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THE SAINT JOHN RIVER BASIN:

Review of Environmental Issues

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Executive Summary

The Saint John River is the largest river in the Maritime provinces and forms the international border with the United States from St. Francis, Maine to Grand Falls, New Brunswick. The region has been the focus of major environmental studies by various federal and provincial agencies. This report compiles the research undertaken and presents the present state of environmental issues in the Saint John River Basin. This background information will be used for evaluating future research opportunities in the area.

Résumé

La rivière Saint-Jean, la plus importante des Maritimes, constitue la frontière entre le Canada et les États-Unis, depuis St. Francis dans le Maine jusqu'à Grand Falls au Nouveau-Brunswick. La région a fait l'objet de grandes études environnementales menées par divers organismes fédéraux et provinciaux. Dans le présent rapport, on a compilé les recherches entreprises et on expose l'état actuel des questions environnementales du bassin de la rivière Saint-Jean. Cette documentation servira à évaluer la recherche ultérieure dans la région.

Introduction

The Saint John River is the largest river in the Maritime provinces and forms the international border with the United States from St. Francis, Maine to Grand Falls, New Brunswick. Approximately 51 % of the river basin is in New Brunswick with 16 % in Quebec and the remainder in the state of Maine.

The Saint John River is important both regionally and nationally. Locally, the river is used for hydroelectric generation, in industry both as process water and for waste disposal, and in the agricultural and fishing industries. The international nature of the river brings it under the jurisdiction of the federal governments of Canada and the United States. The responsibility for setting water quality guidelines and regulatory controls requires the cooperation of both governments as well as provincial and state legislatures.

Historically, there have been a number of environmental concerns in the Saint John River Basin. These include gross pollution from the industrial and municipal sectors and its impact on the fishing industry. Presently, attention is focused on pesticide use in the agricultural and forest industry, siltation, industrial pollution, and protection of fish habitat.

This report outlines the improvements in the water quality of the Saint John River from the late 1960's to the present. The present state of environmental issues are presented as well as the future direction of government funded research. The report provides background information for assessing the region as a potential research site.

Geographical description

The Saint John River Basin is the largest in the Maritime Provinces with a total drainage area of approximately 55,900 square km of which 65 % is in Canada and 35 % in the United States (Figure 1). The source of the Saint John River is Little Saint John Lake in the State of Maine. The river flows in a north-easterly direction to Edmundston, New Brunswick, and forms the international boundary between Canada and the United States from St. Francis, Maine to Grand Falls, New Brunswick. Below Edmundston, the river flows south-easterly to empty into the Bay of Fundy at Saint John. Over its 670 km length the river falls 480 m from its source to sea level at McKinley Ferry, approximately 130 km from its mouth.[15] The last 130 km of the river are tidal, although the exchange of water between the Bay of Fundy and the river is small because of the narrowness of the entrance at the Reversing Falls.

Topography

The Saint John flows through three major topographic regions - the Chaleur Uplands, the New Brunswick Highland, and the New Brunswick Lowland (Figure 2).[2] In Maine, the Chaleur Uplands are characterized by swampy plains and numerous lakes, and in New Brunswick by heavily forested valleys. The geology here consist mainly of Lower Paleozoic sedimentary rock - shale, argillite, sandstone, and limestone.[18] The population is sparse and there is little or no agricultural or industrial pollution.

In the New Brunswick Highlands (Grand Falls to Mactaquac Dam) the river flows through the original preglacial river valley. Here, the Lower Paleozoic rocks are heavily metamorphosed and the topography is more rugged.[18] Farming is concentrated in the river valley and this part of the river has been extensively developed for hydro-electric power. The river receives a heavy load of industrial effluent from pulp and paper mills and from food processing plants.

In the New Brunswick Lowlands the region is floored by Upper Paleozoic sedimentary rocks chiefly sandstones, shales, amd conglomerates, with isolated beds of coal, gypsum, anhydrite, and limestone.[18] Below Mactaquac, the river is influenced by the tides from the Bay of Fundy. Tidal fluctuations are evident only when the river discharge is low for extended periods. Grand Lake, the largest lake in New Brunswick, empties into the main stem from the east at Jemseg. This region also includes three large bays and an inland delta area which are influenced by effluent from pulp and paper mills and from the city of Saint John.

Vegetation

The overburden throughout the basin is mainly glacial till composed of silty, gravelly sand with cobbles and boulders deposited in a blanket of varying thickness over the bedrock.[3] Approximately seven per cent of the New Brunswick portion of the basin is cleared for agriculture; most is located in the river valleys where the soil is a sandy loam and ideal for growing vegetables, particularly potatoes. Eighty-five per cent of the basin is covered by forest,[3] predominantly conifers, and supports the large pulp and paper industry in the region.

Climate

The climate of the Saint John River Basin can be categorized as humid continental with long cold winters, cool summers, and no dry season.[8] The temperature varies considerably over the Basin with cooler temperatures in the northern portion. Minimum temperatures are often lower than -20°C while maximum temperatures can reach 35°C. Annual precipitation in the basin varies from about 90 cm in the headwaters to about 140 cm in the lower portion near the Bay of Fundy.[8] Precipitation is about uniformly distributed over the four seasons with about 30 per cent in the form of snow. Although snow melt usually occurs in April, runoff frequently starts during the first half of May and occasionally in March. The Basin lies on the path of many hurricane-type storms where originate in the Caribbean area and occur from August to October. Rainfalls of up to 30 cm in a 72-hour period have been recorded from these storms which can result in high water levels and localized flooding.

Historical development

The Saint John River was discovered in 1604 by Champlain and became the main route between the Maritimes and Quebec. The French settlers built shipbuilding and lumber industries and the river was used for log driving and transportation. During the 17th century, Acadians moved into the northern part of the basin and established the city of Edmundston while the United Empire Loyalists settled in the lower portion of the basin. Present population of the Saint John River Basin is approximately 70 % English-speaking and 30 % French-speaking.[9] Although the number of people living in rural areas remains high, the concentration of people in urban areas has increased in the past 20 years. The main urban centers are given in Table I and shown in Figure 3.

Table I: Major Population Centers in the Saint John River Basin

Municipality	Population
Saint John	80,500
Fredericton	43,700
Edmundston	12,000
Grand Falls	6,200
Oromocto	9,100
Sussex	4,000
Presque Isle	12,000
Houlton	9,000
Madawaska	6,000

Source : The Canadian World Alminac 1987

The early industries of shipbuilding and sawmilling have been replaced by pulp and paper production and food processing. The major industries in the New Brunswick portion of the Saint John River basin are listed in Table II with Saint John as the major industrial center within the province.

Table II: Major Industries in the Saint John River Basin

Industry	Location
Fraser Pulp and Paper Mill	Edmundston
Fraser Pulp and Paper Mill	Madawaska
McCain Foods Ltd.	Grand Falls
Ste. Anne Pulp and Paper Mill	Nackawic
McCain Foods Ltd.	Florenceville
Hatfield Industries	Hartland
McMillan Rothesay Pulp Mill	Saint John
Irving Pulp and Paper Mill	Saint John
Irving Oil Refinery	Saint John
Kimberly-Clark Paper Mill	Saint John
Atlantic Sugar Ltd.	Saint John
Moosehead Breweries	Saint John

Source: Saint John River Basin Board Part I 1975

The first hydro-electric dam was built at Tinker Falls in 1906 and the first development on the main river at Grand Falls in 1928. With the growth in demand for electrical power for domestic and industrial use, additional dams were built along the river. The Beechwood Dam was constructed in 1957 and the Mactaquac Dam in 1968. In addition, smaller dams exist on the Tobique River at Tobique Narrows, and on the Madawaska at Edmundston.

Tributaries

The south-eastern slopes of the Notre Dame Mountains give rise to numerous short tributaries which flow into the Saint John River. Among these are the Daaquam, Big and Little Black, St. Francis, and Madawaska Rivers, all of which flow from the west and north. Two rivers, the Allagash and the Fish enter from the south, from the upland area of Maine.

Below Grand Falls, the Saint John River is joined from the west by the Aroostook River and from the north and east by tributaries from the New Brunswick Highlands. Of these, the two most important are the Tobique and the Nashwaak.

From the New Brunswick Lowlands, the main tributaries from the east include the Canaan, Salmon, and Kennebacasis Rivers. The Meduxnekeag and Presquile, are two smaller tributaries which originate in Maine and enter the Saint John from the west. The main tributaries and their drainage areas are given in Table III and shown in Figure 2.

Water Usage

One of the principal uses of the waters of the Saint John River is in industry. Water is used both as process water and for waste disposal in many manufacturing plants. The major users in the basin are the pulp and paper mills and the food processing industry.

Hydroelectric developments are particularly important along the main stem of the Saint John River. The New Brunswick Electric Power Commission operates generating stations at Mactaquac, Beechwood, and Grand Falls. The effects of the dams on the river in terms of water quality, aquatic habitat and hydrology have been significant. The distinct nature of the headponds needed for flow regulation has created a different environment within the basin.

The Saint John River is also a source of municipal water use. Although most municipalities use groundwater as their source of drinking water, Oromocto draws its water from the river while Saint John uses water from Spruce Lake and Latimar Lake. Sewage treatment facilities are operational in most municipalities, with the exception of Edmundston (under construction), so the effluent to the river is minimal when compared to the industrial output. Saint John, however, still discharges a portion of its sewage directly to the harbour.[22]

The fishing industry is another important user of the water resource in the Basin. Although the commercial fishery has declined in recent years, sport fishing is common and is a major tourist attraction. The tourist industry also uses the river for boating, swimming, and hunting.

The agriculture and forest industries use large quantities of water in their pesticide spray programs. Although this need is concentrated in a small time frame each year, the volume of water used is considerable. Farmers also use water in irrigation and for livestock consumption.

Environmental studies.

The Saint John River Basin has been the focus of environmental studies since 1967 when the Atlantic Development Board commissioned a study on the water resources in the Maritime Provinces. One of the recommendations of this study was to develop a comprehensive plan for water resource development in the basin.

In 1970, the Canada-New Brunswick Saint John River Basin Agreement was signed and provided for a comprehensive river basin planning study. The objective of the Agreement was "to provide for optimum management of the water resources of the River Basin for the social betterment and economic improvement of the region".[18] Planning for the New Brunswick portion of the basin was to cover present and future water uses. The study was to consider legal implications, citizens' recommendations and the international implications of water planning and management in the Saint John River Basin.[18]

The Saint John River Basin Board was set up to carry out this study and consisted of a six-person team with three Federal and three Provincial members. The work under the agreement was financed 90 per cent by Canada and 10 per cent by New Brunswick with a total budget of $912,000 for a four year period. A large number of specialist researchers were recruited to conduct surveys and report to the Board. A list of these reports is given in Table IV.

Before beginning the long-term studies, the Board issued an interim plan in 1970 to reduce the gross pollution in the river. Specifically, the Board recommended that the Edmundston pulp mill reduce its present pollution load of BOD by at least 90 per cent; that the food-processing plant at Florenceville provide secondary treatment for its effluent; that the largest pulp and paper mill in Saint John reduce its present pollution load by at least 90 per cent; and that discussions commence between Canada and the United States on appropriate steps to reduce waste inputs to the Saint John River Basin from the State of Maine.[4]

An extensive study of the aquatic ecology of the basin was undertaken in 1971-1972 as part of the Saint John River Basin Study. Research on the river and headponds (Figure 3) was conducted by many researchers, including Watt (1972) and Watt & Duerden (1974) and on the estuary by Gillis (1974).

The following data is taken from published reports to the Saint John River Basin Board and describes the ecology of the river and headponds during the early 1970's.

Headponds

Grand Falls headpond is 43 km long and is retained by a dam 10 m high. The maximum depth of water above the dam is 7 m. Here, the physical environment is closer to river than lake or pond and the relatively shallow depth, fast flushing rate, and the surface to bottom intake do not permit thermal stratification. This headpond is affected by the effluent from the pulp and paper mills at Edmundston and Madawaska. During 1971, the oxygen levels were 44-75 % saturation in winter and completely anaerobic in summer.

The Beechwood headpond is 32 km long and stretches from the town of Beechwood to the mouth of the Aroostook River. The dam is 27 m high and the maximum depth of water is 23 m. The water intake for the power plant extends from 7.5 m to the bottom of the river bed which makes thermal stratification unlikely. During low summer flow (1971) the oxygen concentrations were less than 3.0 mg/L. The headpond receives industrial effluent from Edmundston-Madawaska as well as municipal effluent from riverside communities and from the food processing and potato starch industries.

Tobique headpond is 18 km long and is retained by a dam 29 m high built at Tobique Narrows near the river's confluence with the main stem of the Saint John. The maximum water depth immediately above the dam is 23 m. Available data indicate that thermal stratification in Tobique headpond is strongly influenced by the rate of discharge and that during stratification the hypolimnion becomes anoxic. The headpond is subjected to intensive soil erosion and to annual spraying to protect the forest from spruce budworm. Typically, the Tobique River has two flow minima each year, one in winter and the second in late summer. The mean daily discharge from the river for 1972 is shown in Figure 4.

The Mactaquac headpond is 104 km long, stretching from Woodstock to about 11 km upstream from Fredericton. The dam is 55 m high and the maximum water depth is 37 m. In Mactaquac headpond, thermal stratification is more stable than in Tobique because of the much slower flushing rate and greater depth. Vertical thermal stratification is generally established during the summer months from late June to late September and in winter from January to March. During the early 1970's the hypolimnon often became severely depleted in oxygen with concentrations during the summer of 1972 ranging from 0.4 to 3.0 mg/l. During the winters the entire water column became deficient in oxygen.

Estuary

Gillis (1974) found no evidence of oxygen depletion in the estuary during 1972. The nutrient levels are high and the reasons for lack of plankton blooms are not clear. The observed correlation between increasing colour and decreasing production suggests a possible explanation but cannot be confirmed from the data available.

The Saint John River Basin Board completed its study in 1975 and reported the results in terms of a comprehensive framework for management. Although no formal implementation agreement was signed between the governments, over 115 recommendations were directed at water users and water resource managers.[22] The plan is contained in a four-part report entitled "A Plan for Water Management in the Saint John River Basin". Many of these recommendations have been implemented. Two examples are an agreement between the governments of Canada and New Brunswick to undertake a flood damage reduction program and the establishment of a co-operative program to regulate alterations of water courses.[22] In addition to the plan, 16 summary reports were published by the Board and are given in Table V.

Current studies

In addition to the comprehensive river basin planning study, a number of research and monitoring programs are conducted by the federal and provincial governments. The Water Quality Branch of Environment Canada is particularly active on the international portion of the Saint John River and a list of their activities since 1965 are given in Table VI.

In 1972, the International Saint John River Water Quality Committee was formed under an agreement between the governments of Canada and the United States. This committee establishes and monitors water quality objectives for the international waters of the Saint John River.

The Water Quality Branch operates an Automatic Water Quality Monitoring (AWQM) program on the international portion of the Saint John River in support of this committee. The automatic monitors provide hourly measurements of water temperature, pH, percent oxygen saturation, and specific conductance. The mean values for these dissolved oxygen taken at the Grand Falls, N.B. station from June to October, 1983 are shown in Figure 5. For the international portion of the Saint John River, the lowest safe level of oxygen concentration is 80 % saturation while the lowest acute level is 60 % saturation.[26] The data at Grand Falls show that the safe level is exceeded for a major portion of August and early September and the acute level is exceeded for a four-day period in September. Water temperatures follow the seasonal trends while the pH values range from 7.1 to 7.6 with a few higher values observed in October.[26]

The Water Quality Branch also collects grab samples along the Saint John River to compare selected parameters with established Water Quality Objectives. During 1982-1983, samples analyzed for nutrients and major ions show the mean total phosphorus concentrations exceeded the Objective at seven of eleven sites while the maximum values exceeded at ten of eleven sites.[27]

From 1982-1984, the Water Quality Branch conducted yearly surveys to monitor the bacterial levels in the international portion of the Saint John River Basin. The results were compared to the use-specific water quality objectives developed by the International Technical Advisory Subcommittee for waters of the Saint John River Basin. These objectives require that the fecal coliform limit should not exceed the log mean of 200 organisms per 100 mL and that no single sample should exceed 1000 per 100mL based on a minimum of five samples over a thirty day period.[24]

In 1982, seven sites were sampled and most met the objectives under low flow. However, after a rain event, the coliform count increases tenfold and exceeded the water quality objectives at a number of sites.

The 1983 survey increased the number of sites on the main stem and the results showed that two of ten sites exceeded the water quality objectives.[24]

The 1984 survey included many of the tributaries above Edmundston, with one site, Little River, exceeding the objectives under low flow. Following a rain event, several of the sites showed a ten fold increase in coliform count. On the main stem, the sites at Clair, Edmundston, below Edmundston, and at Grand Falls exceeded one or both of the water quality objectives even under low flow.

In a separate study, Dutka et al (1986) analyzed water and sediment for a variety of microbiolgical and toxicant screening tests and found the areas of greatest potential concern were the upper Saint John at Madawaska and Saint John Harbour.

The Water Quality Branch began a survey to screen water and bottom sediment for toxic chemicals in 1979. In 1983, the program was redesigned to identify and quantify agricultural chemicals and to investigate their fate in the environment. Table VII gives a summary of the positive values found in nine impoundments in the middle and upper Saint John River Basin in September-October, 1983. The detailed lists of the toxic parameters analyzed in water, sediment, and fish is shown in Table VIII - Table X . Samples for nutrients and major ions were also taken at this time and the results are shown in Table XI.

Mathematical Models

In 1970, with the passage of the Canada Water Act and the creation of the federal-provincial river basin comprehensive planning units, a study was undertaken to determine if mathematical modelling techniques could be used for water quality planning and management in Canada. The purpose of the study was to select, and modify where necessary, mathematical models of water quality appropriate to Canada, and to apply these models to an example river basin - the Saint John River.[1] The study was carried out by H.G. Acres under contract to the Government of Canada.

Two models were developed in the study; an optimization model using linear programming, and a simulation model. The optimization model was used as a preliminary or screening stage while the simulation model was used to more accurately evaluate the water quality response to varying flow rates and effluent discharge.[1] In general, the models have potential to be applied to a wide range of river basin types and used in the comprehensive planning and management of water resources in Canada.

Current Environmental Issues

There are a number of environmental concerns in the Saint John River Basin. Most are associated with industrial activities, particularly the forest industry and energy production. Among the issues are siltation, the use of pesticides in forestry and agriculture, fish habitat and flood damage.

Siltation

Siltation has become a common problem in the Saint John River Basin. The main sources of siltation are agriculture, logging, road building and general construction. In New Brunswick, the current farming practices of fall plowing, larger farms with fewer protective hedgerows, and land cultivation to the water's edge have contributed to the siltation problem. Soil erosion rates in New Brunswick have increased five times since 1945, with farmers in western New Brunswick losing between 22.5 and 45 tonnes of soil per hectare per year.[6]

The forest industry is another source of stream siltation. Access roads, skidder trails, and stream crossings are the major sources of sediment from forest operations.[6] Some changes inevitably follow the large-scale removal of trees, including increased runoff for a year or two after harvesting, a loss of shade and altered microclimate, and loss of wildlife habitat.[32] Siltation of area streams has resulted in loss of fish habitat. Salmon and trout require clean, silt-free gravel in which to spawn. The result of stream siltation is either rejection of the silted habitat by spawning adult fish, or suffocation and death of eggs and young fish.[6] Siltation also results in increased turbidity, elevated water temperatures, decrease in flow and destruction of habitats for many invertebrate and vertebrates species.

Pesticides

Pesticides have been used extensively in New Brunswick in agriculture and in the forest industry. Chemical pesticides include insecticides, fungicides, and herbicides which are used in the control of plant and animal pests. These chemicals or their degradation products can reach aquatic habitats through surface runoff, leaching, drift from spray areas, and precipitation.

Pesticides have been used in the forest industry in New Brunswick since 1952 when DDT was used to control the outbreak of spruce budworm (*Choristoneura fumiferana*). DDT-in-oil was applied at the rate of 0.24 kg per hectare but was reduced to half that amount the next year.[12] Spraying continued until 1958 and with a decrease in budworm populations in 1959, no pesticides were used.

Aerial spraying resumed in 1960 and DDT was used as the insecticide until 1968. A number of studies were carried out on the effects of DDT on the environment. The effects on caged young salmon and trout,[12] on wild young salmon,[7] and on insects[13] all show a high mortality within three weeks of spraying. The hunting season for American woodcock was affected in the early 1970's because levels of DDT in muscle tissue were considered too high for human consumption.[32]

In 1963, phosphamidon was use in conjunction with DDT but was stopped in 1976 partly because of its acute toxicity to birds.[32] Beginning in 1969, fenitrothion was use (along with phosphamidon) in the control of spruce budworm. Fenitrothion at operational doses is lethal to caged syrphid flies and solitary bees[32] and may reduce breeding success and nestling growth rates in birds.[6] The use of fenitrothion declined since 1976 because of the increasing use of aminocarb. Aminocarb is more toxic to budworm than fenitrothion and is sprayed in lesser quantity to achieve the same effect.[32] Although aminocarb is highly toxic to spiders, wasps, and beetles, it is less toxic than fenitrothion to birds, aquatic invertebrates and pollinators.[6] Aminocarb is generally less persistent than fenitrothion, and is readily broken down by light and biological activity making it the preferred chemical insecticide for the control of spruce budworm.[6]

In addition to insecticides, the forest industry uses a considerable quantity of herbicides. The phenoxy herbicides, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and 2,4-dichlorophenoxyacetic acid (2,4-D), are used to control the growth of deciduous trees and broadleaf weeds. The long term effects of these chemicals have become public debate with incidents of cancer, Reye's Syndrome, and birth defects being associated with their use. With the increasing controversy over the use of 2,4,5-T and 2,4-D, the use of glyphosate as a forestry herbicide is increasing.[6] Studies are underway to determine the fate and effects of this chemical.

The use of pesticides also extends to the agriculture industry. Many areas of the Saint John River Valley use large quantities on their fruit and vegetable crops. The main fungicides used are mancozeb, captan, and chorothalonil; the chief herbicides used are dinoseb and diquat and the insecticides are phorate, disulfoton, carbofuran, and aldicarb.[6] Careless washing or loading of spray equipment at streamside have caused fish kills, however, farmer education and regulations regarding mixing of pesticides have minimized this problem. The fate, persistence, and environmental effects of agricultural pesticides has become a recent focus of monitoring efforts, although few regional studies have yet been completed.[6]

Fisheries

The commercial and sport fisheries in the Saint John River Basin has changed dramatically over the past 30 years. Prior to the construction of hydroelectric dams on the river, Atlantic

Salmon (<u>Salmo salar</u>) were found as far upstream as Grand Falls, where a natural rock barrier prevented further migration. In 1957, the Beechwood Dam was constructed and a mechanical hoist or elevator was installed to assist the fish upstream. The Mactaquac Dam was built in 1968 and fish passage facilities were provided. Most fish are trucked to release points upstream, either the main river at Woodstock or to the Tobique River.[31] A large salmon hatchery was also constructed just below the dam to supplement the smolt run that had been adversely affected by habitat destruction and turbine mortality.[4]

The increased use of the river for power generation combined with the heavy loads of industrial and municipal wastes have caused the salmon population to decline by about 40 percent over the past two decades.[4] The high industrial BOD loading to the river has resulted in poor water quality and deteriorated conditions in the river bed. The formation of headponds behind the dams has changed the assimilative capacity of the river by slowing down the water flow. Water which would normally flow from Edmundston to the downstream side of Mactaquac Dam in about three days, now can take as long as three months.[17] Figure 6 shows the mean flow in m^3/s below Mactaquac in 1967 while Figure 7 shows the mean flow in 1985. The longer residence time in the headponds results in increased oxygen consumption and a lower reaeration rate. This combination can result in severe oxygen depletion and loss of fish habitat.

The dams are also associated with two other problems which impact on fish and fish habitats: (1) large daily fluctuations in the river flow below the dams as a result of regulation of the water for hydroelectric power generation and (2) supersaturation of the water below Mactaquac Dam by nitrogen gas.[4] Two fish kills in 1968, below Mactaquac were attributed to nitrogen supersaturation. Gas bubbles, commonly associated with nitrogen supersaturation, were observed on dead and dying salmon and eels and tests showed that concentrations of dissolved oxygen and nitrogen gases were substantially increased when water passed through the turbine generating system at low generating levels.[14]

Decrease in salmon populations is also attributed to forest spraying with DDT. Kerswill (1967) showed a high mortality in young salmon within three weeks of spraying.

The commercial salmon fishery was closed from 1971 to 1980 because of reduced stock, but opened again in 1981 with stringent quotas and restrictions. However, in 1984 the commercial fishery for salmon was again curtalled.[22] Commercial fishing of American eel (Anguilla rostrata), gaspereau (Alosa pseudoharengus), and shad (Alosa sapidissima) are also important in the Basin.[22]

Sport fishing is very popular along the Saint John River. With the reduction of industrial and municipal wastes and the subsequent improvement in water quality, the number of fish has increased. Brook trout (Salvelinus fontinalis) and Atlantic salmon are the two most popular species although there are restrictions on salmon angling.[22] Sport fishing also extends to species of bass, perch, and pickerel.

Floods

Records of flooding in the basin have been found dating from 1696. One of the most serious floods on record occurred in May 1887, with a newspaper report of the day estimating the total damage at $500,000.[18] Major floods occurred in 1922 and 1936 where ice jams were the major cause of the latter.

Two relatively recent floods occurred in 1973 and 1979. In 1973, the mean daily discharge of the Saint John River below Mataquac was 10000 m^3/s; and in 1979, the discharge was measured at 11130 m^3/s, the highest level recorded to date by Environment Canada.[8] Estimated damage from the 1973 flood was $18.3 million and from the 1979 flood was $6.5 million (both in 1981 dollars).[8] Most of the flood damage occured in the lower Saint John Valley, in the low lying Maugerville-Sheffield area and the Greater Fredericton area.

To minimize future flood damage, planning and regulation of the use of flood-prone land was undertaken. The Canada-New Brunswick Agreement Respecting Flood Risk Mapping of 1977 provides for the designation of flood risk areas.[8] Once an area is designated, the development of floodplain lands is regulated. Flood-proofing existing structures located on flood plains is also part of the flood damage control program.

Since 1972, a computerized program, Streamflow Synthesis and Reservoir Regulation Model (SSARR) has been used to predict flood stages by evaluating snowmelt and rainfall runoff.[8] In 1979, another model, Dynamic Wave Operational Model, (DWOPER) was applied to the Lower Saint John River.[8] Both models are being tested to improve their efficiency.

Regulatory activity

The protection of the water resource is the responsibility of both the federal and provincial governments. Under the Fisheries Act, the federal government has the regulatory power to protect fish habitats. This control is effective in three ways: 1) it requires anyone who builds an obstruction in a waterway to build either a fishway around it or a hatchery to compensate for damaged stock; 2) it prohibits anyone from disturbing fish habitat except with the Minister's approval; 3) it makes it an offence to deposit any deleterious substance of any type in water frequented by fish or anywhere else if it might find its way into such water.[16] The Environment Protection Service of Environment Canada is the main agency regulating point source pollution.

The Water Quality Regulation under the Clean Environment Act provide the basis for provincial pollution control action.[22] The provincial agency regulating point source pollution is the Pollution Control Branch of Environment New Brunswick.

A number of court actions have been undertaken by both governments in an effort to control water resource pollution. A list of recent federal and provincial actions are given in Table XII and Table XIII.

Governments also assist in pollution control by providing financial assistance in the form of grants and loans. In the Saint John River Basin a number of municipalities have used such resources to install or upgrade sewage treatment plants. In 1965, the Canada Department of Fisheries and Forestry made available a pollution control fund to assist industries in eliminating organic pollution loading to the Saint John River upstream of the Mactaquac Dam.[22] Fraser Companies, Carleton Co-operative Ltd.,and McCain Foods Ltd. used these funds to reduce their waste output although the McCain plants still exceed federal and provincial standards.[22]

Assessment

Since the early 1970's many changes have occurred in the water quality of the Saint John River. The most important has been the reduction of industrial wastes from the pulp and paper mills in Edmundston/Madawaska. In 1979, the mill was converted to a bisulphate pulping process which allowed pulping liquor recovery and substantially reduced treated effluent loadings to the river.[22] A kraft mill was added to the Irving Pulp and Paper mill in Saint John in 1977 and the sulphite mill was closed. This has resulted in reduced discharges to the river. However, an odour problem still exists at this site.

The McCain Foods processing plant in Florenceville discharged its untreated effluent into the river until 1969. At that time a primary treatment plant was installed which has reduced the loadings. A secondary treatment facility was never constructed and loadings still exceed the federal and provincial standards. The McCain Foods plant in Grand Falls has expanded beyond its waste treatment capacity resulting in high pollution loadings to the river.

Most municipalities along the river have installed adequate sewage treatment facilities. The exception is the city of Edmundston. However, plans are currently underway to install a treatment system.[22]

The overall improvement in the water quality in the Saint John River was achieved through the co-operation of the various governments and the private sector. Between 1972 and 1982 point source pollution was reduced by 88 % in terms of biological oxygen demand loading, and by 82 % in terms of suspended solids discharge.[6] This co-operation must continue in the future in order to maintain or improve the water quality in the Basin.

Research Direction

Future research in the Saint John River Basin is focused in several areas. Research into the fate and effects of toxic substances and acid rain have been identified by the federal government as priority issues and research is underway in these areas.[22] The monitoring programs of both the federal and provincial governments have changed emphasis from routine water quality monitoring to issue oriented studies. Other areas identified by the federal and provincial governments as priority issues are groundwater, non-point sources of pollution, and the effects of land use practices on the water resources.[22] The continuation of the flood forcasting program and fish habitat protection are other areas of concern in the Saint John River Basin.

Review

Most of the literature cited in this report has been from government or government-sponsored sources. The newspaper archives and Canadian Broadcasting Company in Fredericton were contacted for information, however, very little public information is available regarding water quality of the Saint John River Basin.

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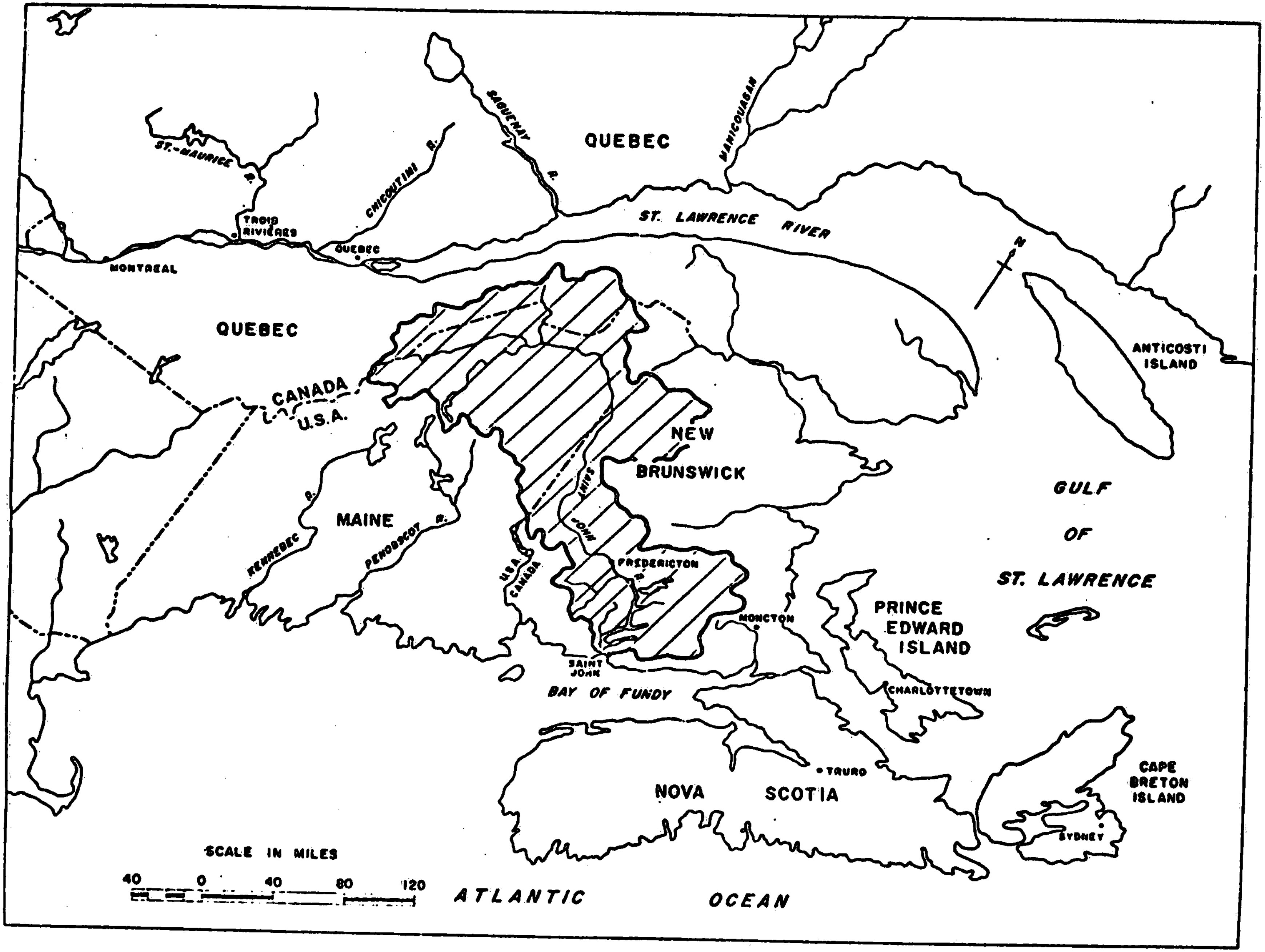

Figure 1. Location of the Saint John River Basin Source : DOE 1974

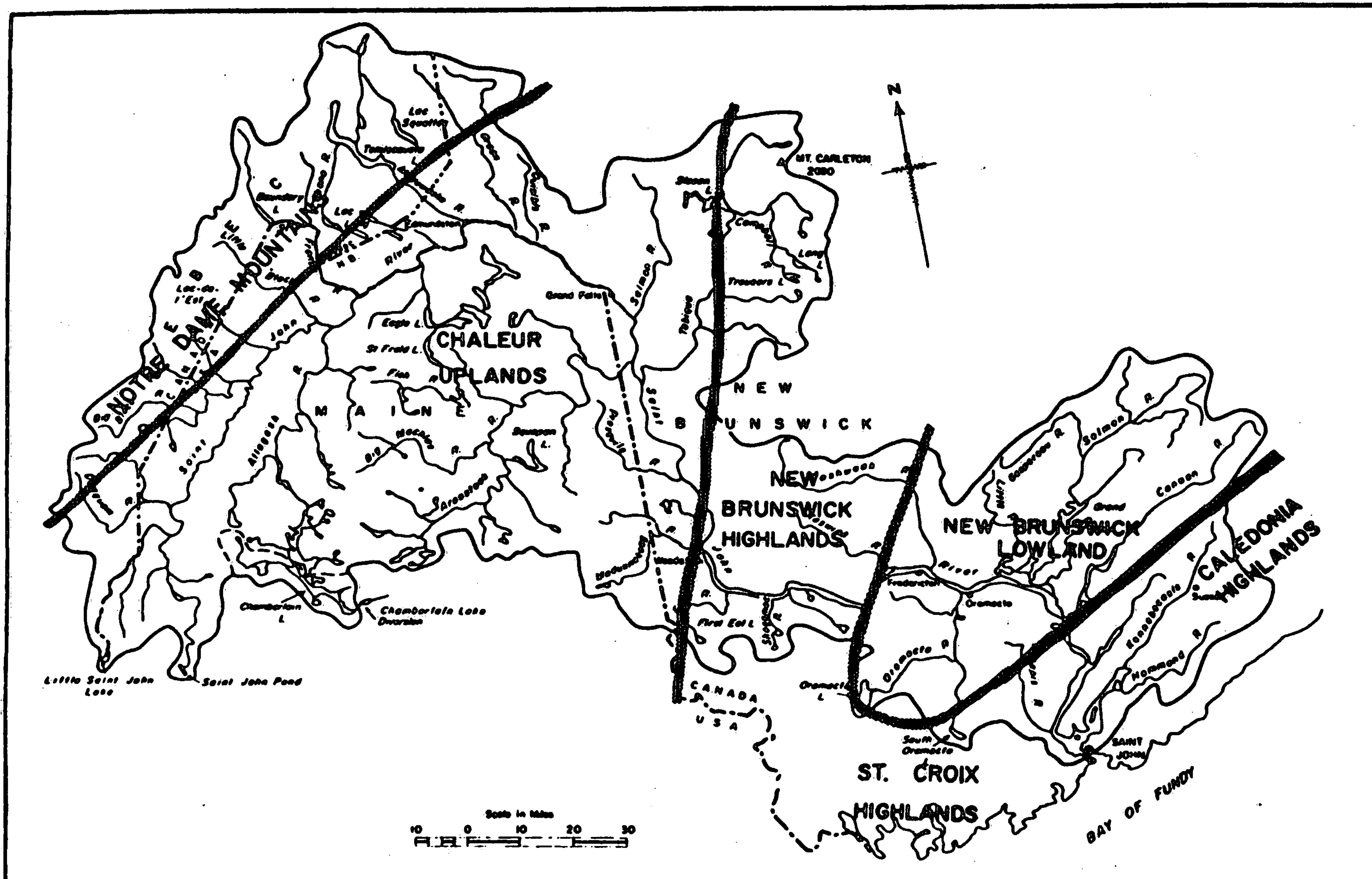

Figure 2. Topography and major tributaries in the Saint John River Basin

Source : DOE 1974

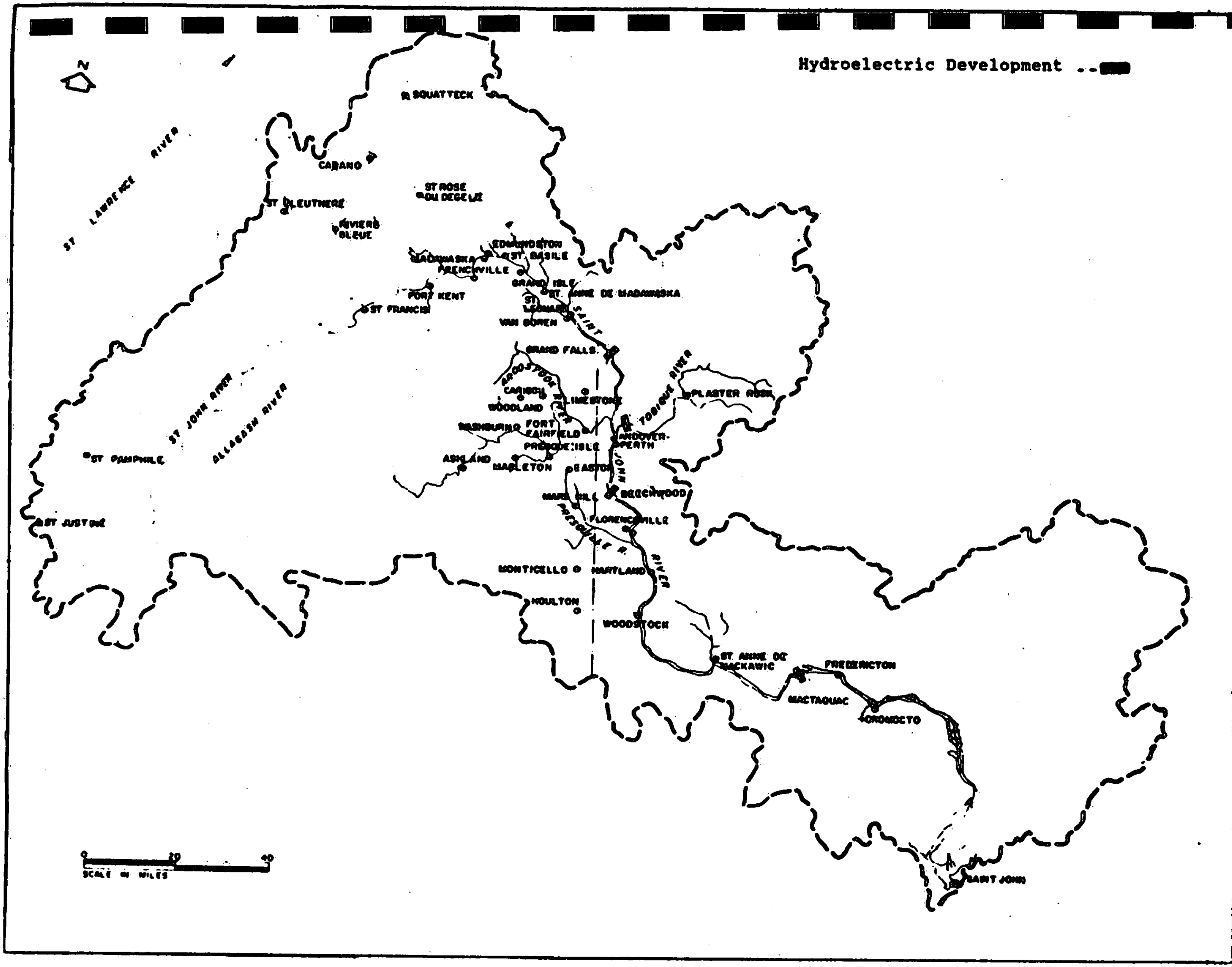

Figure 3. Major urban centers and hydroelectric developments in the Saint John River Basin

Source : Acres 1971

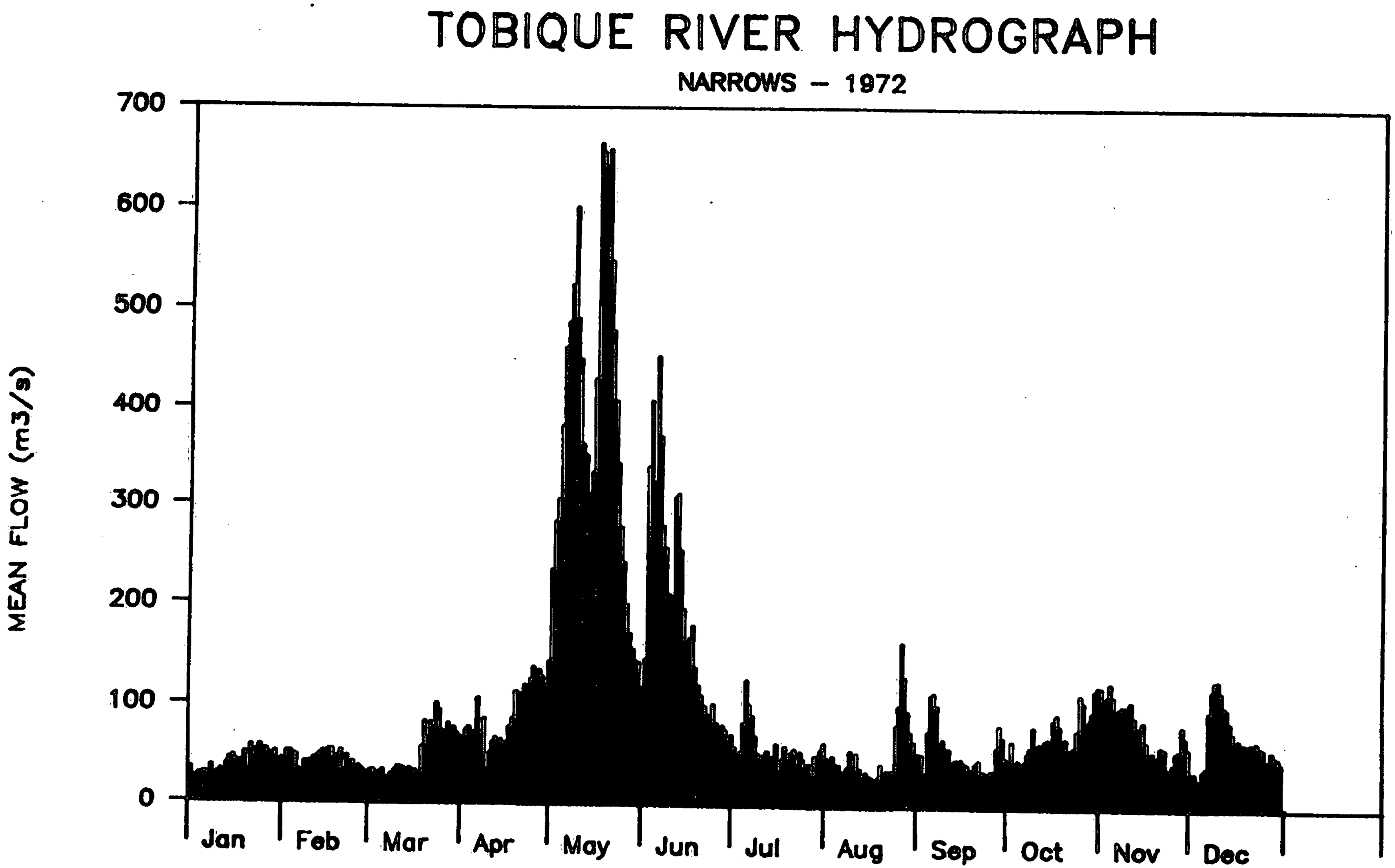

Figure 4. Mean daily discharge from Tobique River - 1972

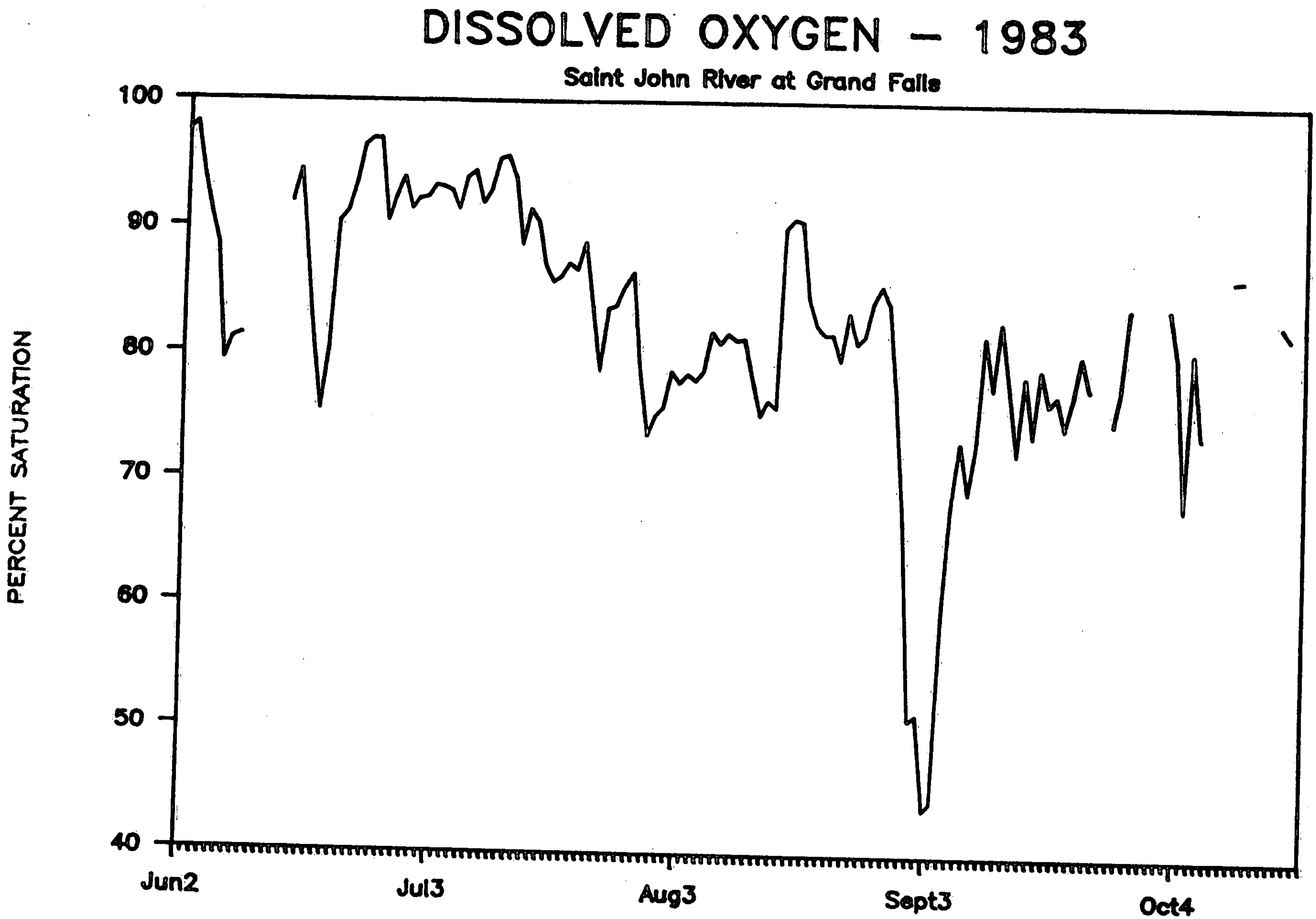

Figure 5. Mean Dissolved Oxygen Concentrations at Grand Falls (AWQM) - 1983

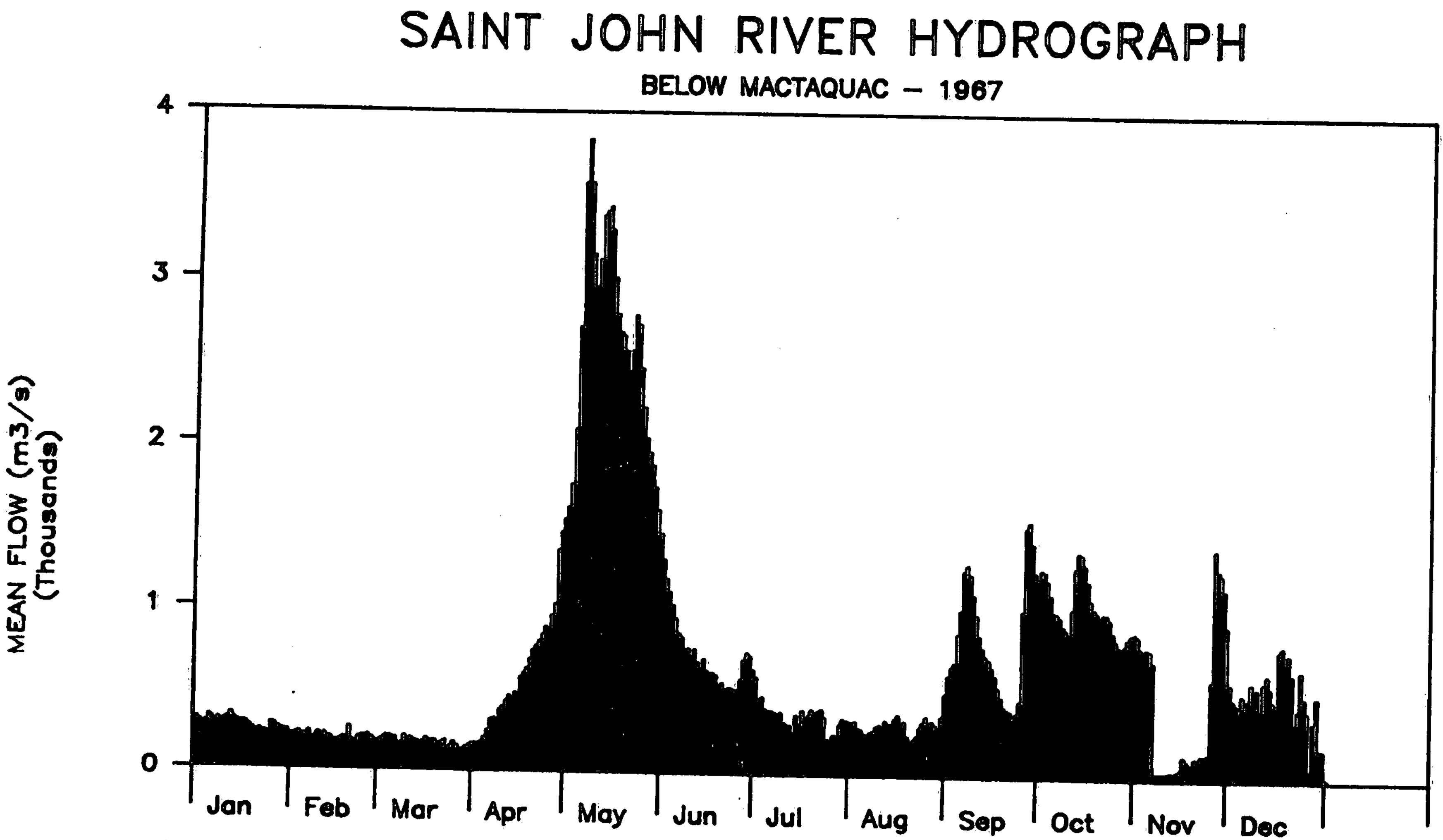

Figure 6. Mean daily discharge below Mactaquac Dam - 1967

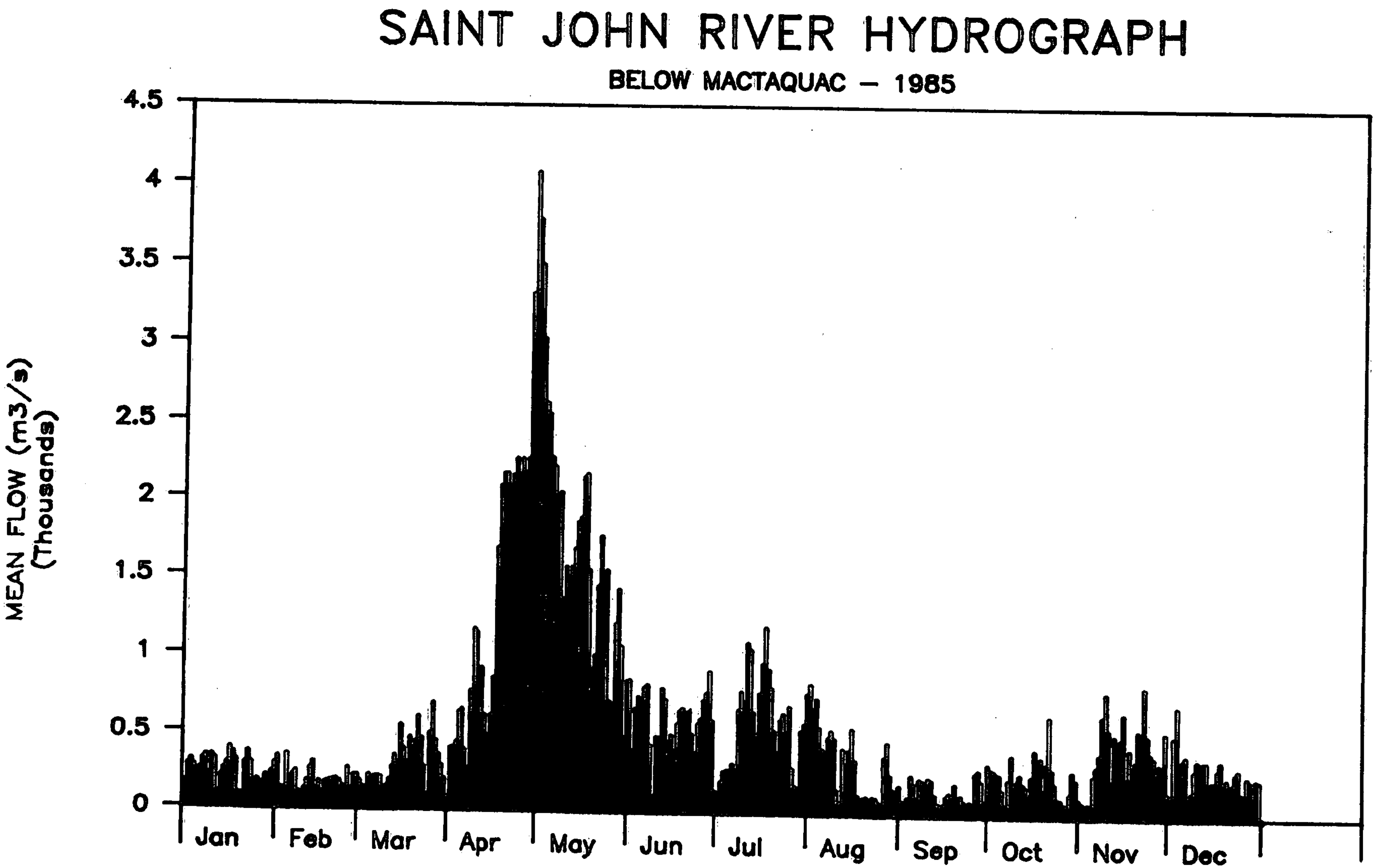

Figure 7. Mean daily discharge below Mactaquac Dam - 1985

Table III: Major Tributaries of the Saint John River

(listed in downstream order)

Tributary	Drainage Area (Km^2)
Big Black River	1620
Little Black River	725
Allagash River	3260
St. Francis River	1425
Fish River	2305
Madawaska River	3060
Green River	1180
Aroostook River	6270
Tobique River	4325
Presquile River	600
Keswick River	520
Meduxnekeag River	1330
Nashwaak River	1760
Oromocto River	2020
Salmon River	3890
Canaan River	1525
Kennebecasis River	1380

Source : Department of Environment 1974

Table IV: REPORTS PREPARED FOR THE SAINT JOHN RIVER BASIN BOARD

1. Population and Economic Trends in the Saint John River Basin
   Peter McLoughlin Associates Ltd.
2. Hydrology of the Saint John River Basin
   Water Planning and Management, IWD - Atlantic
3. The Flooding Problem in the Saint John River Basin
   Water Planning and Management, IWD -Atlantic
4. Water Quality in the Saint John River Basin
   Montreal Engineering Company Ltd.

5.a Agriculture and Water Management in the Saint John River Basin - Vol.1
   Montreal Engineering Company Ltd. for New Brunswick Department of Agriculture and Rural Development

5.b Agriculture and Water Management in the Saint John River Basin - Vol.2
   Montreal Engineering Company Ltd. for New Brunswick Department of Agriculture and Rural Development

6. The Forest Industry and Water Management in the Saint John River Basin
   L.R. Seheult, The New Brunswick Forest Resource Study

7.a Fishes of the Saint John River Basin
   F.F. Meth, Fisheries and Marine Services - Atlantic

7.b Sports and Commercial Fisheries of the Saint John Estuary
   F.F. Meth, Fisheries and Marine Services - Atlantic

Table IV: Continued

7.c	Fishes of the Upper and Middle Saint John River F.F. Meth, Fisheries and Marine Services - Atlantic
7.d	Sports and Commercial Fisheries of the Upper and Middle Saint John River F.F. Meth, Fisheries and Marine Services - Atlantic
7.e	Fishery Management in the Saint John River Basin F.F. Meth, Fisheries and Marine Services - Atlantic
8.a	Wildlife Resources of the Saint John River Basin J.S. Choate, New Brunswick Department of Natural Resources
8.b	The Economics of Wildlife in the Saint John River Basin Perse Bowden Economic Consultants Ltd.
9.	Mineral Development and Water Management in the Saint John River Basin Montreal Engineering Company Ltd. and Resource Associates Ltd.
10.	Tourism and Outdoor Recreation in the Saint John River Basin D.S. Hustins
11.	Outlook for the Potato Starch Industry in the Saint John River Basin P.A. Lewell, New Brunswick Research and Productivity Council

Table IV: Continued

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12. Manufacturing Industries and Water Management in the Saint John River Basin

    Peter McLoughlin Associates Ltd.

13. Municipalities and Water Management in the Saint John River Basin

    New Brunswick Department of Fisheries and Environment

14. Electric Power and Water Management in the Saint John River Basin

    Acres Consulting Services Ltd. for New Brunswick Electric Power Commission

15.a Phytoplankton of the Saint John River Headponds

    W.D. Watt, Fisheries and Marine Services - Atlantic

15.b Summer Headpond Ecology of the Saint John River Basin

    W.D. Watt, Fisheries and Marine Services - Atlantic

15.c Sludgeworms (Oligocheates) as Indicators of Water Pollution in the Saint John River

    W.D. Watt, G.H. Harding, J. Caldwell, and A. McMinn, Fisheries and Marine Services - Atlantic

15.d Zooplankton of the Saint John River Headponds

    F.C. Duerden, A. McMinn, and G.H. Harding, Fisheries and Marine Services - Atlantic

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Table IV: Continued

15.e Macrobenthos of the Saint John River Headponds

F.C. Duerden, A. McMinn, and P. Kearchie, Fisheries and Marine Services - Atlantic

15.f Aquatic Ecology of the Saint John River - Volume 1

W.D. Watt, Fisheries and Marine Services - Atlantic

15.g Aquatic Ecology of the Saint John River - Volume 2

W.D. Watt and F.C. Duerden, Fisheries and Marine Services - Atlantic

15.h An Ecological Survey in the Saint John River Estuary

G.Gillis, Huntsman Marine Laboratory, St. Andrews, New Brunswick

16. Toxic Pollutants in the Saint John River Basin

P.M. Keachie and R.P. Cote, Environment Protection Service - Atlantic

17. A Data System for Water Resources Planning in the Saint John River

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Source : Report of the Saint John River Basin Board 1975

TABLE V: REPORTS ISSUED BY THE SAINT JOHN RIVER BASIN BOARD

S1	Economic Trends in the Saint John River Basin
S2	The Water Resources of the Saint John River Basin
S3	Floods in the Saint John River Basin
S4	Water Quality in the Saint John River Basin
S5	Water Use for Agriculture in the Saint John River Basin
S6	Water Use for the Forest Industries in the Saint John River Basin
S7	Water Use for Fisheries in the Saint John River Basin
S8	Water Use for Wildlife in the Saint John River Basin
S9	Water Use for Mineral Development in the Saint John River Basin
S10	Water Use for Outdoor Recreation in the Saint John River Basin
S11	Water Use for the Potato Starch Industry in the Saint John River Basin
S12	Water Use for Manufacturing in the Saint John River Basin
S13	Water Use by Municipalities in the Saint John River Basin
S14	Water Use for Power Production in the Saint John River Basin
S15	Water Use and Aquatic Ecology in the Saint John River Basin
S16	Water Use and Toxic Pollutants in the Saint John River Basin

Source : Report of the Saint John River Basin Board 1975

TABLE VI: WATER QUALITY BRANCH ACTIVITIES IN NEW BRUNSWICK 1965-1985

1. International Hydrological Decade National Water Quality Monitoring Program : 1965-1974.
2. International Hydrological Decade Research Basin Study : 1970-1974.
3. Saint John River Basin Study : 1971-1973.
4. New Brunswick Surface Water Survey : 1972
5. Water Quality Branch National Water Quality Monitoring : 1974-1978.
6. Automatic Water Quality Monitors Laboratory Program : 1975-1976.
7. Environmental Monitoring of Forest Insect Control Operations : 1976-1980.
8. Atlantic Region Overview Network : 1978-1985.
9. International Saint John River Basin Study : 1978-1985
10. Interprovincial Saint John River Basin Study : 1978-1983.
11. Pollution Specific Survey : 1979-1982.
12. Acid Rain Baseline Sampling Network : 1980-1985.
13. International Saint John River Bacteriological Survey : 1982-1984.
14. Toxic Chemicals Survey : 1982-1984.
15. Municipal Water Toxic Chemical Survey : 1985.

Source : Water Quality Branch 1986

TABLE VII : SUMMARY OF SAMPLES ANALYZED IN 1983 WQB TOXIC SURVEY

PARAMETER	WATER		SEDIMENT		FISH	
	TOTAL	POSITIVE	TOTAL	POSITIVE	TOTAL	POSITIVE
CARBAMATE PESTICIDES	14	5	27	-	-	-
ORGANOCHLORINE PESTICIDES	14	14	27	27	47	46
ORGANOPHOSPHATE PESTICIDES	13	0	27	0	47	0
CHLOROPHENOXY HERBICIDES	14	1	27	0	44	0
TRIAZINE HERBICIDES	14	1	27	0	37	0
POLYCHLORINATED BIPHENYL	14	1	27	4	47	10
POLYNUCLEAR AROMATICS	-	-	15	15	26	0
CADIMUM	-	-	18	18	47	0
MERCURY	-	-	18	18	32	28

Source: Water Quality Branch 1985

TABLE VIII : TOXIC PARAMETERS ANALYZED IN WATER (uG/L)

WQB SURVEY 1983

SITE	LINDANE	ALPHA BHC	PCB	2,4,5-T	CARBOFURAN
GREEN R.RESERVOIR	0.0003	0.001	<0.005	<0.01	<0.025
MADAWASKA R.	0.0003	0.006	trace	<0.01	<0.025
SJR AT GRAND FALLS	0.0003	0.001	<0.005	<0.01	<0.025
TOBIQUE R.	<0.001	0.001	<0.005	<0.01	<0.025
SISSON RESERVOIR	-	-	<0.005	<0.01	<0.025
AROOSTOOK R.	<0.001	0.001	<0.005	<0.01	<0.025
SJR AT BEECHWOOD	0.004	0.002	0.098	<0.01	0.04
SJR AT POKIOK	<0.001	0.001	<0.005	<0.01	0.03
SJR AT MATAQUAC	0.003	0.002	<0.005	<0.01	0.06

Parameters not detected: P,P-DDT; O,P-DDT;P,P-DDD; P,P-DDE; methoxychlor; heptachlor; heptachlor epoxide; alpha endosulphan; beta endosulphan; alpha chloradane; gamma chloradane; mirex; aldrin; endrin; dieldrin; 2,4-T; atrazine; metribuzine; simazine; aldicarb; carbaryl; phorate; guthion; malathion; dimethoate inidan.

Source : Water Quality Branch 1985

TABLE IX : TOXIC PARAMETERS ANALYZED IN SEDIMENT (MG/KG)-WQB SURVEY - 1983

SITE	P,P-DDT	O,P-DDT	P,P-DDD	P,P-DDE	PCB	BENZO-(B) FLUORANTHENE	BENZO-(B) PERYLENE	BENZO-(K) FLUORANTHENE	FLUORAN-THENE	INDENO PYRENE	Cd	Hg
GREEN R.RESERVOIR	<0.001	<0.001	0.002	0.004	<0.005	-	-	-	-	-	-	-
MADAWASKA R.	<0.001	<0.001	0.005	0.001	<0.005	-	-	-	-	-	-	-
SJR AT GRAND FALLS	<0.001	<0.001	0.004	0.003	<0.005	-	-	-	-	-	-	-
TOBIQUE R.	<0.001	<0.001	0.011	0.017	<0.005	-	-	-	-	-	0.37	0.16
SISSON RESERVOIR	0.001	<0.001	0.010	0.012	<0.005	0.011	0.007	0.004	0.022	<0.006	0.36	0.23
AROOSTOOK R.	0.076	0.006	0.031	0.046	<0.005	0.15	0.040	0.081	0.37	0.25	0.33	0.09
SJR AT BEECHWOOD	0.016	0.003	0.010	0.011	<0.005	0.035	0.017	0.016	0.086	0.086	0.17	0.08
SJR AT POKIOK	0.024	0.003	0.008	0.010	0.016	0.023	0.008	0.009	0.062	0.045	0.10	0.12
SJR AT MATAQUAC	0.020	0.004	0.015	0.017	<0.005	0.034	<0.006	0.015	0.064	0.095	0.30	0.11

Source : Water Quality Branch 1985

TABLE X : TOXIC PARAMETERS ANALYZED IN FISH (MG/KG) - WQB SURVEY - 1983

SITE	P,P-DDT	O,P-DDT	P,P-DDD	P,P-DDE	PCB	ALPHA CHLOR.	GAMMA CHLOR	ALPHA BHC	MERCURY
GREEN R.RESERVOIR	0.009	0.001	0.002	0.15	<0.005	<0.005	<0.005	<0.005	0.64
MADAWASKA R.	<0.001	<0.001	0.001	0.006	<0.005	<0.005	<0.005	Trace	0.77
SJR AT GRAND FALLS	0.029	0.005	0.004	0.034	<0.005	Trace	Trace	Trace	0.43
TOBIQUE R.	0.005	0.001	0.002	0.052	<0.005	<0.005	<0.005	<0.001	-
SISSON RESERVOIR	0.008	0.002	0.014	0.17	<0.005	<0.005	<0.005	0.001	1.5
AROOSTOOK R.	0.15	0.077	0.009	0.12	0.023	Trace	Trace	Trace	0.19
SJR AT BEECHWOOD	0.012	0.003	0.004	0.055	0.006	Trace	Trace	Trace	0.42
SJR AT POKIOK	0.017	0.003	0.013	0.10	0.021	Trace	Trace	Trace	0.28

Source : Water Quality Branch 1983

TABLE XI : NUTRIENTS AND MAJOR IONS IN SURFACE WATERS
(September - October, 1983)

Parameter (mg/L)	Green R. Res.	Madawaska R.	SJR at Gd Falls	Sisson Res.	Tobique River	Aroostook River	SJR at Beechwood	SJR at Pokiok	SJR at Mactaquac
Calcium(D)	15	19	15	24	16	14	15	15	17
Magnesium(D)	2.4	2.5	2.4	1.5	1.7	2.2	1.9	2.1	2.1
Potassium(D)	<0.1	0.1	0.4	0.2	0.2	0.2	0.3	0.4	0.5
Sodium(D)	1.6	2.4	3.4	0.8	1.8	1.9	2.3	2.7	3.9
Chloride	1.1	2.8	4.0	0.5	1.1	2.3	2.7	3.3	4.5
Silica(react)	3.8	1.8	3.1	1.8	5.6	4.2	4.2	4.3	3.6
Sulphate (D)	4.4	6.1	11.1	4.2	7.5	8.0	9.2	9.0	9.0
Sulphate(D IC)	4.0	5.6	11.4	4.0	8.0	7.5	8.9	9.2	9.4
Carbon(D Org)	1.3	4.4	9.2	3.4	3.8	11	11	9.3	5.9
Carbon(D Inorg)	12	13	8.6	16	10	7.5	8.0	9.1	11
Nitrogen(T)	0.24	0.13	0.18	0.14	0.18	0.40	0.30	0.37	0.37
Nitrogen(Nitrate)	0.09	0.05	0.06	0.02	0.10	0.22	0.17	0.21	0.26
Phosphorus(T)	0.008	0.007	-	-	-	-	-	-	-

Source : Water Quality Branch 1985

Table XII. FEDERAL COURT ACTIONS

FEDERAL COURT ACTIONS FOR WATER POLLUTION RELATED CHARGES

DEFENDENT	CHARGE	DISPOSITION
Nadeau Poltary Farm St. Francois, N.B.	Discharge of poultry wastes. April 27, 1973.	Found guilty on July 17, 1973. Fined $100.00
Irving Pulp & Paper Saint John, N.B.	Discharge of pulp with effluent. April 5-9, 1976.	Case dismissed. October 1, 1976.
Irving Pulp & Paper Saint John, N.B.	Discharge of pulp with effluent. Jan. 7, 1977.	Found guilty on April 16, 1977. Fined $3500.00
McCain Foods Ltd. Grand Falls, N.B.	Discharge of deleterious substance. May 10-14, 1982	Found guilty on four counts, Feb. 27, 1984. Fined $1.00 each count.
McCain Foods Ltd. Grand Falls, N.B.	Discharge of deleterious substance. May 17-21, 1982.	Found guilty on four counts. Feb. 27, 1984. Fined $1.00 each count.

Source : Washburn 1985

Table XIII: PROVINCIAL COURT ACTIONS

PROVINCIAL COURT ACTIONS FOR WATER POLLUTION RELATED CHARGES		
DEFENDANT	**DETAILS OF CHARGE**	**DISPOSITION**
McCain Foods Ltd.	Discharge of a contaminant.	Pleaded guilty. Fined $1000.00.
Ronald Nadeau Collin, N.B.	Discharge of a contaminant	Case dismissed.
McCain Foods Ltd. Florenceville, N.B.	Discharge of a contaminant	Pleaded guilty. Fined $3500.00.
Ouellette and Freres St. Hilaire, N.B.	Deposit of a contaminant upon the environment.	Found guilty. Fined $400.00.
Herve Hebert Saint Joseph, N.B.	Failure to report a discharge	Found not guilty.

Source : Washburn 1985