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Hydrological and water quality assessment of the Petitcodiac Watershed

Research report R-588

Hydrological and water quality assessment of the Petitcodiac Watershed

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1.0 INTRODUCTION

1.1 CONTEXT

The Petitcodiac River is located in Southeastern New Brunswick. It has a drainage basin area of 1999 km^2, which is home to approximately 120 000 people, most of whom live in the Greater Moncton area.

One of the main features of this river system is the presence of a causeway. It was built in 1968, when it became obvious that the Gunningsville Bridge could not sustain the growing traffic between Moncton and Riverview. The presence of the causeway has changed the hydrodynamic conditions in the river system. A debate on how to best manage these changes and their effects has been ongoing for a number of years. For this reason, a lot of attention has been devoted to this river system by the media, various government departments (both federal and provincial) and the scientific community in recent years.

In 1997, the Petitcodiac Watershed Monitoring Group (PWMG) was founded with a mandate to establish and support a network of volunteers who will conduct long-term water quality monitoring in the Petitcodiac watershed (Frenette, 2000). Since then, water quality data has been gathered by the PWMG at various locations in the watershed. The PWMG has also collected historical water quality data. These past and more recent data allow for spatial and temporal analysis of the water quality in the Petitcodiac drainage basin. Water sample collection and analyses have been carried out in partnership with ELG. In 1999, the PWMG received funding from the Environmental Trust Fund (ETF) to carry out a two-year water classification project.

The Petitcodiac Watershed Monitoring Group has therefore hired Roche Ltd, with the assistance of the Chair in statistical hydrology (INRS-EAU, Université du Québec) to produce a report on water quality data measured on the Petitcodiac watershed.

1.2 OBJECTIVES

The main objective of this mandate is to summarize and interpret the water quality data collected from the Petitcodiac River and some of its tributaries. More specifically, the analyses are aimed at comparing water quality both spatially (i.e. comparisons between stations on the watershed, and temporally (i.e. comparisons between the two sampling periods). In order to facilitate the interpretation of water quality data, an analysis of the prevailing meteorological (i.e. rain and air temperature) and hydrological (i.e. freshwater flows) conditions were also included.

This first report focuses on a brief description of the methodology and the results of the analyses. A second report will be produced to summarize the technical information gathered here for a larger, non-technical audience.

2.0 DRAINAGE BASIN

From its headwaters to the causeway, the Petitcodiac drainage basin covers a surface of 1360 km^2 (Figure 1). Downstream of this structure, the Petitcodiac estuary is modulated by a very important tidal range, leaving very little water at low tide and rapidly increasing to depths greater than 3 m at high tide. The main sub-basins (i.e. drainage area greater than 290 km^2) include the Polett River, North River, and Little River (Table 1). The medium-sized tributaries (drainage area between 100 km^2 and 200 km^2) include Turtle Creek, the Anagance River, and Halls Creek (including Humphrey Brook). Other smaller brooks and streams also discharge into the Petitcodiac River. They include Jonathan Creek in Moncton, Fox Creek in Dieppe, as well as Mill Creek and Weldon Creek (Table 1).

2.1 GEOLOGY AND SOIL TYPES

The bedrock on the drainage basin is mostly composed of Pennsylvanian (or younger) red and grey sandstones, conglomerate and siltstones. On the north shore of the Petitcodiac River, and in the upper reaches of the Anagance River, the North River and the other tributaries on the north shore, the bedrock is mostly made of Mississippian red to grey sandstones, and shales with some volcanic rocks. Similar geological formations are found in the southern part of the basin, around the Memramcook River and on the Weldon Creek sub-basin (New Brunswick Department of Natural Resources, map #NR-1, 1979).

During the late quaternary era, most of the Petitcodiac drainage basin was under sea level, with the DeGeer Sea (extending from the current Bay of Fundy) covering the southern part of the basin and the Goldthwait Sea (extending from the current Northumberland Strait) covering the northern part of the basin.

Most of the basin is characterised by topsoils (first 0.5 m) made of veneer (sand and silt, with some clay), under which there is usually ablation moraines. Near the main river banks, however, the intertidal plains and salt marshes have soils composed mostly of clay and silt, with some fine sand (Geological survey of Canada, map 1594A, 1982).

2.2 LAND USE

The City of Moncton Engineering Department has collected land use data for the Greater Moncton Planning district. These data have been used in a Geographical Information System (GIS) to produce land use maps. The information found in these maps is summarized here. Detailed maps of land use will also be provided in the second report to be produced.

The Petitcodiac watershed is mostly a forested territory, especially in its southern portion. Logging is an important industry in the area. Older forests can usually be found in the upper reaches of the tributaries located on the south shore of the Petitcodiac. The lower reaches have been subjected to logging. The forest in the lower portion of these sub-basins is therefore mostly composed of plantations, young forests and regenerating areas.

Agriculture is concentrated along the shores of the Petitcodiac and its tributaries, especially in the northern portion of the basin. Lands in the vicinity of the Anagance and North Rivers are mostly agricultural. There is also some agricultural activity along the Pollett and Little Rivers. Turtle Creek is used as the main drinking water source for the Greater Moncton area (Moncton, Dieppe and Riverview). Most of its drainage basin is forested, except for the lower reaches near its confluence with the Petitcodiac, which is agricultural.

The largest urban area is the Greater Moncton area with a total population nearing 100 000. It surrounds the lower reaches of Halls Creek and Jonathan Creek in Moncton, as well as Fox Creek in Dieppe. The presence of an old dumpsite on the north shore of the river between the Gunningsville Bridge and the causeway, has recently been a cause of concern and was mentioned as a potential threat to water quality, should there be a major erosion of the river banks at the site. Two other urbanized areas are found upstream of Moncton, along the shore of the Petitcodiac. The town of Petitcodiac is located near the confluence of the North and Anagance Rivers, and the town of Salisbury is located near the confluence of the Little River and the Petitcodiac River.

2.3 MAIN WATER USES

As stated before, water quality in the upper reaches of Turtle Creek is of the upper-most importance, because it is the main source of drinking water for the Greater Moncton area. In the city of Moncton, Jonathan Creek has an important recreational mission. The creek is a central feature in Centennial Park and water quality has been a cause for concern in the past.

Upstream of the causeway, Lake Petitcodiac (the reservoir) is used by boaters for recreational purposes. Angling (mostly for trout) is also popular throughout the river system, upstream of the causeway.

Downstream of the causeway, on the south shore, the collected sewage of the cities of Moncton, Riverview and Dieppe is received in the tidal portion of the river. There is some seasonal commercial fishing (gaspereau, shad and smelt) downstream of Moncton, in the estuary.

3.0 METHODS

3.1 METEOROLOGICAL ANALYSIS

Statistical analyses of meteorological parameters focused on the two variables, which are more likely to cause variations in water quality, namely air temperature and precipitation. Data provided originated from the Moncton airport, and essentially covered the months of May to September for the years 1975-1977 and 1997-2000. Data for the months of April, October and November were provided for some years. Basic descriptive statistics (mean, minimum, and maximum) were computed with the available data for the periods of interest, on a monthly basis.

Time series were tested for homogeneity (i.e. no significant change in means between two periods, 1975-1977 and 1997-2000) using the Wilcoxon signed rank test (Wilcoxon, 1945, 1946; Hollander and Wolfe, 1973) for the mean. The Levene test (Levene 1960) was used to verify if there were shifts in the variance between two data sub sets (i.e. two periods).

3.2 HYDROLOGICAL ANALYSIS

Two gauging stations, operated by Environment Canada are located on the watershed (Figure 1). Station 01BU002, on the Petitcodiac River, near Petitcodiac (lat. 45º 56' 37", long. 65º 10' 13") has a gauged drainage area of 391 km^2. Station 01BU003, on Turtle Creek (lat. 45º 57' 29", long. 64º 52' 44"), is on a tributary of the Petitcodiac River located on the South Shore, with its confluence upstream of the Causeway. The gauged area for this station is 129 km^2.

The Petitcodiac River has been gauged since September 1961, while flow measurements were initiated in Turtle Creek in September 1962.

Caissie (2000) has performed a detailed hydrological analysis of daily flows from station 01BU002. This analysis included flow duration and frequency analysis. Results produced by Caissie (2000) are summarized in the next section. In order to be consistent, most of the analyses performed by Caissie (2000) on station 01BU002 were repeated for station 01BU003 (Turtle Creek), which is the other gauged station on the basin. Basic descriptive statistics (monthly mean flows, annual means, and variance) were also calculated.

Methods used include a study of the variability of annual runoff, analysis of independence within the time series, flow duration analysis and high and low flow frequency analyses.

The Wald-Wolofowitz test (Wald and Wolfowitz, 1943), used by Caissie (2000) on the Petitcodiac River flows, was performed on Turtle Creek data to verify the hypothesis that daily flow observations were independent from one another. The Kendall test (Kendall, 1975) was used to verify stationarity (i.e. no trend in the time series), and 5-year moving averages were calculated and used as a smoothing technique to describe potential long-term variability. The Wilcoxon rank test (Wilcoxon, 1945, 1946; Hollander and Wolfe, 1973) was used to verify homogeneity of the sample sets. Associated p-values (p) were calculated and used to accept or reject the null hypotheses at a level of 5% ($\alpha = 0.05$)

Monthly flow duration analysis were performed to show the distribution of discharge as a function of exceedance, in accordance with the method used by Caissie (2000) for station 01BU003. The percentage of time a specific discharge is equalled or exceeded was calculated for the entire time series at Turtle Creek.

High and low flow analyses were carried out using Turtle Creek data, and the same analyses performed by Caissie (2000) on the Petitcodiac data were reproduced. Annual floods (i.e. maximum daily discharge) were identified and used by fitting different distribution functions to determine the frequency of discharge events. Caissie (2000) used four (4) distribution functions, three (3) of which are used in this report: The Three Parameter Lognormal (LN3), The Type 1 Extremal (Gumbel), and the Log-Pearson Type III (LP3) distribution functions.

Low flow frequency analysis at station 01BU003 with the same method used by Caissie (2000) on station 01BU002. The Type III Extremal (T3E) distribution function was used and the return periods of low daily discharge events were calculated.

The frequency analyses and most statistical tests were done using the HYFRAN software (Bobée et al. 1999) developed at INRS-EAU.

Finally, some of the results of the statistical and frequency analyses were transferred from the reference stations to ungauged sub-basins using the ratio of drainage areas. It was assumed, for a first attempt at extrapolating hydrological information, that basic rainfall-runoff conditions, which depend on the basin topography, stream network and land uses, were relatively homogenous throughout the basin. Discharge can then be estimated using the following equation:

$$Q_u = Q_g \frac{A_u}{A_g}$$

Where:

Q_g = discharge of the gauged drainage basin (m^3/s);
Q_u = discharge of the ungauged drainage basin (m^3/s);
A_i = Area of drainage basin (km^2).

3.3 WATER QUALITY

3.3.1 Data collection

Water quality data were collected at two different periods, 1975-79 and 1997-2000. The first series of data were obtained by the New Brunswick Department of the Environment while the second series were collected by both the Petitcodiac Watershed Monitoring Group (PWMG) and the New Brunswick Department of Environment and Local Government (ELG, formerly DOE). A summary of sampling events is presented in table 2. All water samples were grab samples collected by hand with the exception of samples taken from the causeway in 1997, which were collected by a sample iron in one or two occasions.

Field observations were recorded by the volunteers on site and the field data sheets given to ELG staff who recorded them in their database. In 1997-98, fall field measurements were carried out using LaMotte kits (water temperature, pH and dissolved oxygen). In 1999 and 2000, dissolved oxygen measurements were made using a YSI instrument. The sampling events carried out by the volunteers were usually carried out on the last Sunday of each month. The samples were placed in coolers, packed with ice, and delivered to Fredericton either by bus or by courier. They arrived at the Analytical Services Laboratory of the Department of the Environment and Local Government the next morning where they were preserved and analysed according to accepted protocol. Metals results given are for total extractable metals.

3.3.2 Data analysis

Water quality data were extracted from the ELG water quality database. Four data sets were used in this study. The first comprises the data gathered during the 1975-1979 period. The second corresponds to the 1997-2000 period. Two additional data sets were included in the analysis. These data sets contained additional data from the Jonathan Creek sub-basin and bacterial data for the year 1997.

Prior to statistical treatment, all values lower than detection limit were recoded to half the value of the detection limit for a given parameter (Newman 1989). This step was performed in order to allow the computation of the various descriptive statistics (percentiles, means, etc.). Similarly, coliform results reported as above a given value were re-coded to that value. The descriptive statistics were calculated for the entire database, where the two periods of sampling (1975-77 and 1997-2000) were combined.

For each of the two sampling periods, data have been compared to the Canadian Water Quality Guidelines (CCME 1999) for the protection of aquatic life. The data have been analysed in order to calculate the frequency at which these guidelines were exceeded during the two periods.

The database comprises a total of over 600 sampling events carried out at 45 different locations in the watershed. In order to summarise the information, cluster analyses (Legendre and Legendre 1984) have been performed using the sampling events as objects and water quality parameters as descriptors. The aim of these analyses is to address the spatial variability of water quality within the watershed, by calculating the degree of similarity between the different water bodies. The end result is the formation of clusters of information (i.e. stations or water bodies) with similarities. Only the 1997-2000 data have been used in order to control the temporal variability. The cluster analyses have been performed on the average values for each waterbody for the period. The calculations were done using the hierarchical agglomeration method with average linkage (SAS JMP, v.3).

Temporal variability has been examined at two different time scales, multi-year and monthly. In both cases a subset of stations were selected in order to control spatial variability. Stations with the most extensive records were thus selected. For multi-year comparisons, two sets of stations were used: those on the Petiticodiac River and on Jonathan Creek, which were analysed separately. For monthly comparisons, the analysis used the data from four stations of the Petitcodiac: stations PWMG # 4, 10, 15 & 16.

4.0 RESULTS

4.1 CLIMATE

4.1.1 Air Temperature

Monthly air temperature maximum, minimum and means were calculated for the two periods of interest (1975-1977 and 1997-2000; Table 3). Typically, mean air temperatures increase from around 10 °C in May to close to 20 °C in July and August (Table 3). By October, mean monthly air temperatures have typically decreased to the mid teens. The highest monthly mean temperature between May and September for both periods was 20.6 °C (July 1975). The lowest monthly mean temperature occurred in May 1977 (9.0 °C).

Daily air temperatures from the earlier (1975-1977) and later period (1997-2000) were compared and tested for shifts in means and variance. Both tests (i.e. Levene for variance and Wilcoxon for means) showed no significant differences in the monthly means ($0.06 < p < 0.62$) or variances ($0.15 < p < 0.44$) of air temperatures during the months of May through September. This implies that the air temperature regime can likely be considered similar for the two periods of interest.

4.1.2 Precipitation

Total solid and liquid precipitation was calculated from available data at the Moncton airport during the two periods of interest. 1977 was the year with the wettest spring and summer (May-September) period with a total of 591 mm of rain, followed by 1999 with 514 mm of rain (Table 4). The driest spring and summer period occurred in 1997 with only 389 mm of rain.

Daily precipitation of the earlier (1975-1977) and latter period (1997-2000) were compared on a monthly basis and tested for stationarity. Both tests (i.e. Levene for variance and Wilcoxon for means) showed no significant differences ($p = 0.7$ for mean and $p= 0.11$ for variance) in the precipitation regime during the months of May through September. This means that the precipitation regime can be considered equivalent for the two periods of interest.

4.2 FLOWS

4.2.1 Basic statistics

From the time series of daily flows, the mean annual discharge of the Petitcodiac River at the causeway was calculated by Caissie (2000) to be 27.3 m^3/s, while it was calculated to be 3.6 m^3/s for Turtle Creek (Table 5). These mean flows translate to specific discharge of 0.02 $m^3/s/km^2$ (20 $L/s/km^2$) and 0.03 $m^3/s/km^2$ (30 $L/s/km^2$) respectively. The median flow (flow available 50% of the time) was also calculated and was found to be 11.9 m^3/s on the Petitcodiac at the causeway, and 1.7 m^3/s for Turtle Creek.

Daily discharge measured in Turtle Creek ranged between a minimum of 0.14 m^3/s and a maximum of 96 m^3/s. For the Petitcodiac River at the causeway, Caissie (2000) found the range of discharge to be between 0.36 m^3/s and 730 m^3/s. When converted to specific discharge, the minimum flow in Turtle Creek (1.1 $L/s/km^2$) is higher than the minimum flow in the Petitcodiac River (0.3 $L/s/km^2$). Maximum specific discharge in Turtle Creek (750 $L/s/km^2$) is 1.4 times higher than the maximum discharge measured in the Petitcodiac River (540 $L/s/km^2$).

Maximum, minimum and mean annual discharges were also calculated for each year at both stations (Table 6). As reported by Caissie (2000), the highest mean annual flows were recorded for both stations during the late 1970s and early 1980s. This trend is especially visible when looking at five-year moving average for station 01BU002 (Petitcodiac River, Figure 2). Minimum mean annual flows were reached in the late 1980s at station 01BU002 (Figure 2). Between 1985 and 1989, mean annual flows were consistently less than 7.9 m^3/s, which is the mean for the entire period of measurement. On Turtle Creek, the same period was also characterised by annual means below the average Of 3.57 m^3/s for the entire period of observation (Table 6).

4.2.2 Flow duration analysis

Monthly flow duration analyses were performed for Turtle Creek (station 01BU003, Table 7) and for the entire Petitcodiac drainage basin at the causeway (from Caissie 2000, Table 8) using historical data. The highest observed value (0% exceedance) reached a maximum in November (96.3 m^3/s) and March (91.8 m^3/s) at Turtle Creek (Table 7), while they were in April (730 m^3/s) and January (414 m^3/s) for the Petitcodiac River at the Causeway (Table 8).

Monthly means show that the lowest mean monthly discharge occurred in August and September at Turtle Creek (0.77 m^3/s; and 0.79 m^3/s respectively, Table 7). For the entire basin, the monthly means for the same months are 7.68 m^3/s and 7.10 m^3/s respectively (Caissie 2000). Table 7 shows that the monthly means at Turtle Creek are exceeded between 30% and 40% of the time during the spring months (March to June), while they are typically exceeded between 20% and 30% of the time for the other months. For the Petitcodiac River at the Causeway, mean monthly flows are exceeded 30% of the time in April and November, and 20% of the time for the other months (Table 8).

4.2.3 Flood and low flow frequency analysis

Prior to performing flood frequency analyses, a Kendall test for stationarity was performed on the Turtle Creek data, which revealed that there is no significant trend in the flow time series of station 01BU003 ($|K| = 0.762$, $p = 0.45$). When the data set from Turtle Creek was split in two sub-samples (1962-1983 and 1983-2000), a Wilcoxon test also confirmed that the means of the two sub-samples were not different ($|W| = 0.836$, $p = 0.40$).

Caissie (2000) had found a small decreasing trend in the annual flood data of the Petitcodiac River at the causeway, which is attributed to the high flood value of 1962 (730 m^3/s).

As described in section 3, flood data (annual maximum daily flows) were fitted with three different distribution functions (LN3, Gumbel, LP3) using the method of moments. Results showed that the estimated 2-year flood ranged between 36.6 m^3/s and 37.1 m^3/s at Turtle Creek (Table 9). For the same recurrence interval, floods for the Petitcodiac at the Causeway were calculated to be between 287 m^3/s and 284 m^3/s (Caissie 2000). A 100-year flood at Turtle Creek varied between 93.4 m^3/s and 95.7 m^3/s, while it was calculated to be between 617 m^3/s and 673 m^3/s for the Petitcodiac River at the causeway (Table 9).

Prior to performing a low flow analysis on Turtle Creek, stationarity was verified using the Kendall test (Kendall, 1975). No significant trends were found ($|K| = 1.31$, $p = 0.19$). The Wilcoxon test revealed that the low flow series is not homogenous. When split in two series (1962-1983 and 1984-2000), means of the sub-samples were shown to be significantly different at a confidence level of 5%, but not significantly different at a confidence level of 1% ($|K| = 2.23$, $p = 0.026$). Further analysis was carried out by applying the bayesian procedure, proposed initially by Lee and Heghinian (1977), adapted by Ouarda et al. (1999) for the analysis of hydrometric data, and revised by Perreault et al. (2000) for the detection of shifts in the mean of hydrological and meteorological time-series. This procedure provides an approach to characterise when and by how much a single change has occurred in a sequence of random variables.

Results of this approach show that there is a strong ($p=0.98$) probability that a shift in the means of annual low flows occurred in the time series. The mode of the distribution of probable years of occurrence of this shift is 1984 (standard deviation of 6.8 years). The mode of the distribution of means prior to the shift is 0.37 m^3/s, while the mode for the distribution of means after the shift is 0.27 m^3/s.

Based on the conclusions of the Bayesian analysis of low flow time series, it was decided to break the time series in two subsets (1962-1984 and 1984-2000), and to perform separate low flow frequency analysis for each subset.

The Type 3 Extremal distribution (T3E) was fitted to annual minimum flows at Turtle Creek (two subsets) and for the Petitcodiac River at the Causeway (Table 10). For the first period (1962-1983) a two-year low flow was calculated to be 0.37 m^3/s. For the second period, (1984-2000) a two-year low flow was 0.28 m^3/s at Turtle Creek. Low flows with recurrence periods of 5 years at Turtle Creek were calculated to be 0.26 m^3/s for the first period and 0.19 for the second (Table 10).

For the Petitcodiac River at the Causeway, Caissie (2000) calculated the two-year low flow to be 1.4 m^3/s and the 10-year low flow to be 0.68 m^3/s (Table 10).

This hydrological information will assist in explaining water quality fluctuations in the context of fluctuating flows.

4.2.4 Transposition of data to ungauged basins

Mean, flood and low flow information calculated for the Petitcodiac River and Turtle Creek were transferred to other drainage basins using the ratio of drainage area (Table 11). Because of the difference in specific discharges between the two gauged basins, mean flood and low flow values transferred using the Petitcodiac River as a reference station are different than values calculated using Turtle Creek as a reference station. Mean annual discharge and flood values pro-rated from station 01BU002 (Petitcodiac) are typically 65% to 75% smaller than those transferred using station 01BU003 (Turtle Creek) as a reference.

Low flow values pro-rated from the Petitcodiac are also typically 50% to 65% smaller than those pro-rated from Turtle Creek (Table 11).

For instance, a two-year flood for Fox Creek was calculated to be 0.66 m^3/s using Petitcodiac data, while it was calculated to be 0.92 m^3/s using Turtle Creek data (Table 11). A two-year low flow for the same tributary was calculated to be 30 L/s using station 01BU002 as a reference, while it has a value of 100 L/s if the reference station is 01BU003 (Table 11). This may be indicative that our initial assumption of a relative homogeneity in the hydrological characteristics of sub-basins may need to be reviewed. Such a detailed analysis is beyond the scope of the present mandate, however.

5.0 WATER QUALITY

5.1 DESCRIPTIVE STATISTICS

Descriptive statistics calculated from all available water quality data are presented in Table 12. Based on median values, the waters of the watershed can be generally classified as slightly alkaline (pH slightly above neutrality) with moderate hardness and nutrient loading. Among the nutrients, PO_4 levels are relatively high with a median of 0,02 mg/L and a 75% percentile of 0,04 mg/L. Most metals are generally in low concentrations with the exception of aluminium and iron, which are often found in relatively high concentrations. High levels of copper, lead and zinc have also been observed in a small number of samples, with maximum values of 60, 50 and 906 μg/L respectively.

5.2 COMPARISON TO CANADIAN WATER QUALITY GUIDELINES (CWQG)

A comparison to CWQG is provided in Table 13. For the 1975-79 period, only six parameters are available for comparison to the CWQG: cadmium, dissolved oxygen, lead, mercury, pH and zinc. Zinc levels were above the guideline in all of the nine samples. This may have been caused by the fact that the detection limit was higher than the current guideline value for aquatic life. Cadmium and lead were never detected in the samples; however the detection limit used was greater than the value of the guideline and therefore it cannot be excluded that some of the values were above the guidelines. As for pH, only 5 values out of 97 were below the recommended range of 6,5 – 9. Dissolved oxygen was always within the acceptable range for aquatic life (5,5 – 9,5 mg/L).

Between 1997 and 2000, aluminium and iron were above the guidelines in 39% and 50% of the samples, respectively. It should be noted that for chromium, the criteria used for the comparison is applicable to hexavalent chromium (CrVI), while laboratory results are given in total extractable chromium, which may include both CrVI and the less toxic trivalent species (CrIII). The guideline for CrIII is 8,9 μg/L as compared to 1,0 μg/L for CrVI. The frequency of values above the guideline reported for chromium (67%) treats all chromium as CrVI as no attempt was made to estimate the fraction present as CrVI. This value should thus be considered as conservative.

To a lesser extent, values above the CWQG are reported for other parameters, with frequencies lower than 10%. These parameters are arsenic, cadmium, dissolved oxygen, NO_2, lead, pH and zinc.

5.3 SPATIAL VARIABILITY (1997-2000)

Nineteen different water bodies (rivers or their tributaries) have been sampled during the 1997-2000 period. In order to assess the spatial heterogeneity within the watershed, cluster analyses have been performed at the scale of the water body. These analyses were done for two categories of water quality parameters: inorganic (Table 14) and organic (Table 15).

For inorganic parameters, the results indicate three distinct groups of water bodies within the watershed, as seen in Table 16 and Figure 3. The list of parameters used in the analysis, as well as the average value for each cluster, are presented in table 14. The dendrogram illustrating the different clusters is presented in Figure 3(a). Table 16 lists the rivers included in each cluster for inorganic parameters. The results show that the Memramcook River clearly stands out and forms one of the clusters by itself (cluster INORG2). This illustrates the marine influence that affects both of the stations sampled in this river, especially station PWMG #36, at College Bridge. Another cluster (cluster INORG3) only includes Jones Lake with higher mean concentrations of metals, including lead. Cluster INORG3 comprises all the other sampling stations.

The second cluster analysis, performed on organic and bacterial (E Coli) water quality parameters also showed three groups (Table 17, Figure 3(b)). Rabbit Brook and the west Branch of Halls Creek were grouped in the same cluster (ORG2), characterised by high mean E coli concentrations (3292 MPN/100 mL; Table 15) and high Nitrate concentration (mean of 0.98 mg/L; Table 15). Cluster ORG3 includes Fox Creek, Humphrey Brook, Jones

Lake, the Memramcook River and Mill Creek. They have higher Nitrogen (TKN=0.64 mg/L) concentrations and higher phosphate (PO_4 = 0.06 mg/L) than the other two clusters.

5.4 TEMPORAL VARIABILITY (1975-1979 AND 1997-2000)

Long-term variations in various water quality parameters are presented in Figures 4 (Petitcodiac River) and 5 (Jonathan Creek). Several parameters were measured only during the second period of observation (1997-2000) and therefore the range of parameters for which comparisons are possible is limited to nutrients, pH, alkalinity and colour.

In the Petitcodiac River (Figure 4), one of the most important differences between the two periods is an apparent rise in water pH. While pH values were generally nearly neutral (i.e. 7.0) in the 1970's, values below 7.5 were uncommon during the second period where median values were consistently close to 8.0 (slightly alkaline). Temporal trends are also observed in organic nitrogen (TKN) and orthophosphates (PO_4). These parameters were observed in very high concentrations in some occasions in the 1970's, with maxima in the range of several mg/L. Such extreme values were not observed in the recent period where concentrations were consistently lower. As for NO_x (nitrates – nitrites), no clear trend is apparent in the Petitcodiac data.

In Jonathan Creek (Figure 5), an apparent increase in pH is also observed, albeit less important than in the Petitcodiac River. Median values were close to 8.0 in the second period, about one unit higher than in the 1970's. Othophosphates levels were relatively high in the 1970's and are consistently lower and less variable in the recent period. The same trend is observed for NO_x. No significant trend is observed in the other parameters, including TKN.

Data from the Petitcodiac River and Jonathan Creek suggest a decrease in nutrient loading between the two periods. In particular, PO_4 levels were markedly reduced, which is favourable for the quality of the aquatic environment where this nutrient can be a major cause of eutrophication.

Short-term (monthly) variations have also been investigated. Data collected at four stations of the Petitcodiac (stations PWMG # 4, 10, 15 & 16) during the 1997-2000 period have been used to document these variations. Results are presented in Figure 6. Polynomial trends (second degree) are presented. It should be noted that the amount of variability explained by these models varies greatly from one parameter to another and a large amount of unexplained variability (variability caused by other factors than monthly variations) persists in all cases. The amount of variance explained by each model is quantified using the «RSquare adjusted», shown below the graphs. A model explaining 70% of the variance would have a Rsquare adjusted of 0.7. The trends are presented for illustrative purposes only.

Many parameters showed important variations over months. Aluminium concentrations were higher in June and October and lower in August and September. The same pattern is observed for *E. coli*, iron, NH_3 and PO_4. By contrast, conductivity and pH showed opposite trends, with maximum values in mid-summer. These trends are directly related to the hydrological regime in the watershed. August and September are the months where the lowest flows are observed in the Petitcodiac River (see Table 7). In baseflow conditions, the relative importance of groundwater flow is greater as dilution from rainfall is minimal. Groundwater typically demonstrates higher concentrations in major ions (e.g. Ca, Mg, K) which translates into higher electrical conductivity. Similarly, pH is generally higher in groundwater and greater pH values are thus expected in baseflow conditions. On the other hand, many pollutants, especially nutrients, are significantly related to precipitation and storm events and are expected to reach maximum values at high flows.

Although the months at which observations are available do not cover the months of highest discharge (April, May), the data suggest that various parameters, including aluminium, iron and *E. Coli*, are sensitive to seasonal variations in discharge. It cannot be excluded that high concentrations of various parameters, especially aluminium and nutrients would be found in maximum concentrations during the spring freshet and storm events. Sampling during these events could provide additional information about the general state of the watershed and potential sources of contaminants of the Petitcodiac River.

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TABLES

Table 1. Petitcodiac sub-catchments, with drainage basin areas.

Name	Drainage area (km^2)
Petitcodiac at Causeway	1360
Pollet River	309
Little River	297
North River	290
Turtle Creek	204[1]
Anagance River	144
Halls Creek (including West Branch to Humphrey Brook)	123
Weldon Creek	92.9
Mill Creek	51.4
Jonathan Creek	50.4
Bennett Brook	45.5
Fox Creek	33.0

[1] Gauged sub-basin = 129 km^2

Table 2. Summary of water quality data collection.

Year	Month	Dates	Sampling performed by
1975	May	16 , 21, 26, 28, 29	DOE
	August	13, 15, 25	DOE
1976	May	13	DOE
	June	9, 10	DOE
	July	6, 7	DOE
	November	16	DOE
1977	May	11, 12	DOE
	June	5, 7, 8	DOE
	July	11, 19	DOE
	September	19	DOE
1979	July	4	DOE
1997	June	3, 5, 18	ELG
	July	15, 16	ELG, PWMG
	August	11, 12, 17	ELG
	September	13, 14, 15	PWMG
	October	13	PWMG
1998	June	17, 18	ELG
	July	30	ELG
	August	11, 12, 13	ELG
	September	2, 13	PWMG
	October	12	PWMG
1999	June	9, 21, 22	ELG
	July	12, 27, 28	ELG, PWMG
	August	16, 19, 29	PWMG
	September	1, 13, 22	ELG, PWMG
	October	3, 7, 25, 27, 31	PWMG
	November	2	PWMG
2000	July	6	PWMG
	August	14, 15	ELG, PWMG
	September	7, 24	PWMG
	October	29	PWMG

Table 3. Air temperature statistics from the Moncton Airport during the two periods of interest

Month	Statistics	1975	1976	1977	1997	1998	1999	2000
April	Minimum	-5.9	-6.1	-6.7				
	Maximum	7.8	11.7	14.3				
	Mean	1.2	3.9	2.6				
May	Minimum	2.0	4.7	1.4	4.2	6.4	3.9	
	Maximum	17.2	18.6	22.4	15.6	19.1	21.8	
	Mean	9.6	10.8	9.5	9.0	12.4	13.4	
June	Minimum	4.8	5.6	9.7	6.6	8.5	3.9	
	Maximum	23.9	23.1	20.1	23.4	21.6	21.8	
	Mean	15.5	16.6	14.19	14.1	14.7	13.4	
July	Minimum	13.9	12.8	13.0	13.0	14.2	14.8	14.5
	Maximum	25.0	22.8	24.2	24.2	24.6	26.0	21.4
	Mean	20.6	18.1	18.3	18.3	19.6	19.9	18.1
August	Minimum	12.0	11.7	13.8	13.3	14.0	13.7	14.4
	Maximum	23.9	26.1	25.0	23.3	24.1	22.2	22.4
	Mean	17.7	18.0	17.9	17.7	18.7	18.0	18.2
September	Minimum	7.9	5.9	6.5	5.8	8.0	11.3	4.2
	Maximum	23.3	19.2	18.5	20.3	18.5	22.8	20.5
	Mean	13.6	13.0	11.9	13.8	13.6	17.2	12.7
October	Minimum		-2.2	0.1		1.4	0.6	2.8
	Maximum		16.7	15.4		13.3	14.5	16.8
	Mean		6.7	5.6		7.2	6.5	8.1
November	Minimum		-6.7					
	Maximum		8.6					
	Mean		-0.1					

Table 4. Precipitation (mm) statistics from the Moncton airport, during the periods of interest.

Month		1975	1976	1977	1997	1998	1999	2000
April	Rain	12.6	56.6	40.7				
	Snow	58.4	8.7	18.4				
May	Rain	107.2	89.3	97.9	58.8	98.3	29.7	
	Snow	2	9.3	23	0	0	0.4	
June	Rain	79.8	97.9	169	104.7	51.5	32	
	Snow	0	0	0	0	0	0	
July	Rain	81.9	73.9	92.3	92.3	49.3	100.4	68.6
	Snow	0	0	0	0	0	0	0
August	Rain	34.8	85.6	88.3	43.3	114.7	120.5	0
	Snow	0	0	0	0	0	0	0
September	Rain	129.1	80.4	143.7	89.7	112.1	231.8	76.2
	Snow	0	0	0	0	0	0	0
October	Rain		134.8	12.6	12.6	224.6	88	147
	Snow		0	14.1	14.1	0	2.8	0
November	Rain		68.2					
	Snow		3.3					
Total Rain May-Sept		425.6	427.1	591.2	388.8	425.9	514.4	

Table 5. Hydrological characteristics of the Petitcodiac River at Causeway and Turtle Creek.

	Peticodiac		Turtle Creek	
Parameters	Flow statistics (pro-rated at Causeway)[1] (m^3/s)	Equivalent specific discharge ($m^3/s/km^2$)	Flow statistics (m^3/s)	Equivalent specific discharge ($m^3/s/km^2$)
Drainage basin area (km^2)	1360		129[2]	
Median flow	11.9	0.009	1.70	0.013
Mean annual flow	27.3	0.020	3.58	0.028
Minimum daily discharge	0.36	0.0003	0.14	0.0011
Maximum daily discharge	730	0.54	96.3	0.75

[1] From Caissie (2000)
[2] Gauged area

Table 6. Annual flow statistics, stations 01BU002 (Petitcodiac) and 01BU003 (Turtle Creek).

	01BU002				01BU003		
Year	Minimum	Mean	Maximum	Mean at causeway[1]	Minimum	Mean	Maximum
1961	0.35	5.43	38.50	18.90			
1962	0.83	9.24	210.00	32.14	0.58	4.38	30.60
1963	0.80	9.80	125.00	34.10	0.29	4.97	76.70
1964	0.31	6.52	114.00	22.68	0.31	2.80	73.90
1965	0.18	4.08	30.00	14.19	0.25	1.80	13.80
1966	0.10	5.13	56.90	17.84	0.30	2.39	19.60
1967	0.45	9.49	136.00	33.02	0.28	4.28	42.20
1968	0.28	8.12	106.00	28.25	0.22	3.84	30.60
1969	0.33	5.82	65.10	20.25	0.50	3.75	58.30
1970	0.43	5.72	75.60	19.91	0.43	3.23	59.20
1971	0.30	7.89	88.90	27.43	0.28	3.83	37.40
1972	0.59	9.49	106.00	33.00	0.40	5.04	47.90
1973	0.63	9.24	86.90	32.15	0.50	3.78	26.50
1974	0.36	8.46	91.50	29.42	0.32	3.27	41.60
1975	0.25	8.17	101.00	28.41	0.39	4.20	48.70
1976	0.66	9.73	119.00	33.84	0.52	3.85	28.30
1977	0.48	10.36	78.70	36.03	0.35	4.47	41.30
1978	0.23	6.34	75.90	22.04	0.23	2.55	22.60
1979	0.63	13.62	113.00	47.38	0.44	5.11	37.10
1980	0.48	7.74	63.70	26.92	0.40	3.17	33.10
1981	0.81	11.71	91.90	40.73	0.35	5.12	46.70
1982	0.62	8.00	80.00	27.82	0.51	3.31	45.20
1983	0.68	7.19	83.60	25.02	0.40	3.54	34.10
1984	0.88	9.22	80.40	32.06	0.34	3.99	39.30
1985	0.25	4.19	40.60	14.57	0.25	2.60	28.20
1986	0.50	6.70	73.00	23.30	0.32	2.61	20.50
1987	0.31	5.73	115.00	19.94	0.20	2.94	41.10
1988	0.35	6.17	105.00	21.46	0.28	3.53	44.30
1989	0.39	4.66	72.70	16.20	0.22	1.83	26.90
1990	0.40	10.57	101.00	36.77	0.35	4.95	37.30
1991	0.37	8.46	65.50	29.44	0.14	3.62	35.40
1992	0.35	7.20	94.00	25.05	0.25	2.55	24.50
1993	0.40	8.82	57.20	30.66	0.31	4.15	31.90
1994	0.26	7.69	88.20	26.76	0.28	3.39	37.90
1995	0.19	5.76	40.50	20.05	0.22	3.17	24.00
1996	0.33	8.74	73.20	30.41	0.38	4.78	55.10
1997	0.25	6.61	68.50	22.98	0.29	2.38	29.20
1998	0.18	8.55	118.00	29.74	0.34	4.60	96.30
1999	0.26	8.83	120.00	30.70	0.23	3.46	64.50
2000	0.42	7.41	64.10	25.78	0.21	2.64	26.20
1961-2000	0.10	7.86	210	27.33	0.143	3.57	96.30

[1]Calculated by multiplying mean at station 01BU002 by the ratio of gauged area to drainage basin area at causeway.

Table 7. Flow duration analysis (using daily discharge in m3/s, from 1962-2000) and mean monthly flows for Turtle Creek.

Percentage(%)[1]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	55.1	59.2	91.8	49.8	66.0	28.2	31.1	12.7	64.5	46.5	96.3	9.11
10	4.84	5.20	10.80	19.50	15.70	4.67	2.23	1.33	1.18	4.67	8.35	73.90
20	3.10	3.14	6.80	14.20	10.20	3.31	1.51	0.95	0.85	2.83	5.52	6.17
30	2.50	2.42	4.73	11.50	7.50	2.62	1.14	0.70	0.67	1.87	4.08	4.56
40	2.09	1.89	3.55	9.57	5.97	2.13	0.94	0.59	0.56	1.26	3.17	3.11
50	1.79	1.53	2.80	7.93	4.98	1.77	0.81	0.51	0.48	0.93	2.28	2.44
60	1.50	1.28	2.14	6.87	4.21	1.49	0.71	0.45	0.42	0.72	1.71	1.95
70	1.19	1.05	1.58	5.72	3.57	1.27	0.63	0.41	0.38	0.57	1.30	1.54
80	0.91	0.85	1.10	4.64	2.96	1.10	0.54	0.37	0.34	0.40	0.91	1.18
90	0.69	0.65	0.84	3.55	2.20	0.92	0.46	0.33	0.29	0.32	0.58	0.60
100	0.31	0.09	0.32	1.25	0.91	0.33	0.14	0.18	0.20	0.25	0.30	0.23
Mean monthly flows	2.67	2.59	4.68	10.06	7.43	2.47	1.23	0.77	0.79	2.07	3.93	4.34

[1]Percentage = percentage of time equalled or exceeded

Table 8. Flow duration analysis (using daily discharge in m3/s, from 1961-2000) and mean monthly flows for the Petitcodiac River at the Causeway[1].

Percentage(%)[2]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	414	286	383	730	473	228	302	173	211	320	369	351
10	31.5	37.5	91.8	178	106	40.5	23.9	15.1	17.4	41.6	66	71.3
20	21.4	21.2	50.4	129	61	24.5	14.2	9.5	8.6	26.4	41.9	40.7
30	16.4	14.1	33.4	98.6	45.3	17.5	9.9	6.3	6	16.9	30.3	28.4
40	12.9	10.7	23.9	78.1	36.2	13.4	7.4	4.2	4.3	10.8	23.4	21.1
50	10.7	8.5	17.1	63.9	29.7	10.7	5.6	3.2	3.3	7.2	17.9	16.7
60	9	7.1	13	53.2	25.2	8.8	4.2	2.6	2.7	5.2	13.9	13.6
70	7.5	5.9	9.4	43.6	20.2	7.5	3.2	2.1	2	3.6	10.1	10.7
80	6.1	4.9	6.2	34	16.4	5.8	2.6	1.6	1.6	2.6	6.4	7.8
90	3.6	3.3	4.3	27.3	12.4	4.3	1.8	1.3	1.2	1.7	4	4.1
100	1.7	1.5	1.4	6.6	3.8	2.1	0.79	0.36	0.36	0.71	1.23	0.87
Mean monthly flows	18.2	17.0	36.2	85.2	46.5	18.8	12.7	7.68	7.1	18.4	29	30.6

[1]from Caissie (2000)

[2]Percentage = percentage of time equalled or exceeded

Table 9. Flood Frequency analysis of Turtle Creek and the Petitcodiac River (at Causeway) using different statistical distributions. Floods shown in m³/s.

Turtle Creek	Recurrence Interval (years)					
	2	5	10	20	50	100
LN3	36.7	51.5	61.5	71.4	84.5	94.5
Gumbel	37.1	52.2	62.2	71.7	84.1	93.4
LP3	36.6	51.4	61.6	71.7	85.2	95.7

Petitcodiac at Causeway[1]	Recurrence Interval (years)					
	2	5	10	20	50	100
LN3	294	391	449	503	569	617
Gumbel	290	393	461	526	610	673
LP3	287	383	448	512	596	661

[1] From Caissie (2000)

Table 10. Low-flow Frequency analysis of Turtle Creek and the Petitcodiac River (at Causeway) using different statistical distributions. Flows shown in m³/s.

Turtle Creek 1962-1983	Recurrence Interval (years)					
	2	5	10	20	50	
T3E	0.374	0.256	0.184	0.119	0.041	

Turtle Creek 1984-2000	Recurrence Interval (years)					
	2	5	10	20	50	
T3E	0.277	0.191	0.135	0.082	0.016	

Petitcodiac at Causeway[1]	Recurrence Interval (years)					
	2	5	10	20	50	100
T3E	1.43	0.897	0.678	0.536	0.414	0.355

[1] From Caissie (2000)

Table 11. Mean, flood and low flows (m^3/s) for sub-basins of the Petitcodiac watershed, pro-rated from stations 01BU002 and 01BU003.

	Mean annual discharge		2 year Flood		10 year flood		100 year flood	
Reference station	01BU002	01BU003	01BU002	01BU003	01BU002	01BU003	01BU002	01BU003
Pollett	6.20	8.65	65.96	87.91	102.86	147.31	147.75	226.36
Little	5.96	8.32	63.40	84.50	98.86	141.59	142.01	217.57
North	5.82	8.12	61.90	82.50	96.53	138.26	138.67	212.44
Anagance	2.89	4.03	30.74	40.97	47.93	68.65	68.86	105.49
Halls Creek[1]	2.47	3.44	26.26	34.99	40.94	58.64	58.81	90.10
Weldon Creek	1.86	2.60	19.83	26.43	30.92	44.29	44.42	68.05
Mill Creek	1.03	1.44	10.97	14.62	17.11	24.50	24.58	37.65
Jonathan Creek	1.01	1.41	10.76	14.34	16.78	24.03	24.10	36.92
Bennett Brook	0.91	1.27	9.71	12.94	15.15	21.69	21.76	33.33
Fox Creek	0.66	0.92	7.04	9.39	10.98	15.73	15.78	24.17

	2-year low flow			10-year low flow		
Reference station	01BU002	01BU003 1962-1983	01BU003 1984-2000	01BU002	01BU003 1962-1983	01BU003 1984-2000
Pollett	0.32	0.90	0.66	0.15	0.44	0.32
Little	0.31	0.86	0.64	0.15	0.42	0.31
North	0.30	0.84	0.62	0.14	0.41	0.30
Anagance	0.15	0.42	0.31	0.07	0.21	0.15
Halls Creek	0.13	0.36	0.26	0.06	0.18	0.13
Weldon Creek	0.10	0.27	0.20	0.05	0.13	0.10
Mill Creek	0.05	0.15	0.11	0.03	0.07	0.05
Jonathan Creek	0.05	0.15	0.11	0.03	0.07	0.05
Bennett Brook	0.05	0.13	0.10	0.02	0.06	0.05
Fox Creek	0.03	0.10	0.07	0.02	0.05	0.03

[1]Including Humphrey Brook

Table 12. Water quality results – Descriptive statistics

Statistics	Al	Alkalinity	As	BOD	Ca	Cd	Cl	Colour	Conductivity	Cr	Cu	DO	Client-fld
	mg/L	mg/L	µg/L	mg/L	mg/L	µg/L	mg/L	TCU	µSIE/cm	µg/L	µg/L		mg/L
Minimum	0.0005	0.3	0.05	10.5	2.0	0.05	1.4	0.0	23	0.25	0.25		0.5
Percentile 5%	0.0109	8.5	0.05	10.5	3.8	0.05	2.4	5.0	41	0.25	0.25		6.7
Percentile 25%	0.0260	22.4	0.05	10.5	9.1	0.05	10.5	20.0	109	0.80	0.50		8.8
Median	0.0687	38.6	0.05	10.5	23.4	0.05	33.8	40.0	263	1.60	1.00		9.9
Mean	0.1556	43.7	0.76	10.5	27.7	0.13	66.9	59.6	412	2.10	1.74		9.9
Percentile 75 %	0.1510	62.7	1.21	10.5	37.9	0.05	69.5	60.0	441	3.10	1.95		11.0
Percentile 95 %	0.5458	94.8	2.74	10.5	71.2	0.05	158.0	150.0	871	5.30	5.30		13.0
Maximum	5.1000	144.0	10.60	10.5	175.0	5.00	5707.0	5000.0	22700	11.4	60.0		19.0
Count	*565*	*628*	*566*	*1*	*577*	*575*	*566*	*599*	*597*	*566*	*575*		*275*
CWQG	0.100	.	5.0	.	.	0.017	.	.	.	1-8,9	.		5.5

Table 12 (continued). WATER QUALITY RESULTS-Descriptive statistics

DO Field-ELG	E coli	F	FC-MF	Fe	Hg	Hardness	K	Mg	Mn	Na	NH3T	Ni	NO2	NO3	NOX
mg/L	MPN/100 mL	mg/L	CFU/100 mL	mg/L	µg/L	mg/L CaCO3	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	mg/L
2.6	0	0.05	0	0.01	0.05	6.6	0.0	0.4	0.00	1.6	0.01	2.50	0.03	0.01	0.00
6.7	5	0.05	2	0.03	0.05	12.6	0.3	0.7	0.01	2.4	0.01	2.50	0.03	0.03	0.03
8.9	30	0.05	17	0.11	0.05	28.6	0.6	1.4	0.02	9.2	0.01	2.50	0.03	0.03	0.03
9.8	110	0.05	64	0.30	0.05	71.1	0.9	2.9	0.05	23.4	0.01	5.00	0.03	0.03	0.05
9.7	648	0.08	268	0.49	0.08	87.4	1.1	4.4	0.10	45.3	0.03	4.02	0.03	0.15	0.20
10.6	410	0.11	220	0.58	0.05	113.8	1.4	4.6	0.11	43.5	0.02	5.00	0.03	0.13	0.17
12.0	2419	0.20	1088	1.31	0.22	213.7	2.4	8.5	0.37	102.5	0.08	5.00	0.03	0.81	0.88
18.9	24190	0.50	7250	20.40	0.30	2409	48.4	479	2.31	4070	1.58	50.00	0.12	2.10	6.35
234	*557*	*566*	*289*	*566*	*9*	*566*	*566*	*577*	*566*	*566*	*566*	*566*	*277*	*566*	*666*
.	.	.	.	0.300	0.1	.	.	.	.	.	1.37	25.00	0.060	.	.

Table 12 (continued). WATER QUALITY RESULTS-Descriptive statistics

Statistics	Pb	pH field	pH lab	Sb	SO4	SS	Total coliforms	TDS	TEMP Client-fld	TEMP Field-ELG	TKN	TOC	PO4
	µg/L			µg/L	mg/L	mg/L	MPN/100 mL	mg/L	ºC	ºC	mg/L N	mg/L	mg/L
Minimum	0.50	5.8	4.4	0.50	1.27	0.0	69	12.7	4.0	0.5	0.01	0.50	0.00
Percentile 5%	0.50	6.3	6.7	0.50	2.6	0.0	401	21.6	6.0	2.9	0.10	1.63	0.00
Percentile 25%	0.50	6.9	7.3	0.50	4.9	1.3	1083	68.5	10.0	13.6	0.22	4.30	0.01
Median	0.50	7.5	7.7	0.50	14.20	7.5	2419	155.7	13.0	17.0	0.36	7.20	0.02
Mean	1.48	7.3	7.6	0.70	38.63	72.0	3430	186.6	13.1	16.5	0.44	8.17	0.10
Percentile 75 %	0.50	7.8	8.0	0.50	49.7	7.5	2419	230.4	16.6	20.5	0.50	11.20	0.04
Percentile 95 %	2.00	8.0	8.3	0.50	155.8	41.1	15530	482.4	21.0	25.4	0.90	17.2	0.26
Maximum	50.00	8.5	9.2	34.20	813.00	28000.0	36550	1425.3	25.0	28.5	19.0	31.7	12.8
Count	*575*	*110*	*663*	*566*	*566*	*566*	*289*	*250*	*256*	*357*	*665*	*566*	*665*
CWQG	1.00	6.5	6.5	.	.	.	.	.	.	.	.	.	.

Table 12 (continued). WATER QUALITY RESULTS-Descriptive statistics

Statistics	TURB	Zn
	NTU	μg/L
Minimum	0.0	2.50
Percentile 5%	0.00	2.50
Percentile 25%	0.6	2.50
Median	1.5	5.00
Mean	4.9	11.9
Percentile 75 %	4.1	11.0
Percentile 95 %	20.6	38.3
Maximum	172.0	906.0
Count	*578*	*575*
CWQG	.	30

Table 13. Comparison of water quality data to the Canadian Water Quality Guidelines, by period.

Parameter	Unit	CWQ Guideline	1975-1979			1997-2000		
			Total number of measure-ments	Values above CWQG [1]		Total number of measure-ments	Values above CWQG [1]	
				Count	Frequency		Count	Frequency
Al	mg/L	0,1	0	0	-	554	210	38%
As	µg/L	5	0	0	-	566	6	1%
Cd	µg/L	0,017	9 [3]	0	_	566	5	1%
Cr	µg/L	1 [2]	0	0	-	566	381 [2]	67% [2]
DO	mg/L	5,5	62	0	0%	447	11	2%
Fe	mg/L	0,3	0	0	-	566	283	50%
Hg	µg/L	0,1	9	1	11%	0	0	-
NH3T	mg/L	1,37	0	0	-	566	1	0%
Ni	µg/L	25	0	0	-	566	2	0%
NO2	mg/L	0,06	0	0	-	277	3	1%
Pb	µg/L	1	9 [4]	0	_	566	48	8%
PH	---	6,5	97	5	5%	566	11	2%
Zn	µg/L	30	9	9	100%	553	23	4%

[1] for DO and pH, values below acceptable range

[2] based on the guideline for hexavalent chromium (Cr VI)

[3] all values below detection limit of 10 µg/L

[4] all values below detection limit of 100 µg/L

Table 14. Cluster analysis based on inorganic parameters. Average values of water quality parameters, by cluster (means and standard deviation).

Cluster #	INORG1		INORG2		INORG3	
Number of waterbodies in cluster	17		1		1	
STATISTICS	Mean	*Std Dev*	Mean	*Std Dev*	Mean	*Std Dev*
Al (mg/L)	0,14	*0,10*	0,30	.	0,73	.
Alkalinity (mg/L)	44,4	*24,6*	22,1	.	53,5	.
Ca (mg/L)	25,3	*19,4*	21,1	.	23,4	.
Cd (µg/L)	0,05	*0,01*	0,06	.	0,08	.
Cl (mg/L)	56,4	*78,8*	538,4	.	63,2	.
Conductivity (µSIE/cm)	337	*346*	1720	.	343	.
Cr (µg/L)	2,08	*1,10*	1,51	.	2,78	.
Cu (µg/L)	1,55	*1,31*	3,66	.	4,33	.
F (mg/L)	0,08	*0,03*	0,10	.	0,17	.
Fe (mg/L)	0,49	*0,37*	1,93	.	1,70	.
Hardness (mg/L CaCO3)	76,4	*55,8*	227,0	.	74,5	.
K (mg/L)	1,05	*0,52*	4,43	.	2,08	.
Mg (mg/L)	3,31	*2,06*	42,32	.	3,90	.
Mn (mg/L)	0,15	*0,17*	0,10	.	0,28	.
Na (mg/L)	37,6	*54,2*	374,4	.	39,9	.
Pb (µg/L)	0,65	*0,30*	0,76	.	3,89	.
PH	7,7	*0,3*	7,1	.	7,8	.
SO4 (mg/L)	30,1	*46,8*	76,1	.	14,5	.
Zn (µg/L)	9,4	*3,9*	71,7	.	19,2	.

Table 15. Cluster analysis based on organic and nutrient parameters. Average values of water quality parameters, by cluster (means and standard deviation).

Cluster #	ORG1		ORG2		ORG3	
Number of waterbodies in cluster	12		2		5	
STATISTICS	Mean	*Std. Dev.*	Mean	*Std. Dev.*	Mean	*Std. Dev.*
Colour (TCU)	30,5	*17,6*	68,6	*16,9*	106,4	*12,7*
E coli (MPN/100 mL)	245	*185*	3292	*1531*	784	*762*
NH3T (mg/L)	0,02	*0,02*	0,07	*0,07*	0,05	*0,02*
NO3 (mg/L)	0,08	*0,10*	0,98	*0,30*	0,13	*0,12*
TKN (mg/L as N)	0,26	*0,12*	0,49	*0,15*	0,64	*0,13*
TOC (mg/L)	5,6	*3,0*	5,6	*0,6*	14,0	*2,9*
PO4 (mg/L PO4)	0,01	*0,01*	0,04	*0,03*	0,06	*0,03*

Table 16. Cluster analysis based on inorganic parameters. List of waterbodies by cluster.

Cluster #	Water body
INORG1	Anagance River
	Bennett Brook
	Fox Creek
	Halls Creek
	Humphreys Brook
	Jonathan Creek
	Little River
	Mill Creek
	North Branch Halls Creek
	North River
	Petitcodiac River
	Pollett River
	Prosser Brook
	Rabbit Brook
	Turtle Creek
	Weldon Creek
	West Branch Halls Creek
INORG2	Memramcook River
INORG3	Jones Lake

Table 17. Cluster analysis based on organic and nutrient parameters. List of waterbodies by cluster.

Cluster #	Water body
ORG1	Anagance River
	Bennett Brook
	Halls Creek
	Jonathan Creek
	Little River
	North Branch Halls Creek
	North River
	Petitcodiac River
	Pollett River
	Prosser Brook
	Turtle Creek
	Weldon Creek
ORG2	Rabbit Brook
	West Branch Halls Creek
ORG3	Fox Creek
	Humphreys Brook
	Jones Lake
	Memramcook River
	Mill Creek

FIGURES

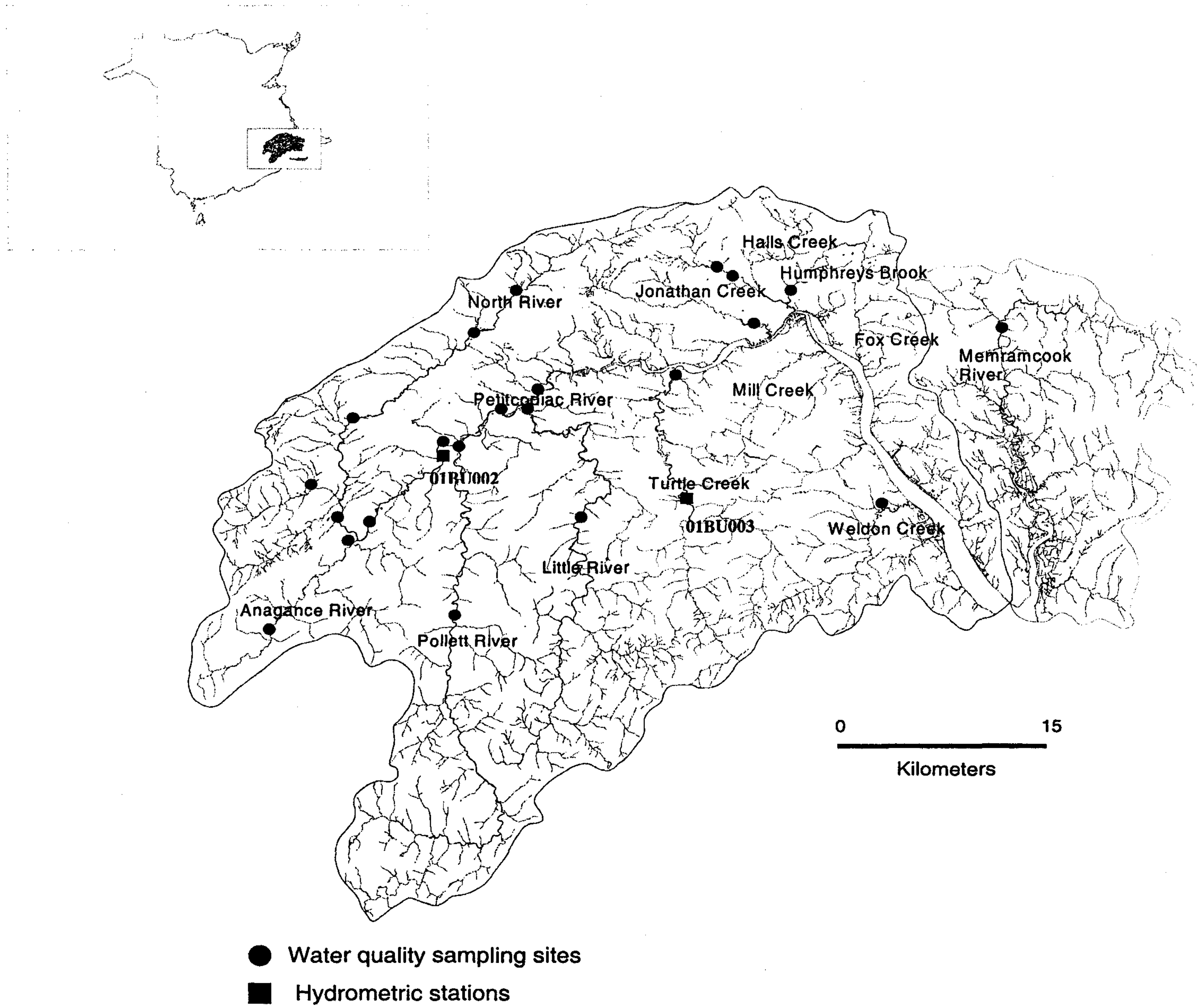


Figure 1. Map of the Petitcodiac watershed showing locations of sampling and hydrometric stations

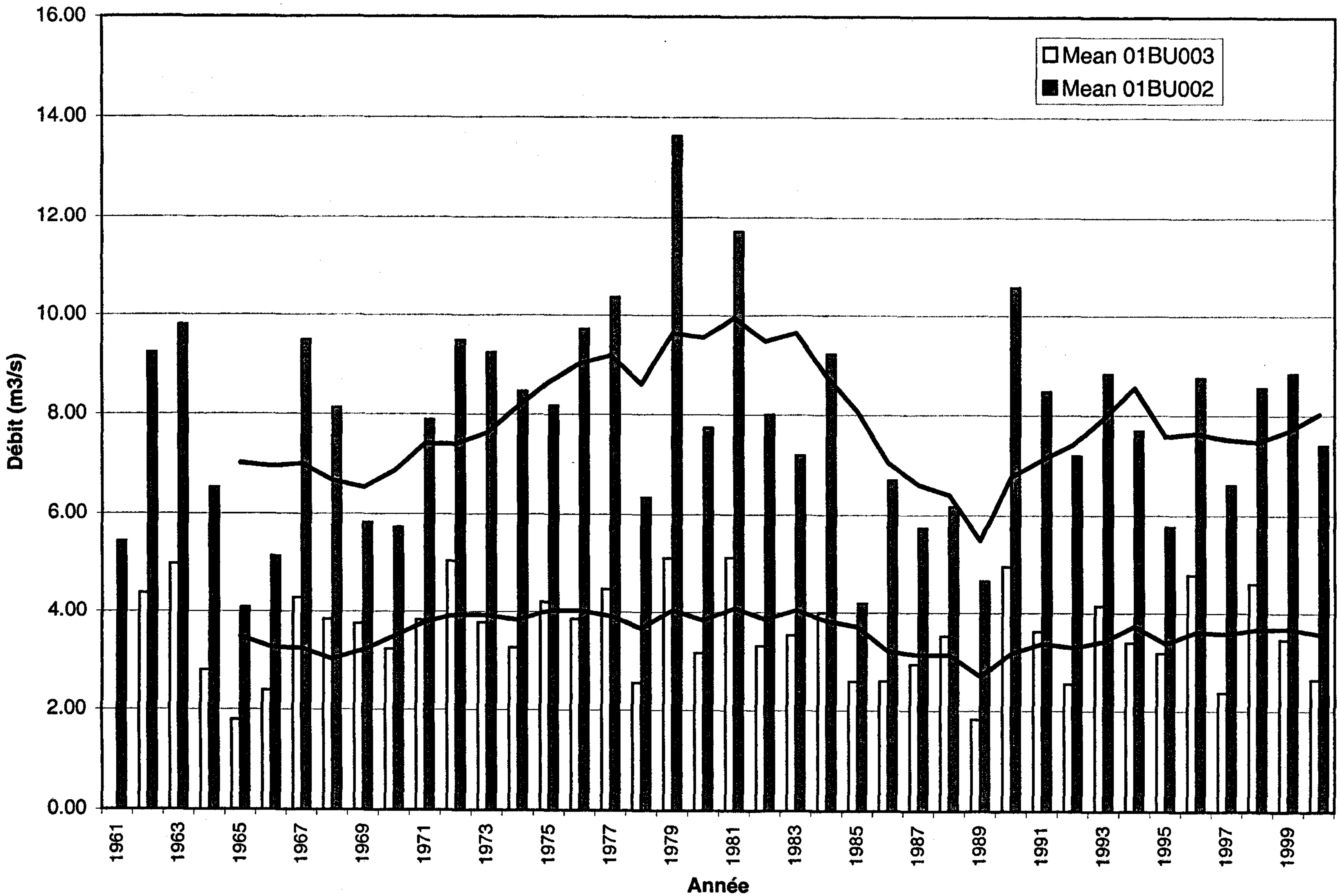
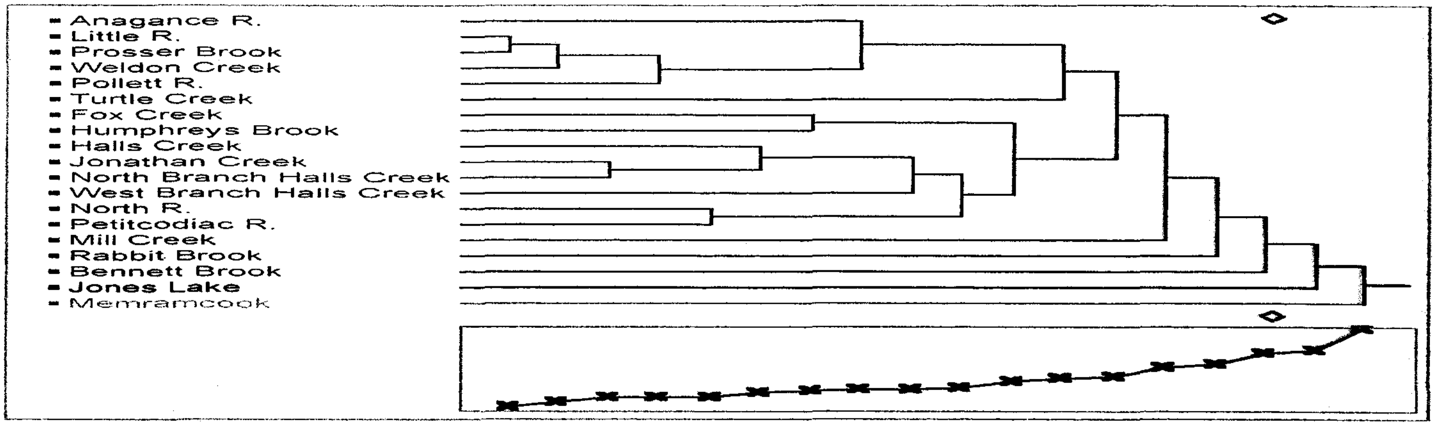


Figure 2. Mean annual discharge at stations 01BU002 and stations 01BU003. Lines

a)



b)

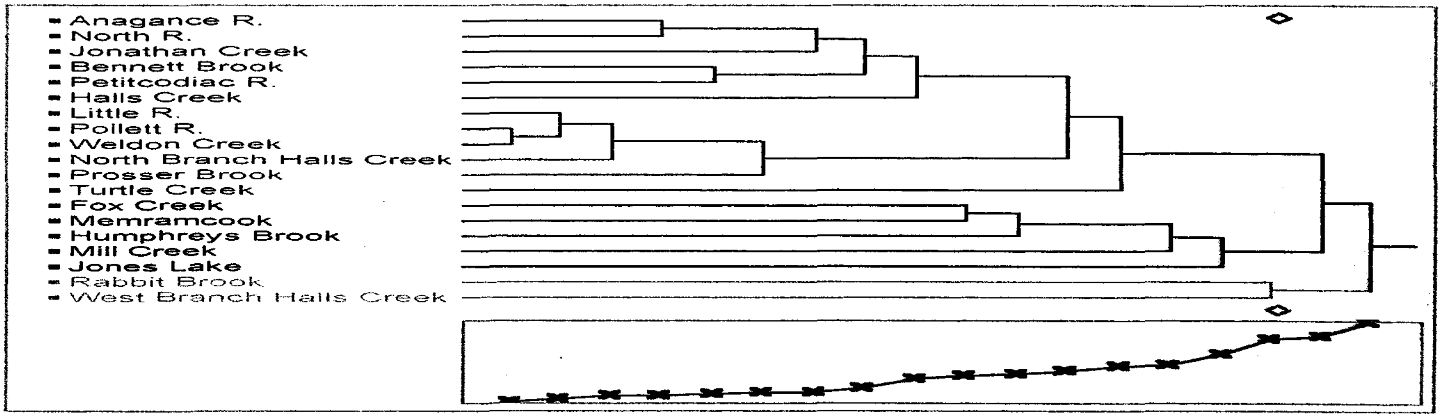


Figure 3. Results of cluster analysis based on a) inorganic parameters and b) organic and nutrient parameters. Parameters used in the analysis are listed in tables 14 and 15. The dendrogram shows the degree of similarity between the different water bodies within the Petitcodiac watershed. Hierarchical clustering using average linkage.

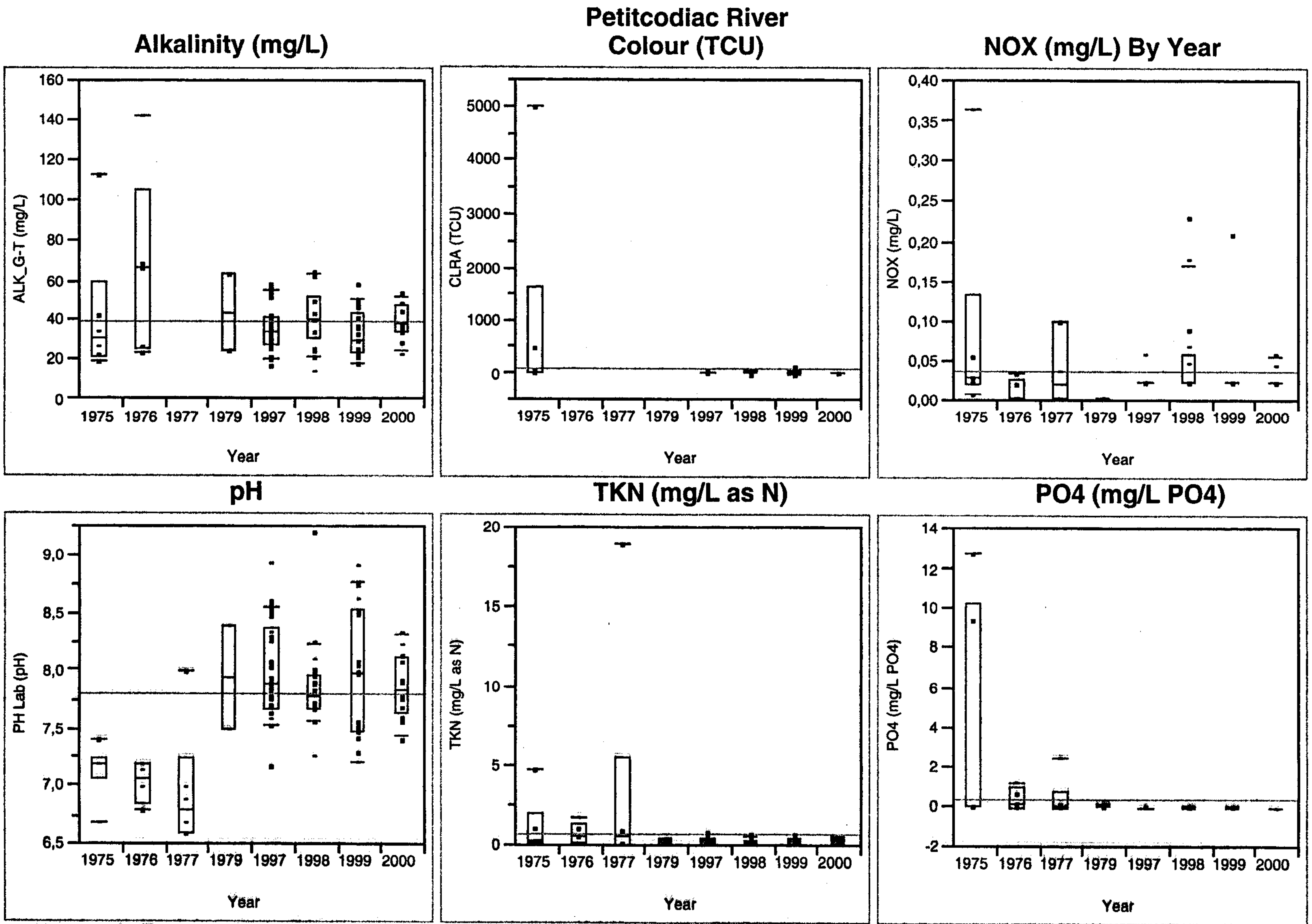


Figure 4. Temporal variations in selected water quality parameters in the Petitcodiac River, 1975-2000. Graphics show individual values and quantile boxes (10th, 25th, 50th, 75th, and 90th quantiles)

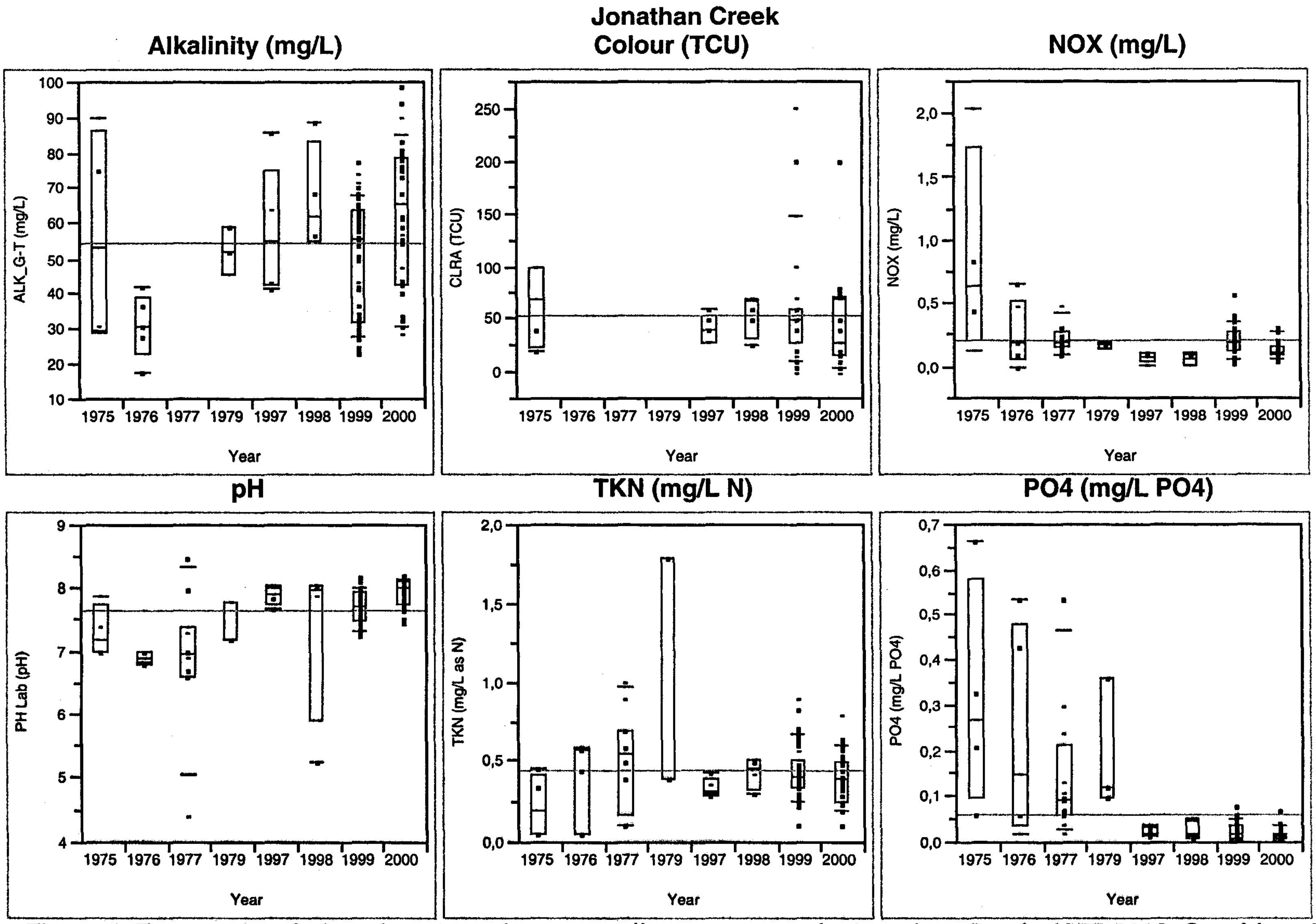
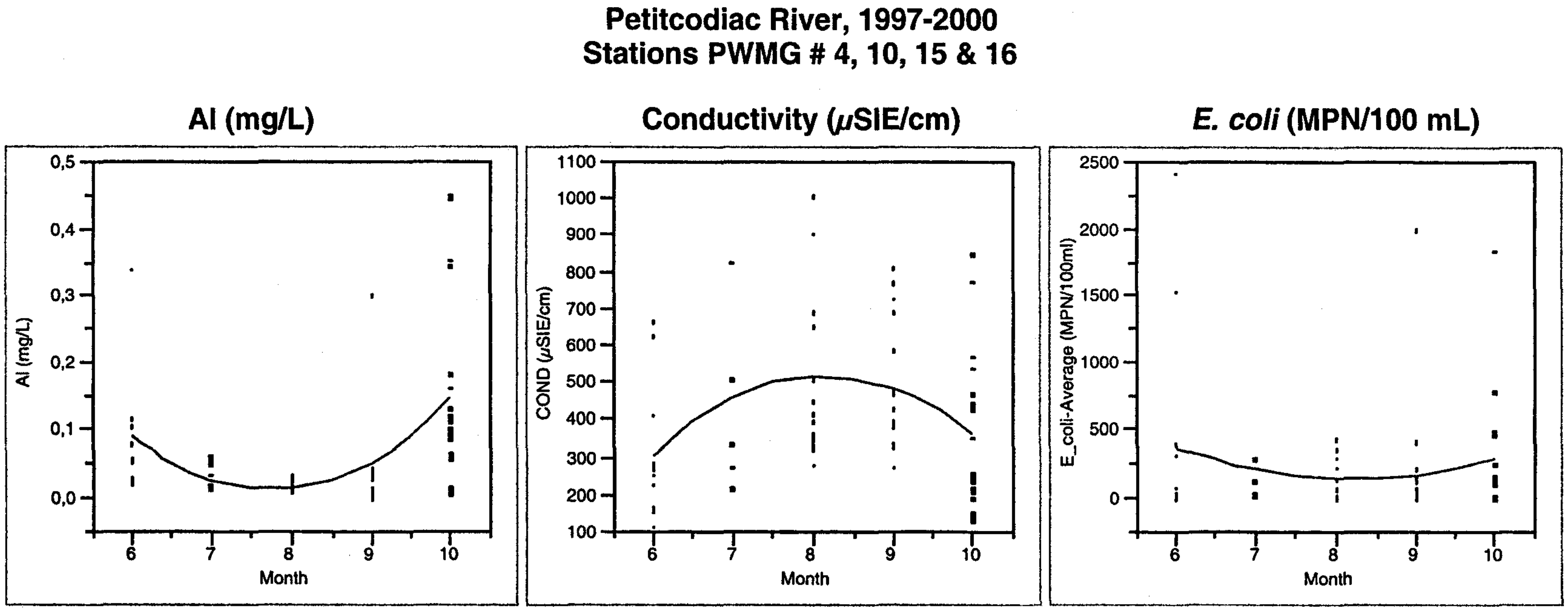


Figure 5. Temporal variations in selected water quality parameters in Jonathan Creek, 1975-2000. Graphics show individual values and quantile boxes (10th, 25th, 50th, 75th, and 90th quantiles)

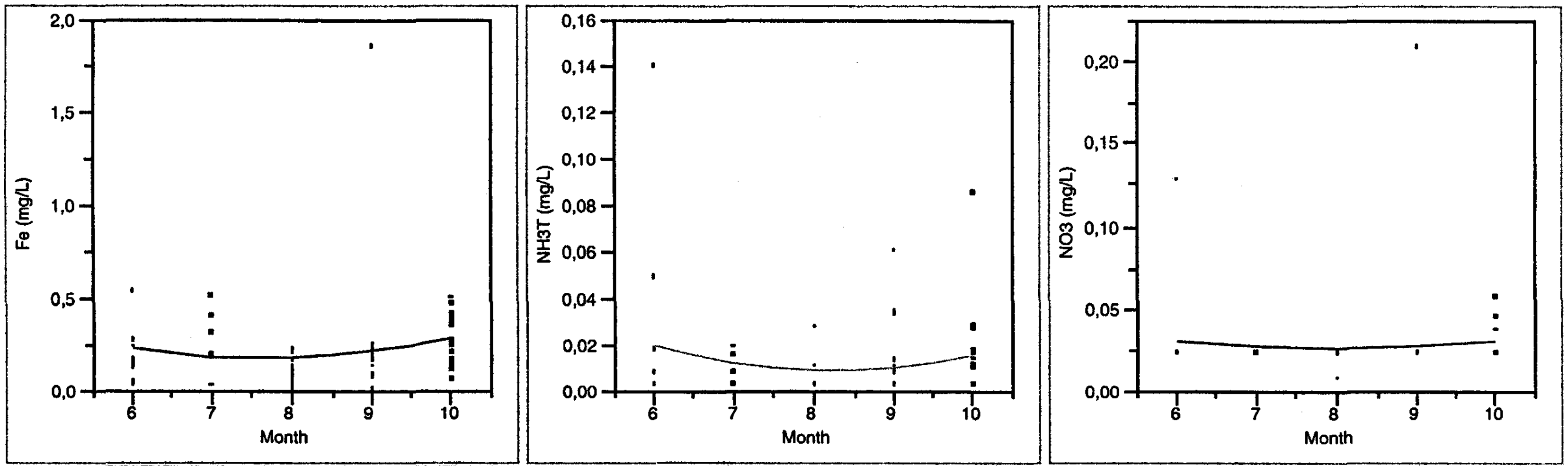


Polynomial Fit degree=2 Al (mg/L) = 1,58235 – 0,40481 Month + 0,0261 Month^2 Rsquare Adj : 0,22 Observations : 67	**Polynomial Fit degree=2** COND (μSIE/cm) = -2520,4 + 745,527 Month – 45,6908 Month^2 RSquare Adj : 0,12 Observations: 67	**Polynomial Fit degree=2** E_coli-Average (MPN/100ml) = 3334,54 – 771,933 Month + 46,7573 Month^2 RSquare Adj : 0,00 Observations : 66

Figure 6. Monthly variations in selected water quality parameters in the Petitcodiac River, 1997-2000.

Petitcodiac River, 1997-2000
Stations PWMG # 4, 10, 15 & 16

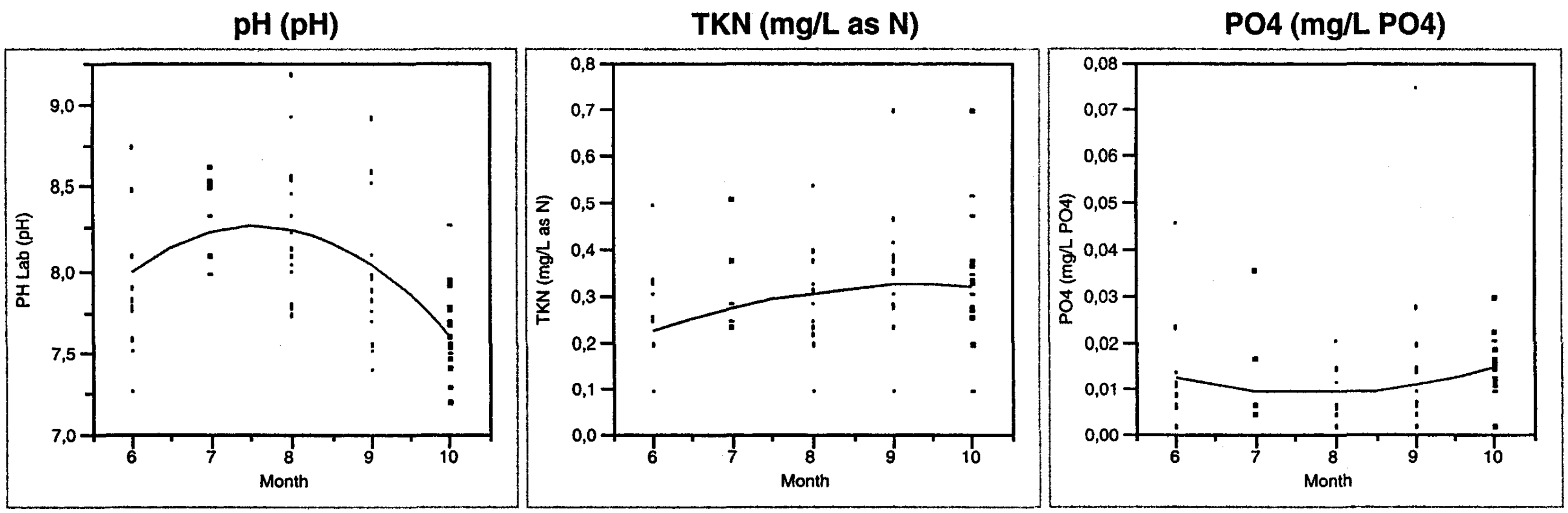
Fe (mg/L) **NH3T (mg/L)** **NO3 (mg/L)**



Polynomial Fit degree=2 Fe (mg/L) = 1,4145 – 0,32081 Month + 0,02094 Month^2 RSquare Adj : 0,00 Observations : 67	**Polynomial Fit degree=2** NH3T (mg/L) = 0,16072 – 0,03664 Month + 0,00222 Month^2 RSquare Adj : 0,00 Observations : 67	**Polynomial Fit degree=2** NO3 (mg/L) = 0,07936 – 0,01264 Month + 0,00078 Month^2 RSquare Adj : 0,03 Observations : 67

Figure 6. Monthly variations in selected water quality parameters in the Petitcodiac River, 1997-2000 (continued)

Petitcodiac River, 1997-2000
Stations PWMG # 4, 10, 15 & 16



Polynomial Fit degree=2 pH = 1,91174 + 1,68301 Month – 0,11132 Month^2 RSquare Adj : 0,29 Observations : 67	**Polynomial Fit degree=2** TKN (mg/L as N) = -0,4162 + 0,15769 Month – 0,00837 Month^2 RSquare Adj : 0,04 Observations : 67	**Polynomial Fit degree=2** PO4 (mg/L PO4) = 0,07645 – 0,01725 Month + 0,00111 Month^2 RSquare Adj : 0,00 Observations : 67

Figure 6. Monthly variations in selected water quality parameters in the Petitcodiac River, 1997-2000 (continued)

APPENDIX A. WATER QUALITY STATIONS LISTING

Station Listing

Station Name: Anagance River Above Mouth PWMG 2
Description: sampled upstream from bridge located just up from mouth . Westmorland Co, Elgin Pa. Follow road through town, turn onto dirt road where DNRE building is located. Drive past DNRE
Site:
Water Body:
StationID: 1211
PID:
Station Status: Active
Latitude: 45.927296
Longitude: 65.1875
Historical ID: 00BR01BU0092
UTM Zone: 20
UTM Northing: 5088079
UTM Easting: 330330

Station Name: Anagance River above North River confluence
Description: below bridge just above the confluence with the North River. Riffle. Stn. 2; For fall 1998 benthic study: (1) rubble substrate (2) unshaded (3) water 1-1.5' deep (4) swamp hardwood
Site:
Water Body: Anagance River; . aka Annagance River
StationID: 8184
PID:
Station Status: Active
Latitude: 45.930191
Longitude: 65.186711
Historical ID: 00BR01BU0166
UTM Zone: 20
UTM Northing: 5088399
UTM Easting: 330400

Station Name: Anagance River Above Rte 895 Bridge PWMG 1
Description: upstream from route 895 bridge.,Kings Co, Cardwell Pa
Site:
Water Body:
StationID: 1210
PID:
Station Status: Active
Latitude: 45.87363
Longitude: 65.257935
Historical ID: 00BR01BU0091
UTM Zone: 20
UTM Northing: 5082269
UTM Easting: 324700

Station Name: Bennett Brook below old ford site
Description: 30m downstream from old ford site located approx. 2km off Rte. 885. Riffle. Stn. 11; For fall 1998 benthic study: (1) rubble substrate with silt (2) fast-moving, < 1' deep (3) narrow brook, some shade from marsh, alder
Site:
Water Body:
StationID: 8192
PID:
Station Status: Active
Latitude: 45.969255
Longitude: 65.214709
Historical ID: 00BR01BU0174
UTM Zone: 20
UTM Northing: 5092799
UTM Easting: 328350

Station Name: Bennett Brook near mouth PWMG 45
Description: Approx 15 m U/ S from the mouth. To access site, take sample from North River at bridge near Intervale. Walk downstream along North River to Bennett. Walk u/s approx 15 - 20 m.
Site:
Water Body: Bennett Brook
StationID: 9848
PID:
Station Status: Active
Latitude: 45.959161
Longitude: 65.201402
Historical ID:
UTM Zone: 20
UTM Northing: 5091649
UTM Easting: 329350

Station Name: Bennett Brook PWMG 6
Description: Upstream from fording site located approx 2km off rte 885, south side of rd,Westmorland Co, Salisbury Pa
Site:
Water Body: | **Historical ID:** 00BR01BU0093
StationID: 1180 | **UTM Zone:** 20
PID: | **Latitude:** 45.966619 | **UTM Northing:** 5092499
Station Status: Active | **Longitude:** 65.211377 | **UTM Easting:** 328600

Station Name: Fox Creek at route 106 PWMG 31
Description: Upstream from culvert on route 106 south of St. Anselme,Westmorland Co. Moncton Pa. Station 1
Site:
Water Body: | **Historical ID:** 00BR01BU0036
StationID: 976 | **UTM Zone:** 20
PID: | **Latitude:** 46.06305 | **UTM Northing:** 5102249
Station Status: Active | **Longitude:** 64.705499 | **UTM Easting:** 368025

Station Name: Halls Creek near mouth PWMG 44
Description: D/S from confluence of NBR and WBR. Site is on creek near baseball field and across the field from new Law Building. The banks are muddy but the site can be accessed from some boulders on the bank. Pull off Wheeler Blvd and park between the baseball and soccer fields.
Site:
Water Body: Halls Creek; Within City of Moncton. aka Hall Creek | **Historical ID:**
StationID: 9847 | **UTM Zone:** 20
PID: | **Latitude:** 46.101362 | **UTM Northing:** 5106649
Station Status: Active | **Longitude:** 64.789807 | **UTM Easting:** 361600

Station Name: Humphreys Brook @ Mill Rd Bridge PWMG 29
Description: located below spillway under bridge on mill rd below humphreys mills pond.,Westmorland Co, Moncton Pa; For fall 1998 benthic study: (1) substrate mixed large and small rocks (2) lots of debris in brook, including bike frame (3) water about 1' deep, brown, fast moving (4) sewage smell
Site:
Water Body: | **Historical ID:** 00BR01BU0120
StationID: 888 | **UTM Zone:** 20
PID: | **Latitude:** 46.109351 | **UTM Northing:** 5107499
Station Status: Active | **Longitude:** 64.768068 | **UTM Easting:** 363300

Station Name: Humphreys Brook @ Stn 1
Description: U/s from lewisville rd, behind metro stn 1997,Westmorland Co. Moncton Pa. Station 1
Site:
Water Body: | **Historical ID:** 00BR01BU0034
StationID: 887 | **UTM Zone:** 20
PID: | **Latitude:** 46.101 | **UTM Northing:** 5106578
Station Status: Inactive | **Longitude:** 64.772 | **UTM Easting:** 362975

Station Name:	Humphreys Brook @ TCH PWMG 30				
Description:	approx 100m u/s from culvert at TCH xing,Westmorland Co. Moncton Pa. Station 2. Walk past standpipe located beside river.				
Site:					
Water Body:				**Historical ID:**	00BR01BU0035
StationID:	886			**UTM Zone:**	20
PID:		**Latitude:**	46.126641	**UTM Northing:**	5109379
Station Status:	Active	**Longitude:**	64.744028	**UTM Easting:**	365200

Station Name:	Jonathan Creek 7 - Below Horsman Road (PWMG 23)				
Description:	approx 15m d/s from culvert under Horsman Road.,Westmorland Co, Moncton				
Site:					
Water Body:				**Historical ID:**	00BR01BU0118
StationID:	863			**UTM Zone:**	20
PID:		**Latitude:**	46.102024	**UTM Northing:**	5106849
Station Status:	Active	**Longitude:**	64.860988	**UTM Easting:**	356100

Station Name:	Jonathan Creek 20m above Horsman Road culvert				
Description:	20m above culvert under Horsman Road. Riffle. Stn. 10; For fall 1998 benthic study: (1) substrate gravelly with rock outcrops (2) water murky, deep (3) partly shaded				
Site:					
Water Body:	Jonathan Creek			**Historical ID:**	00BR01BU0173
StationID:	8191			**UTM Zone:**	20
PID:		**Latitude:**	46.102003	**UTM Northing:**	5106849
Station Status:	Active	**Longitude:**	64.862281	**UTM Easting:**	356000

Station Name:	Jonathan Creek Below Wheeler Blvd				
Description:	approx 100m downstream from culvert passing under wheeler blvd.,Westmorland Co.				
Site:					
Water Body:				**Historical ID:**	00BR01BU0096
StationID:	860			**UTM Zone:**	20
PID:		**Latitude:**	46.092987	**UTM Northing:**	5105799
Station Status:	Inactive	**Longitude:**	64.835459	**UTM Easting:**	358050

Station Name:	Jones Lake PWMG 22				
Description:	sample taken at culvert outlet across Main Street from Jones Lake.,Westmorland Co, Moncton Pa				
Site:					
Water Body:				**Historical ID:**	00BR01BU0097
StationID:	858			**UTM Zone:**	20
PID:		**Latitude:**	46.08241	**UTM Northing:**	5104549
Station Status:	Active	**Longitude:**	64.793074	**UTM Easting:**	361300

Station Name: Little River below Mitton Brook confluence
Description: 200m downstream of confluence of Mitton Brook (below bridge over Little River). Riffle. Stn. 9; For fall 1998 benthic study: (1) substrate ? (2) water fast moving, 1.5-2' deep, murkier and warmer than Prosser (3) shoreline dense alder and willow
Site:
Water Body: Little River; Flows NW. into Petitcodiac River. aka Coverdale
StationID: 8190
PID:
Station Status: Active
Latitude: 45.8662
Longitude: 64.994814
Historical ID: 00BR01BU0172
UTM Zone: 20
UTM Northing: 5080899
UTM Easting: 345100

Station Name: Little River below Prosser Brook PWMG 41
Description: Turn left (north) on 895 after crossing bridge in Parkindale. Turn on road leading to cemetery. Park beside cemetery and follow dirt road to camp with trailer. Sample site is located approx. 25 m D/S from dock in front of camp. Cobble/boulder bottom.
Site:
Water Body:
StationID: 9846
PID:
Station Status: Active
Latitude: 45.869572
Longitude: 64.98205
Historical ID: 00BR01BU0178
UTM Zone: 20
UTM Northing: 5081249
UTM Easting: 346100

Station Name: Little River near mouth PWMG 17
Description: upstream from route 112 bridge, just west of five points.,Albert Co, Coverdale Pa; For fall 1998 benthic study: (1) substrate small stones (2) marsh/hay shore, unshaded
Site:
Water Body:
StationID: 784
PID:
Station Status: Active
Latitude: 46.019628
Longitude: 65.02229
Historical ID: 00BR01BU0098
UTM Zone: 20
UTM Northing: 5097999
UTM Easting: 343400

Station Name: Memramcook River @ Calhoun PWMG 35
Description: Memramcook river @ calhoun ,Westmorland Co, Dorchester Pa
Site:
Water Body:
StationID: 702
PID:
Station Status: Active
Latitude: 46.067
Longitude: 64.572
Historical ID: NB01BU0008
UTM Zone: 20
UTM Northing: 5102475
UTM Easting: 378359

Station Name: Memramcook River @ College Bridge PWMG 36
Description: Memramcook river @ college bridge ,Westmorland Co, Dorchester Pa
Site:
Water Body:
StationID: 701
PID:
Station Status: Inactive
Latitude:
Longitude:
Historical ID: 00BR01BU0121
UTM Zone:
UTM Northing:
UTM Easting:

Station Name: Mill Creek below Pine Glen highway
Description: 30m below Pine Glen highway. Riffle. Stn. 14; For fall 1998 benthic study: (1) substrate large rocks at riffle (2) deep pools of water either side of culvert under road (3) water very turbid, possible rain the previous night (4) willow, alder, swamp shoreline
Site:

Water Body:				**Historical ID:**	00BR01BU0177
StationID:	8195			**UTM Zone:**	20
PID:		**Latitude:**	46.042469	**UTM Northing:**	5100099
Station Status:	Active	**Longitude:**	64.785964	**UTM Easting:**	361750

Station Name: Mill Creek below reservoir PWMG 20
Description: 70-100m below spillway of reservoir at an old crossing (no bridge structure).,Westmorland Co, Coverdale Pa
Site:

Water Body:				**Historical ID:**	00BR01BU0099
StationID:	694			**UTM Zone:**	20
PID:		**Latitude:**	46.060003	**UTM Northing:**	5101999
Station Status:	Active	**Longitude:**	64.758088	**UTM Easting:**	363950

Station Name: North Branch Halls Creek PWMG 28
Description: approx 50m upstream from culvert under TCH.
Site:

Water Body:				**Historical ID:**	00BR01BU0100
StationID:	565			**UTM Zone:**	20
PID:		**Latitude:**	46.127839	**UTM Northing:**	5109619
Station Status:	Active	**Longitude:**	64.805939	**UTM Easting:**	360420

Station Name: North River @ Pacific Junct Rd Bridge PWMG 9
Description: Approx 75m u/s from bridge on Pacific Junct Rd, u/s from garbage thrown on river banks,Westmorland Co, Moncton Pa; Follow path under bridge upstream.
Site:

Water Body:				**Historical ID:**	00BR01BU0103
StationID:	548			**UTM Zone:**	20
PID:		**Latitude:**	46.064722	**UTM Northing:**	5103149
Station Status:	Active	**Longitude:**	65.092141	**UTM Easting:**	338125

Station Name: North River Above Rte 885 Bridge PWMG 5
Description: 30-40m u/s of rte 885 bridge, just west of Intervale; request owner's permission,Westmorland Co, Salisbury Pa
Site:

Water Body:				**Historical ID:**	00BR01BU0101
StationID:	546			**UTM Zone:**	20
PID:		**Latitude:**	45.961909	**UTM Northing:**	5091949
Station Status:	Active	**Longitude:**	65.19893	**UTM Easting:**	329550

Station Name: North River above Rte. 880 crossing PWMG 43
Description: 200m upstream from Rte. 880 crossing. Riffle. Stn. 4; For fall 1998 benthic study: (1) rocky substrate with some silt and algae on rocks (2) about 1' deep (3) partial shade from alder, mixed-wood banks
Site:

Water Body:	North River			**Historical ID:**	00BR01BU0168
StationID:	8186			**UTM Zone:**	20
PID:		**Latitude:**	46.04889	**UTM Northing:**	5101449
Station Status:	Active	**Longitude:**	65.120949	**UTM Easting:**	335850

Station Name: North River below bridge on Morton Rd PWMG 7
Description: Bridge over North R on Morton Road between Fawcett & Wheaton Settlements. Sample D/S from bridge.
Site:

Water Body:				**Historical ID:**	00BR01BU0013
StationID:	547			**UTM Zone:**	20
PID:		**Latitude:**	46.018922	**UTM Northing:**	5098249
Station Status:	Active	**Longitude:**	65.182846	**UTM Easting:**	330970

Station Name: North River Below Rte 112 Bridge PWMG 8
Description: Downstream from route 112 bridge approx 5 to 10 m (upstream side too muddy),Westmorland Co, Salisbury Pa
Site:

Water Body:				**Historical ID:**	00BR01BU0102
StationID:	545			**UTM Zone:**	20
PID:		**Latitude:**	46.064701	**UTM Northing:**	5103148
Station Status:	Active	**Longitude:**	65.092786	**UTM Easting:**	338075

Station Name: North River below Tingley Hill Bridge PWMG 40
Description: 50m downstream from Tingley Hill bridge. Riffle. Stn. 3; For fall 1998 benthic study: (1) mixed substrate, mostly rubble-sized, some much larger (2) unshaded (3) < 1' deep, water clear
Site:

Water Body:	North River			**Historical ID:**	00BR01BU0167
StationID:	8185			**UTM Zone:**	20
PID:		**Latitude:**	45.939911	**UTM Northing:**	5089499
Station Status:	Active	**Longitude:**	65.196124	**UTM Easting:**	329700

Station Name: Petitcodiac River @ Causeway Fishway PWMG 21
Description: >From causeway, new lane, adjacent to fishway from headpond (sample iron used),Albert Co, Coverdale
Site:

Water Body:				**Historical ID:**	00BR01BU0117
StationID:	469			**UTM Zone:**	
PID:		**Latitude:**		**UTM Northing:**	
Station Status:	Inactive	**Longitude:**		**UTM Easting:**	

Station Name: Petitcodiac River 30m below covered bridge
Description: 30m downstream from covered bridge. Turn right on road (approx. 1km after TCH) off Hwy. 6. Run. Stn. 12; For fall 1998 benthic study: (1) substrate large rocks with abundant algal growth (2) slow water, samplers in "run", all others in "riffles"
Site:

Water Body:	Petitcodiac River; Flows S. into Shepody Bay. aka Petcoudiac			**Historical ID:**	00BR01BU0175
StationID:	8193			**UTM Zone:**	20
PID:		**Latitude:**	46.000418	**UTM Northing:**	5095999
Station Status:	Active	**Longitude:**	65.089391	**UTM Easting:**	338150

Station Name: Petitcodiac River 50m above Rte. 112 bridge
Description: 50m above Rte. 112 bridge. Riffle. Stn. 13; For fall 1998 benthic study: (1) substrate rocks smaller than those in sampler (2) water < 1' deep (3) marsh shoreline; unshaded
Site:

Water Body:	Petitcodiac River; Flows S. into Shepody Bay. aka Petcoudiac			**Historical ID:**	00BR01BU0176
StationID:	8194			**UTM Zone:**	20
PID:		**Latitude:**	46.021209	**UTM Northing:**	5098199
Station Status:	Active	**Longitude:**	65.034621	**UTM Easting:**	342450

Station Name: Petitcodiac River Above French Brook PWMG 15
Description: U/s from mouth of french brook on rte 106 (by mail box # 3447, river on east side),Westmorland Co, Salisbury Pa; Approx 1km
Site:

Water Body:				**Historical ID:**	00BR01BU0106
StationID:	461			**UTM Zone:**	20
PID:		**Latitude:**	46.011592	**UTM Northing:**	5097199
Station Status:	Active	**Longitude:**	65.068886	**UTM Easting:**	339770

Station Name: Petitcodiac River Above Rte 905 Bridge PWMG 3
Description: Sampled approx 50 m upstream from bridge on rte 905 in town of Petitcodiac,Westmorland Co.
Site:

Water Body:				**Historical ID:**	00BR01BU0104
StationID:	460			**UTM Zone:**	20
PID:		**Latitude:**	45.933077	**UTM Northing:**	5088699
Station Status:	Active	**Longitude:**	65.177022	**UTM Easting:**	331160

Station Name: Petitcodiac River at TCH Bridge PWMG 4
Description: east of Petitcodiac at TCH bridge.1997 - sample adjacent to wsc gauge stn upstream from tributary,Westmorland Co, Sals Pa, Petitcodiac
Site:

Water Body:				**Historical ID:**	NB01BU0003
StationID:	470			**UTM Zone:**	20
PID:		**Latitude:**	45.946761	**UTM Northing:**	5090199
Station Status:	Active	**Longitude:**	65.167365	**UTM Easting:**	331950

Station Name: Petitcodiac River Below Rte 112 Bridge PWMG 16
Description: 100m downstream from bridge on route 112 ,Westmorland Co, Salisbury Pa
Site:
Water Body:
StationID: 459
PID:
Station Status: Active
Latitude: 46.022581
Longitude: 65.03338
Historical ID: 00BR01BU0107
UTM Zone: 20
UTM Northing: 5098349
UTM Easting: 342550

Station Name: Petitcodiac River near mouth of Pollett R PWMG 10
Description: U/s from mouth of Pollett. Cross covered bridge on Powers Pit rd. Sample u/s from bridge,Westmorland Co., Sals Pa; Stn 3,
Site:
Water Body:
StationID: 465
PID:
Station Status: Active
Latitude: 45.996875
Longitude: 65.091195
Historical ID: 00BR01BU0010
UTM Zone: 20
UTM Northing: 5095609
UTM Easting: 338000

Station Name: Pollett River @ Church's Corner PWMG 14
Description: At bridge west of Church's Corner(cc) 1997 - approx 30m u/s of bridge,Albert Co., Elgin Pa. Station 4. / For benthic study: 30m upstream from bridge at Church's Corner. Riffle. Stn. 5; (1) substrate mixed with several large rocks above water surface (2) marsh and mixed forest on banks (3) < 1' deep, very clear
Site:
Water Body: Pollett River; . aka Pollet River
StationID: 442
PID:
Station Status: Active
Latitude: 45.756879
Longitude: 65.078347
Historical ID: 00BR01BU0018
UTM Zone: 20
UTM Northing: 5068919
UTM Easting: 338300

Station Name: Pollett River @ Mapleton Bridge PWMG 13
Description: approx 30m u/s from bridge on Mapleton Road., Elgin Pa. Station 3.
Site:
Water Body:
StationID: 443
PID:
Station Status: Active
Latitude: 45.812
Longitude: 65.105882
Historical ID: 00BR01BU0017
UTM Zone: 20
UTM Northing: 5075099
UTM Easting: 336320

Station Name: Pollett River 1km Above Mouth PWMG 11
Description: approx 1km u/s from mouth. Adjacent to stn BU0010 on Petitcodiac,Westmorland Co, Salisbury Pa. Continue down Powers Pitt Road after covered bridge, approx 100metres. Follow clearing to river; For fall 1998 benthic study: (1) substrate small rocks similar size and colour to sampler rocks (2) shallow, very clear (3) mixed-wood
Site:
Water Body:
StationID: 441
PID:
Station Status: Active
Latitude: 45.995904
Longitude: 65.090189
Historical ID: 00BR01BU0109
UTM Zone: 20
UTM Northing: 5095499
UTM Easting: 338075

Station Name:	Pollett River 30m above Church's Corner bridge				
Description:	30m upstream from bridge at Church's Corner. Riffle. Stn. 5; For fall 1998 benthic study: (1) substrate mixed with several large rocks above water surface (2) marsh and mixed forest on banks (3) < 1' deep, very clear				
Site:					
Water Body:	Pollett River; . aka Pollet River			**Historical ID:**	00BR01BU0169
StationID:	8187			**UTM Zone:**	20
PID:		**Latitude:**	45.756699	**UTM Northing:**	5068899
Station Status:	Active	**Longitude:**	65.07834	**UTM Easting:**	338300

Station Name:	Pollett River east of Pollett R Settlement PWMG 12				
Description:	Bridge xing on pollett river located just east of pollett river settlement,Westmorland Co, Sals Pa; Sample approx 30 m u/s from bridge.				
Site:					
Water Body:				**Historical ID:**	NB01BU0041
StationID:	446			**UTM Zone:**	20
PID:		**Latitude:**	45.888092	**UTM Northing:**	5083529
Station Status:	Active	**Longitude:**	65.094194	**UTM Easting:**	337450

Station Name:	Pollett River near Elgin above Gordon Falls				
Description:	Pollett River near Elgin above Gordon Falls				
Site:					
Water Body:	Pollett River; . aka Pollet River			**Historical ID:**	00BR01BU0165
StationID:	8998			**UTM Zone:**	20
PID:		**Latitude:**	45.784301	**UTM Northing:**	5071999
Station Status:	Active	**Longitude:**	65.094804	**UTM Easting:**	337100

Station Name:	Prosser Brook above Little River confluence				
Description:	30m above the confluence with Little River through woods at bend in ATV trail. Riffle. Stn. 8; For fall 1998 benthic study: (1) substrate rocks about same size as sampler rocks (2) water cold and fast moving (3) samplers in "holes" > 1.5' deep (4) brook mostly shaded with overhanging willow and alder				
Site:					
Water Body:	Prosser Brook			**Historical ID:**	00BR01BU0171
StationID:	8189			**UTM Zone:**	20
PID:		**Latitude:**	45.86548	**UTM Northing:**	5080799
Station Status:	Active	**Longitude:**	64.984481	**UTM Easting:**	345900

Station Name:	Prosser Brook near mouth PWMG 18				
Description:	at bridge, on small road leading to house just before mouth, off road from Parkindale to Prosser Brook.				
Site:					
Water Body:				**Historical ID:**	00BR01BU0111
StationID:	438			**UTM Zone:**	20
PID:		**Latitude:**	45.863107	**UTM Northing:**	5080529
Station Status:	Active	**Longitude:**	64.981176	**UTM Easting:**	346150

Station Name: Rabbit Brook @ Mapleton Rd PWMG 25
Description: few metres upstream from culvert under Mapleton road.,Westmorland Co, Moncton Pa
Site:

Water Body:				**Historical ID:**	00BR01BU0116
StationID:	434			**UTM Zone:**	20
PID:		**Latitude:**	46.112853	**UTM Northing:**	5107989
Station Status:	Active	**Longitude:**	64.825766	**UTM Easting:**	358850

Station Name: Rabbit Brook near Mouth PWMG 24
Description: Near the mouth , approx 10m upstream from culvert under Wheeler blvd.,Westmorland Co, Moncton Pa
Site:

Water Body:				**Historical ID:**	00BR01BU0105
StationID:	433			**UTM Zone:**	20
PID:		**Latitude:**	46.111406	**UTM Northing:**	5107799
Station Status:	Active	**Longitude:**	64.809219	**UTM Easting:**	360125

Station Name: Turtle Creek @ Bypass Channel
Description: Below pumphouse where bypass channel enters creek,Albert Co, Coverdale Pa
Site:

Water Body:				**Historical ID:**	00BR01BU0112
StationID:	104			**UTM Zone:**	20
PID:		**Latitude:**	46.005542	**UTM Northing:**	5096199
Station Status:	Inactive	**Longitude:**	64.899078	**UTM Easting:**	352900

Station Name: Turtle Creek @ Bypass channel by pumphouse PWMG 19
Description: Station created in 1998. Previous Turtle Creek station could not be accessed for safety reasons. Site manager, Paul Richard must be contacted to unlock the gates. Call 387-8448. Drive down dirt road to pumphouse. Go through gates. Sample channel behind pumphouse.
Site:

Water Body:	Turtle Creek			**Historical ID:**	
StationID:	8323			**UTM Zone:**	20
PID:		**Latitude:**	46.004069	**UTM Northing:**	5096024
Station Status:	Inactive	**Longitude:**	64.892957	**UTM Easting:**	353370

Station Name: Turtle Creek above Rte. 910 bridge PWMG 42
Description: 30m upstream from Rte. 910 bridge crossing. Riffle. Stn. 7; For fall 1998 benthic study: (1) substrate large rocks (2) water knee-deep in places, brown, fast moving
Site:

Water Body:	Turtle Creek			**Historical ID:**	00BR01BU0170
StationID:	8188			**UTM Zone:**	20
PID:		**Latitude:**	45.959085	**UTM Northing:**	5090999
Station Status:	Active	**Longitude:**	64.878132	**UTM Easting:**	354400

Station Name: Weldon Creek D/S from Salem PWMG 32
Description: sampled u/s from covered bridge near Salem settlement.,Albert Co, Hillsborough Pa; For fall 1998 benthic study: (1) substrate rocks larger than in sampler at riffle (2) water clear and fast moving (3) steep banks,
Site:
Water Body: | **Historical ID:** 00BR01BU0113
StationID: 61 | **UTM Zone:** 20
PID: | **Latitude:** 45.916868 | **UTM Northing:** 5085999
Station Status: Active | **Longitude:** 64.700367 | **UTM Easting:** 368075

Station Name: West Branch Halls Creek @ Briardale St PWMG 27
Description: between Briardale and TCH .Access from Briardale st, Park on east end of street and follow (nature ?) path located adjacent to houses to river. Westmorland Co, Moncton
Site:
Water Body: | **Historical ID:** 00BR01BU0119
StationID: 60 | **UTM Zone:** 20
PID: | **Latitude:** 46.127553 | **UTM Northing:** 5109669
Station Status: Active | **Longitude:** 64.851881 | **UTM Easting:** 356870

Station Name: West Branch Halls Creek @ Meadowvale Rd
Description: Near meadowvale road, past new housing area,Westmorland Co, Moncton Pa
Site:
Water Body: | **Historical ID:** 00BR01BU0115
StationID: 59 | **UTM Zone:** 20
PID: | **Latitude:** 46.124848 | **UTM Northing:** 5109349
Station Status: Inactive | **Longitude:** 64.841048 | **UTM Easting:** 357699

Station Name: West Branch Halls Creek @ Wheeler Blvd PWMG 26
Description: d/s from mouth of rabbit brook on east side of wheeler blvd.,Westmorland Co, Moncton
Site:
Water Body: | **Historical ID:** 00BR01BU0114
StationID: 58 | **UTM Zone:** 20
PID: | **Latitude:** 46.111013 | **UTM Northing:** 5107749
Station Status: Active | **Longitude:** 64.805648 | **UTM Easting:** 360400

This is the end of the report