CANADA. INLAND WATERS DIRECTORATE
SCIENTIFIC SERIES
#132

Environment Canada Environnement Canada

# Ottawa River Water Quality, National Capital Region, 1978

J.C. Merriman and R.C. McCrea

SCIENTIFIC SERIES NO. 132



*INLAND WATERS DIRECTORATE*
*ONTARIO REGION*
*WATER QUALITY BRANCH*
*BURLINGTON, ONTARIO, 1982*

Environment Canada Environnement Canada

# Ottawa River Water Quality, National Capital Region, 1978

J.C. Merriman and R.C. McCrea

**SCIENTIFIC SERIES NO. 132**

*INLAND WATERS DIRECTORATE*
*ONTARIO REGION*
*WATER QUALITY BRANCH*
*BURLINGTON, ONTARIO, 1982*

Canada

Cat. No. En 36-502/132E

ISBN 0-662-12323-9

# Contents



# Tables

# Illustrations

# Abstract

In 1978 water quality conditions in the National Capital Region were studied to determine the water quality of the Ottawa River before sewage treatment measures were completed in nearby Quebec municipalities. Several parameters showed spatial variation with significant increases across transects as well as significant downstream increases in concentration. These increases were caused by tributary inputs and municipal and industrial discharges. Total phosphorus exceeded the recommended surface water guideline more than 60% of the time at the downstream transect. Fecal coliform exceeded the recommended guideline for contact recreation 90% of the time in the study area.

# Résumé

En 1978, une étude a été réalisée dans la région de la Capitale nationale pour déterminer la qualité de l'eau avant l'achèvement de la mise en place de mesures correctives par certaines municipalités du Québec. Pour plusieurs paramètres, on a observé des différences significatives entre les stations le long des lignes d'échantillonnage et une augmentation significative de la concentration en aval. Les augmentations observées sont attribuables aux apports des tributaires et aux rejets des municipalités et des industries. Aux stations d'échantillonnage d'aval, la concentration de phosphore total dépassait la limite recommandée pour les eaux de surface, plus de 60 % du temps, et dans l'ensemble de la zone d'étude, la teneur en coliformes fécaux était supérieure à la limite recommandée pour les activités récréatives à contact direct avec l'eau 90 % du temps.

# Ottawa River Water Quality, National Capital Region, 1978

J.C. Merriman and R.C. McCrea

## INTRODUCTION

In 1978, the Water Quality Branch conducted a water quality study of the Ottawa River in the National Capital Region. The purpose of the study was to determine water quality conditions in the area prior to the completion of the Outaouais collector and sewage treatment system. Follow-up surveys are planned once construction is completed to determine changes in water quality resulting from the remedial measures undertaken.

The Outaouais regional interceptor, collectors and sewage treatment system will collect and treat municipal sewage between Aylmer and Templeton. The sewage system, due to be completed by 1982, will provide secondary treatment with phosphorus removal and will eliminate most existing direct discharges of raw sewage into the Ottawa River.

Brewery Creek is fed at its source above the Chaudière Falls by the Ottawa River. It flows through Hull and empties into the Ottawa River almost directly opposite the Rideau River. During construction of the sewage system, a temporary outfall has been in operation along Brewery Creek. As upstream sections of the collector system are completed, more raw sewage will be discharged into Brewery Creek. On completion of the treatment system, all sewage will flow directly to the sewage treatment plant in Templeton.

The study area extends from Chaudière Falls downstream to Hiawatha Park at Transect 17.7 (Fig. 1). It is the most seriously impacted part of the Ottawa River in the National Capital Region with municipal and industrial inputs, including three pulp and paper mills (Environment Canada 1976, 1976a, 1977).

## METHODOLOGY

### Sampling

Four transects on the Ottawa River consisting of four stations each were selected for the study. Stations were also located on Brewery Creek (BC), the Rideau River (RR) and the Gatineau River (GR) to monitor the major tributaries in the study area. Nineteen surveys were carried out between May and October 1978.

All samples were collected at a depth of one metre. Temperature was recorded on site, while pH and turbidity were measured at a field laboratory. Sample preparation, including aliquoting, filtering and preserving was done in the field. Samples were transported back to the Water Quality Branch laboratory in Burlington for analyses of major ions, nutrients and trace metals (Environment Canada 1979). Fecal coliform, fecal streptococcus, biochemical oxygen demand ($BOD_5$) and chemical oxygen demand (COD) samples were analyzed by the Environmental Protection Service laboratory in Ottawa (Environment Canada 1978). A summary of sample containers, preservatives and analytical detection limits is given in Table 1.

### Statistical Treatment of Data

Arithmetic means were calculated for each station for all parameters with the exception of fecal coliform and fecal streptococcus, where geometric means were calculated.

Analysis of variance and individual station contrasts were carried out for selected parameters using a Tektronix 4051 mini-computer (Table 1). For data analyses, the Ottawa River and tributary stations were divided into subsets (Fig. 2). Subsets 1 and 2 were used to evaluate spatial differences between and within transects 3.6 and 5.4 as well as differences between the tributaries and the Ottawa River. Spatial differences at the downstream transects 14.9 and 17.7 were assessed in Subset 3. For each subset, a one-way analysis of variance was carried out and Bartlett's test for homogeneous variance was calculated (Steel and Torrie 1960). Bonferroni tests were used to determine levels of significance for the station contrasts (Douglas 1979).

## RESULTS AND DISCUSSION

### Physical Parameters

There was little mainstream variation of pH with mean values ranging from 6.9 to 7.1 for the Ottawa River

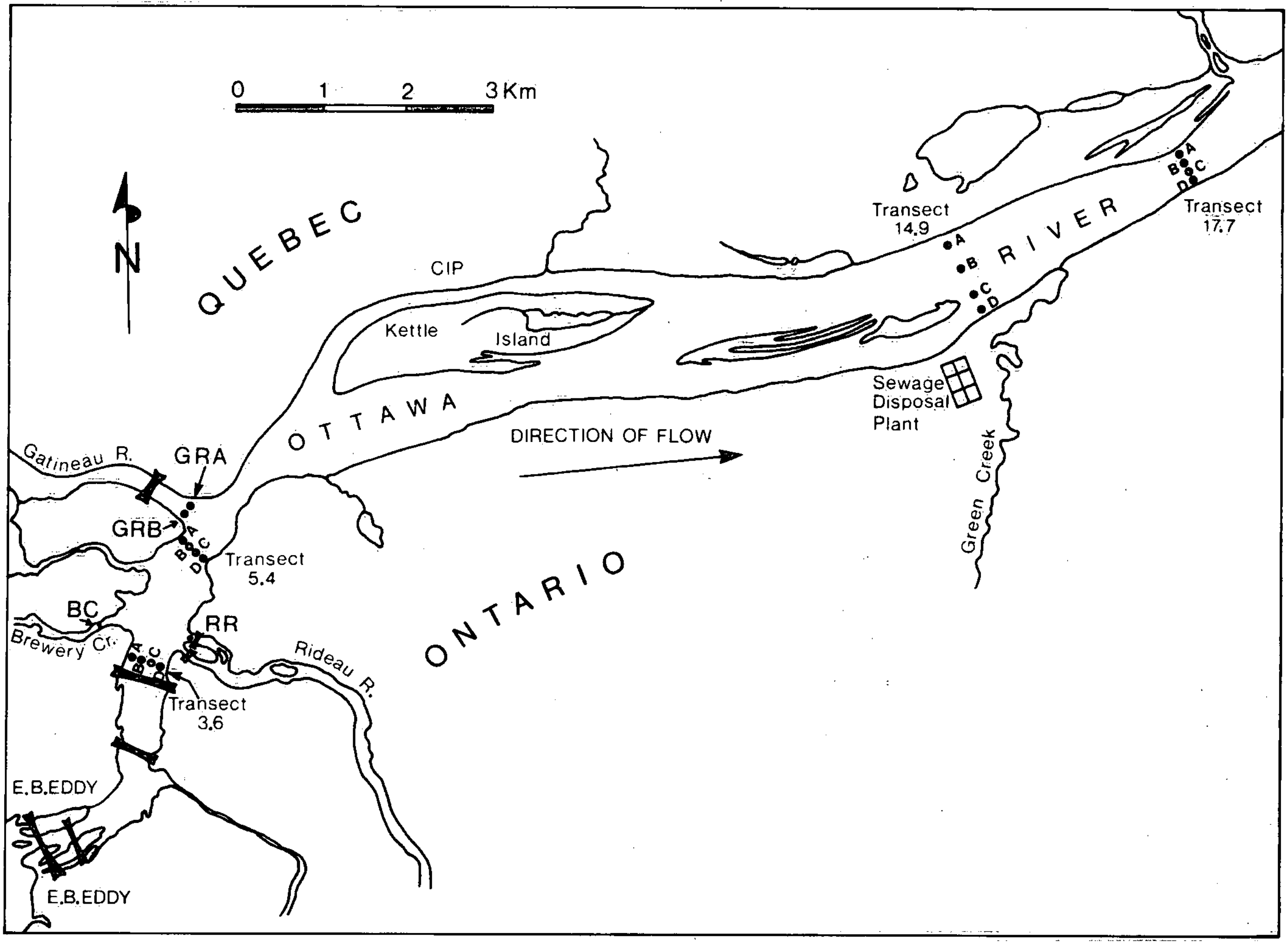


**Figure 1. Ottawa River sampling sites. BC = Brewery Creek, RR = Rideau River, GR = Gatineau River.**

stations. Both Brewery Creek with a pH of 7.4 and the Rideau River with a pH of 7.9 had levels higher than that of the Ottawa River (Table 2).

Specific conductance in the Ottawa River was higher at nearshore stations than in midstream. Tributaries were quite different with the Rideau River having a mean conductance over four times that of the Ottawa River. Brewery Creek specific conductance was 65% higher, while the Gatineau River was over 40% lower than the Ottawa River (Fig. 3).

Nearshore stations along the Quebec shore were influenced by municipal and industrial inputs, resulting in higher specific conductance at these sites. Higher conductivity found along the Ontario shore at 5.4D resulted from the Rideau River outflow, while the higher values at 14.9D and 17.7D were caused by the Green Creek sewage treatment plant effluent upstream from transect 14.9 and the outflow of Green Creek into the Ottawa River between transects 14.9 and 17.7.

Turbidity in the Ottawa River was higher along both shorelines in comparison to midstream stations and increased in a downstream direction. Levels were higher along the Quebec shore due to untreated municipal inputs. A downstream increase of over 70% occurred between 5.4A and 14.9A, primarily the result of the Canadian International Paper Company (CIP) pulp and paper mill discharge, which is located upstream of transect 14.9 on the Quebec shore. Downstream increases from 6.5 JTU to 8.8 JTU between 14.9D and 17.7D were attributed to the input of Green Creek. Both Gatineau River and Rideau River turbidity were similar to levels found at the two upstream Ottawa River transects. Brewery Creek turbidity was twice as high as the Ottawa River because of direct municipal and industrial discharges.

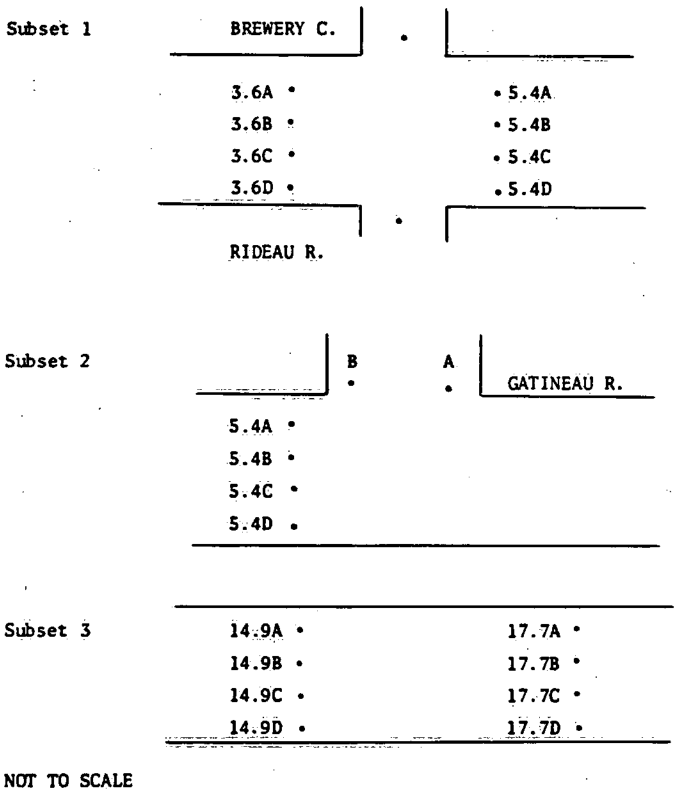


Figure 2. Station subsets.

## Major Ions

Major ion concentrations in Brewery Creek and the Rideau River were significantly higher* than the Ottawa River, whereas concentrations in the Gatineau River were significantly lower than the Ottawa River. The elevated levels of major ions in Brewery Creek, especially sodium and chloride, reflected the input of raw municipal wastes (Table 3).

Major ion concentrations found in the Rideau and Gatineau Rivers can be explained by the geochemistry of their drainage basins. The Rideau River flows through sedimentary limestones and dolomites of the St. Lawrence Lowlands, resulting in high major ion concentrations. The Gatineau River flows through relatively insoluble granites and gneisses of the Canadian Shield, resulting in low concentrations of major ions (Bird 1972).

Significantly higher concentrations of sodium and chloride were found at station 3.6A than at 3.6B. This was attributed to the municipal discharge upstream from the transect (Environment Canada 1977).

*All levels of significance are at the 95% confidence level.

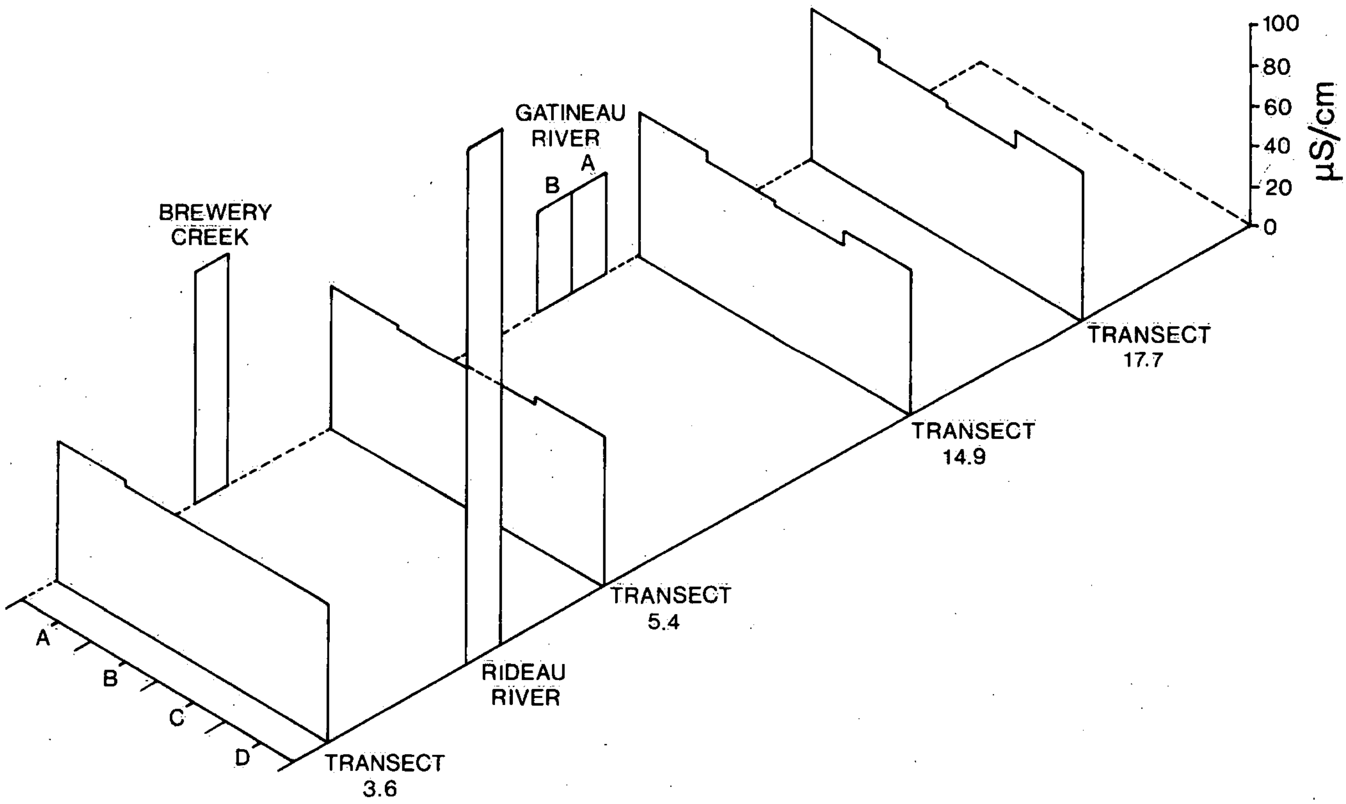


Figure 3. Spatial variation of specific conductance.

Mean downstream concentration increases in major ions were found between stations 3.6D and 5.4D as well as lateral increases between stations 5.4C and 5.4D (Table 3). Chloride and magnesium showed significant downstream increases, while magnesium was significantly higher at 5.4D in comparison to 5.4C. High major ion concentrations in the Rideau River caused the increases found at station 5.4D.

Major ion concentrations at transects 14.9 and 17.7 were higher at nearshore stations. Sulphate, chloride and sodium were significantly higher along the Quebec shore at transect 14.9. Transect 17.7 also showed higher concentrations at both nearshore stations compared with midstream values. Chloride was significantly higher at the D station, whereas sulphate and sodium proved to be significantly higher at the A station. Higher concentrations on the Quebec side resulted from municipal and industrial discharges. Along the Ontario shore, Green Creek Sewage Treatment Plant and Green Creek were the major contributing factors to higher major ion concentrations.

**Nutrients**

Nutrient concentrations in the study area were spatially variable. The effect of the municipal point source discharge above transect 3.6 was shown in the higher nutrient concentrations found at 3.6A in relation to its neighbouring station 3.6B (Table 4). Total phosphorus was found to be significantly higher at station 3.6A.

Both particulate nitrogen and particulate organic carbon concentrations were higher at station A in transect 3.6. At transect 5.4 the concentrations for these parameters were higher at station B, suggesting that point source effluents and the outflow of Brewery Creek do not channel along the shoreline but move out towards the middle of the river, probably because of the confluence of the Gatineau River (Fig. 4).

Untreated municipal wastes discharged into Brewery Creek resulted in high nutrient concentrations at its outflow. Total phosphorus concentrations approached four

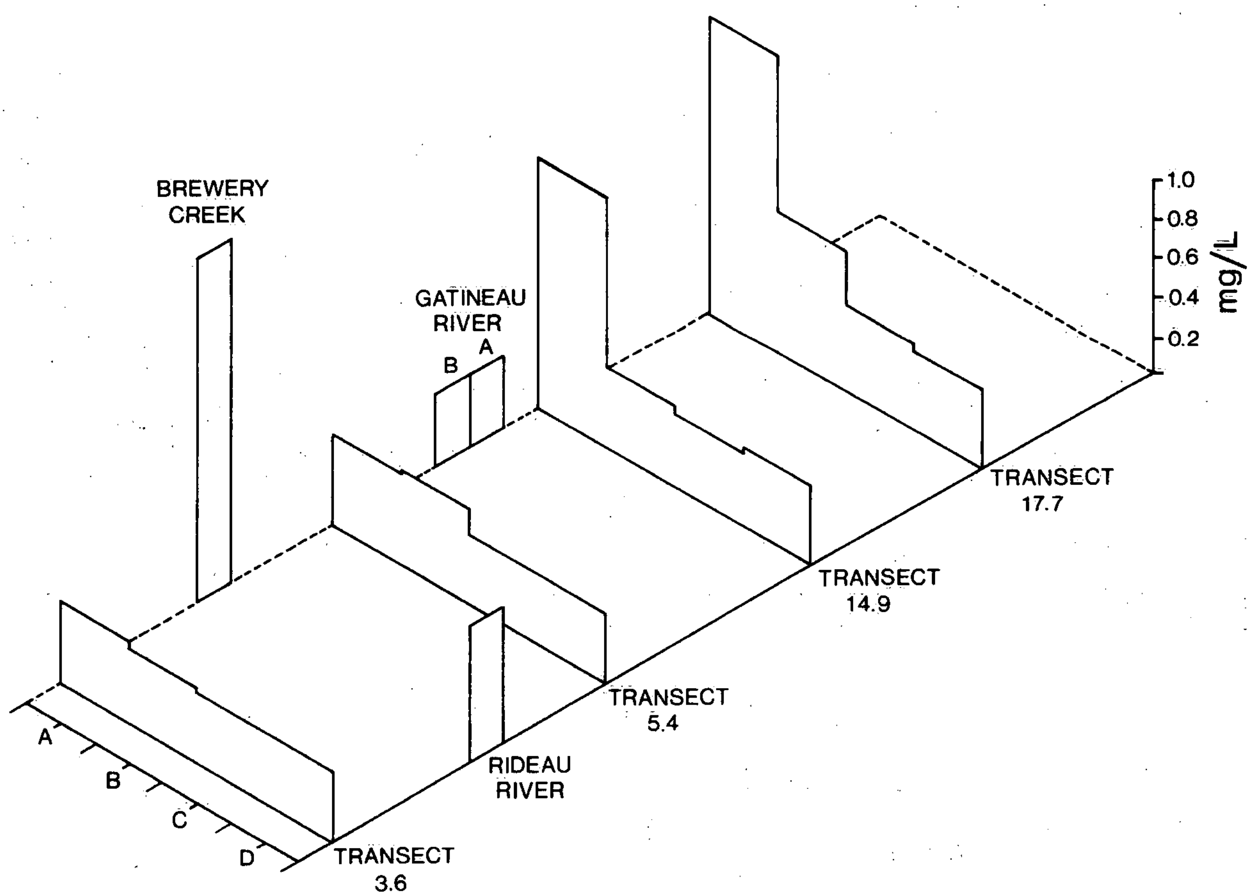


**Figure 4. Spatial variation of particulate organic carbon.**

times those of the Ottawa River; ammonia and particulate nitrogen were twice as high as the Ottawa River and particulate organic carbon concentrations were over three times higher than those of the Ottawa River (Table 4).

Nutrient concentrations in the Rideau River ranged from 25% to 150% higher than those in the Ottawa River except for nitrate + nitrite, which was over 300% lower, and ammonia, which was almost 150% lower than the Ottawa River (Table 4). These lower concentrations may be the result of biological uptake, since particulate nitrogen and particulate organic carbon are approximately twice as high as levels found at station 3.6D. Gatineau River mean nutrient concentrations were lower than those found in the Ottawa River with the exception of reactive silica. Higher silica levels in the Gatineau result from the predominantly silicate rocks found in its drainage basin. Dissolved organic carbon and total phosphorus concentrations were significantly lower in the Gatineau River than those found at station 5.4A.

Transects 14.9 and 17.7 were characterized by higher nutrient concentrations at nearshore stations and increasing concentrations in a downstream direction (Table 4). Total phosphorus increased significantly downstream between stations 14.9A and 17.7A as well as being significantly higher at both 14.9A and 17.7A in comparison with 14.9B and 17.7B (Fig. 5). Dissolved organic carbon was significantly higher at both nearshore stations on the Quebec side, probably owing to the CIP discharge.

Nitrate + nitrite and ammonia concentrations at the downstream stations along the Quebec shoreline are lower than those found at transects 3.6 and 5.4. Ammonia concentrations at the A stations in the upstream transects were twice as high as those found at the downstream transect A stations; as well, nitrate + nitrite concentrations were 65% higher at the upstream transects (Fig. 6). This downstream decrease could be the result of biological uptake of inorganic nitrogen, which is indicated by a decrease in nitrate + nitrite and ammonia with a simultaneous increase in particulate

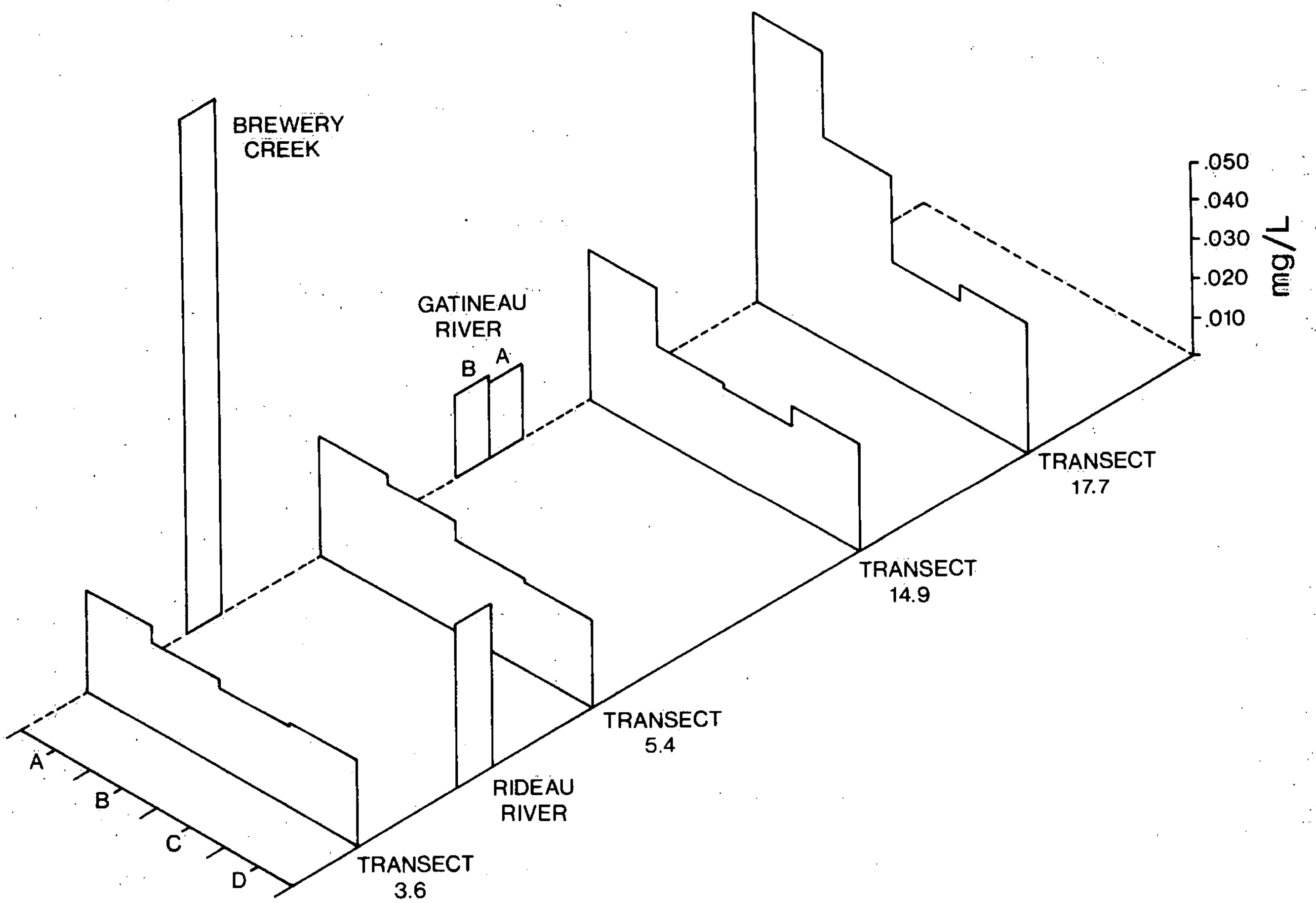


**Figure 5. Spatial variation of total phosphorus.**

nitrogen. In addition, the inflow of the Gatineau River has lower concentrations of both nitrate + nitrite and ammonia.

Nutrient concentrations were generally found to be higher at the nearshore stations on the Ontario side of the river. Ammonia concentrations at the two downstream D stations were over 75% higher than those found at transect 5.4.

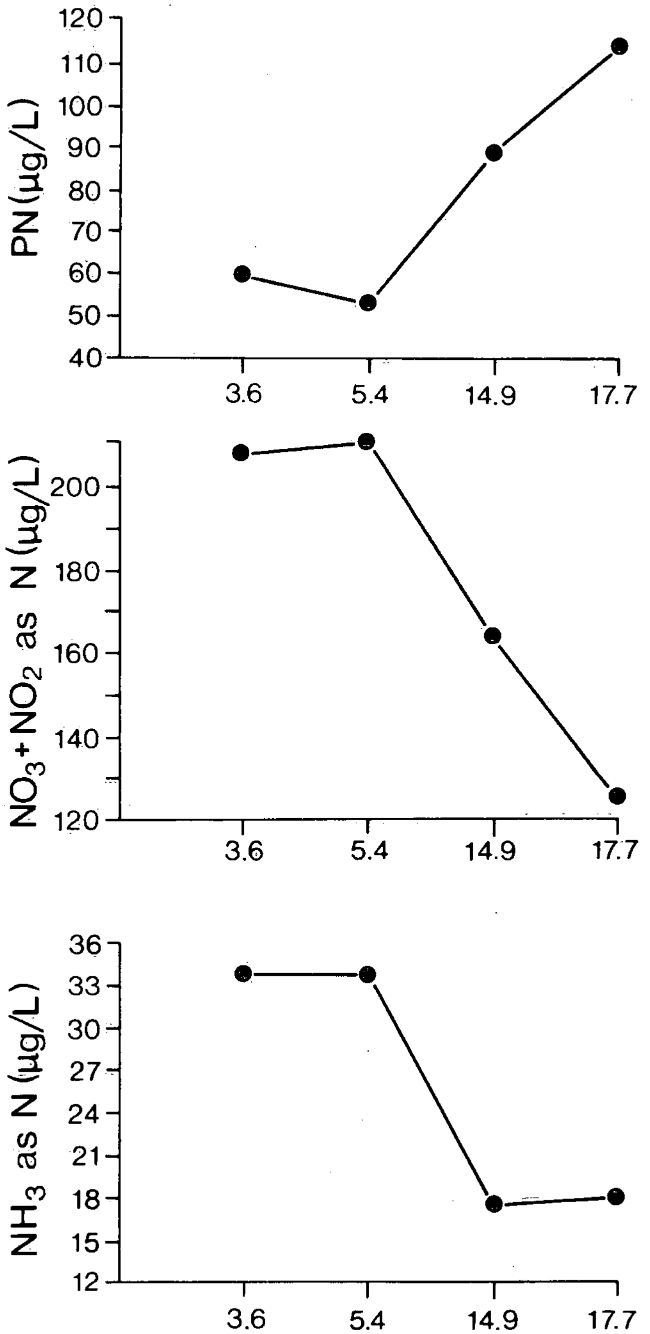


**Figure 6. Mean nutrient concentration changes at "A" stations.**

Both the Green Creek sewage treatment plant effluent located above transect 14.9 and the inflow of Green Creek between the two transects account for the downstream increases in nutrient concentrations (Table 4). Along with the higher nutrient concentrations found on the Quebec side with the exceptions of nitrate + nitrite and ammonia, the effects of municipal sewage treatment with phosphorus removal can be seen in the lower phosphorus and particulate nutrient concentrations found along the Ontario side. It should be noted that the CIP mill effluent is a major source of particulate matter and is also the probable cause of higher dissolved organic carbon concentrations along the Quebec shoreline at the downstream transects. The input from the mill is somewhat masked by municipal effluents, but once the Outaouais sewage treatment system is in operation, the effects of the CIP effluent should be more noticeable.

The ammonia objective established by the Ontario Ministry of the Environment for the protection of aquatic life (0.02 mg/L un-ionized ammonia) was never exceeded. The total phosphorus guideline of 0.030 mg/L was exceeded 33% of the time (Table 5). Most of the exceedances occurred in Brewery Creek, the Rideau River, along the Quebec shore and across transect 17.7. Higher total phosphorus found at transect 17.7 could lead to excessive aquatic growth, particularly downstream from the study area where the water is impounded.

**Bacteriological Parameters**

Fecal coliform and fecal streptococcus increased in concentration across the river from the Ontario to Quebec shore (Table 6); significantly higher concentrations were found at all four A Stations. Both parameters also increased in a downstream direction (Fig. 7). Contamination by fecal material along the Quebec shore is primarily from untreated municipal wastes. Along the Ontario shore, the downstream increases were attributed to storm sewer discharges and the tributary input of Green Creek.

The Rideau River and Brewery Creek had higher levels of fecal coliform and fecal streptococcus than the receiving waters of the Ottawa River. Fecal coliform and fecal streptococcus levels in the Gatineau River were lower than those recorded at station 5.4A with the exception of fecal streptococcus at the Gatineau River B station. Differences in fecal coliforms and fecal streptococcus concentrations were found between the two Gatineau River stations with consistently higher concentrations at the B station. This can be attributed to the larger population located on the west side of the river and the municipal discharges along that bank.

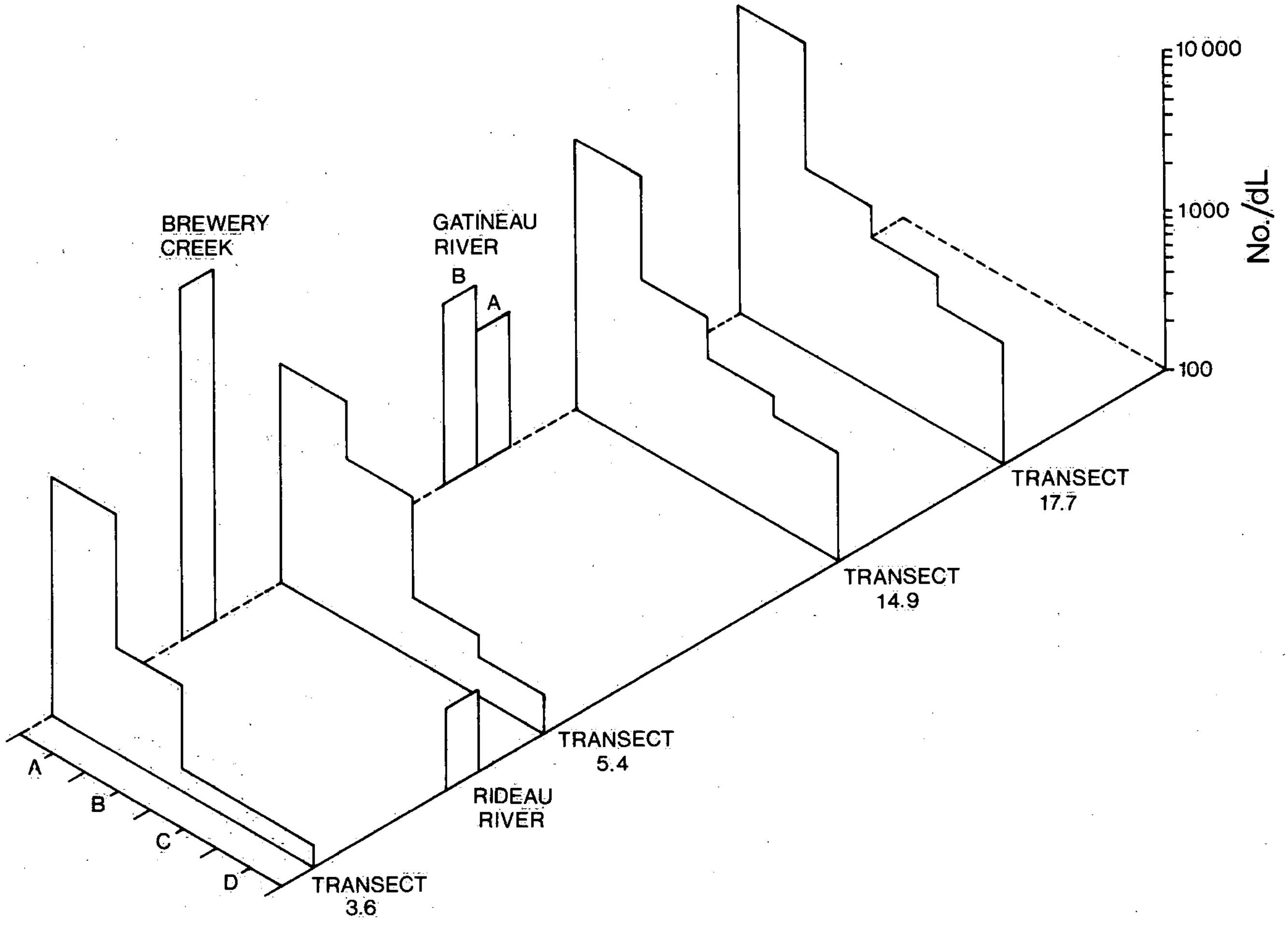


**Figure 7. Spatial variation of fecal coliform.**

Fecal coliform, fecal streptococcus ratios (FC:FS) have been used as a general indicator to determine whether the fecal source is of human or non-human origin. A ratio of less than 0.7 suggests a non-human source, while a ratio greater than 4 is considered likely to be from human sources (Ontario Ministry of the Environment 1978). FC:FS ratios at Brewery Creek, Gatineau River and the A and B stations of the four transects indicated that fecal pollution seemed to be predominantly from human sources. The ratios at the C and D stations of transects 14.9 and 17.7 also suggest the likelihood of human sources (Table 6).

Annual geometric means exceeded the recommended guideline of 100/dL fecal coliform for contact recreation at all stations (Ontario Ministry of the Environment 1978). Geometric mean counts ranged from a low of 136/dL at station 3.6C to a high of 16 839/dL in Brewery Creek (Table 6). The guideline was exceeded almost 90% of the time when individual results were taken into consideration (Table 5).

**Oxygen Demand Parameters**

Both biochemical oxygen demand ($BOD_5$) and chemical oxygen demand (COD) were analyzed as indicators of organic pollution. $BOD_5$ exhibited little variation in the Ottawa River with the exception of stations 14.9A and 17.7A where measurements were significantly higher (Table 6). Rideau River and Brewery Creek had higher $BOD_5$ than the Ottawa River, while the Gatineau River exhibited lower levels. The higher readings indicate areas receiving organic inputs.

COD was significantly higher at station 14.9A owing to the CIP mill effluent. Downstream increases found between stations 14.9D and 17.7D were attributed to the outflow of Green Creek (Table 6). COD was almost 50% higher at the Gatineau River B station in comparison to the A station. This further confirmed the prevalence of discharges along the west shore, as bacteriological and nutrient parameters were also high at the site.

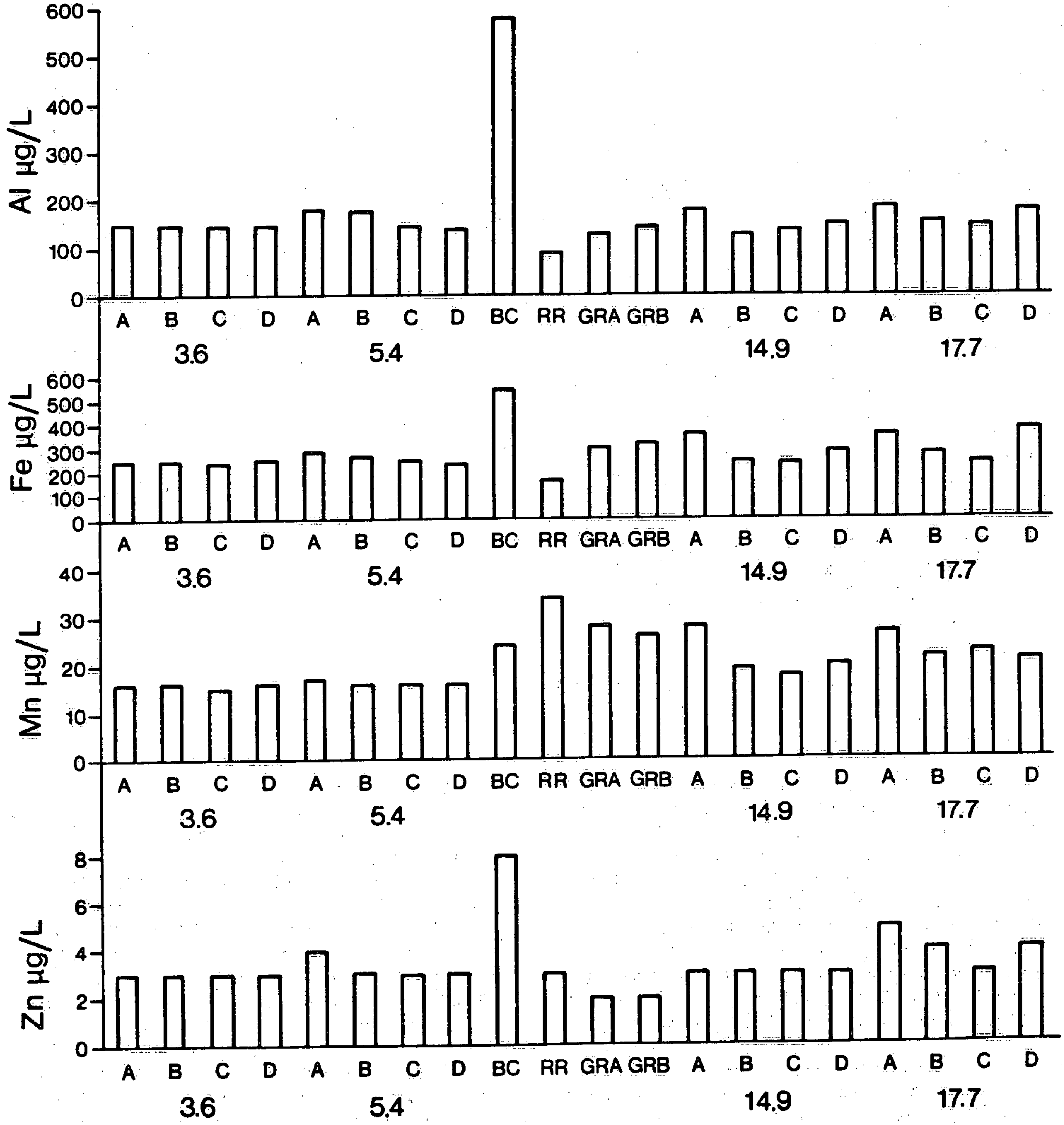


Figure 8. Spatial variation of trace metals.

**Trace Metals**

Unfiltered samples were analyzed for aluminum, copper, iron, manganese, mercury and zinc. Annual mean concentrations for these parameters are reported in Table 7. High analytical values for field blanks were obtained for copper throughout the year and mercury during one survey. Even with the high copper blanks, concentrations were about one-third those reported by Merritt (1975) for filtered samples. Mercury results were below the detection limit with the exception of one sample.

Some variations in metal concentrations are evident between the tributaries and the Ottawa River. Brewery Creek showed consistently higher metal concentrations than those found in the Ottawa River (Fig. 8). With the exception of higher manganese, Rideau River trace metal concentrations are about the same or slightly lower than those found in the Ottawa River at station 5.4D. Higher levels of iron and manganese characterized the Gatineau River; however, aluminum and zinc levels were lower than the Ottawa.

Aluminum and iron were higher at the nearshore stations for transects 14.9 and 17.7. Downstream increases were evident between the two transects for aluminum, iron, manganese and zinc (Fig. 8).

The Ontario Ministry of the Environment (1978) tentative guideline of .100 mg/L aluminum for the protection of aquatic life was exceeded over 90% of the time. The objective of .300 mg/L iron was exceeded almost 30% of the time (Table 5). Most exceedances for iron occurred in Brewery Creek, the Gatineau River and at stations 14.9A and 17.7A.

## SUMMARY


Water quality in the tributaries was markedly different from that found in the Ottawa River. This was primarily due to geochemical differences and the input of municipal and industrial wastes. Most parameters in Brewery Creek and the Rideau River had significantly higher concentrations than those of the Ottawa River. The Gatineau River, for the most part, showed significantly lower concentration than the Ottawa River.

Ottawa River water quality was spatially variable with significant changes in concentrations found across transects and significant downstream increases. These changes were mostly at nearshore stations and caused by tributary inputs and municipal and industrial effluents.

Discharges from E.B. Eddy plants in Ottawa and Hull were not as noticeable as the CIP effluent. This was attributed to the quantity of discharge, which is about 20% that of CIP for $BOD_5$ and suspended solids (Federal-Provincial Working Group 1978). Also, the E.B. Eddy plant discharges into the Chaudière Falls where the effluent is thoroughly mixed with river water. The CIP effluent, on the other hand, channels along the Quebec shoreline with minimal lateral mixing.

Total phosphorus from tributary and municipal inputs resulted in significant downstream increases. The proposed guideline of 0.030 mg/L to prevent excessive aquatic growth was exceeded less than 10% of the time at transect 3.6. The frequency of exceedance increased to over 60% at transect 17.7.

Bacteriological contamination was prevalent throughout the study area. Concentrations along the Quebec shore were significantly higher because of direct discharges of untreated sewage. The fecal coliform guideline of 100/dL for contact recreation recommended by the Ministry of the Environment was exceeded on an average of 90% of the time in the study area.


## ACKNOWLEDGMENTS


The authors wish to thank the staff of Water Quality Branch Headquarters and Quebec Region for their assistance in the study. We also thank the Water Quality Branch, Ontario Region Laboratory; and the Environmental Protection Service, Ontario Region Laboratory, for the analyses of the samples.


## REFERENCES


Bird, J.B. 1972. The Natural Landscapes of Canada—A Study in Regional Earth Sciences. Wiley Publishers of Canada, Toronto.

Douglas, A.W. 1979. On Levels of Significance. Computing and Applied Statistics Directorate, Environment Canada, Ottawa.

Environment Canada. 1976. Status Review of the Ottawa River Cleanup Program. Unpublished Report.

Environment Canada. 1976a. Water Quality Study, Ottawa and Gatineau Rivers. National Capital Area, 1976. Environmental Protection Service, Ontario Region, Draft MS Report No. OR-5.

Environment Canada. 1977. Ottawa River Water Quality, National Capital Area, 1977. Environmental Protection Service, Ontario Region MS Report No. OR-7.

Environment Canada. 1978. Ottawa River Water Quality, National Capital Area, 1978. Environmental Protection Service, Ontario Region, MS Report No. OR-19.

Environment Canada. 1979. Analytical Methods Manual 1979. Inland Waters Directorate, Water Quality Branch, Ottawa.

Federal-Provincial Working Group on Water Quality in the Ottawa River. 1978. A Review of Water Pollution Control Programs on the Ottawa River. Unpublished Report.

Fisheries and Environment Canada. 1977. Monograph on the Ottawa River Basin. Environmental Management Service, Quebec Region.

Merritt, W.F. 1975. Variation in trace element concentrations along the length of the Ottawa River. Can. J. Earth Sci. 12: 850–857.

Ontario Ministry of the Environment. 1978. Water Management—Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment. Toronto.

Steel, R.T.D. and J.H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., Toronto.

## Tables 1-7

**Table 1. Summary of Parameters, Preservation, Sample Containers and Detection Limits**

| Parameter | Preservation | Sample container | Detection limit |
|---|---|---|---|
| Colour | None | Polyethylene, 500 mL | 5 rel. units |
| Conductance, Specific | None | Polyethylene, 500 mL | 0.2 μS/cm |
| Alkalinity, Total | None | Polyethylene, 500 mL | 0.1 mg/L |
| Calcium | None | Polyethylene, 500 mL | 0.1 mg/L |
| Chloride* | None | Polyethylene, 500 mL | 0.1 mg/L |
| Magnesium* | None | Polyethylene, 500 mL | 0.1 mg/L |
| Potassium | None | Polyethylene, 500 mL | 0.1 mg/L |
| Sodium* | None | Polyethylene, 500 mL | 0.1 mg/L |
| Sulphate* | None | Polyethylene, 500 mL | 0.1 mg/L |
| Carbon, Dissolved Organic* | None | Glass, 125 mL | 0.1 mg/L |
| Carbon, Particulate Organic | None | Sample collected on filter | 0.001 mg/L |
| Nitrogen, Ammonia* | None | Glass, 125 mL | 0.001 mg/L |
| Nitrogen, Nitrate + Nitrite* | None | Glass, 125 mL | 0.001 mg/L |
| Nitrogen, Particulate | None | Sample collected on filter | 0.001 mg/L |
| Phosphorus, Soluble Reactive | None | Glass, 125 mL | 0.0002 mg/L |
| Phosphorus, Total* | $H_2SO_4$ (30%), 1 mL | Glass, 125 mL | 0.0005 mg/L |
| Silica, Reactive | None | Glass, 125 mL | 0.2 mg/L |
| Fecal Coliform* | Iced | Glass, 500 mL | 2/dL |
| Fecal Streptococcus* | Iced | Glass, 500 mL | 2/dL |
| Biochemical Oxygen Demand* | None | Polyethylene, 1 L | 0.1 mg/L |
| Chemical Oxygen Demand* | None | Polyethylene, 1 L | 5 mg/L |
| Aluminum, Extractable | $HNO_3$ (50%), 2 mL | Polyethylene, 500 mL | 0.001 mg/L |
| Copper, Total | $HNO_3$ (50%), 2 mL | Polyethylene, 500 mL | 0.001 mg/L |
| Iron, Total* | $HNO_3$ (50%), 2 mL | Polyethylene, 500 mL | 0.001 mg/L |
| Manganese, Total* | $HNO_3$ (50%), 2 mL | Polyethylene, 500 mL | 0.001 mg/L |
| Zinc, Total | $HNO_3$ (50%), 2 mL | Polyethylene, 500 mL | 0.001 mg/L |
| Mercury, Extractable | $H_2SO_4$ (conc.), 1 mL<br>$K_2Cr_2O_7$ (5%), 1 mL | Polypropylene, 125 mL | 0.05 μg/L |

*Parameters used for analysis of variance.

**Table 2. Mean Values of Physical Parameters**

| Station | Colour, rel. units | pH | Spec. cond. at 25°C, μS/cm | Turbidity, JTU |
|---|---|---|---|---|
| 3.6A | 21. | 7.0 | 73. | 6.5 |
| 3.6B | 23. | 7.0 | 71. | 6.1 |
| 3.6C | 23. | 7.1 | 71. | 5.7 |
| 3.6D | 23. | 7.0 | 71. | 5.9 |
| BC | 22. | 7.3 | 120. | 13.0 |
| RR | 16. | 7.9 | 288. | 5.6 |
| 5.4A | 22. | 7.0 | 73. | 6.7 |
| 5.4B | 23. | 7.0 | 72. | 7.0 |
| 5.4C | 22. | 7.1 | 73. | 5.9 |
| 5.4D | 23. | 7.1 | 77. | 6.2 |
| GRA | 20. | 7.0 | 51. | 5.7 |
| GRB | 19. | 6.9 | 52. | 6.3 |
| 14.9A | 22. | 6.9 | 74. | 11.5 |
| 14.9B | 22. | 7.0 | 67. | 6.7 |
| 14.9C | 23. | 7.0 | 66. | 6.3 |
| 14.9D | 23. | 7.0 | 68. | 6.5 |
| 17.7A | 21. | 6.9 | 74. | 10.5 |
| 17.7B | 22. | 7.0 | 70. | 7.2 |
| 17.7C | 22. | 7.0 | 69. | 6.6 |
| 17.7D | 23. | 7.0 | 75. | 8.8 |

**Table 3. Mean Values of Major Ions (mg/L)**

| Station | Total Alk. as $CaCO_3$ | Ca | Cl | Mg | K | Na | $SO_4$ |
|---|---|---|---|---|---|---|---|
| 3.6A | 16.2 | 7.7 | 2.5 | 2.0 | 0.8 | 2.3 | 2.5 |
| 3.6B | 15.4 | 7.5 | 2.1 | 2.0 | 0.8 | 2.2 | 2.1 |
| 3.6C | 15.5 | 7.5 | 1.9 | 2.0 | 0.8 | 2.2 | 1.9 |
| 3.6D | 15.3 | 7.5 | 2.1 | 2.0 | 0.8 | 2.1 | 2.1 |
| BC | 26.2 | 11.9 | 8.9 | 2.4 | 1.1 | 6.5 | 8.9 |
| RR | 108.0 | 32.9 | 14.4 | 11.2 | 1.2 | 8.2 | 14.4 |
| 5.4A | 16.3 | 7.8 | 2.4 | 2.0 | 0.8 | 2.4 | 2.4 |
| 5.4B | 15.9 | 7.8 | 2.3 | 2.0 | 0.8 | 2.3 | 2.3 |
| 5.4C | 16.6 | 7.9 | 2.2 | 2.1 | 0.8 | 2.2 | 2.2 |
| 5.4D | 18.5 | 8.4 | 2.5 | 2.3 | 0.8 | 2.3 | 2.5 |
| GRA | 12.8 | 6.2 | 1.0 | 1.1 | 0.7 | 1.2 | 1.0 |
| GRB | 12.8 | 6.2 | 1.1 | 1.2 | 0.7 | 1.2 | 1.1 |
| 14.9A | 18.5 | 7.7 | 2.2 | 1.9 | 0.9 | 2.8 | 2.2 |
| 14.9B | 15.6 | 7.3 | 2.0 | 1.8 | 0.8 | 2.0 | 2.0 |
| 14.9C | 14.9 | 7.2 | 1.8 | 1.8 | 0.8 | 1.9 | 1.8 |
| 14.9D | 15.5 | 7.4 | 2.0 | 1.8 | 0.8 | 2.0 | 2.0 |
| 17.7A | 18.8 | 7.8 | 2.2 | 1.8 | 0.8 | 2.9 | 2.2 |
| 17.7B | 16.4 | 7.6 | 2.0 | 1.8 | 0.8 | 2.3 | 2.0 |
| 17.7C | 16.1 | 7.4 | 2.0 | 1.9 | 0.8 | 2.1 | 2.0 |
| 17.7D | 16.5 | 7.9 | 2.9 | 2.0 | 0.8 | 2.7 | 2.9 |

Table 4. Mean Concentrations of Nutrients (mg/L)

| Station | DOC | POC | $NH_3$ as N | $NO_3+NO_2$ as N | PN | SRP | TP | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|
| 3.6A | 6.7 | .427 | .034 | .208 | .060 | .004 | .027 | 3.92 |
| 3.6B | 6.7 | .385 | .029 | .208 | .046 | .002 | .023 | 3.93 |
| 3.6C | 6.5 | .364 | .028 | .212 | .041 | .002 | .021 | 3.93 |
| 3.6D | 6.5 | .364 | .029 | .208 | .041 | .002 | .022 | 3.92 |
| BC | 6.9 | 2.766 | .101 | .223 | .182 | .024 | .132 | 4.11 |
| RR | 8.1 | .700 | .012 | .050 | .102 | .005 | .041 | 1.18 |
| 5.4A | 6.8 | .457 | .034 | .210 | .053 | .004 | .032 | 3.93 |
| 5.4B | 6.5 | .486 | .030 | .209 | .057 | .003 | .029 | 3.92 |
| 5.4C | 6.5 | .359 | .026 | .204 | .043 | .002 | .024 | 3.85 |
| 5.4D | 6.7 | .360 | .026 | .202 | .045 | .002 | .023 | 3.83 |
| GRA | 5.1 | .377 | .023 | .109 | .047 | .002 | .021 | 4.08 |
| GRB | 5.0 | .383 | .029 | .142 | .046 | .003 | .022 | 4.05 |
| 14.9A | 7.9 | 1.274 | .017 | .165 | .089 | .003 | .039 | 3.97 |
| 14.9B | 6.3 | .413 | .023 | .184 | .057 | .002 | .024 | 3.89 |
| 14.9C | 6.3 | .375 | .026 | .187 | .040 | .002 | .023 | 3.87 |
| 14.9D | 6.4 | .406 | .046 | .186 | .051 | .003 | .028 | 3.90 |
| 17.7A | 7.9 | 1.509 | .018 | .126 | .114 | .006 | .074 | 4.01 |
| 17.7B | 7.0 | .723 | .018 | .169 | .079 | .002 | .052 | 2.95 |
| 17.7C | 6.3 | .449 | .041 | .186 | .058 | .003 | .030 | 3.91 |
| 17.7D | 6.1 | .424 | .042 | .190 | .065 | .003 | .034 | 3.90 |

Table 5. Guideline Exceedances

| Station | Aluminum, .100 mg/L | | Fecal coliform 100 per 100 dL | | Iron .300 mg/L | | Total phosphorus .030 mg/L | |
|---|---|---|---|---|---|---|---|---|
| | N | E | N | E | N | E | N | E |
| 3.6A | 19 | 19 | 18 | 18 | 19 | 2 | 19 | 3 |
| 3.6B | 19 | 19 | 18 | 16 | 19 | 2 | 19 | 1 |
| 3.6C | 19 | 19 | 18 | 12 | 19 | 4 | 19 | 1 |
| 3.6D | 19 | 18 | 18 | 12 | 19 | 2 | 19 | 1 |
| BC | 19 | 19 | 18 | 18 | 19 | 19 | 19 | 19 |
| RR | 19 | 8 | 18 | 15 | 19 | 3 | 18 | 17 |
| 5.4A | 19 | 19 | 18 | 17 | 19 | 5 | 18 | 8 |
| 5.4B | 19 | 18 | 18 | 15 | 19 | 4 | 19 | 7 |
| 5.4C | 19 | 19 | 18 | 12 | 19 | 2 | 19 | 1 |
| 5.4D | 19 | 19 | 18 | 12 | 19 | 2 | 19 | 1 |
| GRA | 19 | 11 | 19 | 19 | 19 | 11 | 19 | 0 |
| GRB | 19 | 13 | 19 | 19 | 19 | 7 | 19 | 0 |
| 14.9A | 18 | 18 | 19 | 18 | 18 | 10 | 18 | 13 |
| 14.9B | 18 | 15 | 19 | 18 | 18 | 3 | 18 | 1 |
| 14.9C | 18 | 16 | 19 | 17 | 18 | 2 | 18 | 1 |
| 14.9D | 18 | 18 | 19 | 16 | 18 | 3 | 18 | 2 |
| 17.7A | 18 | 18 | 18 | 18 | 18 | 13 | 18 | 17 |
| 17.7B | 18 | 16 | 18 | 18 | 18 | 4 | 18 | 10 |
| 17.7C | 18 | 17 | 18 | 17 | 18 | 2 | 18 | 7 |
| 17.7D | 18 | 18 | 18 | 16 | 18 | 9 | 18 | 11 |

N = Number of data points
E = Number of guideline exceedances

Table 6. Mean Values for Bacteriological and Oxygen Demand Parameters

| Station | Fecal colif., MF/dL* | Fecal strep., MF/dL* | FC:FS Ratios | $BOD_5$ mg/L | COD mg/L |
|---|---|---|---|---|---|
| 3.6A | 3283 | 589 | 1.3 | 29.2 | 5.57 |
| 3.6B | 466 | 104 | 1.4 | 31.0 | 4.48 |
| 3.6C | 136 | 81 | 1.3 | 31.9 | 1.68 |
| 3.6D | 137 | 97 | 1.3 | 27.7 | 1.41 |
| BC | 16839 | 4224 | 2.3 | 29.0 | 3.99 |
| RR | 353 | 211 | 1.8 | 29.2 | 1.67 |
| 5.4A | 2373 | 352 | 1.6 | 30.9 | 6.74 |
| 5.4B | 1050 | 256 | 1.4 | 29.9 | 4.10 |
| 5.4C | 245 | 102 | 1.3 | 34.6 | 2.40 |
| 5.4D | 178 | 82 | 1.4 | 29.6 | 2.17 |
| GRA | 658 | 166 | 1.2 | 21.3 | 3.96 |
| GRB | 1467 | 367 | 1.2 | 21.3 | 3.96 |
| 14.9A | 5191 | 689 | 4.0 | 43.5 | 7.53 |
| 14.9B | 1113 | 243 | 1.4 | 28.5 | 4.58 |
| 14.9C | 634 | 95 | 1.3 | 36.5 | 6.67 |
| 14.9D | 454 | 122 | 1.3 | 27.9 | 3.72 |
| 17.7A | 9150 | 1089 | 4.2 | 35.3 | 8.40 |
| 17.7B | 1452 | 264 | 2.6 | 30.3 | 5.50 |
| 17.7C | 913 | 130 | 1.6 | 35.9 | 7.02 |
| 17.7D | 585 | 100 | 1.5 | 29.9 | 5.85 |

*Geometric means calculated for fecal coliform and fecal streptococcus.

Table 7. Mean Values of Trace Metals (mg/L)

| Station | Extract. Al. | Total Fe | Total Mn | Extract. Hg | Total Zn |
|---|---|---|---|---|---|
| 3.6A | .150 | .250 | .016 | L.00005 | .003 |
| 3.6B | .147 | .250 | .016 | L.00005 | .003 |
| 3.6C | .145 | .250 | .015 | L.00005 | .003 |
| 3.6D | .145 | .240 | .016 | L.00005 | .003 |
| BC | .582 | .550 | .016 | L.00005 | .008 |
| RR | .080 | .170 | .034 | L.00005 | .003 |
| 5.4A | .180 | .290 | .017 | L.00005 | .004 |
| 5.4B | .168 | .260 | .016 | L.00005 | .003 |
| 5.4C | .143 | .250 | .016 | L.00005 | .003 |
| 5.4D | .141 | .240 | .016 | L.00005 | .003 |
| GRA | .129 | .310 | .028 | L.00005 | .002 |
| GRB | .142 | .320 | .026 | L.00005 | .003 |
| 14.9A | .178 | .360 | .028 | L.00005 | .003 |
| 14.9B | .124 | .250 | .019 | L.00005 | .003 |
| 14.9C | .138 | .240 | .018 | L.00005 | .003 |
| 14.9D | .151 | .290 | .020 | L.00005 | .003 |
| 17.7A | .187 | .360 | .027 | L.00005 | .005 |
| 17.7B | .154 | .280 | .022 | L.00005 | .004 |
| 17.7C | .147 | .250 | .023 | L.00005 | .003 |
| 17.7D | .180 | .380 | .021 | L.00005 | .004 |