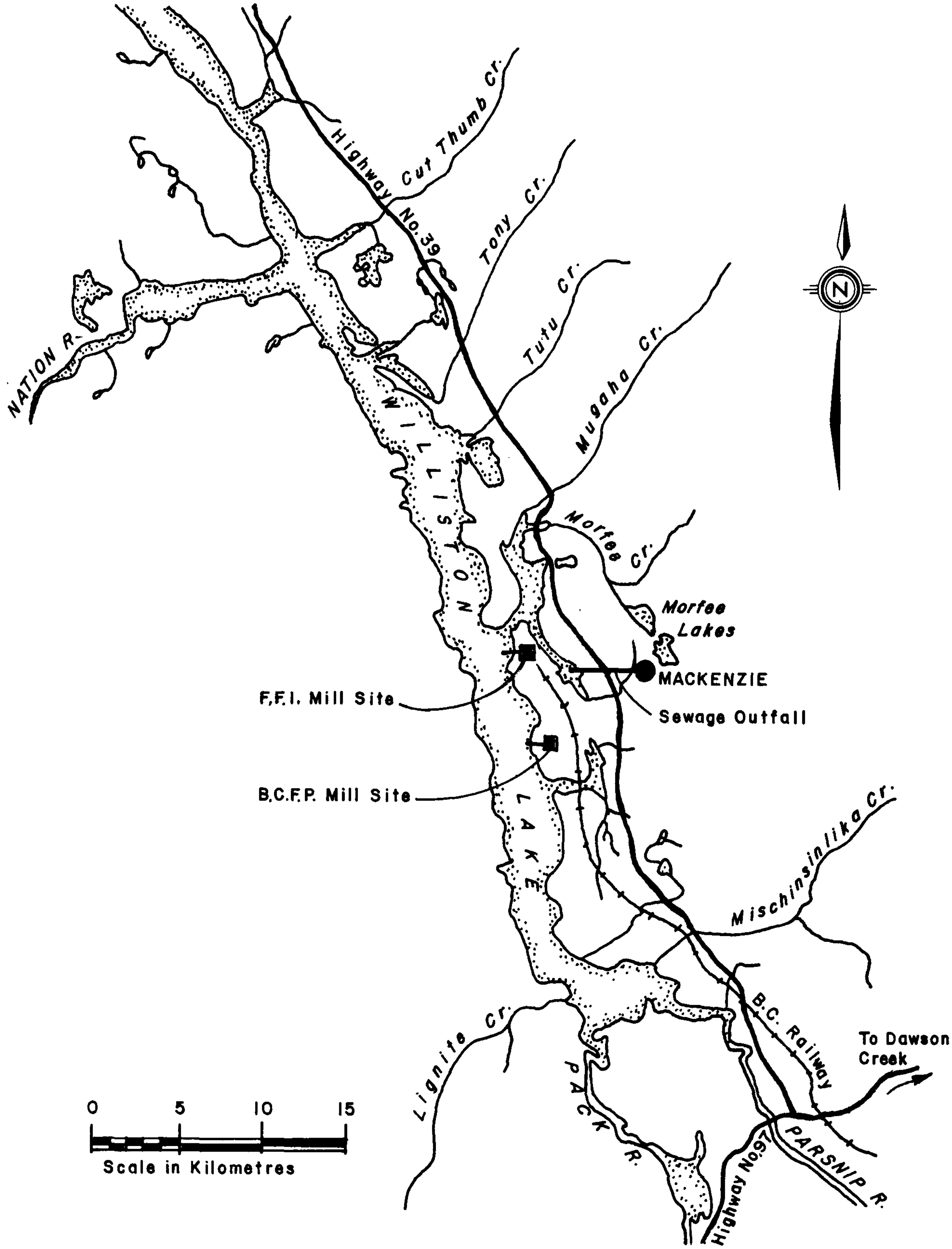

FIGURE 5 TRIBUTARY STREAMS OF PARSNIP REACH IN RELATION TO PULP MILLS AND SEWAGE OUTFALLS

TABLE 6 SPAWNING TIMES OF VARIOUS FISH IN TRIBUTARIES OF PARSNIP ARM

Rainbow trout	Lake whitefish	Mountain whitefish	Arctic grayling	Dolly Varden
Spring Spawners	Fall Spawners	Fall Spawners	Spring Spawners	Fall Spawners
- ripe fish caught through ice in March/ April and peak spawn likely after spring runoff.	- begin to move up Pack and Parsnip rivers in October/ November and likely spawn in mid-November, presumably returning to reservoir after. - emergents observed in streams in June.	- spawn during October and November and emergent fry observed in June.	- peak spawn apparently over by June. - emergence late July and August and many may reside in stream.	- begin to move up creeks during late July and August prior to actively spawning in September.

* Information summarized from Bruce and Starr (2).

6 ENVIRONMENTAL IMPACT AND ASSESSMENT STUDIES

Little receiving water information is presently available with respect to the impact of the Finlay and Mackenzie pulpmill effluent discharges on Williston Lake. Some water quality monitoring is conducted by the mills in the southern portion of Parsnip Reach. Receiving water studies available at this time have dealt with obtaining baseline data on reservoir limnology. This will help determine future changes in trophic status as the reservoir stabilizes.

6.1 Lake Studies

Pre-operational studies consisting of water quality, limited phytoplankton work and effluent dispersion studies were conducted by B.C. Research (3). At that time the reservoir was being filled and was therefore unstable. B.C. Research (4) was also involved in limnological studies in the fall of 1974 and the winter of 1975 for the B.C. Water Investigation Branch and during the summer and fall of 1975 for B.C. Hydro and Power Authority.

In the B.C. Research (4) work, except for a few water quality parameters (temperature, dissolved oxygen, pH, and conductivity) at stations south of and immediately north of the mills, the only station at which biological parameters were measured was some 16 km north of the mills. B.C. Research (5) collected limnological data in 1976 for B.C. Hydro and Power Authority but the station nearest to the pulpmills was in the order of 90 km north. Abelson (20) reports that the pulpmills, as a permit requirement, anually conduct a joint water quality survey in the southern portion of Parsnip Reach (Figure 6). Some data provided by B.C. Forest Products Ltd. (21) has been given a cursory assessment by this author (Table 7, Appendix III and IV).

The Environmental Land Use Secretariat, Victoria, is presently compiling information from a full range of resource studies implemented by that group (22). The topics covered include wildlife, fisheries, recreation, forestry, climatology, hydrology and limnology.

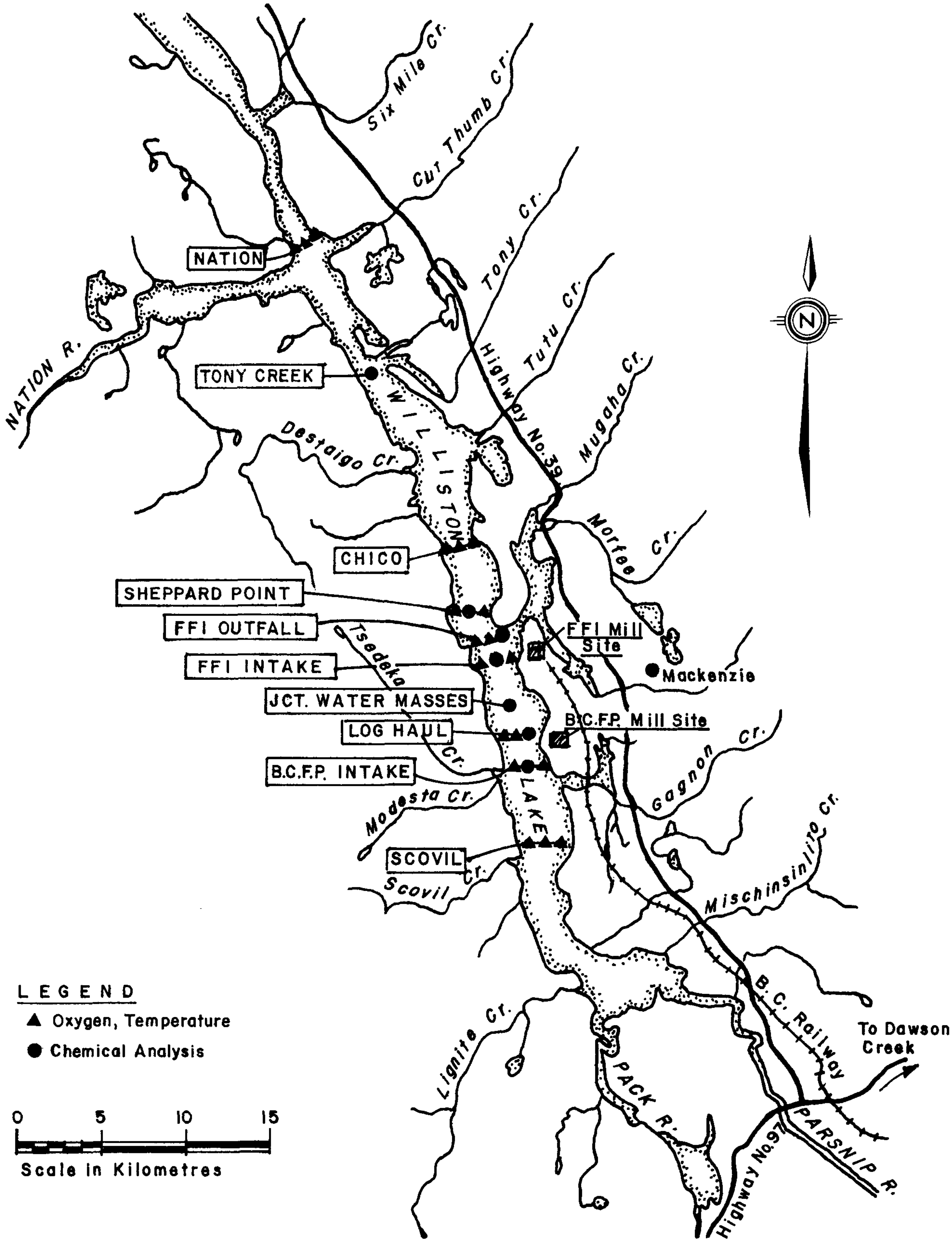

FIGURE 6 PULPMILL WATER QUALITY SAMPLE STATIONS

TABLE 7 SUMMARY OF AVAILABLE RECEIVING WATER QUALITY DATA - (Locations mentioned are shown in Figure 6).

Date	Comments
May 1973	slight increases in sodium, turbidity, suspended solids and iron at BCFP outfall. Concentrations returned to background levels at the junction. No other notable changes evident.
September 1974	slight surface increase in SO_4 noted at BCFP outfall and at the junction. Concentrations returned to background levels by FFI intake and were elevated again at FFI outfall. No other notable changes evident.
September 1975	no notable changes evident.
July 1976	slight turbidity increase at the loghaul and at the junction. Turbidity increased again at FFI outfall. No other notable changes evident.
August 1977	appreciable mid-depth TOC increase and slight increase in sodium, SO_4, conductivity, colour and suspended solids noted at the loghaul and returned to background levels at the junction. Slight increase in TS and SS at FFI outfall.

Parameters measured: Na, Fe, SO_4, Mg, Ca, pH, Temp., D.O., colour, alkalinity, conductivity, turbidity, suspended solids, total solids, volatile suspended solids and TOC.

6.1.1 Lake Study Assessment

6.1.1.1 Water quality. B.C. Research (3) identified dissolved oxygen as a parameter that would be effected during the Williston Reservoir aging process and that the possible effects of pulpmill effluent on lake water quality would be confined to dissolved oxygen and colour. They concluded that a positive flow would always occur past Mackenzie, flows would be lowest in mid-winter and that the main flow would be directed in a north by northwest direction immediately upstream of the B.C. Forest Products Ltd. outfall. To assess if any appreciable changes in dissolved oxygen levels are occurring "downlake" of the pulpmills, data provided for similar sample sites and time of year since 1970 have been given a cursory analysis (Appendix III). Changes in other chemical parameters are noted in Table 7 and the data are tabulated in Appendix IV.

The limited receiving water data reviewed does not indicate an appreciable reduction in water quality even at the outfall sites. It should be noted that samples were collected from a July to September period when the lake is near or at full pool and dilution is high. The Mackenzie pulp mill for August, 1977, reported a 600:1 dilution at the junction sample site and a 188:1 dilution at the outfall. The July to September period for which the uplake-downlake dissolved oxygen data are available does not appear to be showing reductions in the percent saturation of dissolved oxygen. For September 1974 there was an indication that the eastside of the reservoir in the vicinity of the outfalls had an extended zone of lower percent-saturation water (Appendix III). There is evidence of low oxygen levels occurring in the lake and levels below 50% saturation were common uplake and downlake of the outfalls.

B.C. Research (4) reported that the rapid flushing rate and drawdown greatly influenced the pattern of dissolved oxygen and temperature stratification. Although summer temperature stratification was reported, the thermocline in Parsnip and Finlay reaches was poorly developed (4). They reported that dissolved oxygen profiles during summer stratification were orthograde curves characteristic of oligotrophic lakes and were close to saturation at all depths. Where comparable stations existed, percent saturation levels reported by B.C. Research (4) in August 1975 were not unlike those reported by the mills in September 1975 (Appendix III).

6.1.1.2 Biological. Biological parameters have not been monitored respective to the pulpmill outfalls. The only biological station near the pulpmills from which the general trophic state of Parsnip Reach can be described is some 16 km north of the mills (4). B.C. Research (4) reported that the overall reservoir had good water quality with no evidence of internal loading of nitrogen or phosphorus and that nutrient concentrations were low.

B.C. Research (4) reported the phytoplankton community for the period of study (June/July/November) to be dominated by diatoms and that there were no substantial differences in phytoplankton populations in each of the reaches of the reservoir other than for shifts in the relative abundance of species. They reported the general pattern of phytoplankton diversity of Williston Lake to be normal for a dimictic oligotrophic lake at northern latitudes. Blue-green algae often associated with "nuisance" conditions in lakes and reservoirs were present but never abundant. Mean chlorophyll-a values for the photic zone during thermal stratification were 2.25 ug/l (1.26-5.19 ug/l) for the Parsnip Reach, 2.43 ug/l (.19-9.86 ug/l) for the Finlay Reach, and 3.55 ug/l (1.25-9.22 ug/l) for the Peace Reach (8).

B.C. Research (5) conducted late summer and fall overturn biological and water quality surveys in 1976 but the nearest station to the mills was some 90 km north of the pulpmills.

Brownlee and Strachan (25) and Fox (26) reported dehydroabietic acid (DHA) as being the most persistent organic contaminant in the sediment and water of a 25 Km^2 area of Lake Superior influenced by the discharge of a mixed groundwood and bleached kraft pulpmill without biological treatment. Kaiser (27) found DHA in yellow perch, as well as in two species of sucker (*Catastomus commersoni* and *C. catastomus*) which were from areas influenced by the above pulpmill. Dehydroabietic acid is a wood extractive found in pulpmill effluents and has a 96 hr LC_{50} of

0.5 mg/l for yearling sockeye salmon (28). The bioaccumulation of chlorinated phenols in fish has been documented by Landner et al. (29). A sediment and fish collection survey of the southern portion of Parsnip Basin for analysis for DHA and chlorinated organic compounds might be a possible method to assess the areal influence of the pulpmill discharges. The Mackenzie pulpmill effluent would have to be sampled in order to determine for which chlorinated organic compounds to analyze.

6.1.2 Fish Tainting. Reports of tainted fish have not been received by either the Prince George WMB office or the Prince George Fish and Wildlife Office (20, 23).

6.1.3 Miscellaneous Discharges. The District of Mackenzie under provisional Pollution Control Branch Permit PE-327-P, February 17, 1970, is permitted to discharge 1900 m^3/d of treated domestic sewage effluent. Treatment consists of aerated stabilization ponds and the effluent is discharged via diffusion at approximately the 655 m elevation to the Chiconyenily Creek Arm of Williston Lake (Figure 5). The influence of this discharge on the water quality of Williston Lake is not being monitored.

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APPENDIX I

PROVINCIAL POLLUTION ABATEMENT REQUIREMENTS

APPENDIX I PROVINCIAL POLLUTION ABATEMENT REQUIREMENTS

Production Rating	BOD_5	TSS	Toxicity
Finlay Pulpmill[1]			
272 ADt/day	2040 kg/day	2040 kg/day	50% survival in 90% effluent conc. over a 96 hour exposure time.
Mackenzie Pulpmill[2]			
454 ADt/day	2795 kg/day	2795 kg/day	50% survival in 90% effluent conc. over a 96 hour exposure time.

1 Based on 1971 objectives for the Forest Products Industry of B.C. of 7.5 kg/ADt for BOD_5 and TSS.

2 Based on 1971 objectives for the Forest Products Industry of B.C. Daily loading calculated from a production rating of 454 ADt/day and a limit of 6.15 kg/ADt for BOD_5 and TSS as reported in permit PE-1138, February 4, 1972.

Note: Finlay Pulpmill Federal Loading Allowances for TSS: Old mill mechanical pulping (6.5 kg/ADt) and sheet formation (2.5 kg/ADt) plus new mill mechanical pulping (5 kg/ADt) and sheet formation (2 kg/ADt). Overall loading of 8 kg/ADt.

: Mackenzie Pulpmill Federal Loading Allowance for TSS and BOD_5 respectively: kraft pulping (2.5 and 16.5 kg/ADt, respectively), kraft bleaching (2 and 13.5 kg/ADt, respectively and kraft sheet formation 0.5 kg/ADt TSS. Overall loading of 5 kg/ADt TSS and 30 kg/ADt BOD_5.

: Federal TSS loading allowances are for post-primary treatment but pre-secondary treatment.

APPENDIX II

BIOASSAY RESULTS (1973 to 1979)

a) Finlay Pulpmill
b) Mackenzie Pulpmill

APPENDIX II BIOASSAY RESULTS, 1973 to 1979

a) Finlay Pulpmill

Year	Sample Date		Species	Loading Density (gm/l)	% Survival (65% concentration)
B.C. Research Bioassays					
1973	November	14	Coho Salmon	1.02	100
	November	21	(*Oncorhynchus*	1.02	0
	December	6	*kisutch*)	1.30	0
	December	12		1.28	0
	December	18		1.32	0
1974	January	7		1.40	100
	January	17		1.52	0
	January	30		1.58	100
	February	6		1.70	0
	February	11		1.65	0
	February	18		1.72	0
	February	27		1.84	0
	March	6		1.90	0
	March	13		1.92	0
	March	21		1.92	0
	March	27		2.10	0
	April	3		2.25	0
	April	10		2.26	0
	April	18		0.16	100
	April	24		0.17	100
	May	2		0.18	100
	May	8		0.20	100
	May	15		0.30	100
Beak Consultants Bioassays					
1974	November	23	Rainbow Trout	1.0	100
	November	19	(*Salmo gairdneri*)	1.0	100
	November	25		0.40	100
	December	2		0.40	100
	December	9		0.40	100
	December	17		0.40	90
	December	31		0.40	100
1975	January	6		0.40	100
	January	13		0.40	100
	January	20		0.40	100
	January	27		0.40	100
	February	3		0.40	100
	February	11		0.60	100
	February	17		0.40	100
	February	24		0.60	100
	March	3		0.60	100
	March	11		0.60	100

Cont'd...

APPENDIX II (Cont'd.)

Year	Sample Date		Species	Loading Density (gm/l)	% Survival (65% concentration)
Beak Consultants Bioassays (continued)					
1975	March	24	Rainbow Trout	0.15	100
	April	23		0.21	100
	April	30		0.21	100
	May	5		0.21	100
	June	3		0.21	100
	July	7		0.66	100
	September	9		1.20	100
	October	28		0.90	100
	November	28		0.19	100
	December	10		0.19	100

Cont'd......

APPENDIX II (Cont'd)

Year	Sample Date		Species	Loading Density (gm/l)	% Survival Provincial 90% conc.	% Survival Provincial 100% conc.	% Survival Federal 65% conc.	96 hr LC_{50} %
Environmental Protection Service Monitoring								
1976	January	12	Rainbow Trout	0.48	100	100	100	
	February	10		0.49	100	100	100	
	March	08		0.38	40	0	100	87
	April	12		0.20	0	0	80	69
	April	26		0.18	100	90	100	
	July	26		0.50	-	100	100	
	November	01		1.19	100	100	100	
	November	17		1.53	40	0	100	89
	November	29		0.49	0	0	0	
	December	07		0.46	100	100	100	
1977	January	10		0.51	0	0	-	
	January	18		0.47	0	0	0	17.3
	January	31		0.68	0	0	0	44
	February	08		0.68	-	80	100	
	March	14		0.93	0	0	-	
	March	22		0.48	0	0	0	10
	April	05		0.68	0	0	0	10
	April	18		0.35	0	0	0	13.3
	April	25		0.35	0	0	80	73.5
	May	02		0.45	80	40	100	
	July	11		0.50	100	80	100	
	October	10		1.10	100	100	-	
	November	15		0.40	100	100	-	
	December	12		0.30	0	0	-	

Cont'd...

APPENDIX II (Cont'd)

Year	Sample Date		Species	Loading Density (gm/l)	% Survival Provincial 90% conc.	% Survival Provincial 100% conc.	% Survival Federal 65% conc.	96 hr LC_{50} %
Environmental Protection Service Monitoring								
1978	January	01	Rainbow Trout	0.50	0	0	-	
	January	30		0.60	0	0	100	78.5
	February	13		0.60	0	0	0	44
	February	28		0.60	100	0	100	
	May	08		0.20	0	0	100	77
	May	22		0.40	100	80	100	
	July	18		0.30	80	20	-	
	October	16*		0.40	100	100	-	
	November	14		0.50	0	0	-	
	November	27		0.50	100	100	-	
1979	January	08		0.50	0	0	-	
	January	29*		0.50	F	F	F	
	March	26		0.50	0	-	0	44
	April	17*		0.45	87.5	-	100	
	June	11		0.50	0	0	75	70
	July	03		0.50	100	100	100	
	August	07*		0.60	83	100	-	
	November	13*		0.40	100	100	-	
	December	11		0.30	0	0	-	

Note: All bioassays are for final effluent samples. The procedure to the end of 1975 was for a 96 hour static bioassay without solution replacement at 65% v/v effluent. As of 1976, the effluent concentration was raised to provincial levels. Federal pass/fail reported only if a 65% v/v effluent reported.

* Samples required oxygenation to bring up to DO level prior to starting the bioassay. This may account for high survival. For January 29, 1979, dissolved oxygen could not be raised above 1 mg/l and bioassay not run, reported as failure (F).

\- Concentration not tested.

APPENDIX II (Cont'd) BIOASSAY RESULTS, 1973 to 1979

b) Mackenzie Pulpmill

Year	Sample Date		Species	Loading Density (gm/l)	% Survival (65% concentration)
B.C. Research Bioassays					
1973	November	9	Coho Salmon	1.02	100
	November	20	(*Oncorhynchus*	0.98	100
	November	29	*kisutch*)	1.25	100
	December	4		1.30	100
	December	10		1.28	100
	December	18		1.35	100
1974	January	9		1.38	90
	January	14		1.52	100
	January	22		1.52	100
	January	31		1.64	90
	February	4		1.65	100
	February	13		1.68	100
	February	26		1.82	100
	March	5		1.78	20
	March	11		1.88	100
	March	19		2.08	60
	April	1		2.08	100
	April	16		0.16	80
	May	7		0.20	100
	June	3		0.33	100
	July	10		0.50	90
	September	9		0.73	100
	October	7		0.80	100
Beak Consultants Bioassays					
1974	November	4	Rainbow Trout	1.0	100
	December	2	(*Salmo gairdneri*)	0.40	100
1975	January	6		0.40	100
	February	3		0.40	100
	March	2		0.60	100
	April	7		0.20	100
	May	5		0.21	100
	June	2		0.21	100
	July	8		0.72	100
	November	4		0.90	100
	December	2		0.19	90

Cont'd...

APPENDIX II (Cont'd)

Year	Sample Date		Species	Loading Density (gm/l)	% Survival Provincial 90% conc.	% Survival Provincial 100% conc.	% Survival Federal 65% conc.	96 hr LC_{50} %
Environmental Protection Service Monitoring								
1976	January	12	Rainbow Trout	0.47	90	87.5	100	
	February	10		0.47	22	14	100	74
	February	16		0.42	0	14	87.5	71
	March	02		0.35	0	0	70	70
	March	08		0.38	20	10	100	75
	March	23		0.40	100	80	100	
	April	05		0.49	0	0	0	5.6
	April	06		0.49	60	40	100	
	June	22		0.50	-	50	-	
	July	28		0.50	100	100	-	
	October	13		0.15	-	100	-	
1977	January	17		0.47	100	100	-	
	February	15		0.83	100	100	-	
	March	08		0.93	100	100	-	
	May	04		0.50	100	100	-	
	October	17		0.30	100	100	-	
	December	06		0.40	100	100	-	
1978	January	09		0.50	100	100	-	
	February	06		0.60	100	100	-	
	March	06		0.20	0	0	-	
	March	20		0.40	100	80	100	
	April	10		0.40	0	0	-	
	April	24		0.30	70	20	100	
	May	01		0.20	100	60	-	
	July	19		0.50	0	0	-	
	July	25		0.50	90	60	100	
	October	03		-	100	100	-	
	November	06		0.50	100	100	-	

Cont'd...

APPENDIX II (Cont'd)

Year	Sample Date		Species	Loading Density (gm/l)	% Survival: Provincial 90% conc.	% Survival: Provincial 100% conc.	% Survival: Federal 65% conc.	96 hr LC_{50} %
Environmental Protection Service Monitoring								
1978	December	04	Rainbow Trout	0.50	100	110	-	
1979	January	08		0.50	100	100	-	
	February	12		0.50	80	80	-	
	March	05		0.50	83	67	-	
	April	02		0.50	100	100	-	
	May	22		0.50	75	37.5	-	
	August	13		0.50	0	0	60	67
	August	27		0.50	85.7	0	100	
	October	02		0.60	100	100	100	
	November	05		0.40	40	0	-	
	November	19		0.50	0	-	90	
	December	03		0.60	100	-	100	

\- Concentration not tested.

Note: All bioassays are for final effluent samples. The procedure to the end of 1975 was for a 96 hour static bioassay without solution replacement at 65% v/v effluent. As of 1976, the effluent concentration was raised to provincial levels. Federal pass/fail reported only if 65% v/v effluent reported.

APPENDIX III

A CURSORY ASSESSMENT OF DISSOLVED OXYGEN PERCENT SATURATION LEVELS IN PARSNIP REACH OF WILLISTON LAKE

APPENDIX III A CURSORY ASSESSMENT OF DISSOLVED OXYGEN PERCENT SATURATION LEVELS IN PARSNIP REACH OF WILLISTON LAKE

Station*: Nation

Date	West		Centre		East	
	Depth (metres)	Range of Per-cent Saturation (%)	Depth (metres)	Range of Per-cent Saturation (%)	Depth (metres)	Range of Per-cent Saturation (%)
August, 1970 (2)	Upper 10 11 to 31	61 to 103 54 to 38	Upper 10 11 to 18	63 to 101 58 to 38	Upper 10 11 to 17	64 to 101 59 to 37
September, 1974 (1)	Upper 17 19 to 21	71 to 91 69 to 68	Upper 15 17 to 35	70 to 94 66 to 44	Upper 5 7	75 to 99 56
August, 1975 (2)			0 to 30	67 to 102		
September, 1975 (1)	0 to 27	72 to 100	0 to 27	70 to 101	0 to 27	80 to 109
July, 1976 (1)	0 to 45 At 47	73 to 105 8.7	0 to 29 At 31	69 to 103 17	Upper 21 25 to 27	67 to 105 48 to 33
August, 1977 (1)	Surface 3 to 63	87 41 to 12	Upper 3 6 to 57	84 to 87 58 to 12	Upper 9 12 to 73	74 to 106 42 to 2

Calculated from data provided by: (1) B.C. Forest Products Limited
(2) B.C. Research

*Stations referred to are shown on Figure 6.

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APPENDIX III
(Cont'd)

A CURSORY ASSESSMENT OF DISSOLVED OXYGEN PERCENT SATURATION LEVELS IN PARSNIP REACH OF WILLISTON LAKE (Continued)

Station: Tony

Date	West		Centre		East	
	Depth (metres)	Range of Percent Saturation (%)	Depth (metres)	Range of Percent Saturation (%)	Depth (metres)	Range of Percent Saturation (%)
August, 1970 (2)			Upper 9	87 to 102		
			11 to 20	57 to 30		
September, 1974 (1)			Upper 17	62 to 86		
			19 to 41	45 to 33		
July, 1975 (2)			Upper 10	76 to 89		
			12 to 30	57 to 61		
September, 1975 (1)			Upper 17	70 to 98		
			19 to 27	69 to 62		
July, 1976 (1)			Upper 23	70 to 103		
			25 to 35	68 to 67		
			37	9		
August, 1977 (1)			Surface	78		
			3 to 6	64 to 61		
			9 to 51	41 to 16		

Calculated from data provided by: (1) B.C. Forest Products Limited
(2) B.C. Research

Cont'd......

APPENDIX III (Cont'd)

A CURSORY ASSESSMENT OF DISSOLVED OXYGEN PERCENT SATURATION LEVELS IN PARSNIP REACH OF WILLISTON LAKE

Station: Chico

Date	West		Centre		East	
	Depth (metres)	Range of Per-cent Saturation (%)	Depth (metres)	Range of Per-cent Saturation (%)	Depth (metres)	Range of Per-cent Saturation (%)
August, 1970 (2)	Upper 9 11 to 20	87 to 102 57 to 30	Upper 9 11to 17	66 to 98 41 to 9	Upper 9 11 to 14	78 to 90 30 to 19
September, 1974 (1)	0 to 9	82 to 84	Upper 17 19 to 35	60 to 84 57 to 38	Upper 17 19 to 35	69 to 84 57 to 38
August, 1975 (2)			Upper 8 10 to 28	78 to 87 54 60 64		
September, 1975 (1)	0 to 5	102	Upper 19 21 to 27	68 to 105 64 to 63	Upper 11 13 to 27	78 to 102 67 to 52
July, 1976 (1)	0 to 9	84	Upper 19 21 to 29	71 to 102 69 to 63	Upper 27 29 to 33	71 to 106 63 to 66
August, 1977 (1)	Upper 12 15	71 to 104 61	Upper 9 12 to 48	67 to 88 59 to 21	Surface 3 to 57	75 44 to 26

Calculated from data provided by: (1) B.C. Forest Products Limited
(2) B.C. Research

Cont'd......

APPENDIX III
(Cont'd)

A CURSORY ASSESSMENT OF DISSOLVED OXYGEN PERCENT SATURATION LEVELS IN PARSNIP REACH OF WILLISTON LAKE

Station: Sheppard Point

Date	West		Centre		East	
	Depth (metres)	Range of Percent Saturation (%)	Depth (metres)	Range of Percent Saturation (%)	Depth (metres)	Range of Percent Saturation (%)
August, 1970 (2)						
September, 1974 (1)	Upper 11 13 to 25	80 to 88 51 to 32	Upper 13 15 to 27	60 to 85 19 to 29	Upper 11 13 to 21	60 to 83 59 to 44
August, 1975 (2)			Upper 8 10 to 24	72 to 92 46 to 49		
September, 1975 (1)	Upper 17 19 to 27	72 to 100 63 to 62	Upper 15 17 to 27	70 to 99 69 to 58	Upper 15 17 to 29	78 to 101 58 to 57
July, 1976 (1)	0 to 21	75 to 101	0 to 25	71 to 97	0 to 13	87 to 102
August, 1977 (1)	Upper 9 12 to 42	68 to 99 59 to 47	Upper 3 6 to 12 15 to 39	64 to 83 58 to 31 18 to 0	0 to 9	88 to 95

Calculated from data provided by: (1) B.C. Forest Products Limited
(2) B.C. Research

Cont'd......

APPENDIX III

A CURSORY ASSESSMENT OF DISSOLVED OXYGEN PERCENT SATURATION LEVELS IN PARSNIP REACH OF WILLISTON LAKE

Station: FFI Outfall

Date	West		Centre		East	
	Depth (metres)	Range of Per-cent Saturation (%)	Depth (metres)	Range of Per-cent Saturation (%)	Depth (metres)	Range of Per-cent Saturation (%)
August, 1970 (2)						
September, 1974 (1)	Upper 13 12 to 25	60 to 85 53 to 33	Upper 7 9 to 25	67 to 81 59 to 41	Upper 7 9 to 27	60 to 80 56 to 40
August, 1975 (2)						
September, 1975 (1)						
July, 1976 (1)	0 to 25 27	79 to 102 51	0 to 27	79 to 105	0 to 23 25	75 to 104 9,5
August, 1977 (1)	Upper 9 12 to 45	71 to 97 56 to 9	Upper 15 18 to 42	60 to 91 55 to 30	Upper 12 15 to 42	72 to 93 59 to 23

Calculated from data provided by: (1) B.C. Forest Products Limited
(2) B.C. Research

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APPENDIX III
(Cont'd)

A CURSORY ASSESSMENT OF DISSOLVED OXYGEN PERCENT SATURATION LEVELS IN PARSNIP REACH OF WILLISTON LAKE

Station: Junction

Date	West		Centre		East	
	Depth (metres)	Range of Per-cent Saturation (%)	Depth (metres)	Range of Per-cent Saturation (%)	Depth (metres)	Range of Per-cent Saturation (%)
August, 1970 (2)			Upper 7 9 to 12	65 to 101 35 to 0		
September, 1974 (1)			Upper 7 9 to 23	63 to 85 58 to 30		
August, 1975 (2)						
September, 1975 (1)			Upper 9 11 to 25	93 to 96 78 to 56		
July, 1976 (1)			0 to 19	77 to 98		
August, 1977 (1)			Upper 15 18 to 39	73 to 98 66 to 34		

Calculated from data provided by: (1) B.C. Forest Products Limited
(2) B.C. Research

Cont'd......

APPENDIX III (Cont'd)

A CURSORY ASSESSMENT OF DISSOLVED OXYGEN PERCENT SATURATION LEVELS IN PARSNIP REACH OF WILLISTON LAKE

Station: BCFP Log Haul Outfall

Date	West		Centre		East	
	Depth (metres)	Range of Per-cent Saturation (%)	Depth (metres)	Range of Per-cent Saturation (%)	Depth (metres)	Range of Per-cent Saturation (%)
August, 1970 (2)	Upper 8 9 to 17	70 to 101 19 to 0	Upper 8 9 to 12	87 to 101 49 to 1	Upper 8 9	79 to 95 26
September, 1974 (1)	Upper 9 11 to 21	63 to 83 53 to 33	Upper 9 11 to 23	65 to 80 54 to 34	Upper 7 9 to 21	64 to 78 58 to 35
August, 1975 (2)						
September, 1975 (1)	Upper 11 13 to 21	72 to 97 61 to 53	Upper 11 13 to 34	80 to 96 61 to 51	Upper 11 13 to 21	72 to 88 57 to 40
July, 1976 (1)	0 to 19	85 to 98	0 to 21	82 to 104	0 to 25	78 to 100
August, 1977 (1)	Upper 12 15 to 36	71 to 97 55 to 23	Upper 12 15 to 33	74 to 97 60 to 32	Upper 15 18 to 33	63 to 97 53 to 14

Calculated from data provided by: (1) B.C. Forest Products Limited
(2) B.C. Research

Cont'd......

APPENDIX III (Cont'd) — A CURSORY ASSESSMENT OF DISSOLVED OXYGEN PERCENT SATURATION LEVELS IN PARSNIP REACH OF WILLISTON LAKE

Station: BCFP Intake Control

Date	West		Centre		East	
	Depth (metres)	Range of Percent Saturation (%)	Depth (metres)	Range of Percent Saturation (%)	Depth (metres)	Range of Percent Saturation (%)
August, 1970 (2)	Upper 6 7 to 10	77 to 87 15	0 to 5	87	Upper 7 8	89 to 101 24
September, 1974 (1)	Upper 11 13 to 19	74 to 85 54 to 31	Upper 9 11 to 17	61 to 81 57 to 45	Upper 13 15 to 19	69 to 83 53 to 32
August, 1975 (2)			0 to 18	67 to 100		
September, 1975 (1)			Upper 11 13 to 21	60 to 92 56 to 46	Upper 11 13 to 17	68 to 87 51 to 39
July, 1976 (1)	0 to 15	82 to 97	0 to 17	86 to 104	0 to 17	85 to 101
August, 1977 (1)	Upper 6 9 to 30	63 to 95 52 to 25	Upper 21 24 to 30	58 to 94 20 to 11	Upper 3 6 to 39	67 to 94 53 to 15

Calculated from data provided by: (1) B.C. Forest Products Limited
(2) B.C. Research

APPENDIX IV

PARTIAL SUMMARY OF PULPMILL WATER QUALITY MONITORING PROGRAM DATA

APPENDIX IV PARTIAL SUMMARY OF PULPMILL WATER QUALITY MONITORING PROGRAM DATA

Date	Parameter	BCFP INTAKE			LOG HAUL		
		surface	mid-depth	bottom	surface	mid-depth	bottom
5/09/74	Na (ppm)	0.6	0.6	0.6	0.6	0.8	0.8
	Fe (ppm)	0.06	0.16	0.25	0.06	0.11	0.19
	SO_4 (ppm)	2.9	1.9	2.3	4.5	2.9	4.7
	Mg (ppm)	2.7	2.8	2.7	2.6	2.7	2.5
	Ca (ppm)	14.9	15.9	15.2	14.8	15.8	14.9
	Alk. (ppm $CaCO_3$)	49.5	54.0	50.0	46.0	49.0	47.5
	Cond. (umhos/cm)	96	103	97	94	98	97
	pH	7.4	7.3	7.3	7.3	7.3	7.2
	Colour (APHA)	8.5	7.5	7.5	7.0	7.0	10.0
	SS (ppm)	0.6	1.4	2.6	2.4	0.2	1.8
	TOC (ppm)	3	3	4	2	3	3
	Turb. (APHA)	0.5	1.5	2.0	2.5	2.5	3.5
10/09/75	Na (ppm)	1.5	2.0	2.5	2.0	2.0	2.5
	Fe (ppm)	0.19	0.22	10.8	0.19	0.25	0.39
	SO_4 (ppm)	4.9	3.5	17.1	2.5	2.5	3.5
	Mg (ppm)	3.5	3.5	4.0	3.5	3.5	4.0
	Ca (ppm)	15	13	18	11	17	16
	Alk. (ppm $CaCO_3$)	58.0	58.0	62.5	56.0	58.0	63.0
	Cond. (umhos/cm)	122	123	133	120	123	133
	pH	7.5	7.6	7.3	7.4	7.3	7.1
	Colour (APHA)	7.5	8.4	9.5	8.8	9.2	10.5
	SS (ppm)	1.0	1.0	99.8	1.4	1.2	4.0
	TOC (ppm)	6	7	11	7	8	8
	Turb. (APHA)	2.3	2.3	G50	1.5	1.8	3.2

G = greater than

continued...

APPENDIX IV PARTIAL SUMMARY OF PULPMILL WATER QUALITY MONITORING PROGRAM DATA (continued)

Date	Parameter	JUNCTION surface	JUNCTION mid-depth	JUNCTION bottom	FFI INTAKE surface	FFI INTAKE mid-depth	FFI INTAKE bottom
5/09/74	Na (ppm)	0.6	1.1	0.6	0.7	0.8	0.6
	Fe (ppm)	0.07	0.15	0.38	0.10	0.16	0.66
	SO_4 (ppm)	4.2	3.0	2.9	2.3	2.1	2.5
	Mg (ppm)	2.6	2.6	2.6	2.5	2.5	2.6
	Ca (ppm)	14.6	14.7	14.8	14.2	14.8	14.8
	Alk. (ppm $CaCO_3$)	44.5	45.5	47.5	48.0	47.0	48.0
	Cond. (umhos/cm)	90	96	92	91	93	94
	pH	7.5	7.2	7.1	7.3	7.0	7.0
	Colour (APHA)	6.5	10.5	10.5	8.5	12.0	10.0
	SS (ppm)	2.4	1.8	6.2	2.0	1.0	6.6
	TOC (ppm)	2	3	3	3	3	4
	Turb. (APHA)	1.5	5.0	6.0	1.5	1.5	8.0
10/09/75	Na (ppm)	2.0	2.0	2.0			
	Fe (ppm)	0.14	0.22	0.25			
	SO_4 (ppm)	1.5	3.1	4.2			
	Mg (ppm)	3.5	4.0	4.0			
	Ca (ppm)	15	15	18			
	Alk. (ppm $CaCO_3$)	55.5	59.5	65.5			
	Cond. (umhos/cm)	119	131	137			
	pH	7.5	7.4	7.3			
	Colour (APHA)	7.5	6.2	8.8			
	SS (ppm)	1.0	1.4	1.6			
	TOC (ppm)	6	7	7			
	Turb. (APHA)	1.5	0.7	0.7			

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APPENDIX IV PARTIAL SUMMARY OF PULPMILL WATER QUALITY MONITORING PROGRAM DATA (continued)

Date	Parameter	FFI OUTLET			SHEPPARD POINT		
		surface	mid-depth	bottom	surface	mid-depth	bottom
5/09/74	Na (ppm)	0.60	0.70	0.60	0.60	0.90	0.60
	Fe (ppm)	0.18	0.14	0.24	0.08	0.11	0.32
	SO_4 (ppm)	3.6	2.5	4.2	2.3	2.7	3.3
	Mg (ppm)	2.6	2.5	2.7	2.5	2.5	2.8
	Ca (ppm)	15.3	15.0	15.4	14.3	14.9	15.6
	Alk. (ppm $CaCO_3$)	48.0	47.0	48.0	46.5	46.0	49.0
	Cond. (umhos/cm)	94	93	97	94	97	98
	pH	7.4	7.0	7.0	7.2	7.1	7.2
	Colour (APHA)	9.5	9.5	12.0	10.0	9.5	12.0
	SS (ppm)	0.8	-	2.4	2.8	3.2	2.6
	TOC (ppm)	4	3	4	3	3	4
	Turb. (APHA)	1.5	2.5	2.5	1.0	1.0	2.0
10/09/75	Na (ppm)				2.0	2.0	2.0
	Fe (ppm)				0.14	0.16	0.22
	SO_4 (ppm)				2.5	1.0	4.4
	Mg (ppm)				3.5	3.5	4.0
	Ca (ppm)				16	16	17
	Alk. (ppm $CaCO_3$)				55.5	56.5	62.5
	Cond. (umhos/cm)				118	118	138
	pH				7.5	7.6	7.3
	Colour (APHA)				7.0	7.5	8.8
	SS (ppm)				1.2	1.5	1.4
	TOC (ppm)				6	6	8
	Turb. (APHA)				1.0	1.5	1.8

continued...

APPENDIX IV PARTIAL SUMMARY OF PULPMILL WATER QUALITY MONITORING PROGRAM DATA (continued)

Date	Parameter	BCFP INTAKE			LOG HAUL		
		surface	mid-depth	bottom	surface	mid-depth	bottom
8/07/76 - 10/07/76	Na (ppm)	0.50	0.35	0.40	0.70	0.40	0.35
	Fe (ppm)	0.40	0.26	0.80	0.25	0.32	0.26
	SO_4 (ppm)	4.2	5.6	9.1	5.0	5.9	4.5
	Mg (ppm)	1.18	1.20	1.22	1.18	1.15	1.28
	Ca (ppm)	17.0	17.0	17.5	17.0	17.0	17.5
	Alk. (ppm $CaCO_3$)	39.0	34.0	40.0	40.0	36.5	41.0
	Cond. (umhos/cm)	81	78	78	81	76	83
	pH	7.60	7.40	7.40	7.45	7.45	7.30
	Colour (APHA)	11.0	10.5	11.0	8.5	8.5	6.5
	SS (ppm)	3.4	6.6	62.0	5.6	7.6	5.0
	TOC (ppm)	2	2	2	3	3	4
	Turb. (APHA)	2.0	1.5	2.0	7.0	9.5	10.5
6/08/77	Na (ppm)	1.0	0.75	1.1	1.1	5.1	1.5
	Fe (ppm)	0.14	0.22	0.26	0.16	0.16	0.42
	SO_4 (ppm)	3.0	4.0	3.4	2.3	7.3	4.4
	Mg (ppm)	3.07	3.09	2.89	3.03	3.11	3.39
	Ca (ppm)	14.0	14.0	13.5	14.0	15.5	14.5
	Alk. (ppm $CaCO_3$)	50.4	50.4	46.4	50.2	52.0	53.4
	Cond. (umhos/cm)	92	90	89	90	134	103
	pH	7.2	7.1	7.1	7.0	6.9	6.9
	Colour (APHA)	7.5	8.0	11.0	5.5	27.5	9.5
	SS (ppm)	5.2	9.2	8.8	6.2	13.5	9.1
	TOC (ppm)	7	6	5	15	44	4
	Turb. (APHA)	0.5	2.5	1.0	0.5	3.5	3.0

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