Environment Canada Environnement Canada

Environmental Protection Service

MANUSCRIPT REPORT

No. 72-10

The ecological impact of the pulp and paper industry in Newfoundland

by

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ATLANTIC REGION
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THE ECOLOGICAL IMPACT OF
THE PULP AND PAPER INDUSTRY IN NEWFOUNDLAND

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St. John's, Nfld.

1972

Manuscript Report No. 72-10
Atlantic Region

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INTRODUCTION:

The people of Newfoundland commonly believe that although the pulp and paper industry in their province has altered the environment around its mills, the benefits to economic and social development which it has brought far outweigh the damage done. It is the purpose of this report to present an initial examination of the relationship between the industry and the environment. At the time of writing, there are two existing, well-established pulp and paper mills in Newfoundland, and a third mill at which the production of linerboard is scheduled to begin late in 1972. The two existing mills are Price (Nfld.) Ltd. at Grand Falls, in the center of the Island, and Bowaters (Nfld.) Ltd. at Corner Brook, on the west coast. The nascent Labrador Linerboard mill is also located on the west coast, at Stephenville. A fourth mill, to manufacture pulp and paper at Come-By-Chance on the Avalon Peninsula, has been under discussion for several years, but work on it has not yet progressed into the design stage.

THE FOREST RESOURCE:

An industry is no stronger than its resource base. In the case of renewable resources industries, intelligent resource management coupled with long range planning can conserve or even improve the state of the resource base. More than half the province of Newfoundland and Labrador is covered with forest. Unfortunately most of the forest land is interspersed with non-forested areas of open bog, heath, and tundra to such an extent that 60% of it is classed as being nonproductive, or incapable of producing at least 5 cords per acre of merchantable timber. There are approximately 21.7 million acres of productive forest land in the province, 8.38 million acres on the Island and 13.36 million acres in Labrador (1, 2) (Fig. 1). Of this, it is presently economic to harvest only about 75%, which reduces the provincial total to 16.3 million acres of economically merchantable timber. Even this figure can be further limited by the lack of accessibility and suitable forest type. For instance, the authoritative work on forestry in Labrador has stated (3) that while there are 26.6 million acres of merchantable timber in Labrador, 74% is only marginal to fair forest. Much of this is a long way from the coast and potential users (Fig. 2)

Almost all of the productive forest area is balsam fir and black spruce-dominated softwood. The distribution

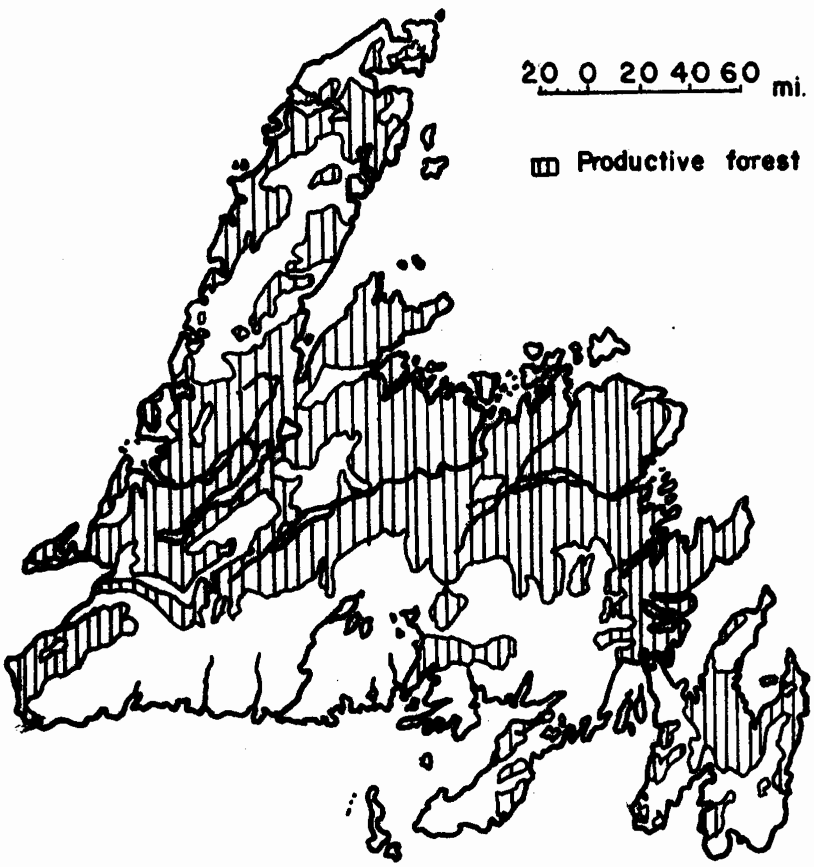

Fig. I. Productive forest in Newfoundland. (1)

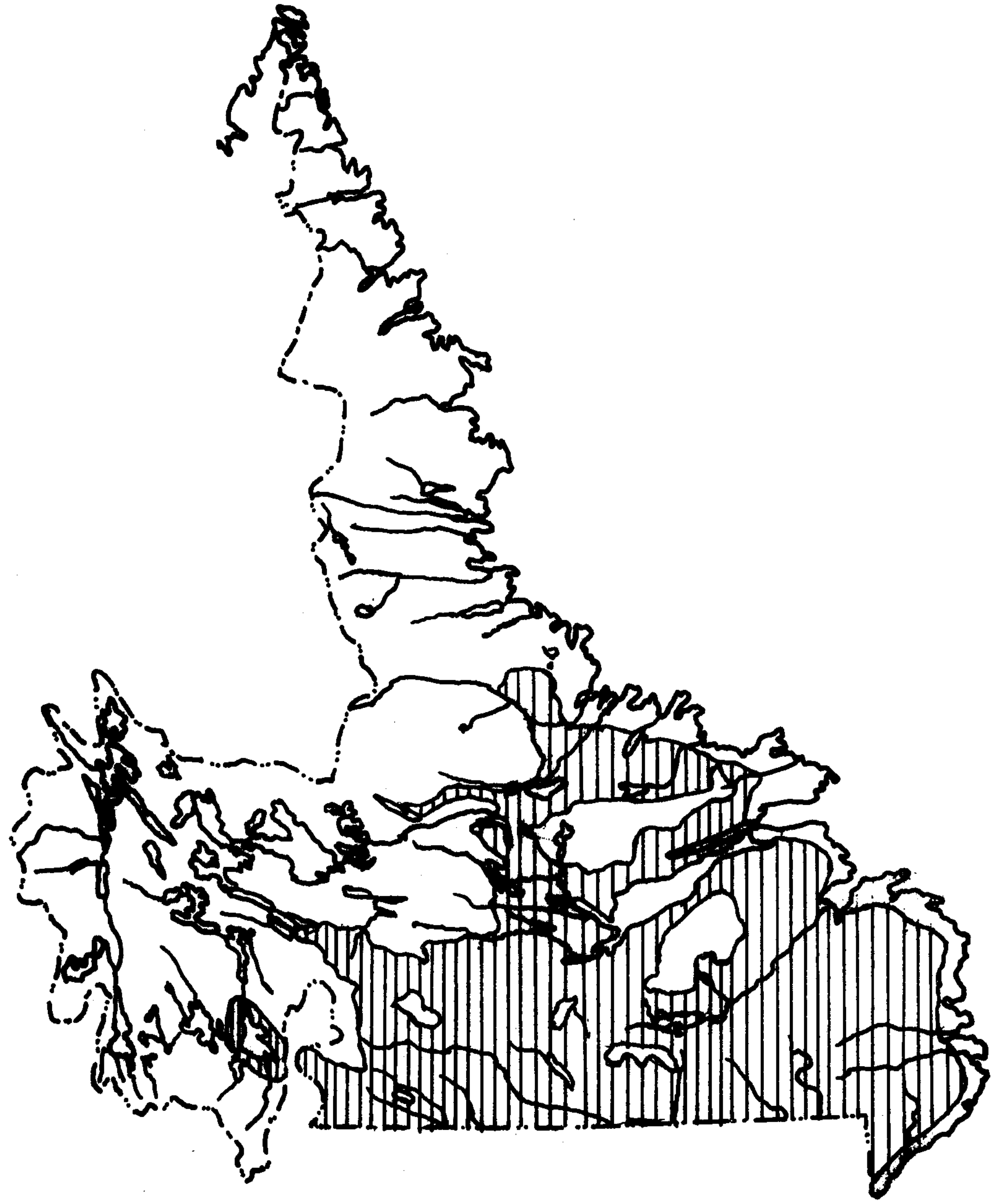

Fig. 2. Better than marginal and marginal forest land in Labrador. (3)

of black spruce is important to the industry because this tree makes an excellent quality pulp. About 70% of the forest in Labrador and 30% of the Island forest is spruce, but the latter is scattered across the central and eastern sections of the Island (3, 4). This patchy distribution has led to widely dispersed timber holdings for both the established pulp mills, and has been a factor in the use of rail transportation for pulpwood on the Island.

The growing conditions for pulpwood in Newfoundland are among the poorest in Canada. About 80 years are required for a tree to reach maturity, after which little growth occurs (1). In Labrador, up to 180 years are required for stands to reach maximum volume, even in areas of comparatively excellent forest growth (3). About 30% of the productive forest land on the Island is in the mature 80+ year age category, while almost 45% is in the unharvestable 40-age group. Estimates of the annual recruitment of new trees and the maximum sustainable yield vary with the growing region. The annual recruitment average for the whole province has been estimated to be 0.18 cords per acre per year, or roughly 4.6 million cords, but part of this goes into unmerchantable timber and part is unavoidably lost through fire and similar natural catastrophes. A recent estimate for the Island gave the potential annual growth total after unsalvable losses as 1.7 million cords (4). However, the Island timber presently sustains an annual cut of about 1 million cords. Most of it comes from the 80+ year category and is used by the two existing pulp mills. The Rousseau Commission has stated that, with our present technology, future expansion of the industry in Newfoundland would have to be met from a steadily diminishing resource base (4).

The Atlantic Development Board has estimated that the annual allowable cut is 1.6 million cords on the Island and 1.6 million cords in Labrador (1). Table 1 illustrates the decline in the total Newfoundland growing stocks which

Table 1. Projected depletion of the Island's timber at the present rate of cutting (1).

Period	Area Cut	Volume Cut	Growing Stock at End of Period
	000 acres	000 cords	000 cords
1967-1976	1048	19,882	46,798
1977-1986	1047	14,667	39,810
1987-1996	1048	14,882	33,741
1997-2006	1047	15,810	29,855
2007-2016	1048	15,825	29,897
2017-2026	1047	14,256	32,783
2027-2036	1048	14,253	35,297
2037-2046	1047	15,810	35,305

they have predicted for one rotation of 80 years at the present rate of cutting. All losses due to fire and other causes have been assumed to come out of the 40-80 year class, with the logging being selective for the largest trees. The decline from 1967 to 2026 is due to the steadily lessening amount of mature trees, as the 80+ year class is depleted. In fact, Table 1 presents an exceedingly optimistic view because it does not allow for any industrial expansion. Already, an additional 0.5 million cords are being removed by the Labrador Linerboard operation, and the fourth mill at Come-by-Chance holds important timber concessions on the Island. It is not difficult to imagine the effect of an annual cut of 1.75 million cords on the Island, which the Rousseau Commission predicted would be required to supply Price, Bowaters, and the projected mill at Come-By-Chance by the late 1970's; the annual allowable cut is only 1.6-1.7 million cords.

Reforestation is not a standard practice in the province. Cut over areas are left to recover naturally, and are occasionally thinned when they become too dense, to promote the growth of the surviving trees. The resulting slash is left on the ground, where it tends to discourage further natural seeding.

There are two obvious solutions to the problem of resource depletion. Both would involve a change from the policies of the previous decade. First is an increasing utilization of the Labrador forests. However, over half the merchantable timber in Labrador has already been committed, so that Crown timber reserves there are low (4). Also, there is the question of the additional cost involved in cutting wood in Labrador for use on the Island, and the short shipping season for northern Labrador ports. Labrador Linerboard has already shifted from its initial plan of obtaining all its wood from Labrador. In a 1965 study of the industry, Peters wrote (5): "The manufacture of pulp and paper may be called an input-oriented industry since it tends to be located near the source of its raw materials, of which pulpwood is of overwhelming importance. Since pulpwood is bulky and loses much of its weight through manufacture, the advantage of minimizing the distance over which it must travel is obvious. Access to an adequate and cheap supply of wood is a basic condition for the location of a mill."

The second solution, of more long term benefit, would involve increasing the average volume per acre of mature stands through alternative forestry techniques. Since the average stand volume of 14.2 cords per acre in Newfoundland is only 60% of that on the worst sites in Nova Scotia, such an increase should be quite possible (1).

RESOURCE AND THE INDUSTRY:

The first pulp and paper mill in the province was built at Black River, Placentia Bay, by the Newfoundland Wood Pulp Company Limited in 1895, and it ran for five years. The next important mill in the province was built by the Anglo Newfoundland Development Company Limited at Grand Falls, in central Newfoundland, between the years 1905 and 1909. Known until recently as the A.N.D. Company Limited, it was sold to Price Brothers & Company, Limited of Montreal and is presently called Price (Nfld.) Company, Limited. The second major mill constructed was the Bowaters operation at Corner Brook. It began operations in 1925 under the Newfoundland Power and Paper Company Limited, but was purchased a year later by the International Power and Paper Company Inc., who in turn sold out to the Bowaters organization in 1938.[1] The third mill with which we are concerned was formed by the Melville Pulp and Paper Company Limited. Planning for this mill started in 1966, but the operation was sold to the Javelin Corporation of Montreal before construction began. In 1972, the operation was taken over by the provincial government shortly before completion, and renamed the Labrador Linerboard Company Limited.

In addition to these three, the provincial government has made provision for the construction of a pulp and paper mill to be part of the industrial complex

1. A half interest in the Corner Brook mill was obtained by Kruger Corp. in late 1972.

located at Come-by-Chance. This mill would be operated by the Newfoundland Pulp and Chemical Company Limited, but work on it has not entered the design phase, and its future is uncertain.

Until 1971, Price and Bowaters together accounted for almost all of the pulpwood and most of the logging production of the province (2). A small quantity of pulpwood is exported, principally by Bowaters, and the production of sawlogs for timber is small in comparison to the production of pulpwood. Most of the wood cut is, therefore, used domestically for pulping. Each of the mills obtains its wood from land held under a complicated system of tenure. The two established companies control about three-quarters of the forest land on the Island through private holdings, leases, and concessions. Bowaters rights extend to about 3 million acres of productive forest land on the Island, while Price holds about 2 million acres. Price, being established before Bowaters, was able to secure more concentrated holdings, chiefly on the Exploits River drainage basin but with smaller holdings at Halls Bay, Terra Nova, and on the Great Northern Peninsula. Bowaters holdings are more scattered. Their largest ones are in the Humber River and Harry's River valleys on the west coast, with additional rights in the area drained by the Gander River at Indian Bay and on the Great Northern Peninsula (Fig. 3) (5).

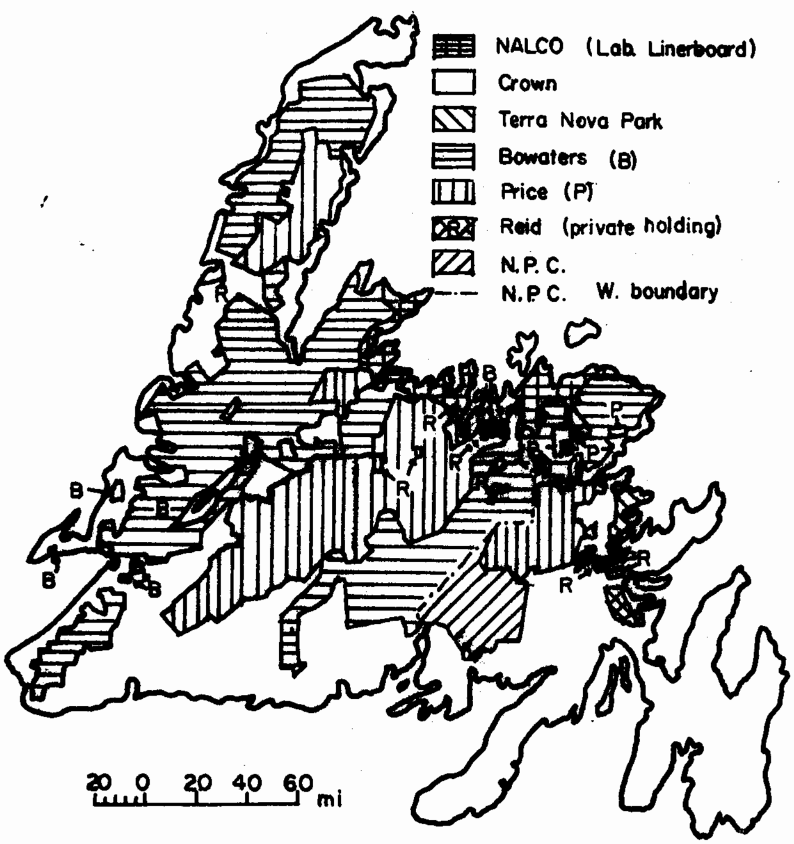

Fig. 3. Land tenure in Newfoundland. (4)

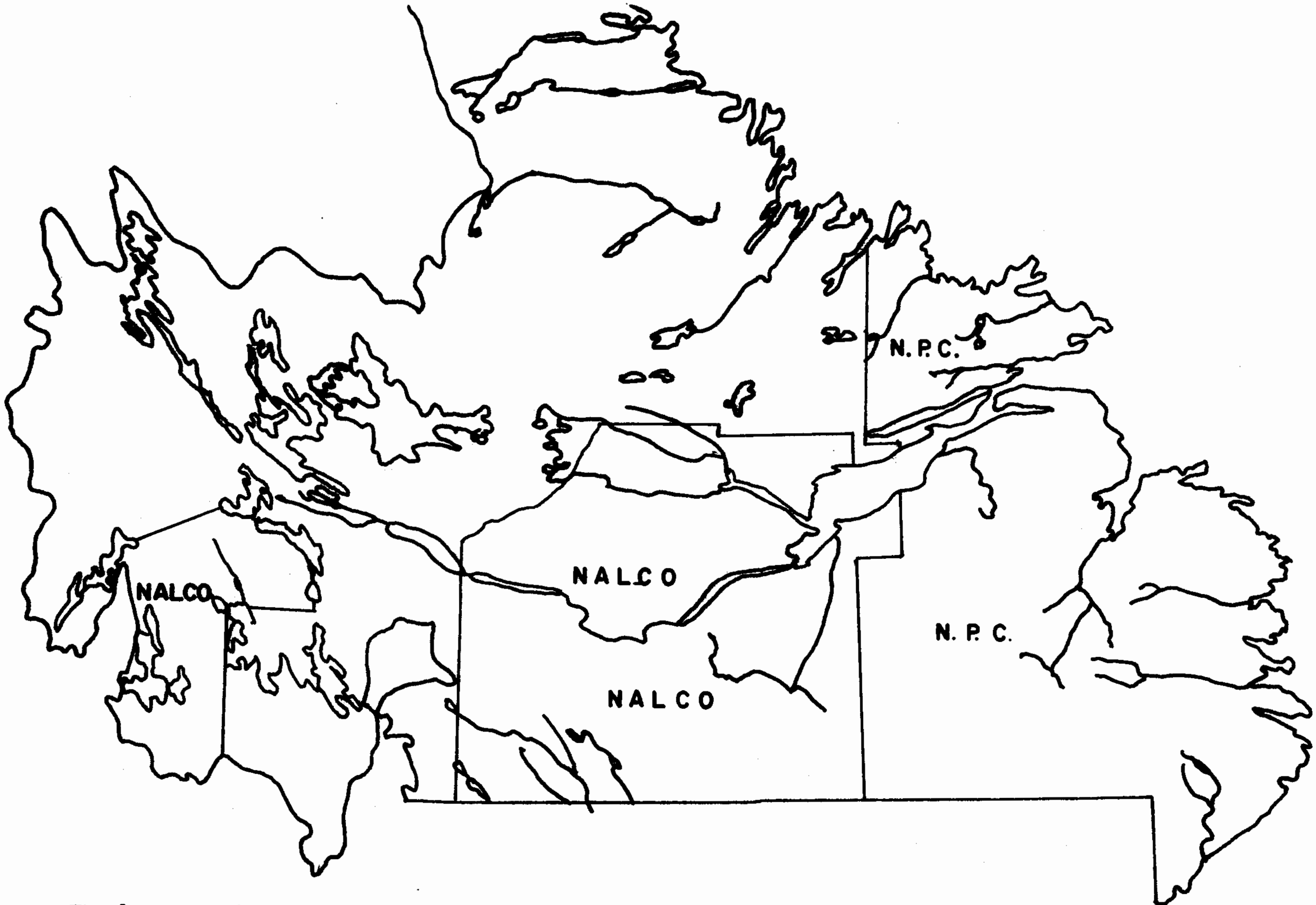

Fig. 4. Land tenure in Labrador. There are no holdings in the North

The two later arrivals have largely had to settle for timber rights in Labrador (Fig. 4), although Newfoundland Pulp and Chemical holds options on some 1.9 million acres of marginally productive land in the eastern portion of the Island. There is no unallocated productive softwood forest left on the Island (2). Newfoundland Pulp and Chemical also has options on about 4.7 million acres of productive forest in Labrador, principally on the coast around Alexis Bay and Sandwich Bay, and around Kaipokok Bay further north. The Newfoundland and Labrador Corporation, which supplies Labrador Linerboard with wood, has rights within the Lake Melville area, which includes all of the best forest in Labrador, and within a second plot which straddles the Quebec North Shore and Labrador Railway line. Vast tracts of unclaimed land remain to the Crown in Labrador, but most of it is tundra and scrub and none of it is better than fair to marginal forest according to the classification scheme of Wilton (3). It is evident that there is virtually no productive softwood forest left unclaimed in the province, and that future expansion in the industry must be met from the resources presently held by these four companies.

PULP AND PAPER AND THE ECONOMY:

The relative contribution of the pulp and paper industry to the total provincial economy has been declining in importance for some time. When the Anglo Newfoundland Development Company built the nucleus of the Price mill between the years 1905 and 1909, they spent over $6,000,000., a figure which contrasts with the colonial revenue of only $2,100,000. in 1900. By 1951, the value of pulp, paper and concomitant logging operations to Newfoundland was $45,000,000. The industry produced 22% of the gross provincial product, and paid 20% of the wages in the province. In 1961, the value of the industry had risen to $60,300,000., but it accounted for only 14% of the gross provincial product and 12.3% of the wage payments (5). By 1969, the contribution of the industry to the provincial economy was $63,300,000., 5.3% of the gross provincial product and only 4.3% of the wages and salaries (6).

In absolute terms, however, the well-being of the industry appears to be vital to the economy of Grand Falls, Windsor, and Corner Brook, as well as towns and settlements where woods operations employ most of the male workers. In 1969, 2294 workers were employed in manufacturing at the two mills, and an additional 455 were employed in other fields.

By comparison, in 1971, the inshore fishery in the Bay of Exploits from Point of Bay to Little Burnt Bay brought in $25,782. to the fishermen, and the fishery in the Bay of Islands from Frenchman's Cove to McIvers brought in $32,136. from a total of nine different species of fish and shellfish.

Sulfite pulping is presently regarded as a non-growth segment of the industry. Over 30% of the sulfite mills operating in the U.S.A. ten years ago are now closed, and the world production of sulfite pulp is expected to remain steady or decrease in the coming decade. The industry faces two basic problems. Paper made with sulfite furnish has a lower strength than paper made with a Kraft furnish, so that there is an increasing impetus towards changing the sulfite process, particularly the acid sulfite and bisulfite methods, to produce a higher strength product. Second, intensified environmental protection requirements are resulting in a heavy economic burden on existing mills, and they have been cited as the deciding factor in the closure of a number of U.S. sulfite mills.

POLLUTION AND THE PULP AND PAPER PROCESS:

Both Price and Bowaters use a mixed sulfite-groundwood system to produce pulp fibres which are then compacted into newsprint. In the groundwood operation, debarked logs are fed end onwards at the face of rotating grindstones, which shred the wood into long fibres. Pulpwood used in the sulfite process is first chipped and then cooked in a strong liquor of acid-bisulfite ions. The liquor digests the soluble fraction of the wood, leaving behind the supporting cellulose fibers. As a consequence of the removal of the soluble fraction, sulfite pulp is stronger than groundwood pulp, and both companies mix the two in a ratio of about three parts groundwood to one part sulfite. Neither company uses a full bleach process to brighten the end product, but Bowaters occasionally uses a hydrosulfite brightener and several color dyes. None of the Newfoundland companies use chemicals to preserve stored wood from rot, thereby avoiding the use of a potentially toxic class of substance.

The Labrador Linerboard mill is designed to make linerboard by the Kraft process, which produces a stronger fiber than the sulfite process by digesting chipped wood in an alkaline mixture of sodium salts. The end product, in this case, is a coarse brown paper used in the production of cardboard and corrugate, where strength is a a necessity. By increasing the amount of sodium sulfide used in the cooking liquor, it is possible to produce a satisfactory Kraft pulp from hardwoods (7), which have shorter fibers than softwood and are inherently unsuitable for sulfite or groundwood pulping. The addition of the rather considerable stands of birch to the Island pulpwood inventory would add significantly to the available resource while providing the mill with Island wood, but no hardwood pulping is presently contemplated (8).

There is a very important difference between the sulfite and Kraft processes from the point of view of pollution control. Although it is possible, sulfite mills seldom recover the chemicals exhausted in used cooking liquor because of the expense. In a Kraft mill, recovery of the used chemicals is economically mandatory. The spent Kraft cooking solution, called black liquor, contains all the dissolved solids from the wood together with residual sulfur compounds. It is oxidized to drive off the volatile sulfur as gases, and then burned in a furnace to drive off the volatile wood components. The residue after burning is dissolved in water and then regenerated into white cooking liquor with caustic lime. The used lime is recovered by burning. Waste heat from the oxidation furnaces is usually captured and used to drive in-plant processes.

PRICE (NFLD.) LIMITED:

Effluent

The Price mill is old, and does not have even primary wastewater treatment or stack controls. The production of newsprint at Price is about 1000 tpd, of which about one-third is made from sulfite pulp. The sulfite process has a sodium base and produces an average yield near 45%. The remaining two-thirds of the pulp is made from groundwood at an average yield of 96%.

There are four sewers (Fig. 5) of varying effluent characteristics (Table 2) and a number of smaller sewers. All of the woodroom wastes are contained in one sewer, and all of the pulping wastes in another. However, wastes from the paper mill are more generally distributed, with the result that pulp fiber is present in all the sewers

Table 2. Price (Nfld.) effluent characteristics

Sewer	Discharge (US mgd)	Process Component	BOD_5 (000 lbs./day)			TSS (000 lbs./day		
			high	ave.	low	high	ave.	low
North	58	pulp, paper mills	174	125	87	193	96	10
South	10	paper mill	18	13	9	31	22	14
Number 3	4	paper mill	17	13	10	51	26	8
Woodroom	7	woodroom	14	9	2	32	16	4

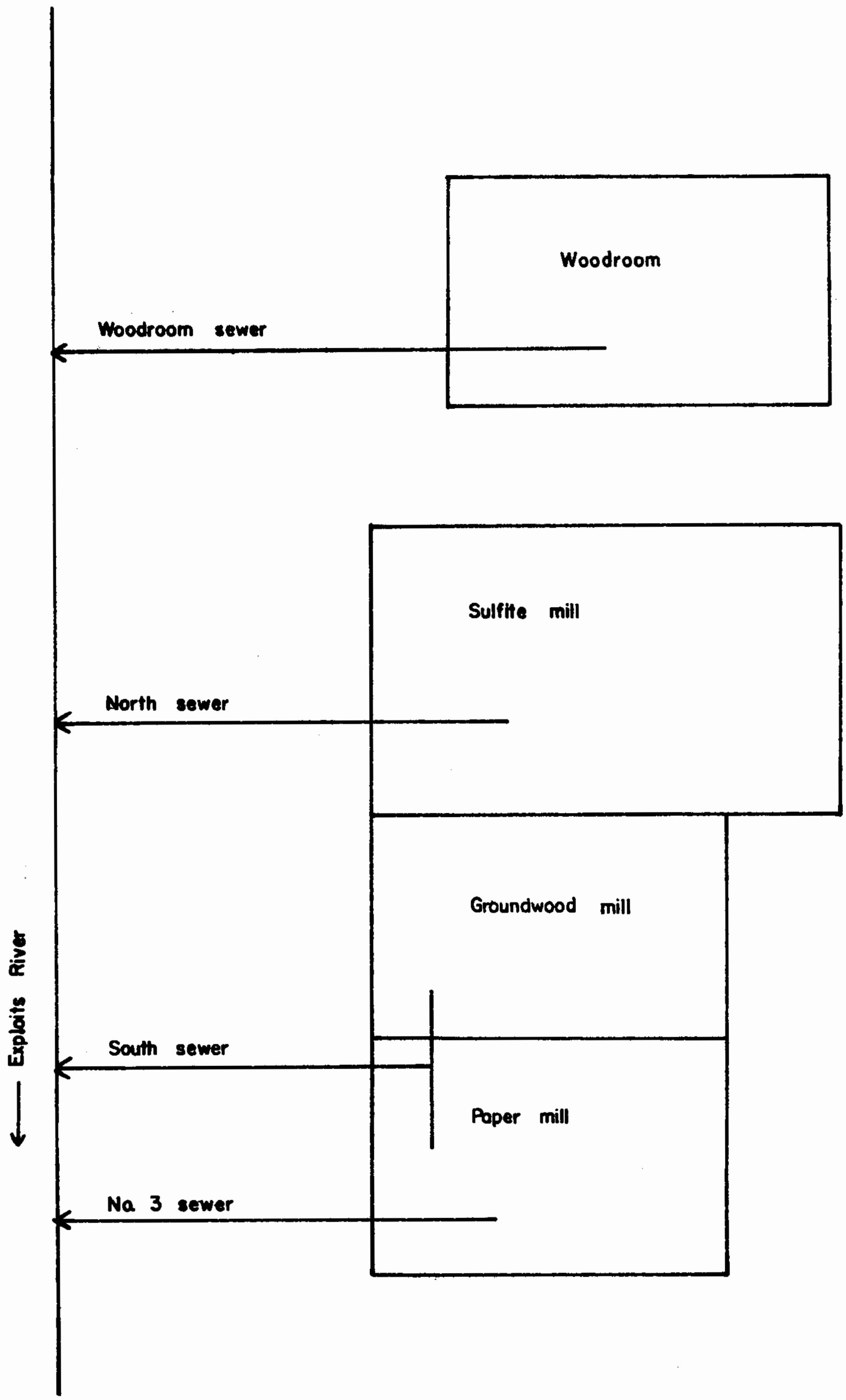

Fig. 5. Schematic sewer layout at Price

except the woodroom sewer. The North sewer contains a large volume of water diverted from the mill's turbines at Grand Falls, together with some paper fiber and all the pulping wastes: sulfur compounds (mostly sulfur dioxide and sulfite), wood sugars, lignins as lignosulfonates, catechol, formic and acetic acids, acetone, alcohols, furfural, resin acids, bark, knots, pitch, sawdust, and small fibers (9). The South and Number 3 machine sewers contain pulp fibers and white water, and the Woodroom sewer contains bark, wood splinters, chips, and resin acids in the water discharged from the hydraulic drum barkers. Of the smaller sewers, the most significant discharges an estimated 19,000 lbs/day TSS, comprised of oversize particles rejected at the grinder heads in the groundwood mill.

Each of the sewers discharges separately into the Exploits River, where the flow is greater than 3000 cfs. 99% of the time and usually is greater than 5000 cfs. However, the woodroom sewer discharges into a short stretch of the river between the intake for the mill's generating turbines and the tailrace. The diversion of the river through the turbines removes 3-4000 cfs. from the water initially available to dilute the woodroom waste.

Effluent control at Price is in its infancy. There is no chemical recovery system, and the BOD of the pulping waste is consequently high. The last few years have seen an attempt to control uneconomic solids losses. New screens were put on the barking system in 1971 which reduced the TSS loss from the woodroom by about 40%, and an additional fine screening system is planned. In 1972, a program was started to reduce the pulp fiber losses in the south and number 3 sewers by an estimated 90%, by recycling the screener room rejects back into the groundwood system.

Wood Transport

Wood destined for the mill is delivered by truck, the Exploits River, or a combination of both. The use of the Exploits River watershed, which is the largest on the Island, has traditionally provided a cheap source of transport. However, as the cost of pulpwood rises, losses through sinking and stranding have become more important; the company estimates that it may lose as much as 8% of the river driven wood in this way (10). While the practice of river driving is reported to be on the decline, in 1970 53% of the wood received at Price was still transported by water (4). Logs which have floated even a short distance downstream lose a substantial proportion of their bark by abrasion and hydraulic action, and the total loss of wood and bark to the watershed above the mill may have exceeded 30,000 tpy in recent years. When they reach the mill, the logs are stored in piles, often for periods as long as two years. As they are needed, they are fed into the groundwood mill or chipped and stored on a large outside chip pile for use in the sulfite mill. No preservatives are used.

Effects

The Exploits River system, with its drainage area of about 4,300 square miles, is the largest drainage basin on the Island. As such, it has been considered to offer the Island's largest single potential for Atlantic salmon development. There are three dynamic zones in the system: the upper section which includes Red Indian Lake and the drainage area above the Exploits River, the middle section which runs from the dam at Red Indian Lake down to the complete obstruction at Grand Falls, and the lower section running down to the mouth (Fig. 6). By chance, these same boundaries define three distinct zones of pollution in the river. The upper section receives base metal mining wastes and untreated sewage, the middle section is a dilution and recovery zone, and the lower section received more sewage and the effluent from the Price (Nfld.) mill.

Prior to 1956, less than 10% of the drainage area was available to migrating salmon, which were blocked from spawning in tributaries of the middle and upper section by a partial obstruction at Bishop's Falls and a complete obstruction at Grand Falls. During the period

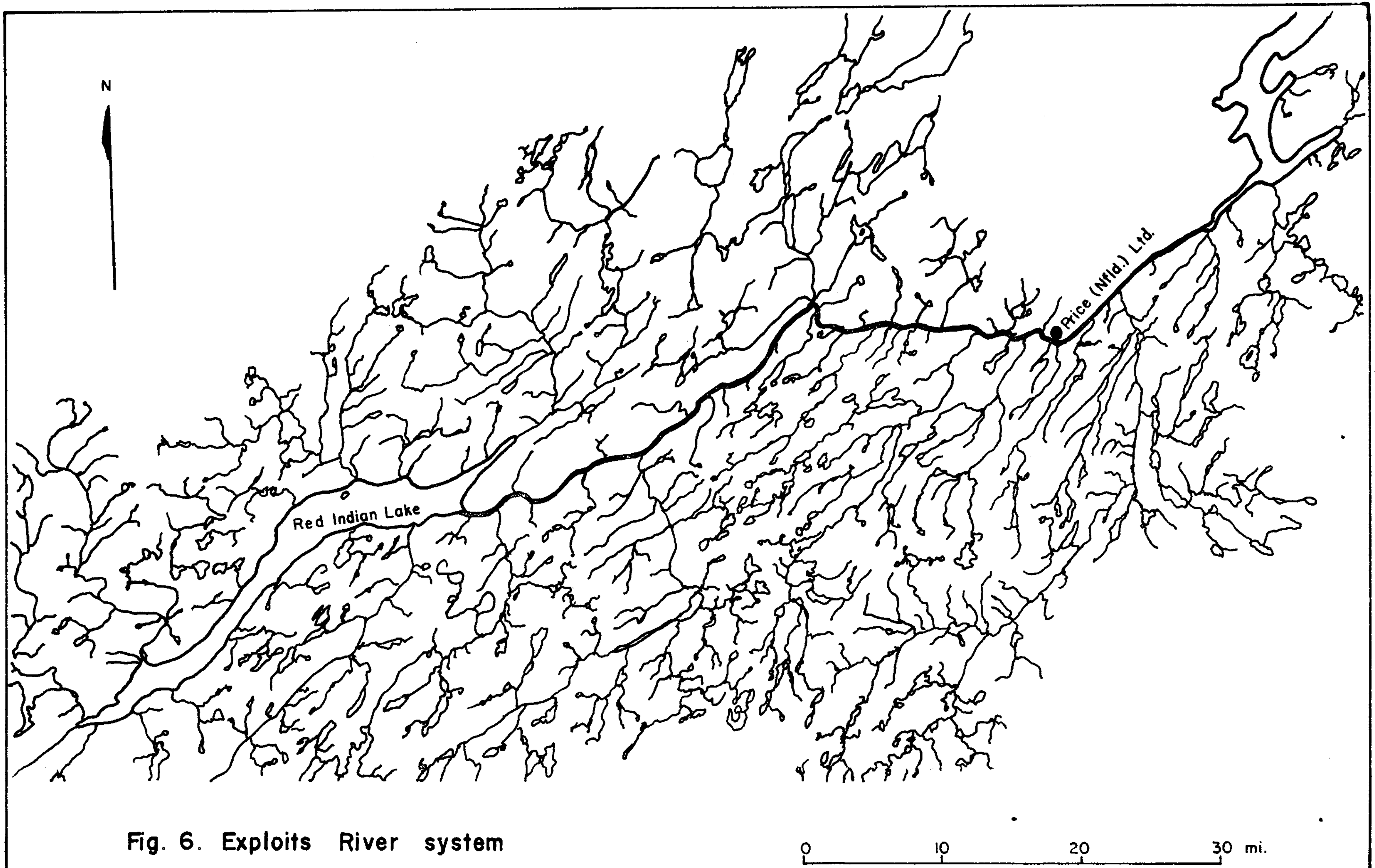

Fig. 6. Exploits River system

1956-1964, a large tributary in the lower section was made accessible to sea run salmon by constructing a fishway, performing stream clearance work, and stocking the tributary with salmon from a smaller tributary which had been completely blocked off by a hydro-electric development. In 1966, development began on the middle section, with construction of a controlled flow spawning channel for salmon on Noel Paul's Brook, which drains into the Exploits below Red Indian Lake. In 1971, a fishway was completed over Bishop's Falls, and a fishway over Grand Falls is presently being built to allow returning salmon access to Noel Paul's Brook. The environment-altering capability of Price results from the mill effluent and from wood driving practices.

The most serious ecological effect of driving wood down rivers appears to be the result of log stranding and the formation of log jams. A hydraulic head forms on the upstream side of a log stranded on the bottom, which causes increased water velocity under the log and consequent erosion of the stream bed. If a log jam builds up, incoming logs may be forced under the jam to a depth of several meters, seriously deepening the water and eroding the bottom. Erosion of the banks of a river from similar hydraulic effects may lead to rechannelling. All these processes may result in a loss of spawning area and egg destruction (11).

There have been several studies on the effects of logging practices on the aquatic resource. The sedimentation of streams caused by runoff from clearcut areas and from poorly constructed logging roads has been generally recorded (e.g., 12 and 13). Although such sedimentation reduces the level of primary productivity by cutting off the light needed for photosynthesis (14), in oligotrophic streams these reductions can be unimportant in the availability of food to higher organisms. In such cases, the reduction of natural detritus originating outside the stream would be more significant (15). Logging along the banks of a river may also raise the water temperature undesirably by removing shade (e.g., 13 and 16), but this practice has not been followed in Newfoundland for several years. In addition, heavy deposits of bark interfere with the benthos by providing a noxious, unstable habitat, and their oxygen-depleting decay can promote the growth of a hydrogen sulfide producing fungus, Sphaerotilus, which prevents the normal hatching of salmon eggs and the development of fry (17).

This has never been important in the Exploits because salmon have not been known to spawn in the lower river, and because the upper river and its bark-polluted tributaries have been traditionally blocked off to migration. The bark tends to concentrate in the frequent steadies of the tributaries and in the main river, where deposits in eddies and in front of sills may reach a depth greater than one meter. The influence of bark deposits on migrating fish may be assessed from the extreme example of deposition which occurs in the forebay and headpond area of the hydro dam at Bishop's Falls. Salmon smolt and adults migrating downstream have been trapped here by the gate arrangement for periods of about a month with no abnormal mortalities. The major effect of bark deposition, therefore, has been on the bottom oxygen supply and invertebrate fauna of the steadies.

The bottom fauna at several points in the Exploits River has been sampled to show effects of the mill. Both numbers and types of organisms decline below the mill. Organisms present above Grand Falls, but not below, include the genera Heptagenia (Ephemeroptera:Heptageniidae), Arctopsyche, Hydropsyche, and Macronemum (Trichoptera: Hydropsychidae), Gyretes (Coleoptera:Gyrinidae), Hydraena (Coleoptera:Hydraenidae), and Hyallela and Gammarus (Crustacea:Amphipoda). The mayflies and caddisflies have generally been regarded as being intolerant of organic pollution (e.g., 18 and 19). Above the mill, the influence of a Price log boom has been observed in the absence of mayflies and caddisflies just below it and their presence above.

Effluent from the Price mill has four major characteristics: toxicity, BOD, suspended and dissolved solids, and colour. While these types of pollution have remained the same since the mill started operation, it should be remembered that their quantities have changed.

Each of the four sewers at Price discharges an effluent toxic to fish. Table 3 presents the results of a single test which was performed using 65% effluent and Atlantic salmon parr. Only three fish died in the South sewer effluent, but mortality was complete in the effluent from the other three sewers. The effluent from the South and No. 3 machine sewers was heavily loaded with fiber;

Table 3. Toxicity of sewers at Price (Nfld)., at 65% concentration, to Atlantic salmon parr. (MST: Mean Survival Time)

Sewer	Process Component	MST (hr.)	96-hr Mortality (%)
North	Sulfite pulping, groundwood pulping, paper	16	100
South	paper	-	30
No. 3 Machine	paper	2	100
Woodroom	Woodroom	6	100

total suspended solids level were 198 and 328 mg/l respectively. All of the mortalities in the No. 3 machine effluent, and two of the three mortalities in the South sewer effluent were found with their throats and gills partially or completely blocked off by fiber. It is likely that they suffocated. Death in the Woodroom and North sewers can be attributed to chemical toxicity: resin acids in the case of the Woodroom sewer (20 and spent sulfite liquor in the case of the North sewer (21).

The discharge of spent sulfite liquor is known to affect the pH, BOD, COD and transparency of a receiving water (22). These effects reflect the essential characteristics of the liquor; it contains a substantial amount of organic matter, which causes turbidity in its native state and oxygen depletion during its degredation, and it contains a quantity of acidic hydrogen ions. Among the potentially toxic contents are resin acids, turpenes, and lignosulfonates. The LC50 of spent sulfite liquor from Price varies between 2000 and 2400 ppm, and the toxicity is not particularly amenable to removal by oxidation (21). Levels above 546 ppm have never been measured in the lower Exploits.

The woodroom sewer discharges into a section of the Exploits where the flow is partially depleted because of diversion of up to 4000 cfs through the mill turbines. Water for the turbines is diverted from the river into the power generating system at a point above the woodroom, and re-enters the river via penstocks at the mill. At the intake, the water level in the river is partially controlled by the spill over a dam. Consequently, there is a stretch of the Exploits River about 1850 ft. long between the turbine inlet and penstocks where the flow may be low during a dry season. At times, the woodroom sewer effluent discharged into this stretch may receive only 1:1 dilution by the depleted river (23). Caged adult salmon held in the river in this stretch have actually been killed by a combination of mechanical and chemical toxicity, and the 96-hr. LC50 of the effluent to salmon parr lies between 1 and 10%.

Considerable attention has been focused on the problems which occur in the lower river and the estuary as a result of Price's effluent. The river and estuary have been monitored throughout the hot summer months at about 100 sampling stations to check for the presence of low oxygen conditions which might present a barrier to fish migration. Such a barrier would occur if deleterious oxygen levels existed throughout the water column across a complete transect of the river or estuary. No such barrier has ever been demonstrated, although localized areas of oxygen depletion are apparent in pools below the mill and in the estuary. Oxygen depletion in the estuary, which is very shallow, appears to be more severe than in the river, possibly as a result of the electrically-charged fiber particles sinking out when they reach the salt wedge. A diving study has shown indications of a pattern in the bottom deposits which might be related to water circulation. In several areas of the estuary, these deposits are anaerobic below the sediment-water interface, both during the summer months and in the middle of winter under ice cover, but the high rate of oxygen transport caused by diffusion, tidal action, and entrainment from the river discharge appears to minimize the oxygen problem in the upper overlying water throughout the year. In stagnant areas of the river, oxygen levels occasionally fall below 65% saturation.

A deteriorated market for newsprint caused Price to shut down intermittently throughout the summer and fall of 1971. During the shutdowns, it became apparent that the oxygen demand in the lower river is largely the result of suspended and dissolved solids and that the contribution of material settled on the bottom to the total BOD is relatively lower. In contrast, oxygen drawdown in the estuary is largely due to the decomposition of the settled solids.

Nine species of fish and shellfish are taken in commercial quantities in the Bay of Exploits. Table 4 presents fisheries data for the area from Point of Bay to Little Burnt Bay, representing the maximum zone of influence from the mill for the year 1971. Unfortunately, comparable data for 1961 are not available, and it has not, in the past, been possible to separate the catch on the basis of origin. It is apparent, however, that a commercial fishery for several sensitive species still exists in this area.

Table 4. 1971 catch statistics for the portion of the Bay of Exploits between Point of Bay and Little Burnt Bay.

Species	Landings (000 lb)	Value ($)
Cod	82	3,939
herring	112	1,956
salmon	5	2,833
lobster	11	9,531
mackerel	3	92
capelin	26	435
plaice	50	1,866
Greenland halibut	129	4,878
mussels	13	252

It should be remembered that the Price mill is not the only source of effluent in the river. The towns of Windsor, Grand Falls and Bishop's Falls and Bishop's Falls, with a combined population of nearly 10,000 sewer their untreated municipal and sanitary wastes directly into the lower section of the river. At Buchans, a base metal mining and concentrator operation deposited untreated wastes directly into Red Indian Lake for the 38 years between 1927 and 1965. Although this effluent is now treated, the deposition of copper, lead and zinc on the lake bottom is extensive, and heavy metal levels in the Exploits have been a constant source of concern for environmental protection authorities. It is significant that, in spite of its effluent loading, the lower section of the Exploits has supported the migration of a small run of salmon every year within memory.

BOWATERS (NFLD.) LTD.:

Effluent

The newsprint capacity of the Bowaters mill is about 1250 tpd, but a weakness in the product market caused part of the operation to be temporarily shut down late in 1971. Production has fluctuated since, and is presently about 850 TPD of which about one-third comes from sulfite pulp. A regular sodium base process was used until recently, but the plant was converted to a 65% high yield process in 1971. Data since the conversion are scanty, but a tentative comparison of effluent characteristics before and after the conversion is shown in Table 5; the major effect was a drop in BOD output following the process change.

Three sewers discharge into the Humber Arm area of the Bay of Islands, as shown in Figure 7. All wastes from the wood processing operation and about 52% of the white water wastes end up in the West sewer. The rest of the white water is discharged from the East sewer. The sulfite pulping waste is discharged into Corner Brook River, near the mouth, through the Sulfite sewer. Waste from the groundwood mill goes into the West sewer.

There are no external waste treatment facilities at Bowaters. A coarse bark recovery system installed in 1965 greatly reduced the suspended solids loss, but it has been baulky in the past and is frequently not working. In operation, the bark is screened out, dried by pressing, and then burned for process heat.

Table 5. Suspended solids and BOD losses at Bowaters, compiled from Departmental, Canadian Pulp and Paper Association and Company reports:

Year*	1968		1969		1970		1972	
	CPPA	DOE	CPPA	DOE	CPPA	DOE	Bowaters	DOE
Suspended Solids (TPD)	40.2	43.5	56.4	35.4	51.6	49.4	38.5	23.1
BOD (TPD)	-	78.7	84.8	56.9	84.8	80.3		34.5

* No data available for 1971.

Wood Transport

Bowaters brings more of its wood to the mill by truck and rail than does Price. In 1970, only 25% of the pulpwood used was transported by water (4). The river driven wood comes principally from holdings around Grand Lake, Deer Lake, and the Upper Humber River. A short canal connects the north end of Grand Lake to the north end of Deer Lake; wood is sent down it to a boom in Deer Lake. The booms are towed to the south end of Deer Lake into a large holding boom, from which individual logs are released to float down the Humber River to the mouth, near the mill.

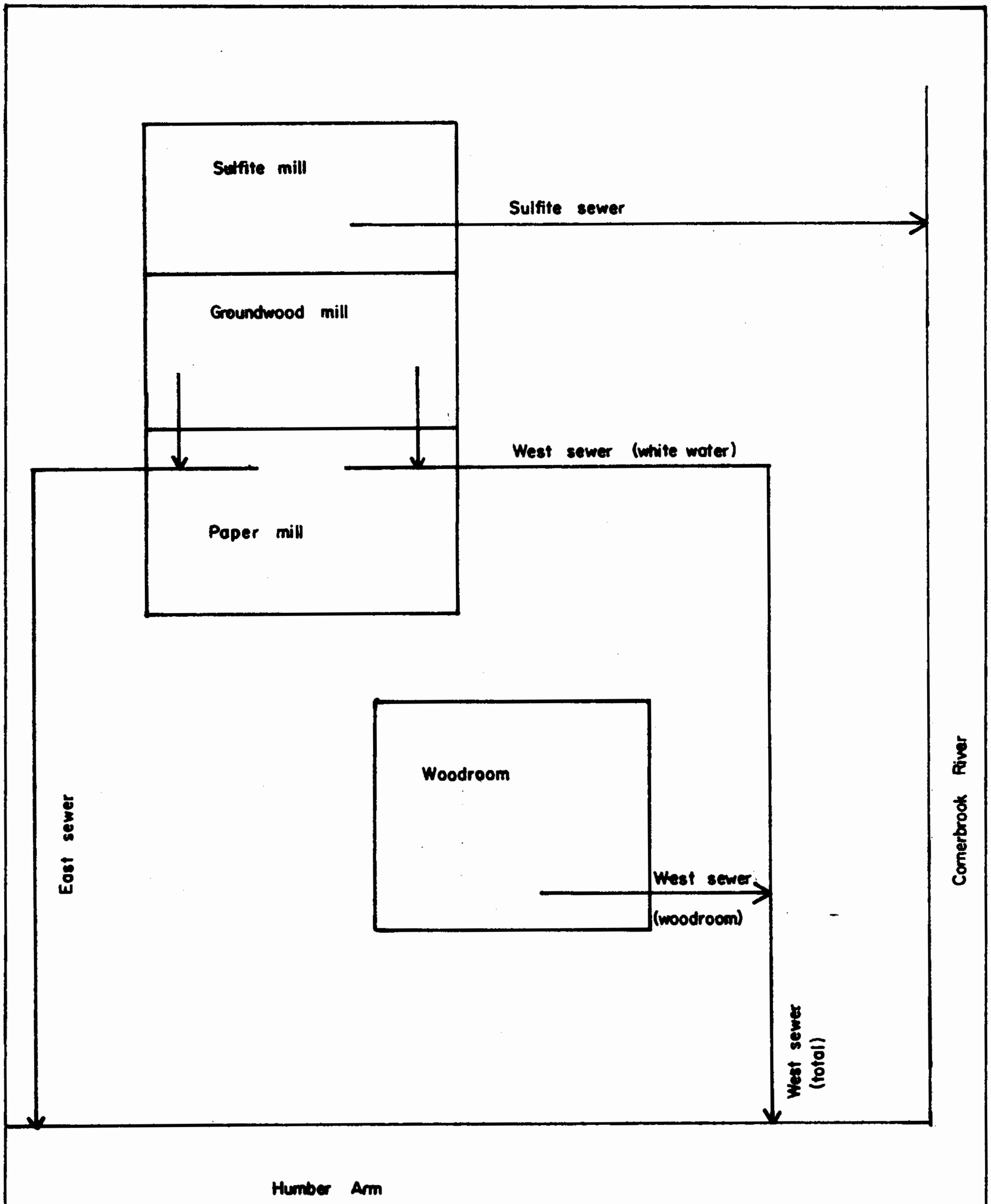

Fig. 7. Sewer layout at Bowaters

A physical and chemical survey of Deer Lake in 1971 showed that the bottom of some areas in the lake was coated with bark, wood fiber and sunken logs. However, water quality throughout most of the lake was generally good. In the rivers, however, log jams are frequent, and scouring and erosion of the bottom probably occur (11).

Effects

Approximately 3230 square miles of the western portion of the Island drain into Humber Arm, Bay of Islands, the site of the Bowaters mill. Most of this area is drained by the Humber River system, which flows from the central and western highlands through Grand Lake, into Deer Lake and then to the bottom of Humber Arm about two miles from the mill (Fig. 8). The system has always supported a salmon run, and it contains some of the most productive rearing waters on the Island.

Effluent from the mill adversely affects the water of Humber Arm (24, 25, 26). Bottom sediments at the head of the bay in the area of the mill are anaerobic, and the overlying water is more alkaline and turbid. The deep water of the bay is characterized by high stability and minimal advective mixing, so that decomposition of the bottom sediments causes a rapid uptake of dissolved oxygen. Approximately 2-3 sq. mi. of the estuary bottom at the head of the arm is covered by a blanket of hydrogen sulfide laden sludge, fiber and bark deposits. Benthic grab samples indicate that little life is present in this area (Fig. 9), with the south shore to the west of the mill being the most severely affected.

The effect of the soluble portion of the effluent appears less serious. Slight oxygen depletion occurs in the brackish surface waters of the first five miles around the bay, where the warm freshwater effluent collects, but oxygen saturation levels below 80% have never been recorded in this water. Water coming out of the mill is less dense than the water of Humber Arm, so that effluent is generally confined to the upper 2 m of the water column. Horizontal dispersion of the effluent is very rapid. The general circulation pattern of the surface water appears to be counterclockwise, so that the effluent plume fans out mainly to the west of the mill where it is uniformly distributed across the width within about 2.5 km. Under some conditions of incoming tide the effluent may spread across the southeastern portion of the Arm, near the mouth of the Humber River, but this is only a temporary condition. The surface water values for BOD_5 and spent sulfite liquor, used as indicators of effluent concentration, are near 2 mg/l and 10 ppm respectively over most of the surface water outside the immediate vicinity of the mill.

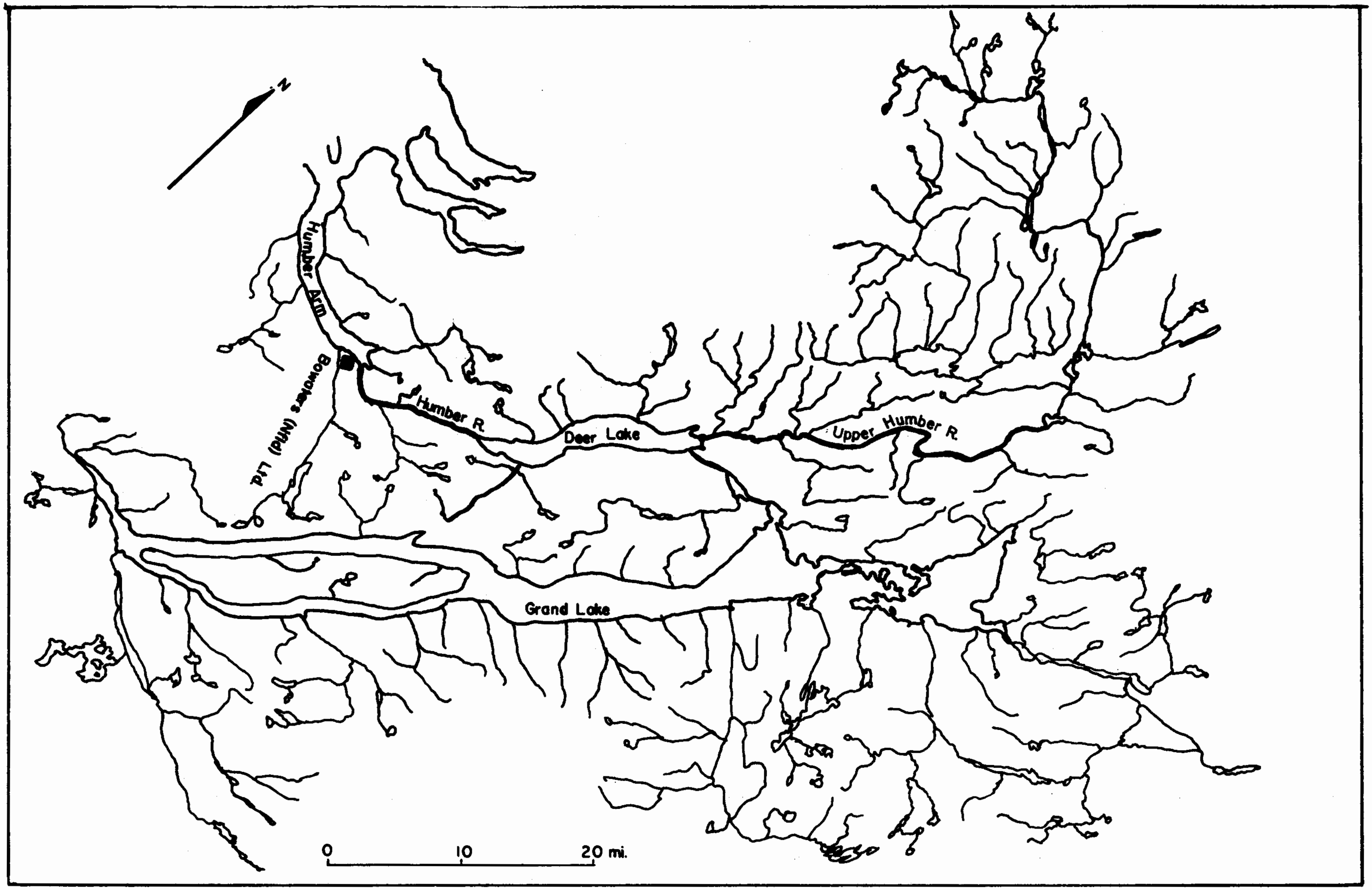

Fig. 8. Humber River system

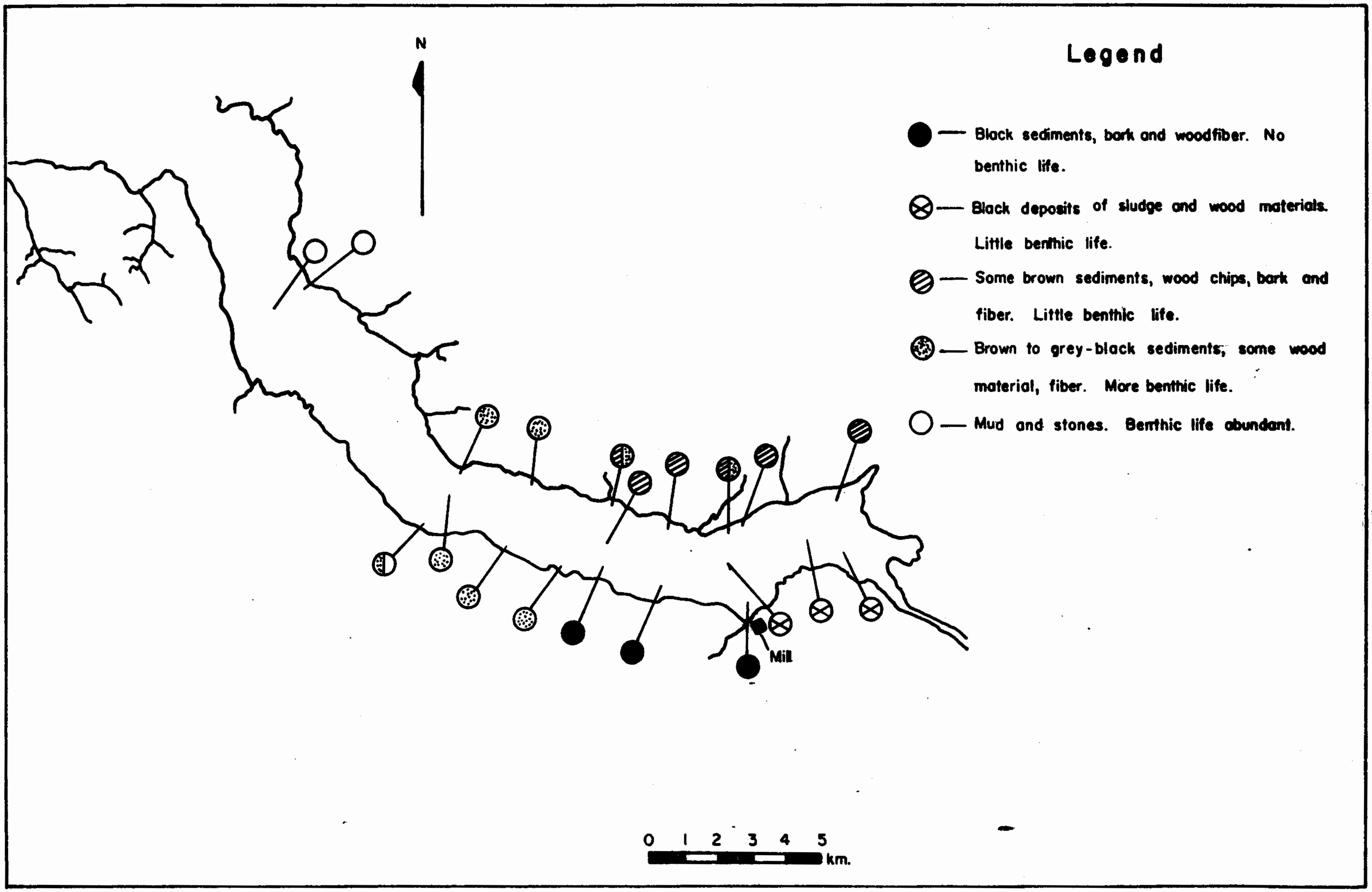

Fig. 9. Benthic life in Humber Arm. (adapted from 25)

Table 6 lists the catch and value of six species of fish in 1971 for the area of the Bay of Islands between Frenchman's Cove and McIvers. Unfortunately, comparable data for a reasonable period before this are not available, but it is apparent that a commercial fishery for several sensitive species still exists in this area.

Table 6. 1971 Fishery statistics for the Humber Arm area

Species	Landings (000 lb)	Value ($)
cod	190	10,215
plaice	13	432
herring	295	5,840
salmon	3	1,901
capelin	28	390
lobster	16	12,649
halibut	2	709

LABRADOR LINERBOARD LTD.:

Effluent

Liquid pulping effluents are characterized by high BOD, suspended and dissolved solids, and an acidic or basic pH. During the recovery of white liquor, much of the BOD of the total plant effluent is removed at the cost of producing air contaminants, such as mercaptans, hydrogen sulfide, and particulates. Because of the odour of mercaptans and hydrogen sulfide, the treatment of such losses is essential. At Labrador Linerboard, no scheme for the treatment of air pollution has been finalized.

Liquid waste is to be discharged from three sewers called the Alkaline, Neutral, and Woodroom sewers. The Alkaline sewer will hold pulping process and stock washing wastes, which typically contain sulfur compounds (dimethyl sulfide, disodium sulfide, methyl mercaptan, thiosulfates and sulfites), wood sugars and their degradation products, lignins (mostly as thiolignin), terpenes, formaldehyde, resin acids, and fatty acids. Of these, the formaldehyde, resin acids, and sulfides are particularly toxic to aquatic life, while the rest contribute much of the total dissolved solids output; the sewer will also contain fiber (9). The major solid compenent of the Neutral sewer will also be fiber, which can kill fish at reasonably high levels by inhibiting gas exchange across their gill surfaces, and impair their activity at sublethal levels (27). In addition, the normal development of many marine organisms with a pelagic larval phase in their life cycle, such as barnacles, mussels, and scallops, may be hindered by the presence of pulp fibers, which settle rapidly in salt water (24) and may thus inhibit the setting response of the larvae. The woodroom sewer will contain bark, wood particles and resin acids, the latter being toxic to salmon at about 1 ppm.

Labrador Linerboard is presently constructing primary and secondary treatment facilities for their liquid wastes. The Alkaline sewer waste is subject to settling and aeration for a total of nearly six days, while the effluent from the other two sewers is to be first clarified and then combined with the alkaline sewer waste for aeration. The dewatered underflow from the clarifier and screened solids from the woodroom will be dumped as landfill, and the final liquid effluent will be discharged into St. George's Bay from a 2500 ft. multiport submarine diffuser. Since the mill has not yet started operation, the actual characteristics of the final effluent are unknown, but it is predicted that 20 tons of BOD and 44.5 tons of suspended solids will be discharged each day during the summer.

Wood Transport

Initially, all the wood was to have been cut in

Labrador and transported by ship to Stephenville. However, it is presently believed that about half of the wood will come from sources on the Island. Details concerning the storage of wood at the millsite have not yet been finalized.

Effects

Although the mill has not yet begun production, it is thought that the pollution control facilities will effectively minimize environmental damage. In assessing the impact of the existing mills, we have been faced with the problem of no pre-mill data. With this in mind, the Department began a comparative monitoring program in 1971 designed to detect changes in the biota on the bottom of St. George's Bay. Much has been written on the utility of benthic macroinvertebrates as integrators of environmental conditions. At Stephenville, the benthos are being collected once each year from a number of locations near the mill, and from control stations half-way out the bay. The contents of each sample are compared with each other and with the controls by the technique of cluster analysis; data are stored on punch cards. This system provides an annual comparative record of events, with the option of changing the method of data treatment at some future date. In 1971, the Department took background measurements of selected chemical and physical parameters. In 1972, a baseline chemical, physical, and air pollution survey was carried out by T.W. Beak Consultants Ltd. in co-operation with the Provincial government. The effluent treatment system was designed to meet or exceed the new federal pulp and paper regulations.

CONCLUDING REMARKS:

Price and Bowaters face essentially the same set of problems in installing wastewater treatment facilities. In each case, the city has grown up around the mill. While both probably have enough adjacent space to install primary treatment, both would have difficulty in locating secondary treatment facilities in close proximity to the mill. In addition, both mills were constructed at a time when pollution was an unimportant issue, so that process and waste pipes have been arranged without regard to the eventual collection of effluent into a single treatment area. As at many such mills, the installation of treatment facilities beyond the simple control of suspended solids loss would prove expensive.

It is notoriously difficult to present an environmental balance sheet. In the case of the pulp and paper industry in Newfoundland, economic and social development benefits must weigh heavily on the positive side. Although the relative contribution of the industry to the gross provincial product is decreasing, several regions of the province are economically and socially dependent on logging, pulp and paper. To weigh against this, we have instances of localized environmental damage: a changed benthos, streams whose water quality is altered by logging and whose bottoms are altered by wood driving, river and estuary bottoms drastically modified by settled solids, reduction of water quality, impairment of recreational opportunities near population centers, and a potential for depletion of the province's timber resources. Of these, there has been very little assessment of the effects of stream bed erosion and the value lost through the impairment of recreational opportunities; more work in these areas is needed. Nothing at all has been said in this report on the effects of forestry practices on wildlife.

Three factors are of particular concern. The depletion of the Island's timber resources projected by the Atlantic Development Board in 1968 is a reality already compounded by the expansion of the industry. Research programs must lead to better productivity and increasing efficiency in the utilization of the forest. The Exploits and humber River watersheds are the largest on the Island; they must be preserved from habitat destruction due to logging and wood driving practices in order to keep habitat areas which are vital to the maintenance of fish stocks. Finally, chemical and physical pollution from mill effluent must be curtailed in order to improve the quality of the receiving environment.

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