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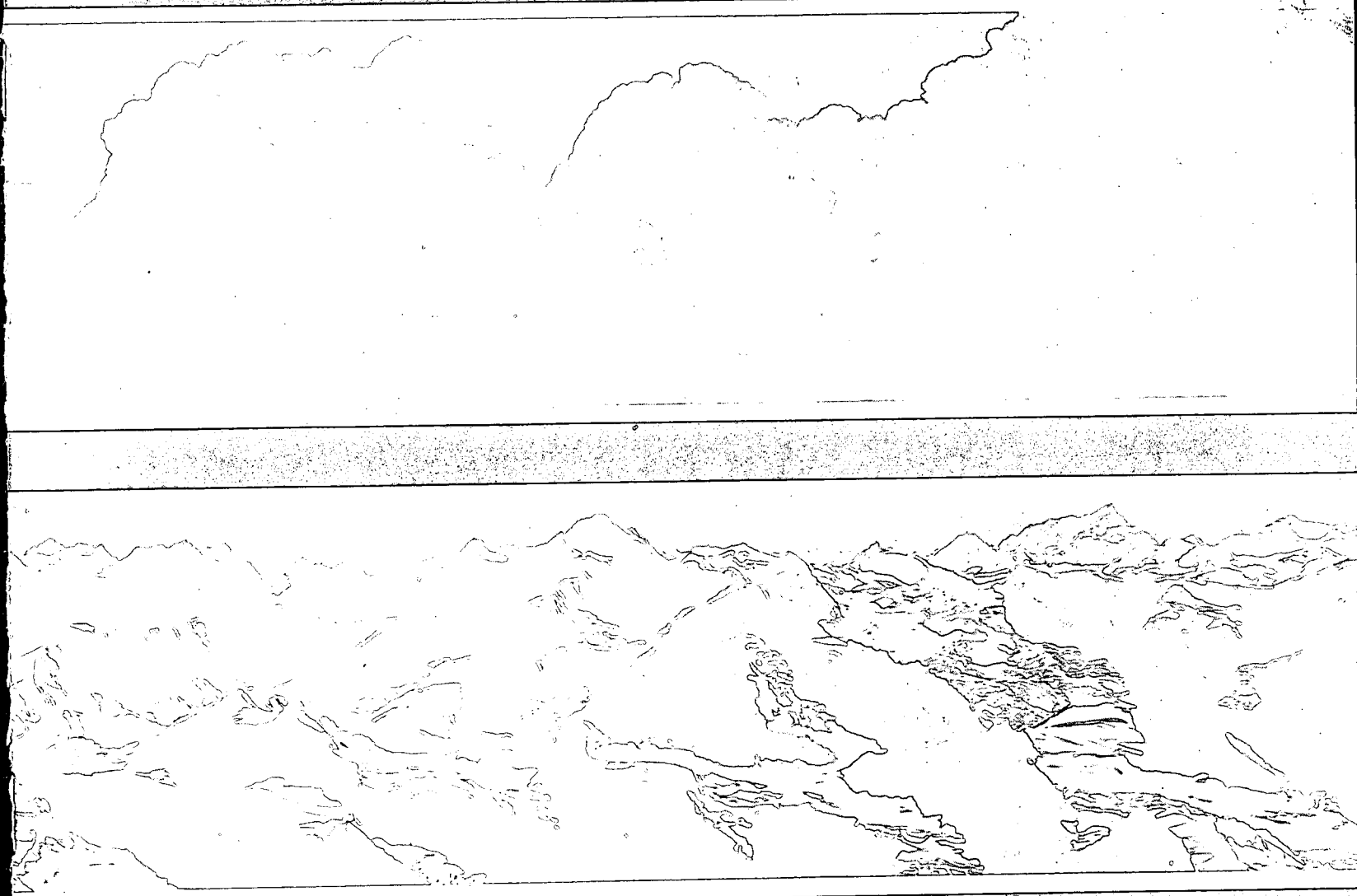
Water Quality in the Moose River — A Pilot Study, 1977-1978

R. C. McCrea and J. C. Merriman



REPORT SERIES NO. 70

Canada.

INLAND WATERS DIRECTORATE, ONTARIO REGION
WATER QUALITY BRANCH
BURLINGTON, ONTARIO, 1981

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Abstract

The Moose River Pilot Study was carried out near the mouth of the Moose River to examine the temporal, lateral and seasonal variability in the water chemistry and to design a baseline water quality sampling program to determine seasonal variation and future long-term trends. In all, eight surveys were conducted between March 1977 and March 1978. Water samples were collected from four locations across the Moose River and were analyzed for major ions, nutrients and trace metals. The results indicated that short-term variations in the water chemistry were not significant and that the Moose River was highly channelized. Many parameter concentrations (especially major ions) showed strong seasonal dependence. Furthermore, it was concluded that baseline water quality conditions would be evaluated better if future sampling were carried out on a biweekly (14-day intervals) basis in the midstream channels.

Résumé

L'étude pilote de la rivière Moose, effectuée près de l'embouchure de la rivière, portait sur la variabilité de la chimie de l'eau en fonction du temps, des saisons et du point de prélèvement dans la section transversale. Elle avait pour but la création d'un programme de base d'échantillonnage de l'eau permettant de déterminer les variations saisonnières et l'évolution future de la qualité de l'eau. En tout, on a fait huit relevés de mars 1977 à mars 1978. Les échantillons ont été prélevés à quatre points différents en travers de la rivière; on y a dosé les ions principaux, les substances nutritives et les métaux à l'état de traces. Les résultats ont indiqué que la variation à court terme de la composition chimique était négligeable et que la rivière se divise en multiples chenaux d'écoulement. Néanmoins, la concentration de nombreux paramètres (en particulier celle des ions principaux) variait considérablement en fonction des saisons. On a conclu que l'évaluation de base de la qualité de l'eau serait optimale si on faisait tous les quinze jours un échantillonnage dans les chenaux du centre de la rivière.

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INTRODUCTION

The Hudson Bay Lowland is a vast coastal plain occupying about one-quarter of the Province of Ontario. This region, which is located between the Canadian Shield and the south shore of Hudson Bay, is very flat and poorly drained. Virtually the entire Lowland is covered with an organic mat of peat, varying in depth from 1 to 4 m. The only significant barriers to this unconfined peat complex are the seven major rivers flowing through the Lowland. These are the Moose, Albany, Attawapiskat, Winisk, Severn, Nelson and Churchill Rivers (Cowell *et al.* 1979).

The coastal region of the Hudson Bay Lowland is of major national and international importance as a nesting and feeding area for many species of geese, ducks and shorebirds. As a result, the Environmental Conservation Service of Environment Canada has undertaken an integrated research program in the area. A significant part of this program involves studying the physical, chemical, biological and hydrological components of the aquatic environment. This report will detail the results from a water quality pilot study carried out near the mouth of the Moose River.

STUDY AREA

The Moose River drainage basin is located in the northeast sector of the Province of Ontario and drains an area of approximately 109 000 km^2 (Fig. 1). Its three main tributaries, the Missinaibi, Mattagami and Abitibi Rivers, descend approximately 500 m over a distance of about 500 km from their source in the south to the mouth of the Moose River on James Bay.

The Moose River watershed extends over substantial portions of two major physiographic regions: the Canadian Shield and the Hudson Bay Lowland. The Canadian Shield portion of the basin is composed of ancient crystalline granites interspersed with meta-sedimentary and meta-volcanic rocks. Outcrops of the bedrock are common. Extensive areas of the Shield within the Moose River basin (especially in the eastern sector) are covered with unconsolidated lacustrine sediments. These sediments were deposited in the glacial Lake Barlow-Ojibway and are now known as the clay belt (Hutton and Black 1975).

Unlike the Shield, the Lowland area is very flat. The bedrock underlying this region is composed of limestones and shales. Outcrops of the sedimentary bedrock are few and occur mainly in the Shield-Lowland contact zone. The primary surficial covering in the Lowland is marine clay, which was deposited at the end of the Pleistocene glaciation. This region is poorly drained and is characterized by an extensive bog and fen complex in combination with a myriad of pools, ponds and lakes.

With few exceptions, the Hudson Bay Lowland is a very gently sloping coastal plain having a gradient of only 0.5 to 1.0 m/km from the Shield to the Bay. Consequently, tidal effects may alter the water quality in the Moose River for a significant distance upstream from the mouth. Langford (1963) suggests that salt water enters the Moose River and travels upstream to a point just north of Moosonee, while tidal movements can be observed upstream from the south end of Bushy Island (Fig. 2). The maximum range for tides at the mouth of the Moose River is approximately 3 m.

Hydrologically, the Moose River is quite complex. In addition to the daily tidal fluctuations in its lower reaches, its water levels are regulated in the headwaters to maximize hydroelectric generation. This regulation results in substantial changes in discharge in both the Abitibi and Mattagami Rivers.

The lower reaches of the Moose River and estuary present a complex pattern of islands and channels. Immediately upstream from this region are the confluences of the Kwataboahegan, Abitibi and North French Rivers. For the purpose of clarity, the Moose River upstream from the confluence with Abitibi River will be referred to in this report as the upper Moose River and downstream from the confluence as the lower Moose River.

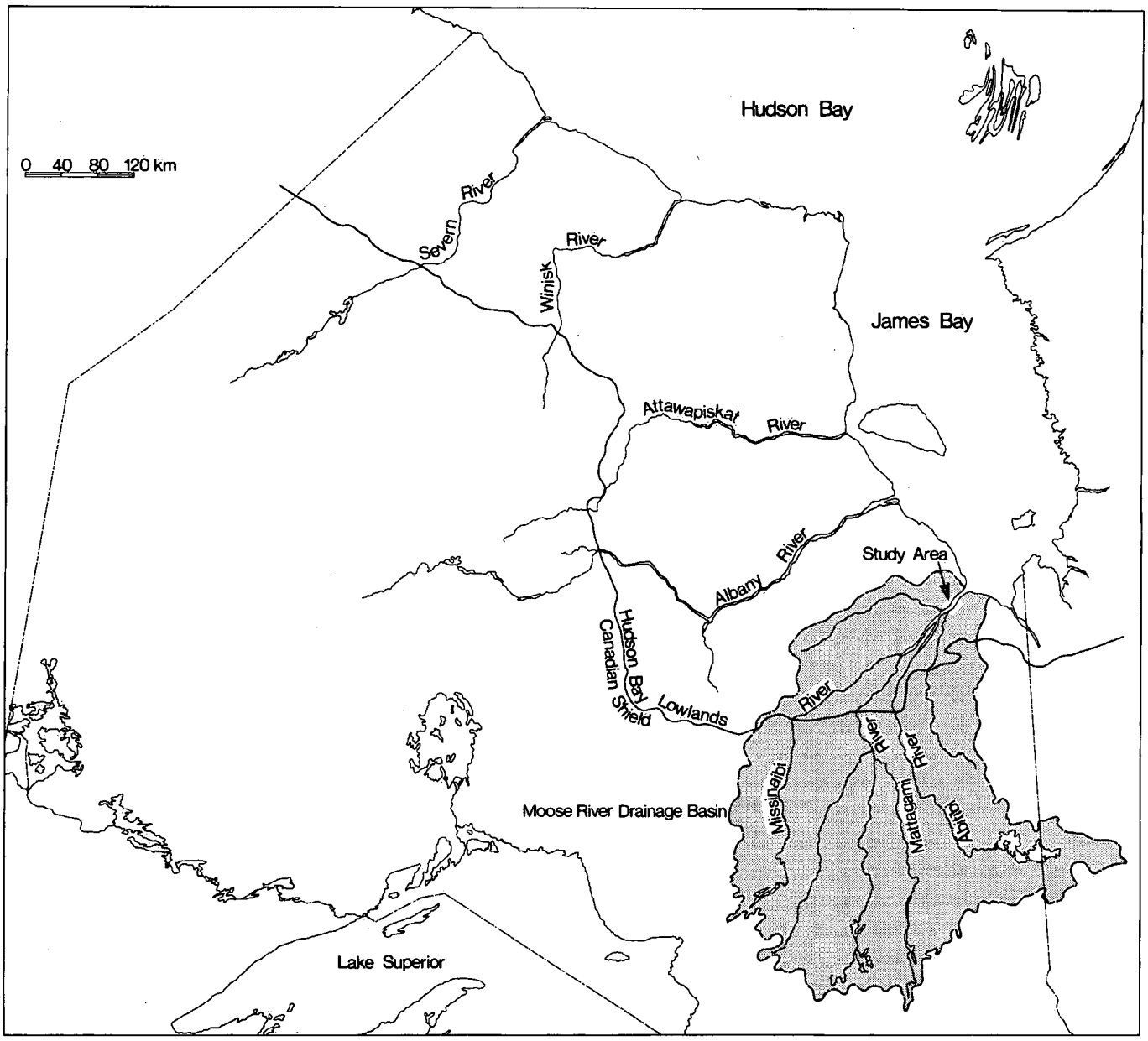

Figure 1. Moose River drainage basin.

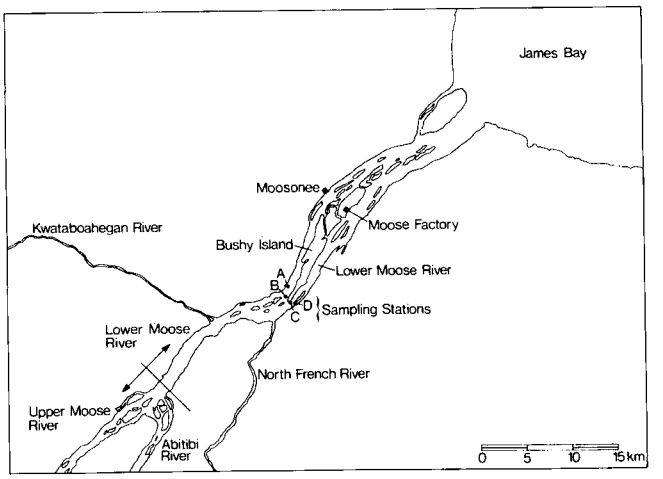

Figure 2. Moose River and tributaries.

OBJECTIVES

The main objectives of the pilot study were:

(i) To provide information on the temporal (short term), lateral and seasonal variation in the water quality of the lower Moose River and to determine whether these variations are significant.

(ii) To design a baseline water quality sampling program that would be suitable for determining seasonal variations and future long-term trends in the lower Moose River.

EXPERIMENTAL DESIGN

The approach adopted was to sample the Moose River upstream from Moosonee on a transect located at the south end of Bushy Island. Four sampling sites were selected (Fig. 2) and surveys were carried out at a 5- to 6-week time interval. In all, eight surveys were completed between March 1977 and March 1978. Because of dangerous ice conditions the river could not be sampled during spring breakup and fall freezeup.

Each survey was scheduled to consist of two consecutive days of sampling; however, unpredictable events such as adverse weather conditions and equipment failure sometimes altered the schedule.

During each day of sampling, six samples (three at low tide and three at high tide) were collected from all stations at a depth of 1 m. In the winter months a hole was drilled through the ice, and after the stagnant water and ice chips were removed, a sampling device was lowered into the free-flowing water (below the ice) to collect the water samples.

Water temperature was measured in situ, but other physical parameters such as pH, conductance and turbidity were measured upon return to the field base. All sample preparation such as filtering and preserving was completed within 8 h of collection. The samples were then returned

Table 1. Listing of the Parameters Measured and Their Detection Limits, Sample Containers and the Preservatives Used

Parameter	Detection limit (mg/L)	Preservative	Sample container (material/size)
Alkalinity, total	0.1	none	Polyethylene, 1 L
Calcium	0.1	none	Polyethylene, 1 L
Chloride	0.1	none	Polyethylene, 1 L
Magnesium	0.1	none	Polyethylene, 1 L
Potassium	0.1	none	Polyethylene, 1 L
Sodium	0.1	none	Polyethylene, 1 L
Sulphate	0.1	none	Polyethylene, 1 L
Carbon, diss. organic	0.1	H_2SO_4 (30%), 1 mL	Glass, 125 mL
Carbon, part. organic	0.001	none	*
Nitrogen, part.	0.001	none	*
Nitrogen, total Kjeldahl	0.01	H_2SO_4 (30%), 1 mL	Glass, 125 mL
Phosphorus, total	0.0005	H_2SO_4 (30%), 1 mL	Glass, 125 mL
Aluminum	0.001	HNO_3 (50%), 4 mL	Polyethylene, 1 L
Copper	0.001	HNO_3 (50%), 4 mL	Polyethylene, 1 L
Iron	0.001	HNO_3 (50%), 4 mL	Polyethylene, 1 L
Manganese	0.001	HNO_3 (50%), 4 mL	Polyethylene, 1 L
Zinc	0.001	HNO_3 (50%), 4 mL	Polyethylene, 1 L
Mercury	0.00005	H_2SO_4 (Conc.), 1 mL + $K_2Cr_2O_7$ (5%), 1 mL	Polypropylene, 125 mL

*Samples collected on glass fibre filters.

to the Water Quality Branch laboratory in Burlington for the analysis of major ions, nutrients and trace metals (Environment Canada 1979). Details regarding sample containers, preservatives and analytical detection limits are outlined in Table 1.

STATISTICAL TREATMENT OF DATA

A two-way analysis of variance was performed on 14 water quality parameters to determine whether short-term variations (T) and lateral variations (L) were significant. The UCLA Biomedical computer program BMD OV8 (Dixon 1971) was used to calculate the F values. If the calculated F value exceeded the critical F value (obtained from mathematical tables), then the observed changes were considered to be significant.

The 14 parameters chosen for the analysis were the most accurately measured of the data set. Trace metal data were excluded from statistical analysis because of uncertainty in the data. The concentrations of zinc and copper in the lower Moose River were generally low (often near the 0.001 mg/L detection limit). At these low levels analytical errors and sample contamination can be quite significant. High concentrations of humic acids, which are natural chelating agents (Gjessing 1976), also reduced the reliability and reproducibility of the trace metal analyses. Results of analysis of variance based on samples collected at each station during the 2-day surveys are presented in Table 2.

RESULTS AND DISCUSSION

Short-term Variation

Less than 20% of the cases tested for temporal variation (T) had F values greater than the critical F value (at the 95% confidence level). This suggests that the short-term water quality variations (those differences observed at any station over the 2-day study periods) in the lower Moose River were not significant.

Table 2. Temporal and Lateral Variance in the Lower Moose River Water Quality

Parameter	Survey 2 May 10-11, 1977 L	T	Survey 4 July 9-10, 1977 L	T	Survey 5 August 30-31, 1977 L	T	Survey 6 October 18-19, 1977 L	T
Alkalinity, total	148.0	2.10	88.0	1.71	41.0	2.35	417.0	0.20
Calcium	82.0	2.77	21.0	1.68	100.0	1.89	57.0	1.18
Chloride	65.0	1.38	147.0	1.19	43.0	1.02	40.0	0.44
Magnesium	218.0	1.50	436.0	11.3	77.0	1.95	107.0	0.45
Potassium	10^{11}	10^{-9}	47.0	1.50	45.0	1.00	11.4	1.00
Sodium	308.0	1.00	167.0	2.25	92.0	2.62	17.6	0.55
Sulphate	14.7	5.61	7.1	0.41	2.3	6.08	14.6	2.17
Carbon, diss. organic	0.7	3.88	4.8	0.27	43.0	5.04	1.8	0.50
Carbon, part. organic	21.1	0.58	1.4	4.70	-	-	23.1	2.56
Nitrogen, part.	10.4	1.70	0.2	2.74	-	-	37.5	1.81
Nitrogen, total Kjeldahl	39.0	0.58	11.8	1.32	6.0	0.10	15.4	0.97
Phosphorus, total	50.0	5.96	1.9	2.14	29.0	9.60	16.7	0.54
Turbidity	134.0	4.57	26.0	7.41	20.0	1.79	7.5	1.56
Conductivity	68.0	2.66	61.0	4.69	1.5	1.08	1870.0	1.00

L = Variance between sampling locations (calculated F-values)
T = Variance between sampling times (calculated F-values)
95% Critical F value: L = 3.86, T = 3.86
99% Critical F value: L = 6.99, T = 6.99

Those cases which showed significant concentration differences with time ($P>0.05$) usually varied by only 5%–10% from the mean value of samples collected at that station during the 2-day surveys. This magnitude of short-term variation was relatively unimportant when compared with the large seasonal variation exhibited by most parameters. Even the more conservative parameters such as major ions (conductivity) showed seasonal variations of between 200% and 600%, with individual ions varying up to 2800% (Cl, station D) over the study period.

Since the short-term variations in the water quality in the lower Moose River were not significant, future water quality sampling at the Bushy Island transect can be conducted independent of time of day.

Lateral Variation

As a result of reconnaissance survey carried out in 1976, it was thought that distinct channels of differing water quality might occur in the lower Moose River owing to the convergence of the Kwataboahegan, upper Moose, Abitibi and North French Rivers (Fig. 2). The four sampling sites A, B, C and D were selected to reflect the water quality of the above rivers.

The results of the analysis of variance (Table 2) showed that 88% of the cases tested for lateral variation (L) surpassed the critical F value, at the 95% confidence level. Physical evidence such as sharp changes in colouration and distinct differences in turbidity across the river also indicated the strong channelization of flow.

This channelization indicates that the water from the four tributaries does not mix significantly. This is probably due to the generally low gradient in the lower Moose River and to the relatively short distance from the confluence of the Abitibi (20 km), Kwataboahegan (9 km) and North French Rivers (3 km) to the Bushy Island transect. The lack of mixing may also be attributed in part to differences in water temperature and density in the four tributaries.

While the lateral variations in the water quality were significant throughout the year, they were at a minimum in the summer and maximum in the winter. Figure 3 illustrates the seasonal variation in concentration differences across the Moose River for calcium.

A one-way analysis of variance comparing the water quality of adjacent stations showed that the greatest differences occurred between the side channels and the mainstream channels (A to B and C to D). These differences exist because the drainage basins of the side channels

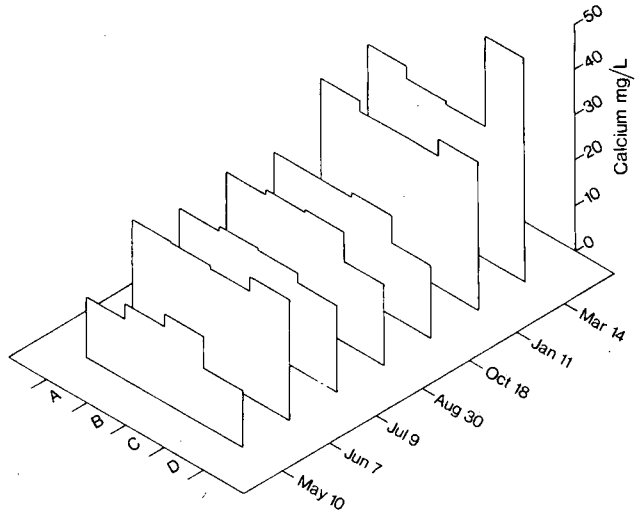

Figure 3. Lateral variation in the concentration of calcium across the lower Moose River (May 1977 to March 1978).

(A and D) are located primarily in the Hudson Bay Lowland, whereas the drainage basins of the midstream channels (B and C) originate on the Shield. The lateral variations are accentuated during the winter because of the low discharge of the Kwataboahegan and North French Rivers (Fig. 4). Their low flows lead to elevated concentrations in the side channels and thus cause increases in the lateral variations.

Seasonal Variation

The largest variations in the water quality of the lower Moose River occurred on a seasonal basis, with some parameter concentrations showing flow-related changes. The discharge of the lower Moose River into James Bay varied greatly throughout the year. During the study period, maximum discharge approached 9900 cubic metres per second (April 23–25, 1977) and decreased to an average low of approximately 420 cubic metres per second (January-March, 1978). Figure 4 illustrates the large seasonal variation in the four tributaries of the lower Moose River. Discharge measurements were recorded by Water Survey of Canada on the Kwataboahegan River near its mouth, the upper Moose River at Moose River Crossing, the Abitibi River at Onakawana and the North French River near its mouth.

The sharp fluctuations in the discharge of the Abitibi and upper Moose Rivers were due to hydroelectric dams upstream holding back or impounding the water to maximize electrical generation. The North French and Kwataboahegan Rivers were undammed and had natural flow regimes.

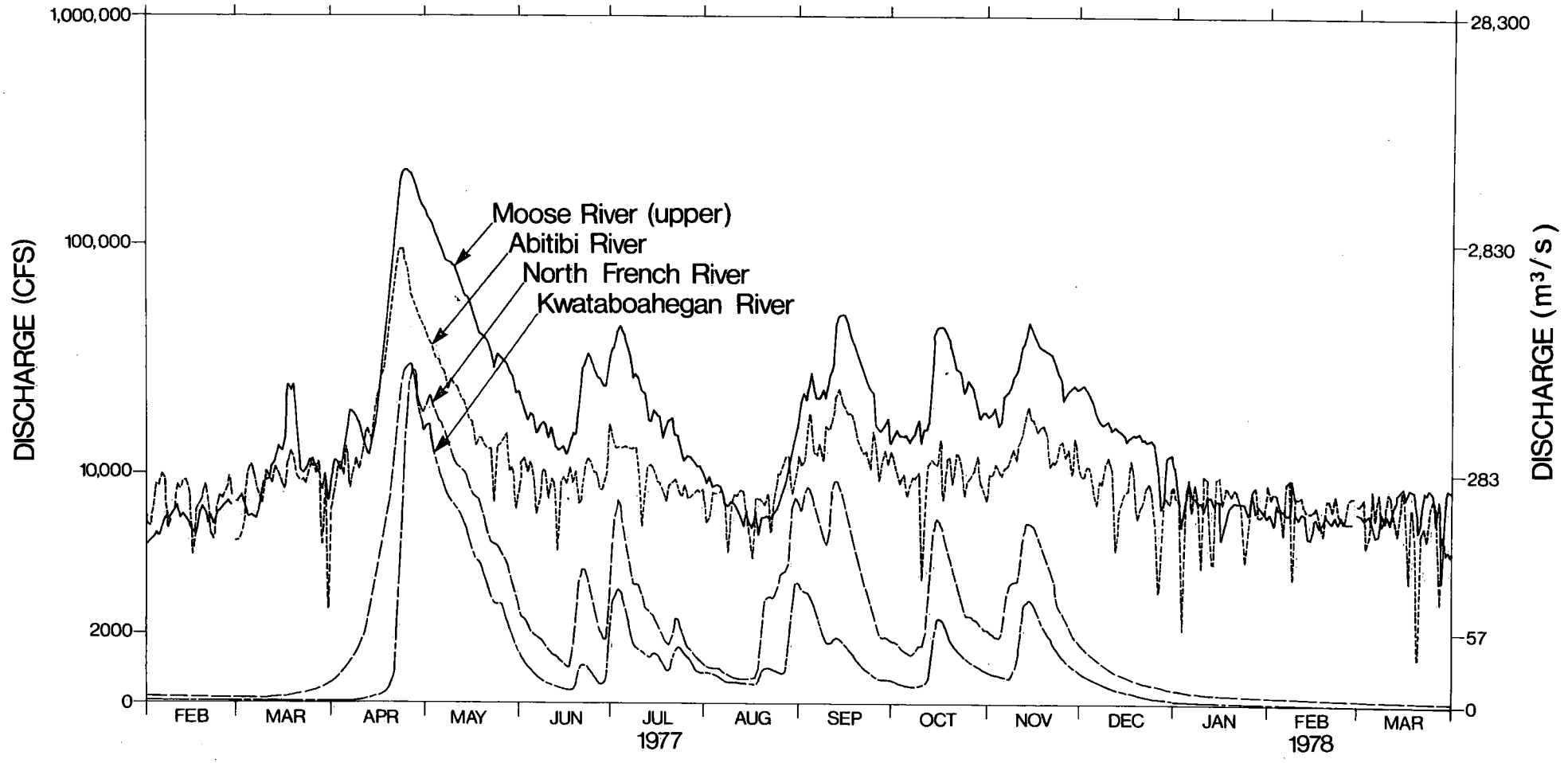

Figure 4. Hydrographs of the lower Moose River tributaries.

The major ion concentrations in the Moose River showed a strong seasonal trend varying inversely with the flow. Their concentrations were at a minimum during spring runoff (April-May) and reached their maximum level under low flow conditions (November-March). A 6-year record of discharge and conductivity for the upper Moose River at Moose River Crossing is displayed in Figure 5.

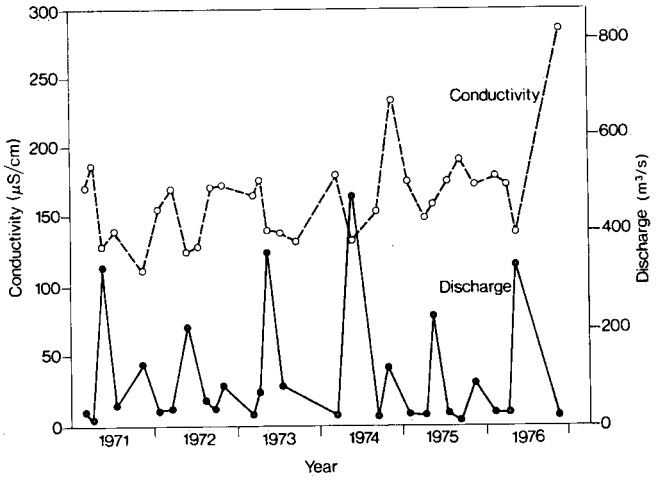

Figure 5. Seasonal discharge and conductivity of the upper Moose River.

The maximum seasonal variation in the major ion chemistry (measured at the Bushy Island transect) occurred in the side channels at stations D and A, which reflect the water quality of the North French and Kwataboahegan Rivers respectively. The flows of these rivers, which were extremely low during the winter (often less than 5 cm), gave rise to the elevated concentrations. During the study period individual ions varied up to 2800% in the side channels (chloride, station D), while the greatest variation in the midstream channel was only 680% (chloride, station B). Conductivity, a measure of the total major ion concentration, varied up to 600% in the side channels but only 200% in the midstream channels (Table 3).

The concentrations of nutrients and trace metals, which in many cases reflected both dissolved and particulate species, did not vary directly with flow, but they were strongly affected by flow. While spring runoff or snowmelt tended to dilute the concentrations, severe erosion of the banks and river bottom tended to increase the concentrations. Furthermore, the Moose River was very shallow; therefore, significant changes in the trace metal levels may have occurred due to resuspension of bottom sediments by wave action. Although many of the parameters varied considerably throughout the year (Table 3), they did not follow a simple seasonal pattern.

Table 3. Annual Range in the Lower Moose River Water Quality

Parameter	Station A High (mg/L)	Station A Low (mg/L)	Station B High (mg/L)	Station B Low (mg/L)	Station C High (mg/L)	Station C Low (mg/L)	Station D High (mg/L)	Station D Low (mg/L)
Alkalinity, total	84.0	30.0	75.0	36.0	76.0	43.0	133.	22.0
Calcium	33.0	12.0	30.0	16.0	29.0	18.0	52.0	11.0
Chloride	12.0	1.8	7.5	1.1	3.7	1.1	34.0	1.2
Magnesium	7.2	2.0	6.2	2.8	6.2	3.1	12.0	1.7
Potassium	0.8	0.4	0.8	0.4	1.4	0.5	2.3	0.20
Sodium	8.2	1.4	4.2	1.0	3.6	1.0	23.0	1.0
Sulphate	13.0	4.2	12.0	4.7	14.0	4.9	37.0	4.8
Conductivity*	245.0	79.0	206.0	97.8	193.0	115.0	443.0	72.0
Carbon, diss. organic	30.0	12.0	39.0	14.0	39.0	13.0	25.0	11.0
Carbon, part. organic	1.6	0.30	3.1	0.34	3.7	0.33	1.6	0.17
Nitrogen, part.	0.09	0.022	0.1	0.022	0.18	0.001	0.11	0.001
Nitrogen, total Kjeldahl	0.60	0.28	0.73	0.28	1.3	0.31	0.77	0.27
Phosphorus, total	0.085	0.011	0.042	0.016	0.13	0.018	0.055	0.010
Aluminum, diss.	0.084	0.0028	0.13	0.024	0.20	0.038	0.18	0.025
Aluminum, extractable	0.524	0.048	0.721	0.051	2.150	0.163	1.60	0.118
Copper, diss.	0.019	0.0005	0.016	0.002	0.020	0.002	0.023	0.002
Copper, total	0.017	0.002	0.011	0.004	0.021	0.0004	0.007	0.003
Iron, diss.	0.35	0.14	0.30	0.140	0.32	0.14	0.32	0.12
Iron, total	0.88	0.28	1.28	0.34	2.87	0.48	2.02	0.24
Manganese, diss.	0.031	0.0007	0.030	0.0008	0.030	0.003	0.023	0.004
Manganese, total	0.088	0.015	0.095	0.016	0.079	0.016	0.148	0.010
Zinc, diss.	0.010	0.0005	0.015	0.0005	0.012	0.0005	0.008	0.00005
Zinc, total	0.006	0.001	0.007	0.002	0.017	0.0009	0.009	0.001

*Conductivity expressed in µS/cm

The concentrations of total iron and extractable aluminum in the lower Moose River were considerably higher than that of other trace metals. Maximum values of 2.87 and 2.15 mg/L respectively were measured at station C, on January 11-12, 1978. In general, these levels were extremely variable and were strongly affected by the suspended sediment load. The elevated concentrations of total iron measured in May 1977 at station B (Fig. 6) reflected the high suspended sediment load associated with spring runoff. Conversely, the concentration of dissolved iron was relatively stable over the study period and thus unaffected by erosion and bottom disturbances.

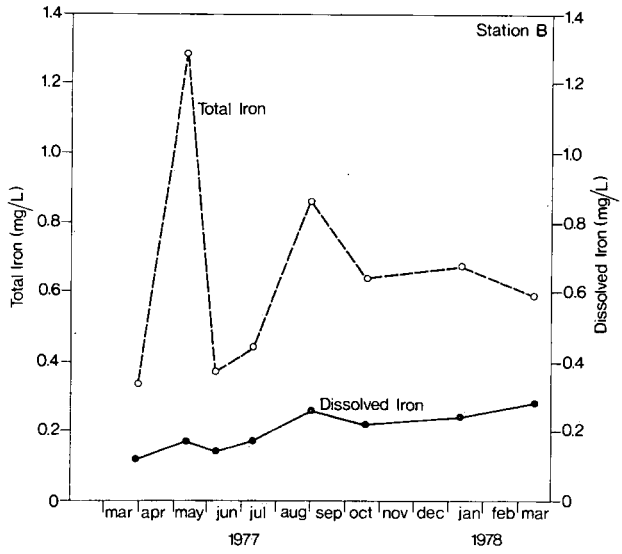

Figure 6. Seasonal variation of total and dissolved iron.

The lower Moose River contained high levels of dissolved organic carbon (DOC). During the study period the mean DOC value at station B was 20 mg/L. These levels exceeded all other nutrient, trace metal and major ion concentrations except bicarbonate. The major variation in DOC, as well as other nutrients, did not follow a simple flow-related pattern. The relatively low levels of dissolved organic carbon measured in May and June 1977 (Fig. 7) reflected the dilution effect of spring runoff. During the moderate flows of summer and fall the DOC level increased to 24 mg/L; however, the concentration of DOC decreased during the low winter flows (January-March, 1978). This decrease was probably due to the freezeup of the small creeks that drain the peatlands.

The concentration of particulate organic carbon (POC) in the lower Moose River was a small fraction of the total organic carbon. The mean POC value at station B during the study period was only 0.8 mg/L. The elevated concentrations of POC (2.0 mg/L) measured in May 1977

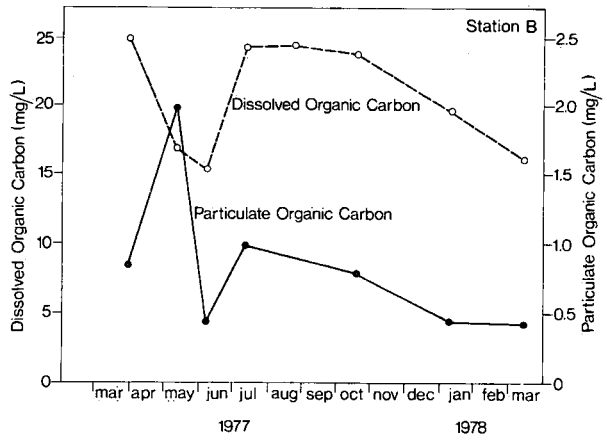

Figure 7. Seasonal variation of dissolved and particulate organic carbon.

reflected the high suspended sediment load during spring runoff.

Similarly, the levels of particulate nitrogen (PN) represented only a small portion of the total nitrogen in the Moose River. The mean total Kjeldahl nitrogen (TKN) value at station B was 0.44 mg/L, while the mean PN value was 0.056 mg/L. Although 87% of the TKN is soluble nitrogen, its levels were very stable (Fig. 8) and seemed unaffected by the dilution effect of spring runoff. The concentration of particulate nitrogen varied much more throughout the year, but its concentration in May did not reflect the high suspended sediment load associated with spring runoff. The reason for these atypical trends is not known.

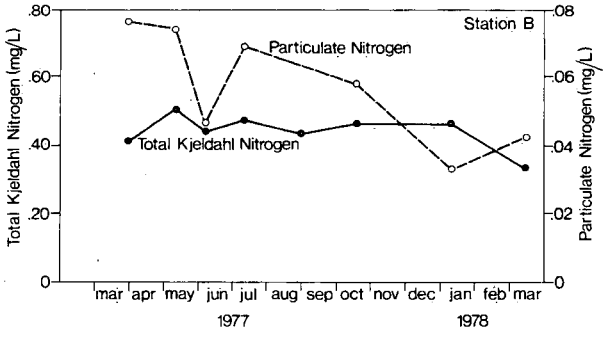

Figure 8. Seasonal variation of total Kjeldahl and particulate nitrogen.

SUMMARY

Results from this study have revealed the following information about the lower Moose River:

(i) Short-term (temporal) variations in the water quality

were found to be insignificant; therefore, water quality sampling at the Bushy Island transect can be conducted independent of time of day.

(ii) Lateral variations in the water quality across the lower Moose River were very significant throughout the year with the largest variation occurring in the winter. These differences in water quality resulted from the high channelized flow in the lower Moose River.

(iii) The greatest single factor affecting the major ion concentration of the Moose River was the annual flow cycle. Highest concentrations occurred during periods of lowest flow (fall and winter) and lowest chemical concentrations were found during spring runoff. Both flow and major ion concentrations were highly variable. In any single year, flow may vary up to 2000%, while chemical concentrations may vary up to 2800%.

(iv) The high suspended sediment load associated with spring runoff caused substantial increases in the concentration of total iron, extractable aluminum and particulate organic carbon; whereas the concentration of dissolved organic carbon decreased as a result of the dilution effect of spring runoff.

CONCLUSION

The selection of a suitable sampling frequency is required in order to generate meaningful baseline water quality data. Without sufficient data points, future long-term trends in the lower Moose River will not be detected. Since there was insignificant variation in the water quality in the short term (2 days) and because substantial concentration changes were detected between surveys carried out on a 5- to 6-week time interval, it is felt that biweekly sampling (14-day intervals) would yield a data set suitable for meaningful trend analysis.

To collect baseline water quality data in the lower Moose River, sampling sites must also be chosen carefully. Since the flow of the lower Moose River is highly channelized and the discharge of the Abitibi and upper Moose Rivers accounts for approximately 90% of the total discharge of the lower Moose River, it is felt that future sampling at two sites in the midstream channels (B and C) would be most cost effective.

It is also recommended that future water quality sampling of the lower Moose River should be carried out by qualified lay collectors in Moosonee to be cost effective. The collection of two water samples in the midstream channels on a biweekly basis would provide a data set suitable for determining seasonal variation and future long-term trends. The data base generated could also be useful for assessing the environmental impact of future developments in the Moose River basin.

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