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REGIONAL TREND DETECTION AND POWER ANALYSES AT ALGOMA, MUSKOKA AND SUDBURY BIOMONITORING SITES (1988-1995)

**REGIONAL TREND DETECTION AND POWER ANALYSES
FOR CHEMICAL PARAMETERS MONITORED AT THE CWS LRTAP BIOMONITORING SITES
IN ALGOMA, MUSKOKA AND SUDBURY
(1988-1995)**

**Contract # KR405-5-0179
Environment Canada
CWS ,Ontario Region
LRTAP Program**

by

Daniel Cluis and Claude Laberge

INRS-EAU

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ABSTRACT

This report presents the first results of regional regressions over time performed on data sets containing chemical analyses of parameters measured for different groupings of lakes of the Muskoka, Algoma and Sudbury regions. The data analysed were monitored as part of the Canadian Wildlife Service Monitoring Program (LRTAP).

For each region, data are available for 17 parameters. The regional trend detection analyses are performed using simple linear regression. The results in this part of the contract are of two kinds:

- **Brief result summary for all combinations** of parameters (17) x regions (3) x classification levels (18) : 918 regressions. The results presented are : number of observations, RMSE, slope, significance of slope, predicted value for 1990 (initial) and for 1995 (final). Given the large number of regressions to be performed, no validation of the results are presented. The absence of validation forces the user to : a) validate the results before using them in particular studies or; b) use the results as descriptives.

- **Complete regression analyses for pH, alcalinity, calcium and sulfate values** in each of the three regions. The analyses include a graphical exploratory data analysis.

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Section 1: Regional trend detection analyses

In this first part of the contract, **all data available** will be used in the regional trend detection analyses. The possible use of only part of the years for each lake, or of only part of the lakes available will be discussed **in the second part** of the contract with the study of detection power of the statistical methods used.

1.1 Results of regional regressions for all combinations of regions and classifications

The analyses presented here use all data available. The results are summarized in 85 tables which can be divided in 5 groups of 17 tables associated to the 17 parameters. The first group of tables (tables 1-17) gives the results of regional regressions with all lakes in the region. The second group of tables (tables 18-34) gives the results of regional regressions with lakes grouped in each of the 7 levels of classification #1. The third group of tables (tables 35-51) gives the results of regional regressions with lakes grouped in each of the 3 levels of classification #2. The fourth group of tables (tables 52-68) gives the results of regional regressions with lakes grouped in each of the 4 levels of classification #3. The fifth and final group of tables (tables 69-85) gives the results of regional regressions with lakes grouped in each of the 3 levels of classification #4.

The results are summarized for each parameter in section 1.2. For each table, the content of each column is :

Column 1 : code for the region, 1 = Muskoka, 12 = Algoma, 37 = Sudbury
Column 2 : level code for the classification treated (when necessary)
Column 3 : number of observations in the regressions (lakes x years)
Column 4 : Significance of slope : Y=Yes, N=No
Column 5 : Root mean square error
Column 6 : Intercept of the regression model (value at year 0)
Column 7 : Slope estimate; cell is shaded when slope is significant.
Column 8 : Initial value estimate (1990); cell is shaded when slope is significant.
Column 9 : Final value estimate (1995); cell is shaded when slope is significant.

Since the results of these regressions are not validated (no residual analyses to detect possible outliers, no study of spatial or temporal correlation), **we want to point out that the presence of outliers will affect the estimates for RMSE, intercept, slope, initial and final values, while the presence of spatial or temporal correlation will affect the estimates of RMSE and the significance test for the slope. The presence of high correlation between lakes or years may bias the results by inducing artificially too many trends to be detected as significant .** The effect of spatial and temporal correlation will be discussed in more details in the power analysis section of the final report.

1.1.1 Results when no classification is used

Tables 1 through 17 present the results of regional regressions for each region when no classification is considered. The regressions use all lakes in each region and all years with measured values. Four parameters are treated in more details in section 2 : pH, sulfate concentrations, calcium concentrations and alkalinity.

Tables 1 through 17 show that four parameters contains significant trends in all three regions: pH, sulfate concentrations, TKN concentrations and NO_2 NO_3 concentrations. However, the results for NO_2 NO_3 concentrations are quite strange: very small significant slopes and slopes in different direction (increase in Muskoka and Algoma; decrease in Sudbury). Only three parameters show no significant trends in all three regions : TIC, DOC and ammoniac concentrations. All other parameters show different conclusions from on region to another.

The results associated to each parameter will be discussed in section 1.2.

1.1.2 Regional regression results associated to levels of classification #1

Tables 18 through 34 give the regional trend detection results for the 17 parameters for each of the 7 levels of classification #1. The results presented in these tables allow a more detailed description on the type of lakes presenting the trends pattern in tables 1-17. Although, all types of lake often contain the same trend patterns than the ones in tables 1-17, several particularities exist and can easily be identified in tables 18-34.

For example, table 1 showed significant positive trends in all three regions for pH values. On the other hand, table 18 shows non significant trends for level 0 of classification #1 in the Muskoka region and for levels 0, 1 and 2 of classification #1 in the Sudbury region.

It's possible with these tables to see situations where outliers must have an effect on the conclusions. For example, in table 27 we see significant trends in levels 2, 4, 5 and 6 of classification #1 for the Muskoka region while for level 3 a slope of larger magnitude is not significant. The value of the RMSE, more than 30 times larger than those of the other levels, is a good hint of possibly large outlier(s). If this is the case, all estimates will be affected: a quick look at estimates of B1, initial and final values shows that it seems to be the case.

1.1.3 Regional regression results associated to levels of classification #2

Tables 35 through 51 give the regional trend detection results for the 17 parameters for each of the 4 levels of classification #3. Lakes with classification -9 are also presented even if they don't represent large groups of lakes and even if they don't represent a defined level for this classification. Note that the NA code in tables 35 through 51 means that the estimate RMSE or the significance of the slope is "not applicable" (meaning that RMSE can't be computed and that the test on the slope can not be executed). In table 49, the NA code is necessary because observations are available for only one year so that no slope can be computed for the Muskoka region.

1.1.4 Regional regression results associated to levels of classification #3

Tables 52 through 68 give the regional trend detection results for the 17 parameters for each of the 4 levels of classification #3. Lakes with classification -9 are also presented even if they don't represent large groups of lakes and even if they don't represent a defined level for this classification. In table 66, the NA code is necessary because observations are available for only one year so no slope can be computed for the Muskoka region.

1.1.5 Regional regression results associated to levels of classification #4

Tables 69 through 85 give the regional trend detection results for the 17 parameters for each of the 3 levels of classification #4. Lakes with classification -9 are also presented even if they don't represent large groups of lakes and even if they don't represent a defined level for this classification.

The NA codes in these tables mean that the estimate RMSE or the significance of the slope is "not applicable" (meaning that RMSE can't be computed and that the test on the slope can not be executed). In table 83, the NA code is necessary because observations are available for only one year so no slope can be computed for the Muskoka region.

1.2 Summary for each parameter

1.2.1 pH values

Table 1 shows significant regional regressions for all three regions with positive slopes of 0.09 unit/year in the Muskoka and the Sudbury regions while the Algoma region shows a positive slope of 0.06 unit/year.

Table 18 shows significant regional regressions for 17 out of 21 combinations of region by classification #1 levels. The only combinations for which the regressions are not significant are: level 0 for the Muskoka region and levels 0, 1 and 2 for the Sudbury region.

Table 35 shows significant regional regressions for 8 out of 9 combinations of region by classification #2 levels (levels -9 not considered). The only combination for which the regression is not significant is: level 2 for the Sudbury region.

Table 52 shows significant regional regressions for 9 out of 12 of region by classification #3 levels combinations (levels -9 not considered). The only combinations for which the regressions are not significant are: level 2 for the Algoma region and levels 0 and 1 for the Sudbury region.

Table 69 shows significant regional regressions for 8 out of 9 combinations of region by classification #4 levels (levels -9 not considered). The only combination for which the regression is not significant is: level 1 for the Sudbury region.

The magnitudes of the significant trend slopes are very consistent from one classification level to the other. They vary from around .03 unit/year to .12 unit per year. No large outlier seems to affect greatly any particular case.

The general conclusion for pH values is that all regions show a significant increase from 1990 through 1995. The increases go from 5.57 to 6.02 for the Muskoka region , from 5.77 to 6.09 for the Algoma region and from 5.42 to 5.89 for the Sudbury region. However some types of lakes do not show significant trends, this could be explained by the characteristics associated to the corresponding classification levels.

1.2.2 Conductivity values

Table 2 shows significant regional regressions for the Muskoka and Algoma regions with negative slopes of respectively -1.27 units/year and -1.00 unit/year. For the Sudbury region the slope of -0.70 is not significant. The RMSE for the Sudbury region shows a greater variability for this region, this larger variability can be resulting from the presence of outlier(s).

Tables 19, 36, 53 and 70 show that the different types of lakes rarely present a conclusion different from the one for the whole region. Meaning that if a trend is detected in the region, a trend will likely be detected for all types of lakes. The exceptions are : A) in the Muskoka region the level 0 of classification #3 is not significant and; B) in the Sudbury region level 5 of classification #1 and level 0 of classification #4 are significant.

The general conclusion for conductivity values is that the Muskoka and Algoma regions show a significant decrease from 1990 through 1995. The decreases go from 27.08 to 20.74 for the Muskoka region, from 26.18 to 21.16 for the Algoma region. For the Sudbury region the decrease from 38.49 (1990) to 34.96 (1995) is not significant. These conclusions are the same for almost all types of lakes.

1.2.3 Alkalinity values

Table 3 shows significant regional regression for the Algoma region only with a positive slope of 3.53 units/year. For the Sudbury region the slope of 4.92 units/year is not significant. The RMSE for the Sudbury region shows a greater variability for this region, this large variability may be induced by the presence of outlier(s). For the Muskoka region, the trend slope of 0.90 unit/year is a lot smaller than those of the other regions and is not significant.

For the Muskoka and Sudbury regions, tables 20, 37, 54 and 71 show that the different types of lakes rarely present a different conclusion than the one for the whole region. Meaning that if a trend is detected in the region, a trend will likely be detected for all types of lakes. The exceptions are in the Muskoka region where level 5 of classification #1, level 2 of classification #2 and level 1 of classification #4 are significant and. For the Algoma region, tables 20, 37, 54 and 71 show that different types of lakes often bring different conclusions compared to the conclusions of the whole region.

The general conclusion for alkalinity values is that only the Algoma region show a significant increase from 1990 through 1995 but the increase is not significant in all types of lakes. The increase goes from 39.55 to 57.22 for the Algoma region. For the Muskoka and Sudbury regions the increases from 19.96 (1990) to 24.46 (1995) and from 54.34 (1990) to 78.96 (1995) are not significant. The conclusion of non significant trends is valid for almost all types of lakes.

1.2.4 Calcium concentrations

Table 4 shows significant regional regressions for the Muskoka and Algoma regions with negative slopes of respectively -0.12 ppm/year and -0.09 ppm/year. For the Sudbury region the slope of -0.07 ppm/year is not significant. The RMSE for the Sudbury region shows a greater variability for this region.

Table 21, 38, 55 and 72 show that the different types of lakes rarely present a conclusion different from the one for the whole region. The exceptions are : A) in the Algoma region the level 0, 1 and 2 of classification #1 and level 1 of classification #3 are not significant and; B) in the Sudbury region level 2 of classification #2 is significant.

The general conclusion for calcium concentrations is that the Muskoka and Algoma regions show a significant decrease from 1990 through 1995. The decreases go from 2.22 ppm to 1.60 ppm for the Muskoka region and from 2.63 ppm to 2.15 ppm for the Algoma region. For the Sudbury region the decrease from 3.68 ppm (1990) to 3.35 ppm (1995) is not significant. These conclusions are the same for almost all types of lakes.

1.2.5 Magnesium concentrations

Table 5 shows significant regional regressions for the Muskoka and Algoma regions with negative slopes of respectively -0.033 ppm/year and -0.021 ppm/year. For the Sudbury region the slope of

-0.009 ppm/year is not significant. The RMSE for the Sudbury region shows a greater variability for this region.

Table 22, 39, 56 and 73 show that the different types of lakes rarely present a conclusion different from the one for the whole region. The exceptions are : A) in the Algoma region the level 0 of classification #1 is significant and; B) in the Sudbury region level 2 of classification #2 is significant.

The general conclusion for magnesium concentrations is that the Muskoka and Algoma regions show a significant decrease from 1990 through 1995. The decreases go from 0.67 ppm to 0.51 ppm for the Muskoka region and from 0.54 ppm to 0.43 ppm for the Algoma region. For the Sudbury region the decrease from 0.83 ppm (1990) to 0.79 ppm (1995) is not significant. These conclusions are the same for almost all types of lakes.

1.2.6 Potassium concentrations

Table 6 shows significant regional regressions for the Algoma region only. The trend is associated with a negative slope of -0.002 ppm/year. For the Muskoka and Sudbury regions the slopes of -0.002 ppm/year and 0.002 ppm/year are not significant. The RMSE for these regions shows a greater variability than for the Algoma region.

Table 23, 40, 57 and 74 show that trends are rarely detected for the different types of lakes and that is true even in the Algoma region where a significant trend is detected for the whole region. This particularity is probably due to the lower sample sizes when working in a type of lake.

The general conclusion for potassium concentrations is that the Algoma region show a significant decrease from 1990 through 1995; the decrease go from 0.21 ppm to 0.20 ppm for the this region. For the Muskoka and Sudbury regions the decreases from 0.34 ppm (1990) to 0.33 ppm (1995) and the increase from 0.31 ppm to 0.32 ppm are not significant. When working in lake type levels, very few significant trends are detected.

1.2.7 Sodium concentrations

Table 7 shows significant regional regressions for the Algoma region only. The trend is associated with a negative slope of -0.029 ppm/year. For the Muskoka and Sudbury regions the slopes of -0.032 ppm/year and -0.009 ppm/year are not significant. The RMSE for these regions shows a greater variability than for the Algoma region.

Table 24, 41, 58 and 75 show that trends are often detected for the different types of lakes and that is true even in the Muskoka region where no significant trend can be detected for the whole region. This particularity could be attributed to : A) a type of lake with very large variability (for example level 3 of classification #1 in the Muskoka region) or: B) a large heterogeneity between lake types for sodium concentrations. In both cases, working with the whole region induces a large variability and makes it difficult to detect trends. On the other hand, when working in lake types, the cases where the variability is low show significant trends.

The general conclusion for sodium concentrations is that the Algoma region show a significant decrease from 1990 through 1995; the decrease go from 0.66 ppm to 0.52 ppm for the this region. For the Muskoka and Sudbury regions the decreases from 0.81 ppm (1990) to 0.65 ppm (1995) and from 0.83 ppm to 0.78 ppm are not significant. When working in lake type levels, more trends are detected, probably because some lake types presenting very large variability make it difficult to detect regional trend in the whole Muskoka and Sudbury regions.

1.2.8 Sulfate concentrations

Table 8 shows significant regional regressions for all three regions. The slopes are respectively -0.51 ppm/year, -0.45 ppm/year and -0.28 ppm/year for the Muskoka, Algoma and Sudbury regions. The RMSE is larger in the Sudbury region.

Table 25, 42, 59 and 76 show that trends are detected for almost all types of lakes. The only exceptions are in the Sudbury region where levels 0 and 1 of classification #1, level 1 of classification #2 and level 1 of classification#4 are not significant.

The general conclusion for sulfate concentrations is that all three regions show a significant decrease from 1990 through 1995. The decreases go from 6.93 ppm to 4.39 ppm for the Muskoka region, from 5.60 ppm to 3.36 ppm for the Algoma region and from 9.41 ppm to 8.01 ppm for the Sudbury region. Significant decreasing trends are detected for almost all lake types in all three regions.

1.2.9 Silicate concentrations

Table 9 shows significant regional regressions for the Muskoka and Algoma regions. The slopes are respectively 0.08 ppm/year, -0.11 ppm/year for the Muskoka and Algoma regions showing different trend directions in these regions. These particular results should be studied in more details since silicate and NO2NO3 are the only parameters with significant trends of opposite directions in two different regions. For the Sudbury region, the trend of 0.02 ppm/year is not significant.

Table 26, 43, 60 and 77 show that for Muskoka and Algoma regions, several lake types do not show significant. For the Sudbury region no significant trends are detected in all lake types.

The general conclusion for silicate concentrations is that the Muskoka and Algoma regions show a significant trend: Muskoka presents a significant increase going from 1.25 ppm (1990) to 1.66 ppm (1995) and Algoma presents a significant decrease going from 2.92 ppm (1990) to 2.39 ppm (1995). These trends are not found in all lake types. For the Sudbury region, the increase from 1.76 ppm (1990) to 1.84 ppm (1995) is not significant.

1.2.10 Chloride concentrations

Table 10 shows significant regional regressions for the Algoma region only. The trend is associated with a negative slope of -0.018 ppm/year. For the Muskoka and Sudbury regions the slopes of -0.028 ppm/year and -0.002 ppm/year are not significant. The RMSE for these regions shows a greater variability than for the Algoma region.

Table 27, 44, 61 and 78 show that trends are often detected for the different types of lakes and that is true even in the Muskoka and Sudbury regions where no significant trends can be detected for the whole regions. This particularity could be attributed to : A) a type of lake with very large variability (for example level 3 of classification #1 in the Muskoka region) or: B) a large heterogeneity between lake types for chloride concentrations. In both cases, working with the whole region induces a large variability and makes it difficult to detect trends. On the other hand, when working in lake types, the cases where the variability is low show significant trends.

The general conclusion for sodium concentrations is that the Algoma region show a significant decrease from 1990 through 1995; the decrease go from 0.27 ppm to 0.19 ppm for the this region. For the Muskoka and Sudbury regions the decreases from 0.52 ppm (1990) to 0.38 ppm (1995) and from 0.244 ppm to 0.236 ppm are not significant. When working in lake type levels, more trends are detected, probably because some lake types presenting very large variability make it difficult to detect regional trend in the whole Muskoka and Sudbury regions. The results for chloride concentrations are similar to those of the sodium concentrations.

1.2.11 TIC concentrations

Table 11 shows the absence of significant regional trends for all three regions. Table 28, 45, 62 and 79 show that no regional trends are detected for all lake types in each of the three regions.

The general conclusion for TIC concentrations is that no significant trends are detected in each region and for all types of lakes in all three regions.

1.2.12 DOC concentrations

Table 12 shows the absence of significant regional trends for all three regions. Table 29, 46, 63 and 80 show that no regional trends are detected for all lake types in each of the three regions.

The general conclusion for DOC concentrations is that no significant trends are detected in each region and for all types of lakes in all three regions

1.2.13 TKN concentrations

Table 13 shows significant regional regressions for all three regions. The slopes are respectively -0.02 ppm/year, -0.02 ppm/year and -0.03 ppm/year for the Muskoka, Algoma and Sudbury regions. Table 30, 47, 64 and 81 show that in several lake types, no significant trends are detected.

The general conclusion for TKN concentrations is that all three regions show a significant decrease from 1990 through 1995. The decreases go from 0.47 ppm to 0.35 ppm for the Muskoka region, from 0.48 ppm to 0.36 ppm for the Algoma region and from 0.48 ppm to 0.33 ppm for the Sudbury region. However, in several lake types, no significant trends are detected.

1.2.14 NO_2NO_3 concentrations

Table 14 shows significant regional regressions for all three regions. The slopes are respectively 0.002 ppm/year, 0.005 ppm/year and -0.001 ppm/year for the Muskoka, Algoma and Sudbury regions. Table 31, 48, 65 and 82 show that in several lake types, no significant trends are detected.

The general conclusion for NO_2NO_3 concentrations is that all three regions show a significant trend between 1990 and 1995. The trends consist of an increase going from 0.01 ppm to 0.02 ppm for the Muskoka region, from 0.01 ppm to 0.03 ppm for the Algoma region while the Sudbury region show a decrease from 0.02 ppm to 0.01. However, in several lake types, no significant trends are detected. The particular results for this parameter suggest a more detailed analysis before adequate conclusions could be drawn.

1.2.15 Total nitrogen concentrations

Table 15 shows significant regional regressions for the Sudbury region only. The trend is associated with a negative slope of -0.065 ppm/year. For the Muskoka and Algoma regions the slopes of 0.000 ppm/year and 0.010 ppm/year are not significant. For the Muskoka region, no slope can be estimated since values are available for 1995 only.

Table 32, 49, 56 and 83 show several distinctions between whole region regressions and regressions for each type of lakes.

The general conclusion for total nitrogen concentrations is that the Sudbury region show a significant decrease from 1990 through 1995; the decrease go from 0.60 ppm to 0.28 ppm for the this region. For the Algoma region the increase from 0.36 ppm (1990) to 0.41 ppm (1995) is not significant. For the Muskoka region, no slope can be estimated since values are available for 1995 only.

1.2.16 Ammoniac concentrations

Table 16 shows the absence of significant regional trends for all three regions. Table 33, 50, 67 and 84 show that only a couple of regional trends are detected for lake types : A significant decrease is detected in level 5 of classification #1 and in level 2 of classification #4 for the Algoma region.

The general conclusion for ammoniac concentrations is that no significant trends are detected in each region and only a couple of trends are detected in all the combinations of lake types and regions.

1.2.17 Total phosphorus concentrations

Table 17 shows significant regional regressions for the Muskoka and Sudbury regions. The slopes are respectively -1.17 ppm/year, -0.35 ppm/year for the Muskoka and Sudbury regions. For the Algoma region, the trend of -0.02 ppm/year is not significant.

Table 26, 43, 60 and 77 show that for Muskoka and Sudbury regions, several lake types do not exhibit significant trends. For the Algoma region no significant trends are detected in all lake types.

The general conclusion for total phosphorus concentrations is that the Muskoka and Sudbury regions show a significant trend: Muskoka presents a significant decrease going from 13.51 ppm (1990) to 7.66 ppm (1995) and Sudbury presents a significant decrease going from 8.46 ppm (1990) to 6.69 ppm (1995). These trends are not found in all lake types. For the Algoma region, the decrease from 6.48 ppm (1990) to 6.38 ppm (1995) is not significant and all lake types show non significant trends in this region.

Section 2: Complete regression analyses

2.1 pH values

Muskoka region

For the Muskoka region, data are available for 260 lakes and 4 years (1990, 1991, 1993 and 1995). Several missing values being present, only 782 observations are used for this regional trend detection analysis of pH values.

Figure 1 : Box-Plot graph for the pH values in the Muskoka region

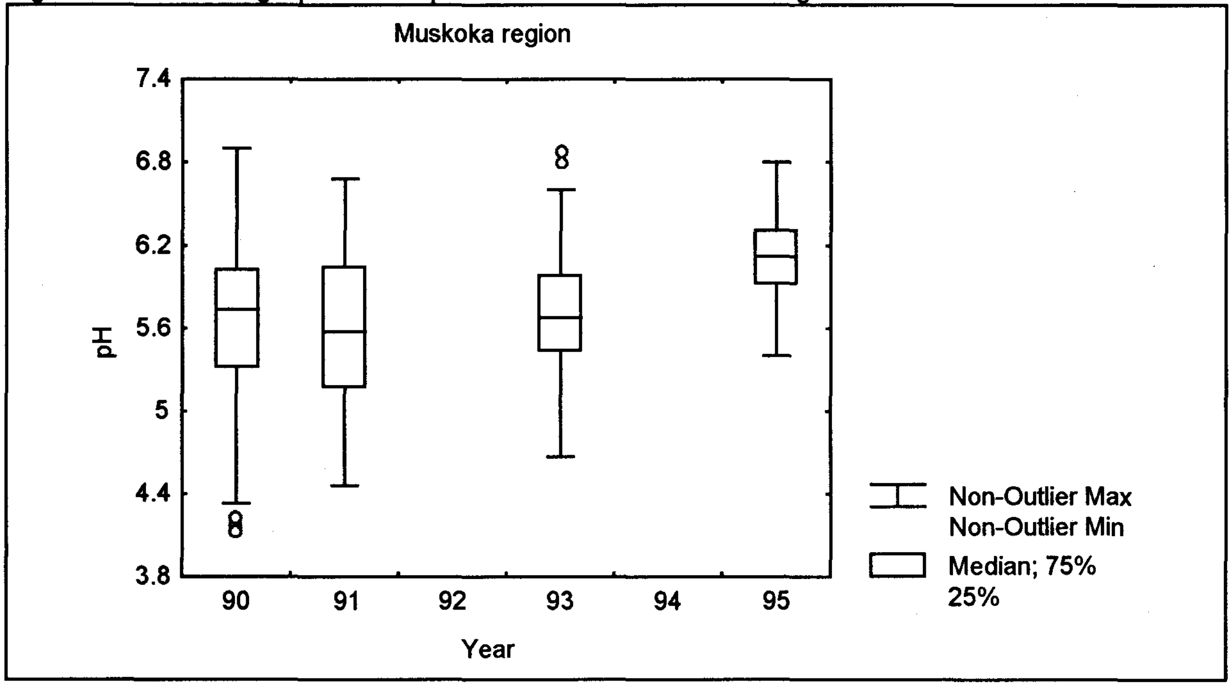
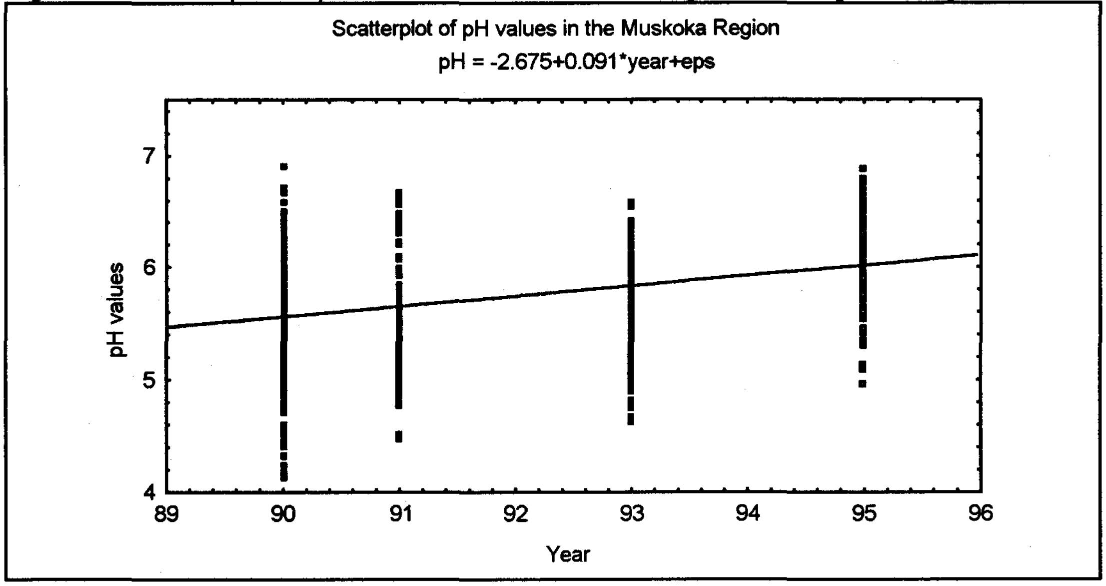


Figure 1 shows a couple of very low pH values in 1990 and a couple of very high values in 1993. However, these "outlier" values are not far enough to affect significantly the regional regression. Boxes and Whiskers show a tendancy for pH values to increase in time. The results of the regional regression support this fact :

n	:	782
R^2	:	0.14
Intercept estimate (year 0)	:	-2.675
Slope estimate	:	0.0915/year
Initial value estimate (1990)	:	5.56
Final value estimate (1995)	:	6.02

The regression is highly significant (p=0.0001). Figure 2 shows the regression line passing through the cloud of observations associated to each year. This plot shows the particularity of using linear regression with several lakes measured at a reduced number of years. Such a plot (data on only four levels of the independent variable) could suggest the use of analysis of variance to detect changes in years instead of linear regression. The comparison of both approaches will be discussed in the final report.

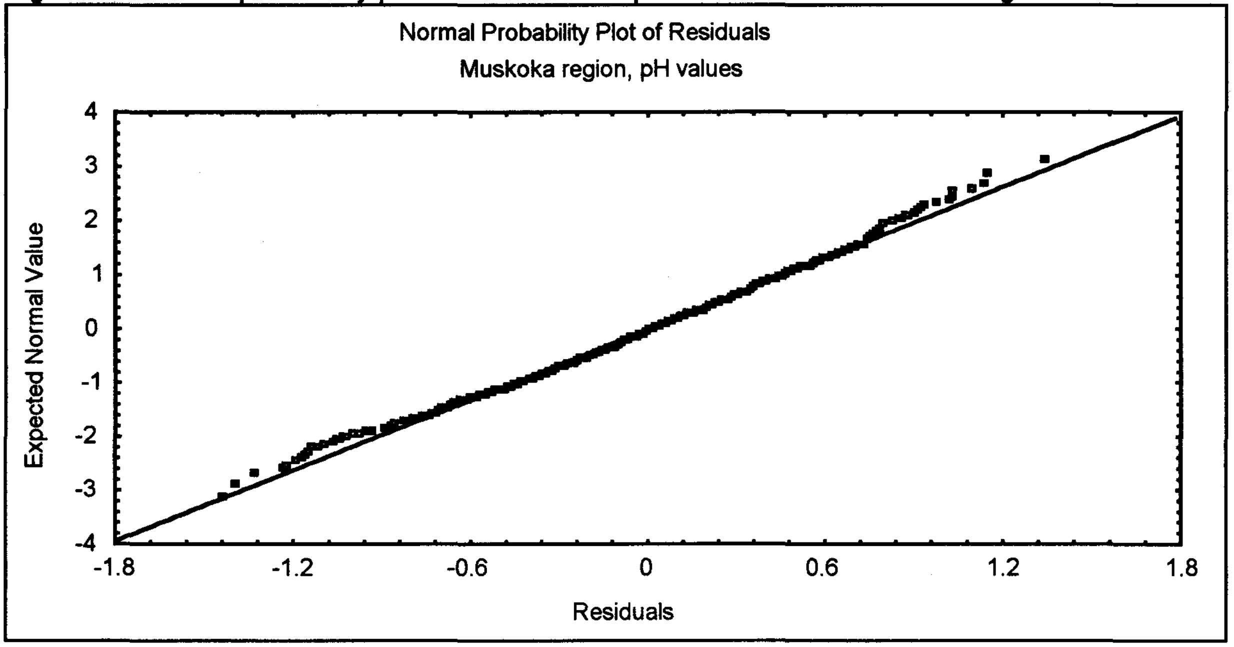
Figure 2 : Scatterplot of pH values in the Muskoka region with regional regression line



The regional regression shows a clear increasing trend for pH values in the Muskoka region. The increase of 0.09 unit/year appears linear and no large outlier could affect significantly the conclusion of the regression. Figures 1 and 2 show that the variability of pH values between lakes seems to decrease in time. These graphs also suggest that lakes with very low pH in 1990 tend to increase more and could be the main reason for the significant regional regression. This hypothesis could be studied in more details.

Figure 3 presents the normal probability plot of the regional regression residuals. This graph supports the hypothesis that no large outliers affect significantly the conclusion of the regional regression.

Figure 3 : Normal probability plot of residuals for pH values in the Muskoka region



Algoma region

For the Algoma region, data are available for 256 lakes and 4 years (1988, 1992, 1994 and 1995). Several missing values being present, only 935 observations are used for this regional trend detection analysis of pH values.

Figure 4 : Box-Plot graph for the pH values in the Algoma region

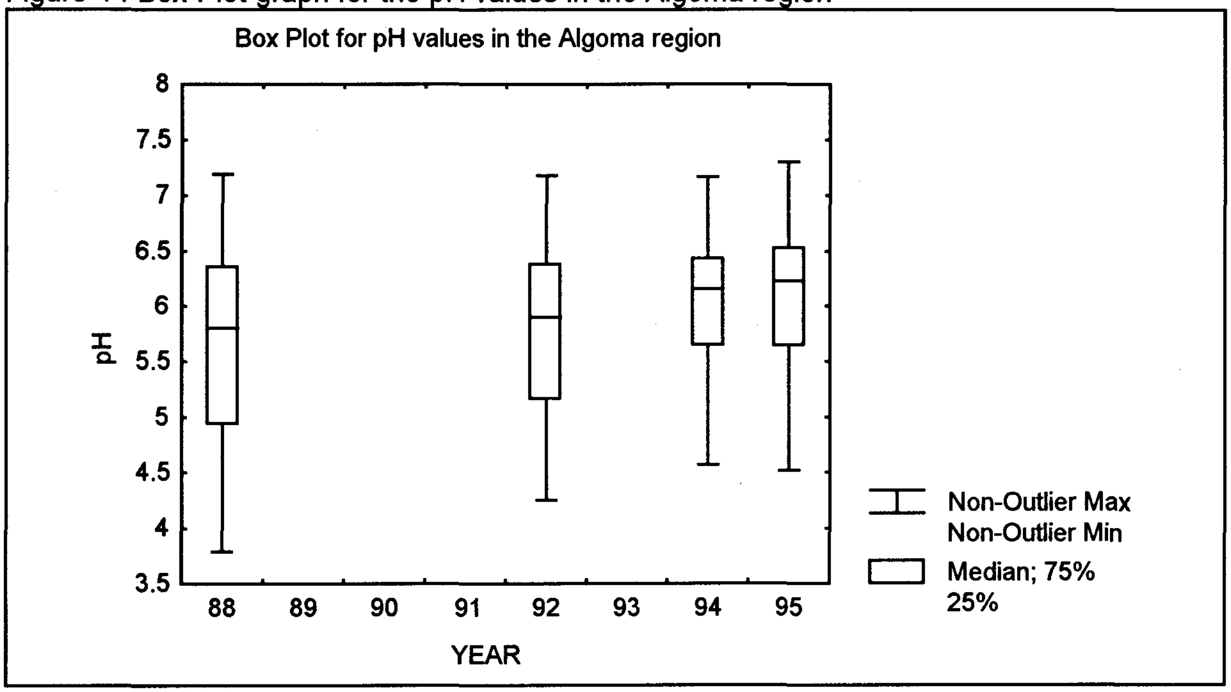
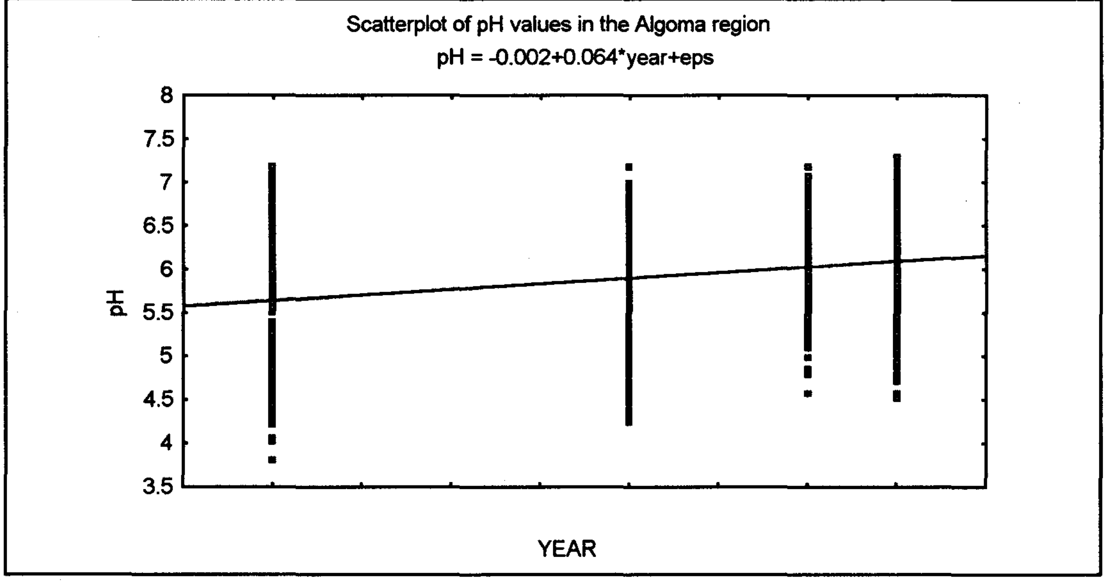


Figure 4 shows that the non-outlier maximum changes less in time than the non outlier minimum. Boxes and Whiskers show a tendency for pH values to increase in time. The results of the regional regression support this fact:

n	:	935
R^2	:	0.06
Intercept estimate (year 0)	:	0.00
Slope estimate	:	0.064/year
Initial value estimate (1990)	:	5.77
Final value estimate (1995)	:	6.09

The regression is highly significant (p=0.0001). Figure 5 shows the regression line passing through the cloud of observations associated to each year.

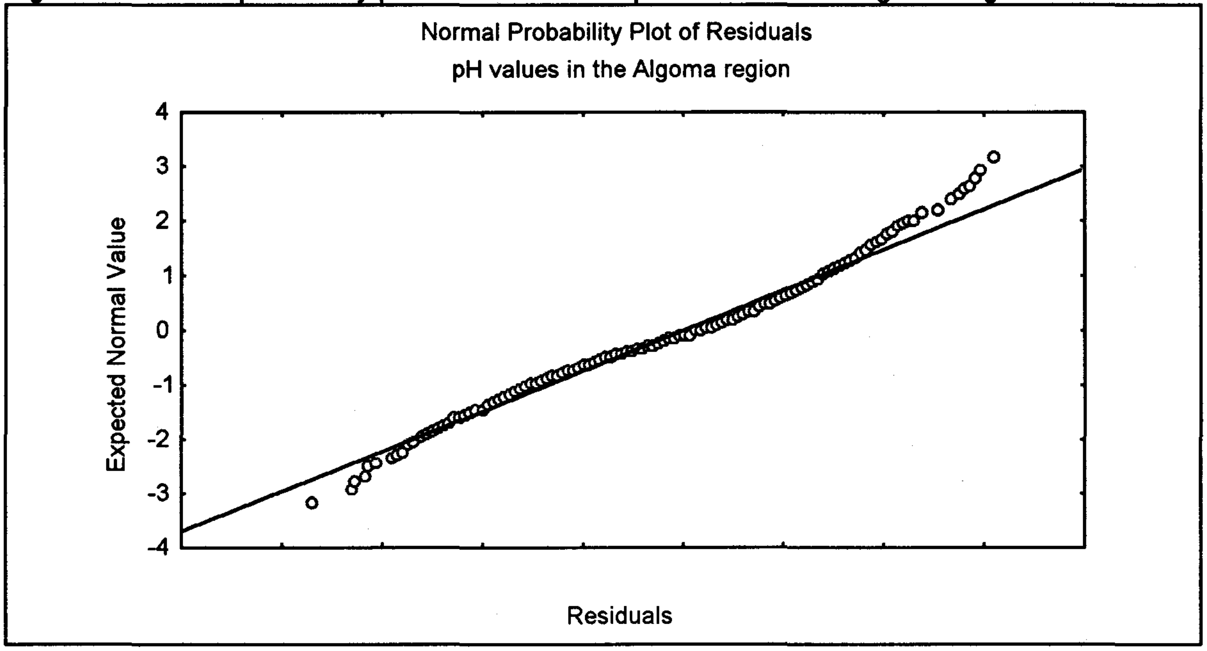
Figure 5 : Scatterplot of pH values in the Algoma region with regional regression line



The regional regression shows a clear increasing trend for pH values in the Algoma region. The increase of 0.06 unit/year appears linear and no large outlier could affect significantly the conclusion of the regression. Figures 4 and 5 show that the variability of pH values between lakes seems to be more stable in time than in the Muskoka region. Like for the Muskoka region, these graphs suggest that lakes with low pH in 1988 tend to increase more and could be the main reason for the significant regional regression. This hypothesis could be studied in more details.

Figure 6 presents the normal probability plot of the regional regression residuals. This graph supports the hypothesis that no large outliers affect significantly the conclusion of the regional regression, but shows that the distribution of residuals has larger tails than the normal distribution.

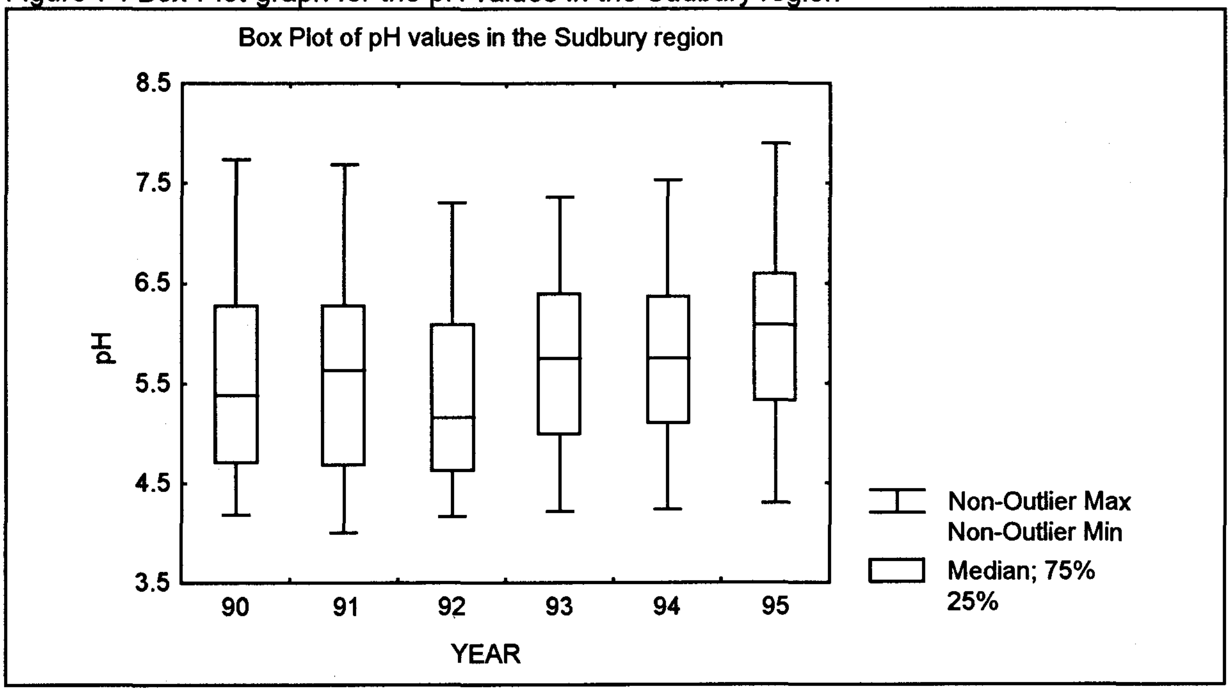
Figure 6 : Normal probability plot of residuals for pH values in the Algoma region



Sudbury region

For the Sudbury region, data are available for 160 lakes and 6 years (1990 through 1995). Several missing values being present, only 755 observations are used for this regional trend detection analysis of pH values.

Figure 7 : Box-Plot graph for the pH values in the Sudbury region

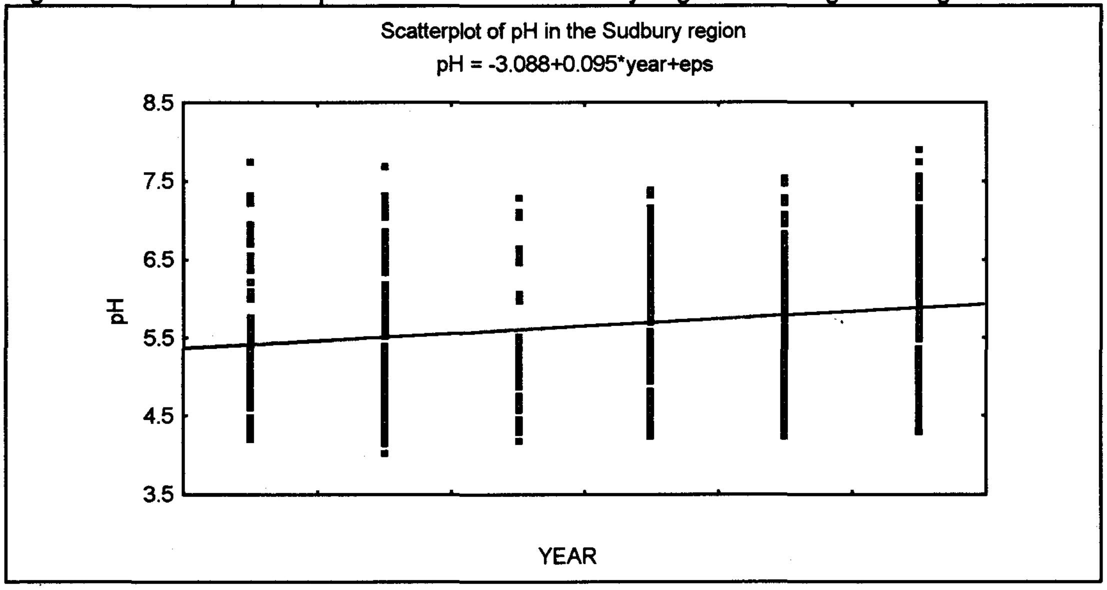


In figure 7 boxes and whiskers show no clear trend pattern for pH values in the Sudbury region. The results of the regional regression, however, conclude to a significant positive trend :

n	:	755
R^2	:	0.03
Intercept estimate (year 0)	:	-3.09
Slope estimate	:	0.09 unit/year
Initial value estimate (1990)	:	5.42
Final value estimate (1995)	:	5.89

The regression is highly significant (p=0.0001). Figure 8 shows the regression line passing through the cloud of observations associated to each year.

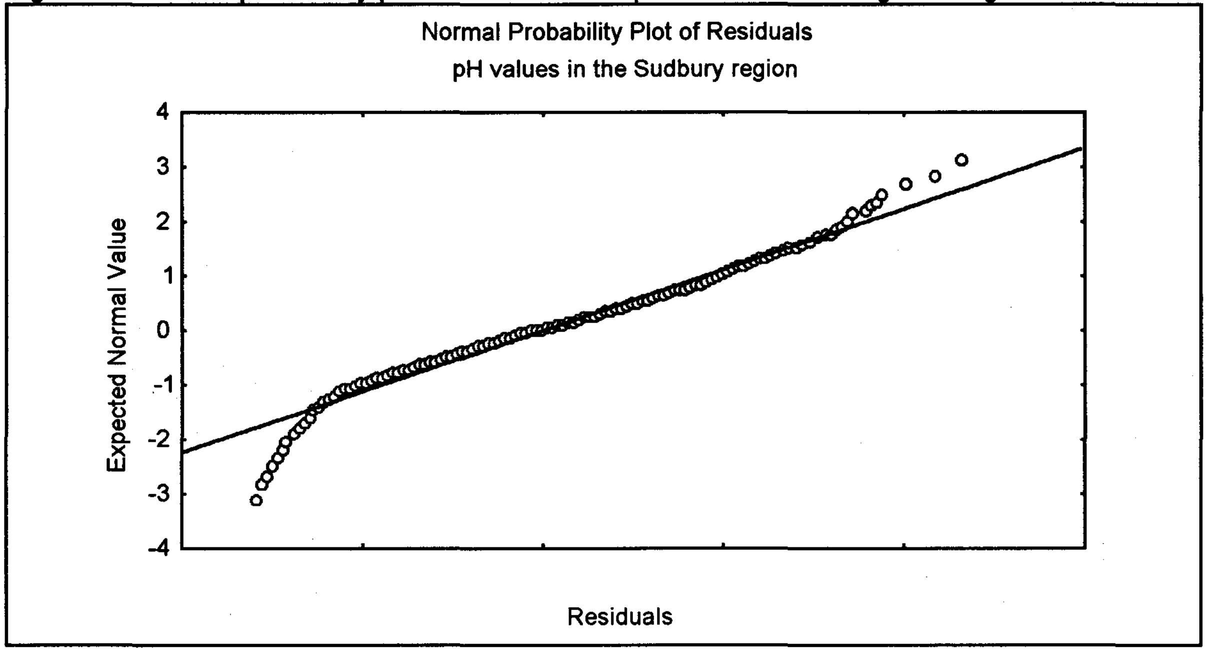
Figure 8 : Scatterplot of pH values in the Sudbury region with regional regression line



The regional regression line shows an increasing trend for pH values in the Sudbury region. The increase of 0.09 unit/year appears linear and no large outlier could affect significantly the conclusion of the regression. Figures 7 and 8 show that the variability of pH values between lakes seems quite stable in time like in the Algoma region.

Figure 9 presents the normal probability plot of the regional regression residuals. This graph supports the hypothesis that no large outliers affect significantly the conclusion of the regional regression, but shows that the distribution of residuals has larger tails than the normal distribution.

Figure 9 : Normal probability plot of residuals for pH values in the Algoma region



2.2 Alkalinity values

Muskoka region

For the Muskoka region, data are available for 260 lakes and 4 years (1990, 1991, 1993 and 1995). Several missing values being present, only 782 observations are used for this regional trend detection analysis of alkalinity values.

Figure 10 : Box-Plot graph for the alkalinity values in the Muskoka region

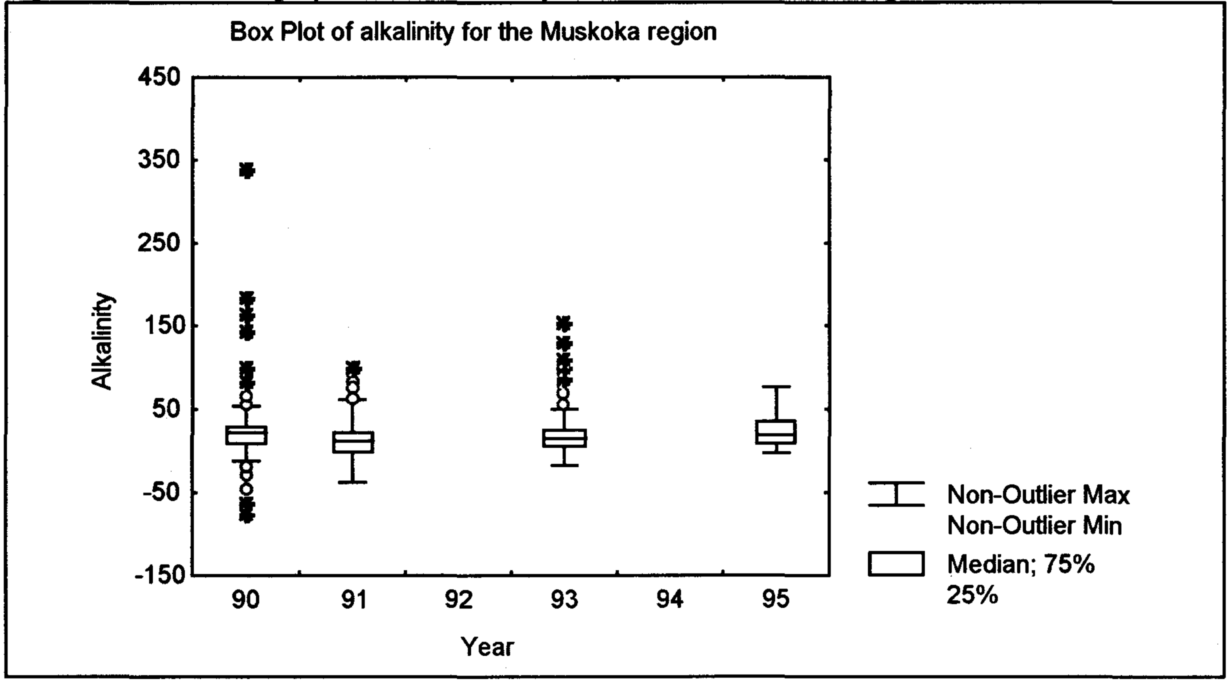
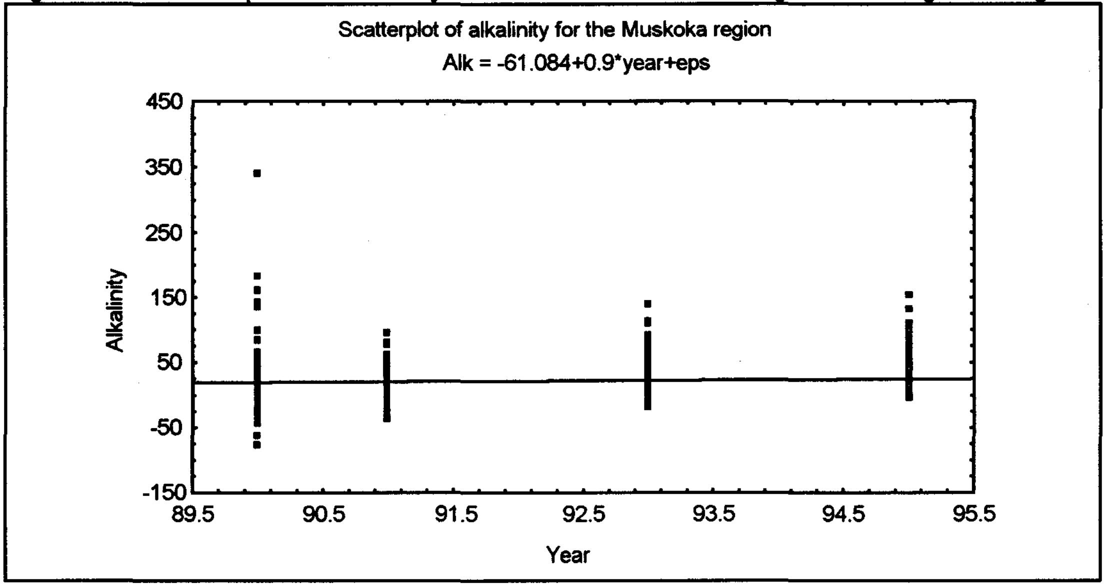


Figure 10 shows several very high values in 1990 and a couple in 1993. These "outlier" values can affect significantly the regional regression. But the "nonparametric" boxes and whiskers do not show a clear trend pattern in the alkalinity values. The following results of the regional regression support this fact, while the positive slope suggests that the high outliers of 1990 do not affect significantly the conclusion of the regional trend detection :

n	:	782
R^2	:	0.004
Intercept estimate (year 0)	:	-61.08
Slope estimate	:	0.90 ppm/year
Initial value estimate (1990)	:	19.96
Final value estimate (1995)	:	24.46

The regression is not significant (p=0.087). Figure 11 shows the regression line passing through the cloud of observations associated to each year, while figure 12 presents the normal probability plot of the regional regression residuals.

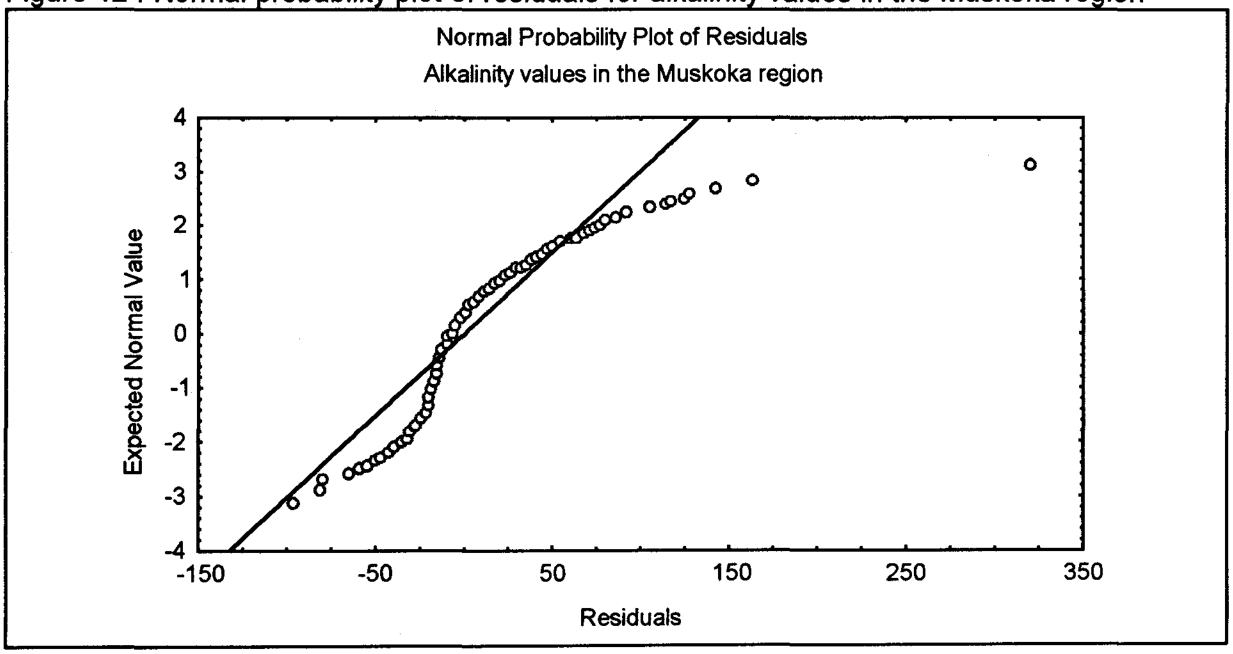
Figure 11 : Scatterplot of alkalinity values in the Muskoka region with regional regression line



The regional regression scatterplot illustrates the non significance of the 0.90 ppm/year increase. Figures 10 and 11 show that the variability of alkalinity values between lakes seems to decrease in time. These graphs also suggest that lakes with very high alkalinity in 1990, do show smaller alkalinity values for the other years.

Figure 12 presents the normal probability plot of the regional regression residuals of the alkalinity values in the Muskoka region. This graph suggest non normal residuals but the results presented earlier should not be largely affected by this non normality. However, the very large(s) alkalinity value(s) in 1990 could be the reason why the regional regression does not conclude to a significant positive trend.

Figure 12 : Normal probability plot of residuals for alkalinity values in the Muskoka region



Algoma region

For the Algoma region, data are available for 256 lakes and 4 years (1988, 1992, 1994 and 1995). Several missing values being present, only 929 observations are used for this regional trend detection analysis of alkalinity values.

Figure 13 : Box-Plot graph for the alkalinity values in the Algoma region

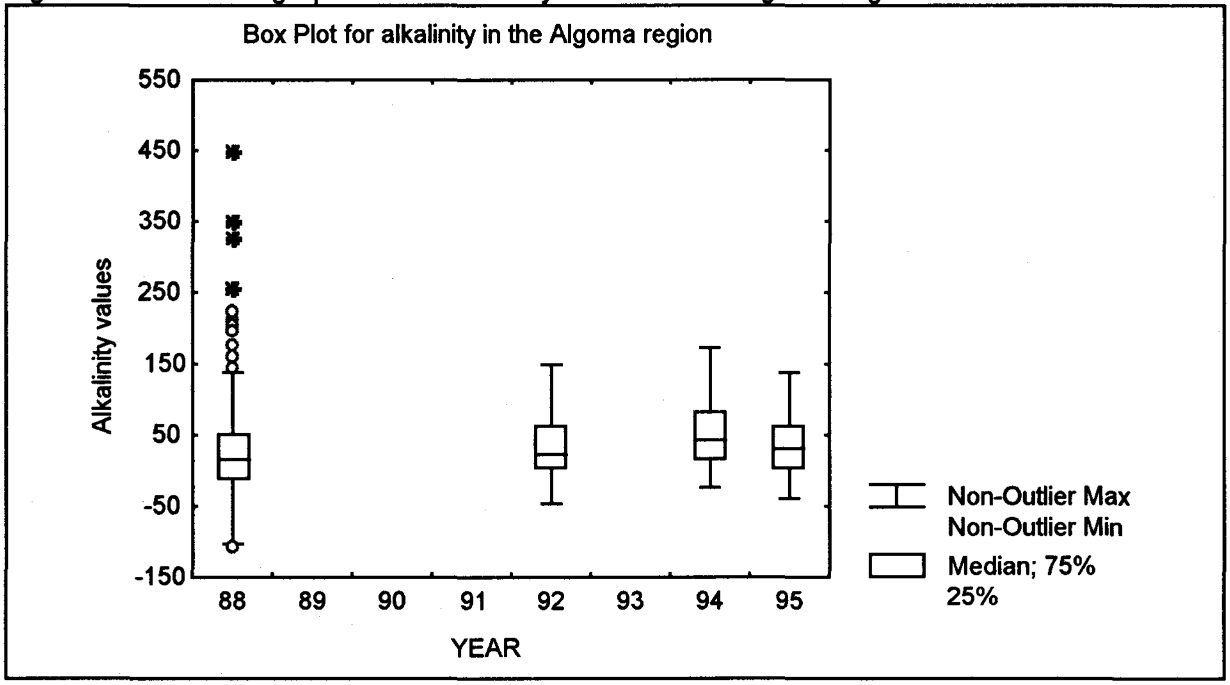
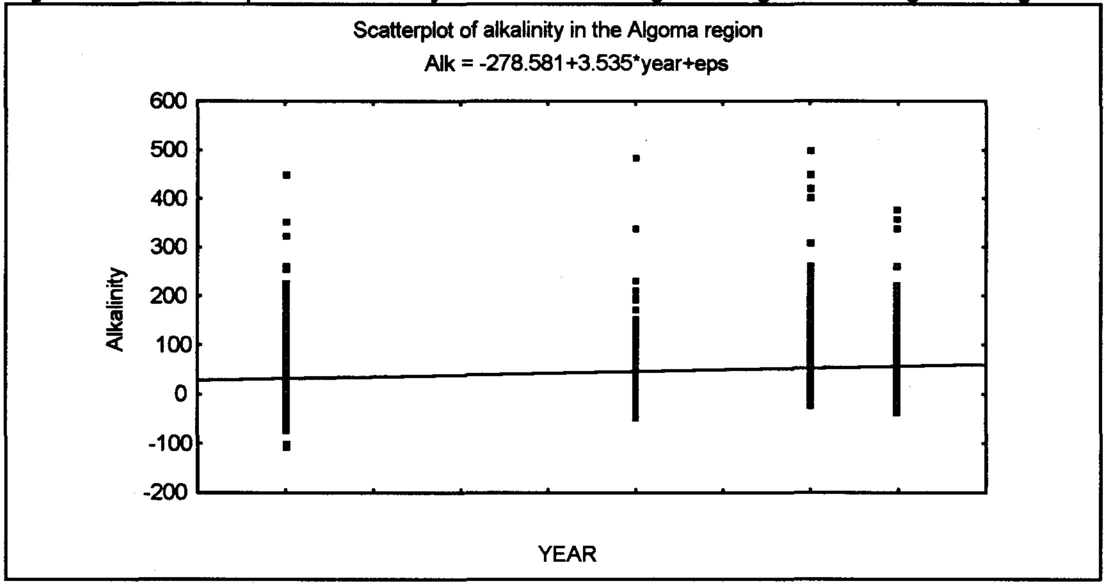


Figure 13 shows several very high values in 1988. These "outlier" values can affect significantly the regional regression. The "nonparametric" Boxes and Whiskers show a increasing trend pattern in the alkalinity values for the 1988 through 1994 period. The following results of the regional regression support this fact. The high values of alkalinity in 1988 do not appear to affect significantly the conclusion of the regional trend detection :

n	:	929
R^2	:	0.02
Intercept estimate (year 0)	:	-278.58
Slope estimate	:	3.53 units/year
Initial value estimate (1990)	:	39.55
Final value estimate (1995)	:	57.22

The regression is highly significant (p=0.0001). Figure 14 shows the regression line passing through the cloud of observations associated to each year, while figure 15 presents the normal probability plot of the regional regression residuals.

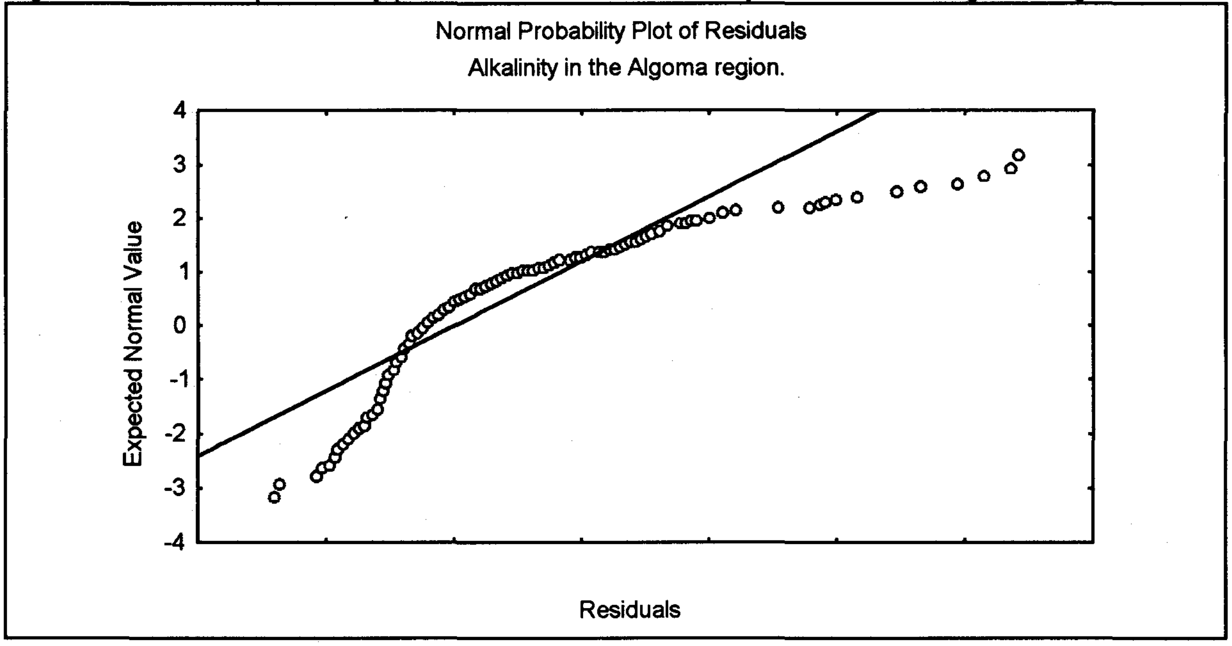
Figure 14 : Scatterplot of alkalinity values in the Algoma region with regional regression line



The regional regression scatterplot illustrates a 3.53 units/year increase. Figures 13 and 14 show that the variability of alkalinity values between lakes seems stable in time. These graphs also suggest that lakes with very high alkalinity in 1988, could also present high alkalinity values for the other years but this should be studied in more details to be sure that the same lakes are associated to high values from year to year.

Figure 15 presents the normal probability plot of the regional regression residuals for the alkalinity values in the Algoma region. This graph suggests non normal residuals but the results presented earlier should not be largely affected by this non normality. However, the very large(s) alkalinity value(s) in 1994 could be a reason why the regional regression does conclude to a significant positive trend.

Figure 15 : Normal probability plot of residuals for alkalinity values in the Algoma region



Sudbury region

For the Sudbury region, data are available for 160 lakes and 6 years (1990-1995). Several missing values being present, only 755 observations are used for this regional trend detection analysis of alkalinity values.

Figure 16 : Box-Plot graph for the alkalinity values in the Sudbury region

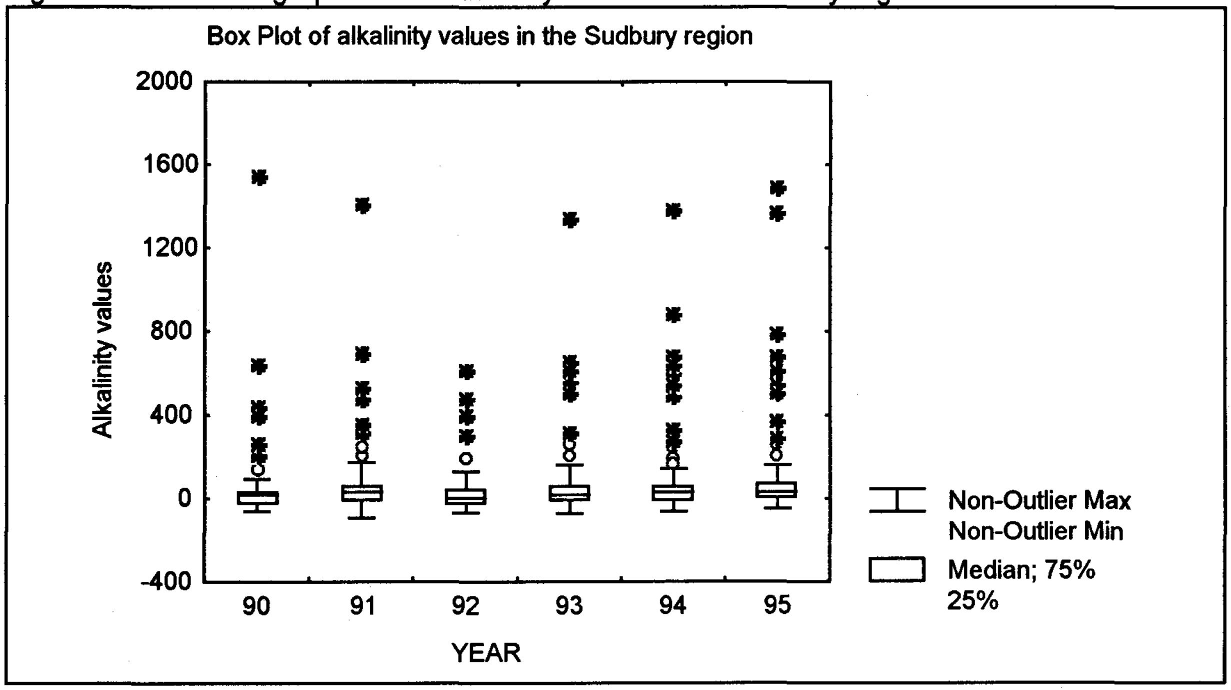
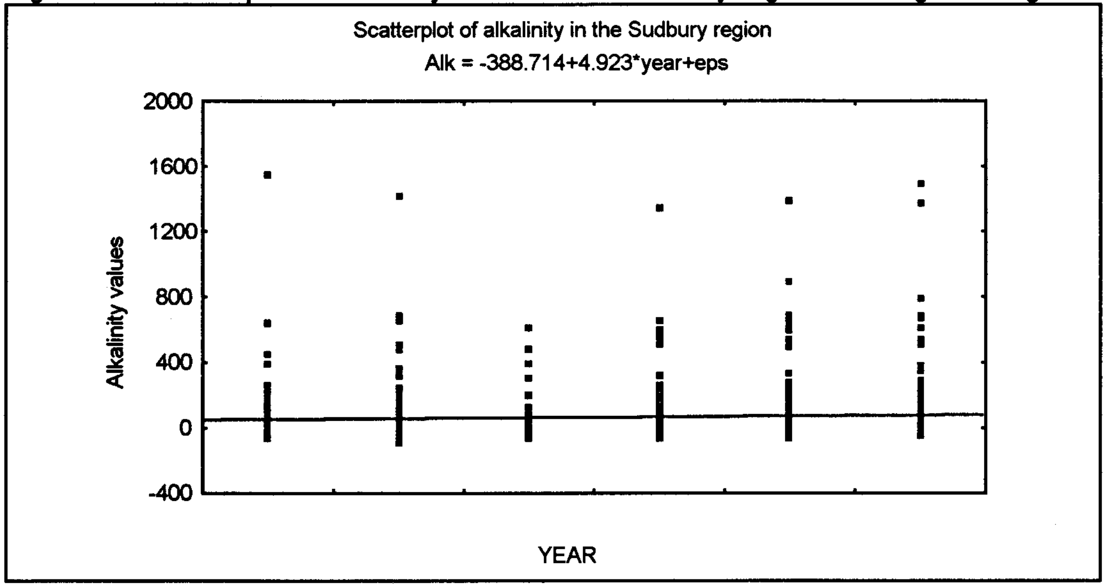


Figure 16 shows several very high values in for all years. These "outlier" values can affect significantly the regional regression in particular for the great variability they introduced in the data. The "nonparametric" boxes and whiskers show no clear trend pattern in the alkalinity values. The following results of the regional regression support this fact :

n	:	755
R^2	:	0.00
Intercept estimate (year 0)	:	-388.71
Slope estimate	:	4.92 units/year
Initial value estimate (1990)	:	54.34
Final value estimate (1995)	:	78.96

The regression is not significant (p=0.22). Figure 17 shows the regression line passing through the cloud of observations associated to each year, while figure 18 presents the normal probability plot of the regional regression residuals.

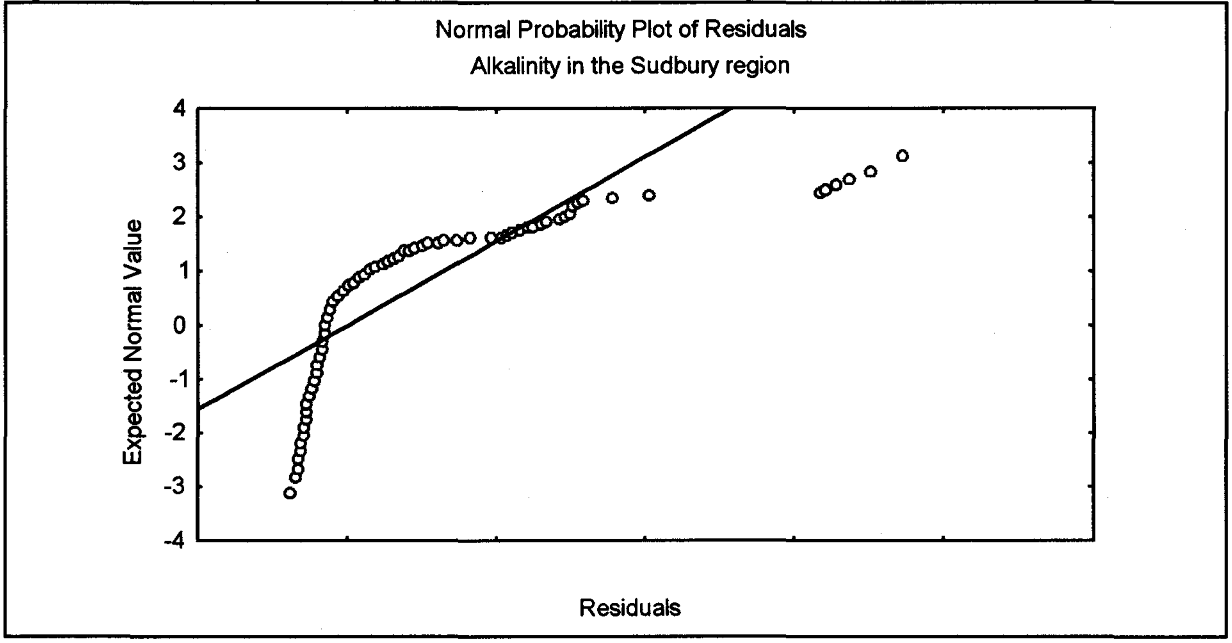
Figure 17 : Scatterplot of alkalinity values in the Sudbury region with regional regression line



The regional regression scatterplot illustrates 4.92 units/year increase and its lack of significance compared to the large variability in the data. Figures 16 and 17 show that the variability of alkalinity values between lakes seems stable in time but appear quite large. These graphs also suggest that lakes with very high alkalinity in 1988, could also present high alkalinity values for the other years but this should be studied in more details to be sure that the same lakes are associated to high values from year to year.

Figure 18 presents the normal probability plot of the regional regression residuals for the alkalinity values in the Sudbury region. This graph suggests non normal residuals and the presence of very large outliers. The results presented earlier could be largely affected by this non normality and by the outliers. A nonparametric approach would be more appropriate to detect regional trend in the present case.

Figure 18 : Normal probability plot of residuals for alkalinity values in the Sudbury region



2.3 Calcium concentrations

Muskoka region

For the Muskoka region, data are available for 260 lakes and 4 years (1990, 1991, 1993 and 1995). Several missing values being present, only 790 observations are used for this regional trend detection analysis of calcium concentrations.

Figure 19 : Box-Plot graph for the calcium concentrations in the Muskoka region

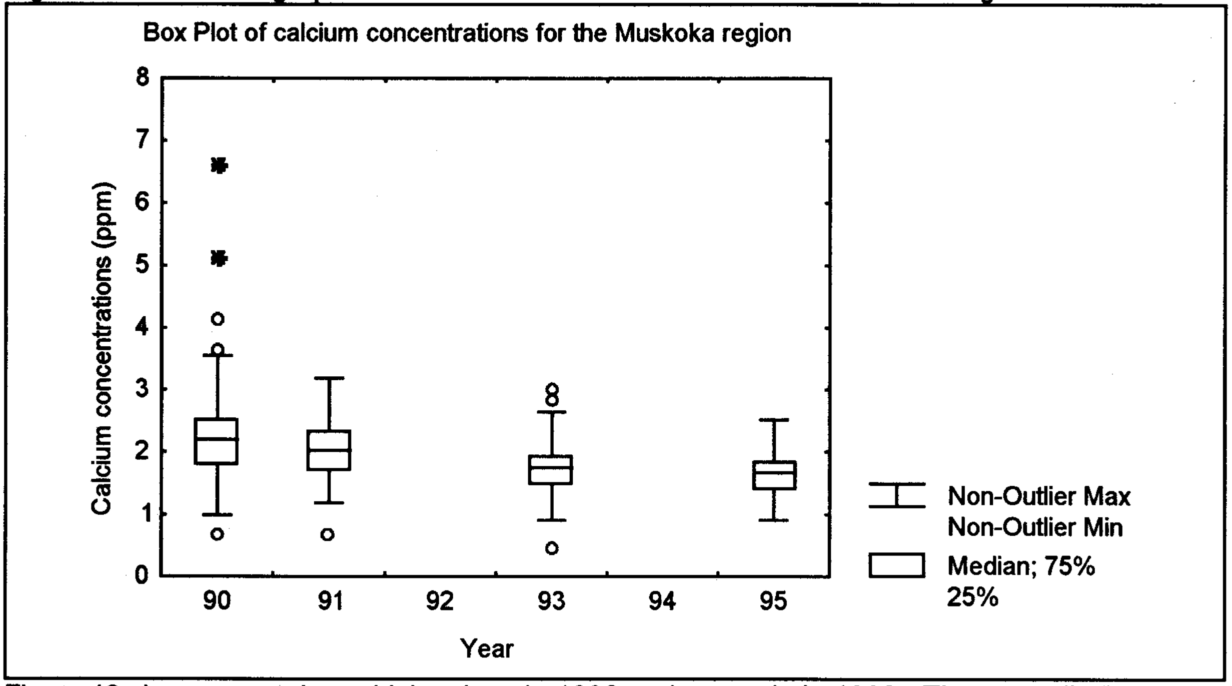
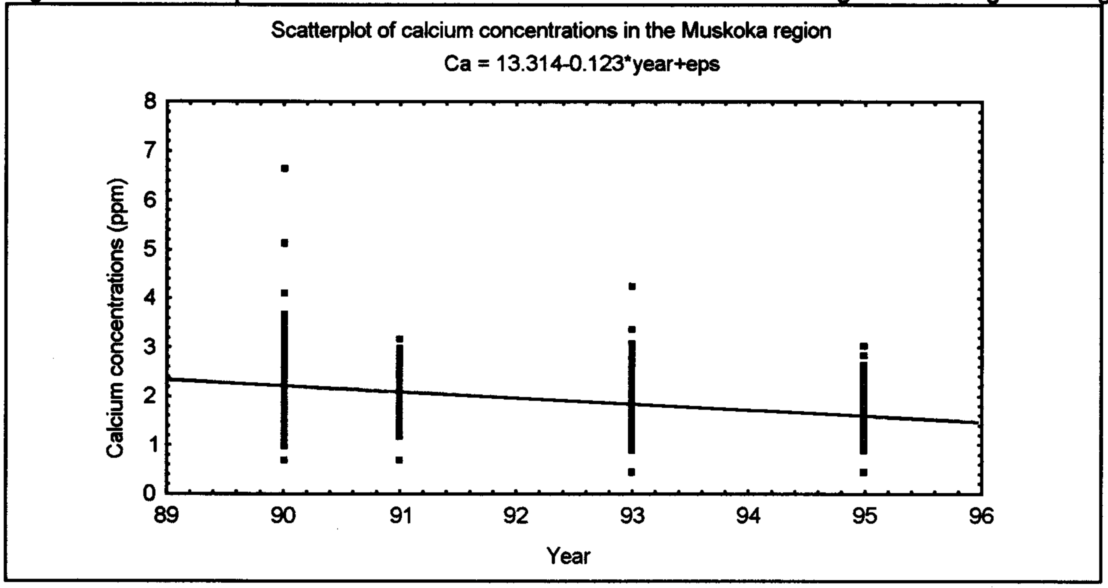


Figure 19 shows several very high values in 1990 and a couple in 1993. These "outlier" values can affect significantly the regional regression. The "nonparametric" boxes and whiskers show a clear decreasing trend pattern in the calcium concentrations. The following results of the regional regression support this fact:

n	:	790
R^2	:	0.16
Intercept estimate (year 0)	:	13.31
Slope estimate	:	-0.12 ppm/year
Initial value estimate (1990)	:	2.22
Final value estimate (1995)	:	1.60

The regression is highly significant (p=0.0001). It must be kept in mind that the high outliers of 1990 can "artificially" inflate the negative trend amplitude. Figure 20 shows the regression line passing through the cloud of observations associated to each year, while figure 21 presents the normal probability plot of the regional regression residuals.

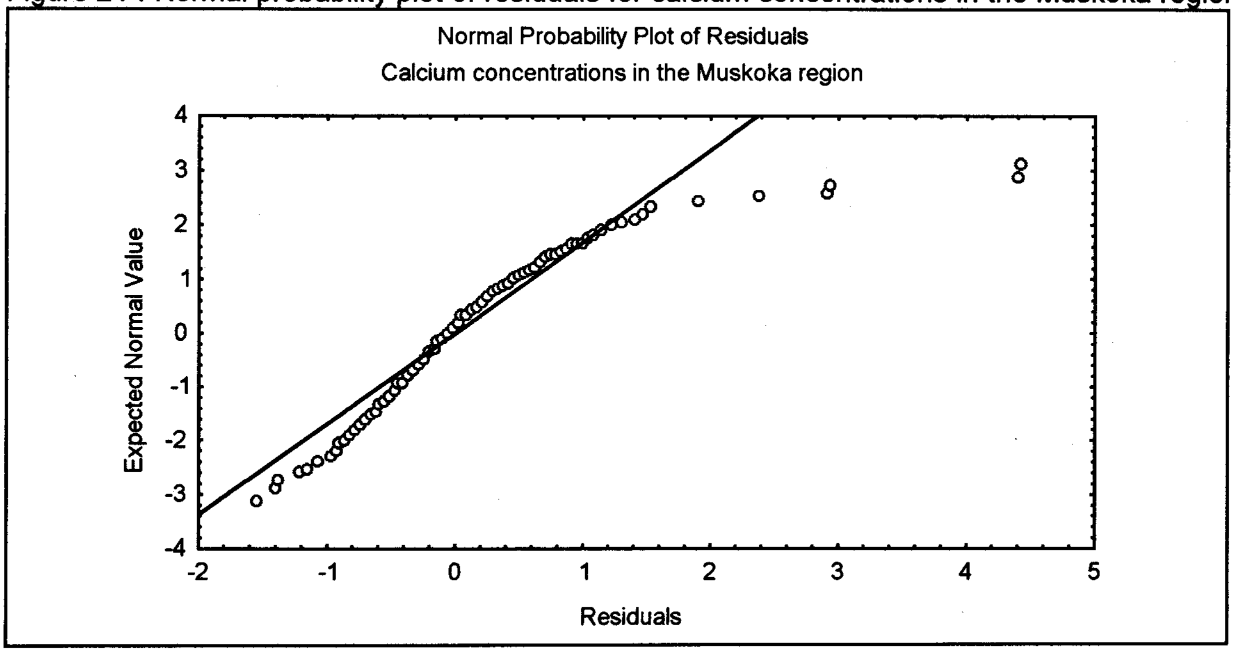
Figure 20 : Scatterplot of calcium concentrations in the Muskoka region with regional regression line



The regional regression scatterplot clearly shows the significant decreasing trend of -0.12 ppm/year. Figures 19 and 20 show that the variability of calcium concentrations between lakes seems to decrease in time. These graphs also suggest that lakes with very high calcium concentrations in 1990, do show smaller concentrations for the later years. The latter result was also seen in the alkalinity values.

Figure 21 presents the normal probability plot of the regional regression residuals of the calcium concentrations in the Muskoka region. This graph shows the presence of possible high outliers, but except for a possible inflated trend slope, the results presented earlier should not be largely affected by these possible outliers.

Figure 21 : Normal probability plot of residuals for calcium concentrations in the Muskoka region



Algoma region

For the Algoma region, data are available for 256 lakes and 4 years (1988, 1992, 1994 and 1995). Several missing values being present, only 917 observations are used for this regional trend detection analysis of calcium concentrations.

Figure 22 : Box-Plot graph for the calcium concentrations in the Algoma region

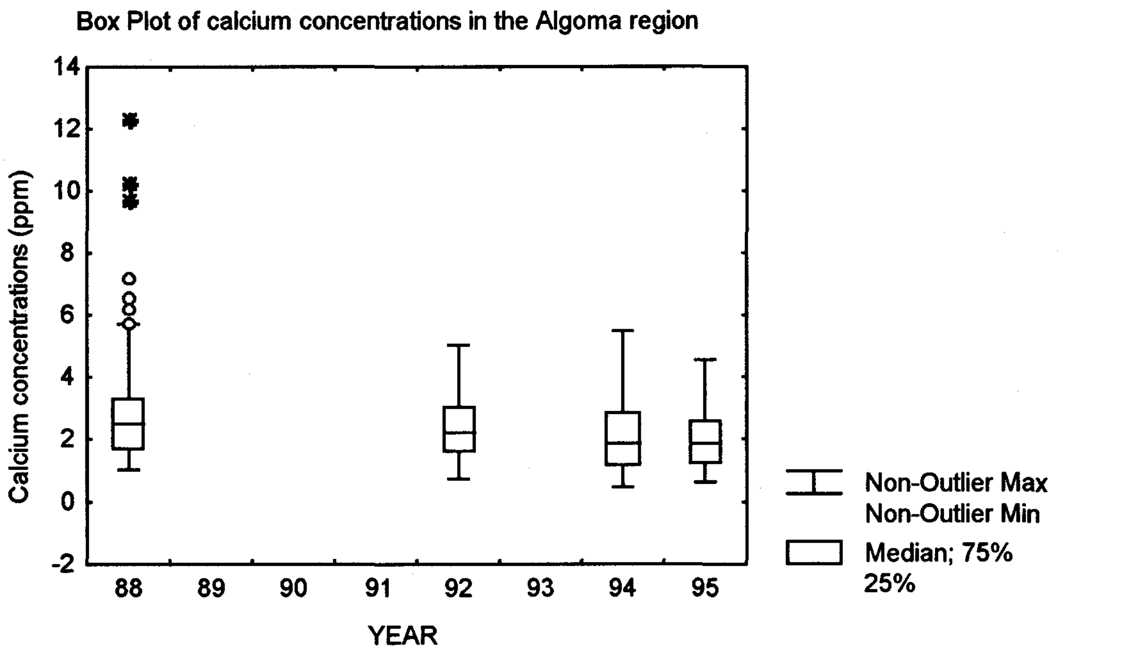
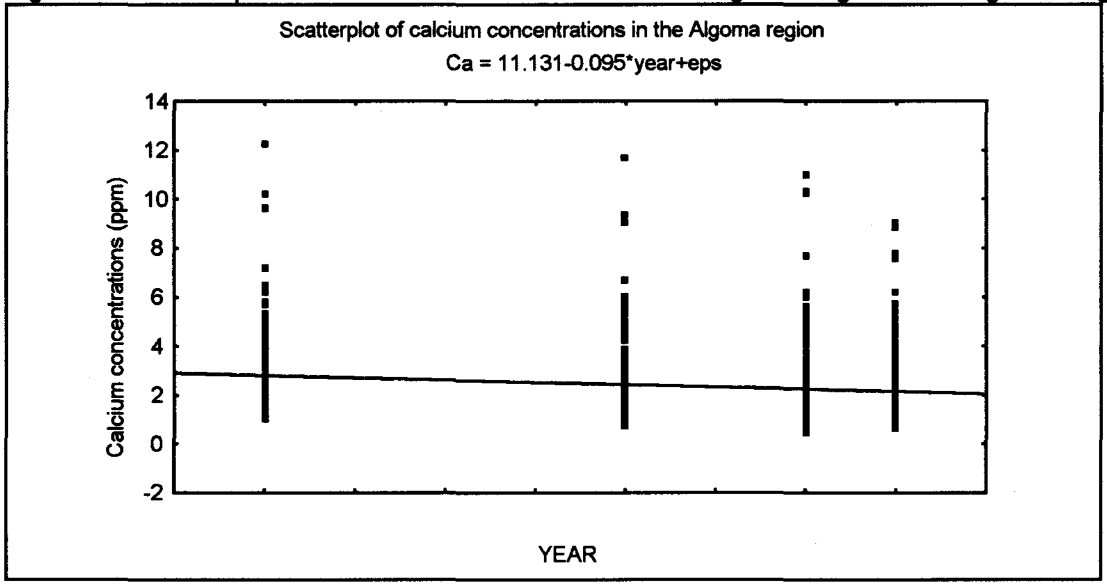


Figure 22 shows several very high values in 1988. These "outlier" values can affect significantly the regional regression. The "nonparametric" boxes and whiskers show a possible decreasing trend pattern in the calcium concentrations. The following results of the regional regression support this possibility:

n	:	917
R^2	:	0.02
Intercept estimate (year 0)	:	11.13
Slope estimate	:	-0.09 ppm/year
Initial value estimate (1990)	:	2.63
Final value estimate (1995)	:	1.15

The regression is highly significant (p=0.0001). It must be kept in mind that the high outliers of 1988 can "artificially" inflate the negative trend amplitude. Figure 23 shows the regression line passing through the cloud of observations associated to each year, while figure 24 presents the normal probability plot of the regional regression residuals.

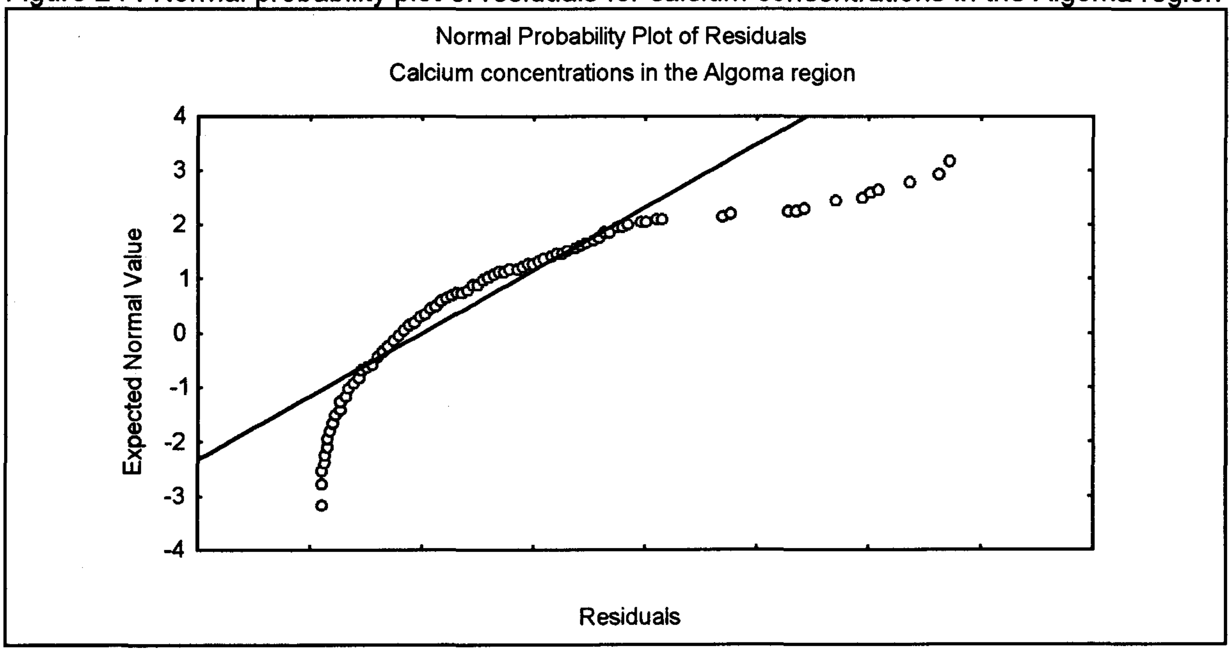
Figure 23 : Scatterplot of calcium concentrations in the Algoma region with regional regression line



The regional regression scatterplot clearly shows the significant decreasing trend of -0.09 ppm/year. Figures 22 and 23 suggest that lakes with very high calcium concentrations in 1988 could also present high alkalinity values for the other years but this should be studied in more details to be sure that the same lakes are associated to high values from year to year.

Figure 24 presents the normal probability plot of the regional regression residuals of the calcium concentrations in the Algoma region. This graph shows the presence of a possible non normal distribution of the residuals, but the conclusion presented earlier should not be largely affected by this possible violation of the underlying normality assumption.

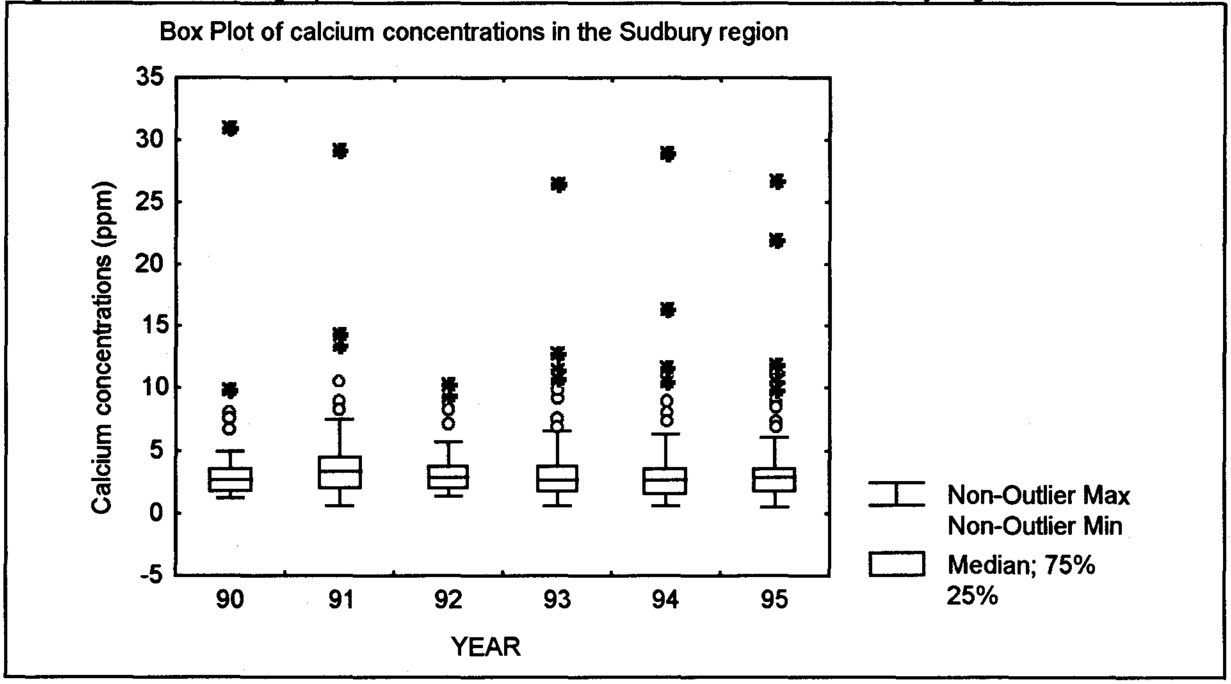
Figure 24 : Normal probability plot of residuals for calcium concentrations in the Algoma region



Sudbury region

For the Sudbury region, data are available for 160 lakes and 6 years (1990-1995). Several missing values being present, only 755 observations are used for this regional trend detection analysis of calcium concentrations.

Figure 25 : Box-Plot graph for the calcium concentrations in the Sudbury region

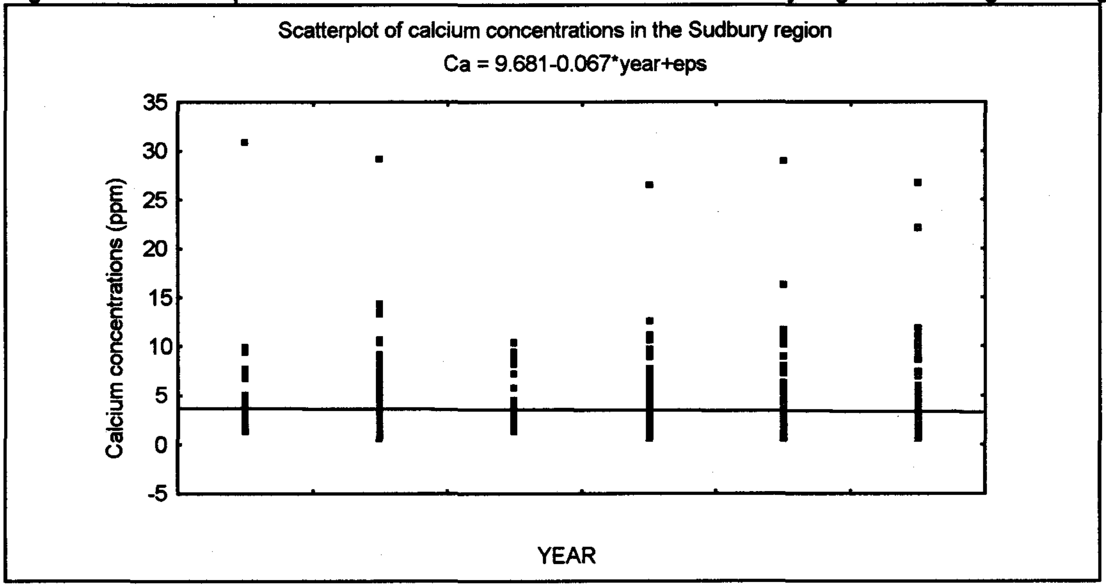


Like for the alkalinity values, figure 25 shows several very high values for all years in the calcium concentrations. These "outlier" values can affect significantly the regional regression. The "nonparametric" Boxes and Whiskers show no clear trend pattern in the calcium concentrations. The following results of the regional regression support the absence of significant trend:

n	:	755
R^2	:	0.00
Intercept estimate (year 0)	:	9.68
Slope estimate	:	-0.07 ppm/year
Initial value estimate (1990)	:	3.68
Final value estimate (1995)	:	3.35

The regression is not significant (p=0.34). Figure 26 shows the regression line passing through the cloud of observations associated to each year, while figure 27 presents the normal probability plot of the regional regression residuals.

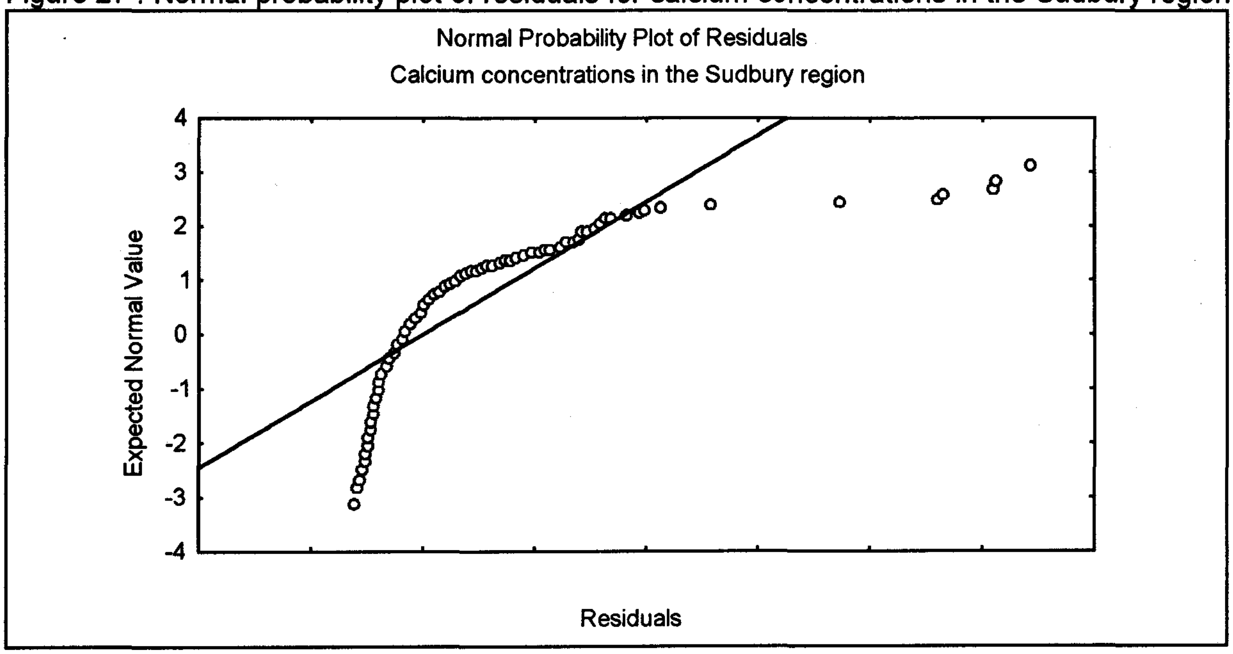
Figure 26 : Scatterplot of calcium concentrations in the Sudbury region with regional regression line



The regional regression scatterplot illustrates the absence of significant trend. Figures 25 and 26 suggest that lakes with very high calcium concentrations in 1990 could also present high alkalinity values for the other years but this should be studied in more details to be sure that the same lakes are associated to high values from year to year.

Figure 27 presents the normal probability plot of the regional regression residuals of the calcium concentrations in the Sudbury region. This graph shows the presence of a possible non normal distribution of the residuals and the presence of very large outliers. The conclusion presented earlier could be largely affected by this possible violation of two underlying assumptions.

Figure 27 : Normal probability plot of residuals for calcium concentrations in the Sudbury region



2.4 Sulfate concentrations

Muskoka region

For the Muskoka region, data are available for 260 lakes and 4 years (1990, 1991, 1993 and 1995). Several missing values being present, only 790 observations are used for this regional trend detection analysis of sulfate concentrations.

Figure 28 : Box-Plot graph for the sulfate concentrations in the Muskoka region

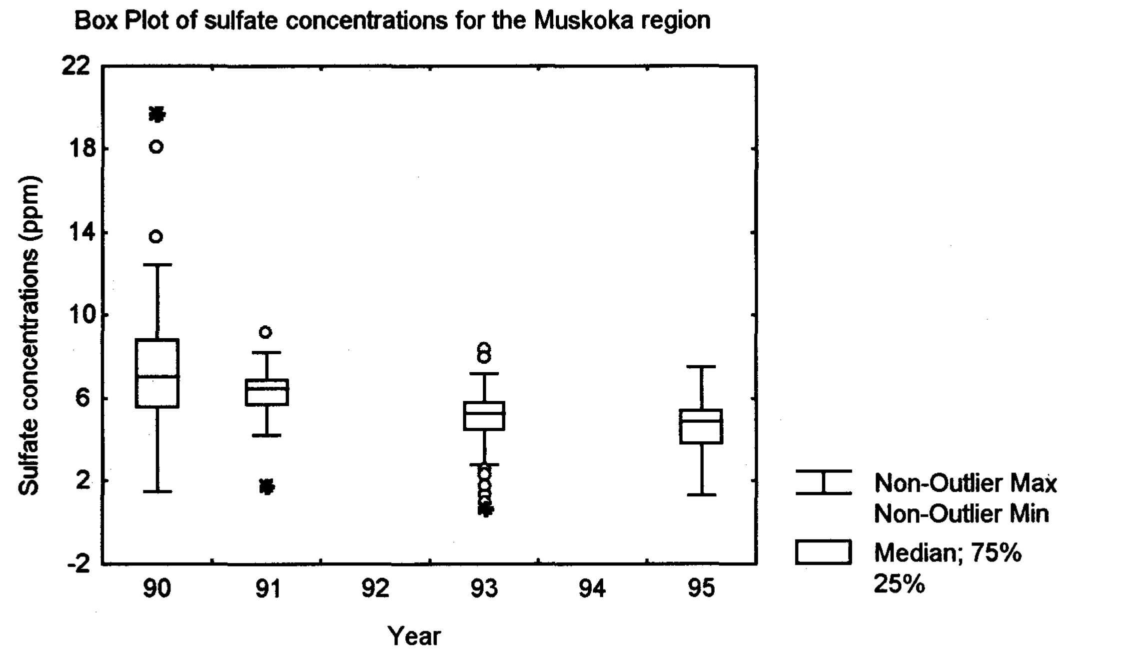
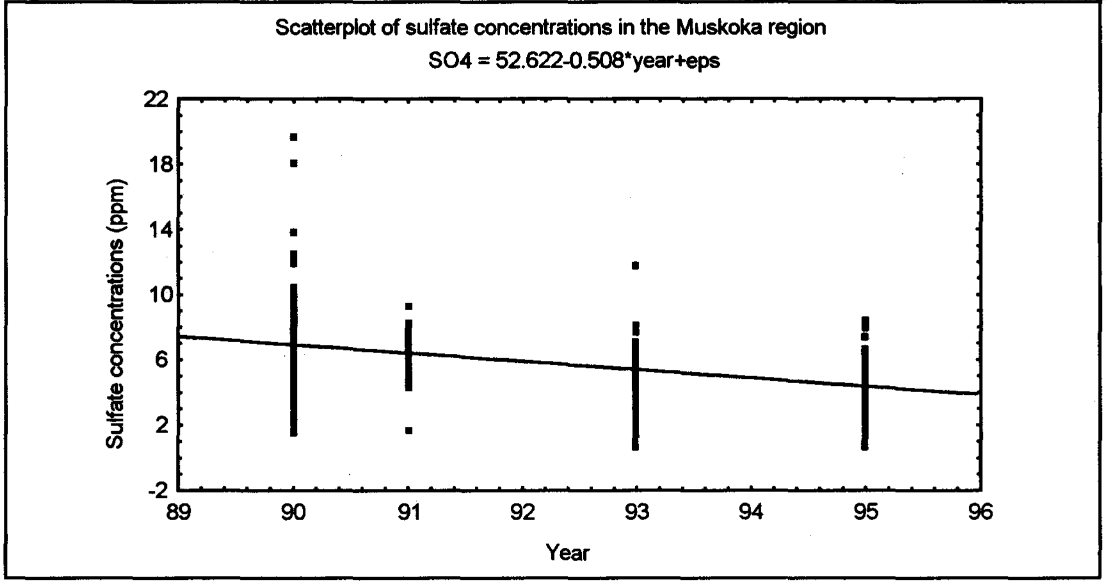


Figure 28 shows several very high values in 1990 and a couple in 1993. These "outlier" values can affect significantly the regional regression. The "nonparametric" boxes and whiskers show a decreasing trend pattern in the sulfate concentrations. The following results of the regional regression support this fact:

n	:	790
R^2	:	0.26
Intercept estimate (year 0)	:	52.62
Slope estimate	:	-0.51 ppm/year
Initial value estimate (1990)	:	6.93
Final value estimate (1995)	:	4.39

The regression is highly significant (p=0.0001). It must be kept in mind that the high outliers of 1990 can "artificially" inflate the negative trend amplitude. Figure 29 shows the regression line passing through the cloud of observations associated to each year, while figure 30 presents the normal probability plot of the regional regression residuals.

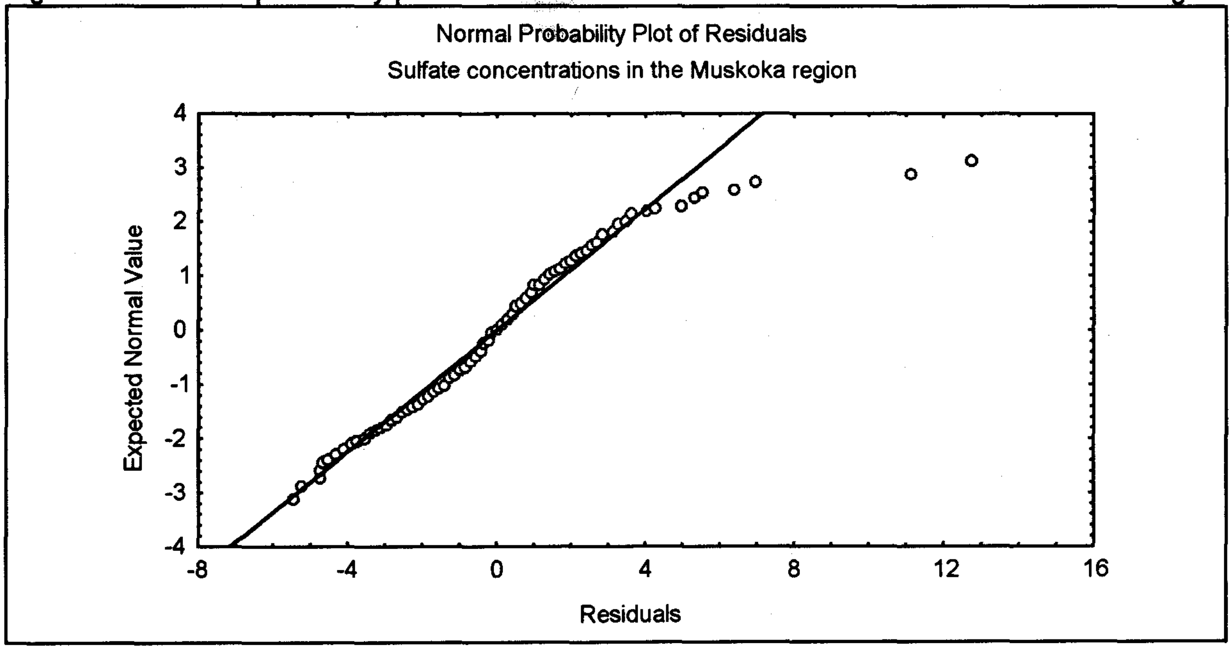
Figure 29 : Scatterplot of sulfate concentrations in the Muskoka region with regional regression line



The regional regression scatterplot clearly shows the significant decreasing trend of -0.51 ppm/year. Figures 28 and 29 show that like for the three other parameters discussed, the variability of sulfate concentrations between lakes seems to decrease in time for the Muskoka region. These graphs also suggest that lakes with very high sulfate concentrations in 1990, do show smaller concentrations for the later years.

Figure 30 presents the normal probability plot of the regional regression residuals of the sulfate concentrations in the Muskoka region. This graph shows the presence of possible high outliers, but except for a possible inflated trend slope, the results presented earlier should not be largely affected by these possible outliers.

Figure 30 : Normal probability plot of residuals for sulfate concentrations in the Muskoka region



Algoma region

For the Algoma region, data are available for 256 lakes and 4 years (1988, 1992, 1994 and 1995). Several missing values being present, only 942 observations are used for this regional trend detection analysis of sulfate concentrations.

Figure 31 : Box-Plot graph for the sulfate concentrations in the Algoma region

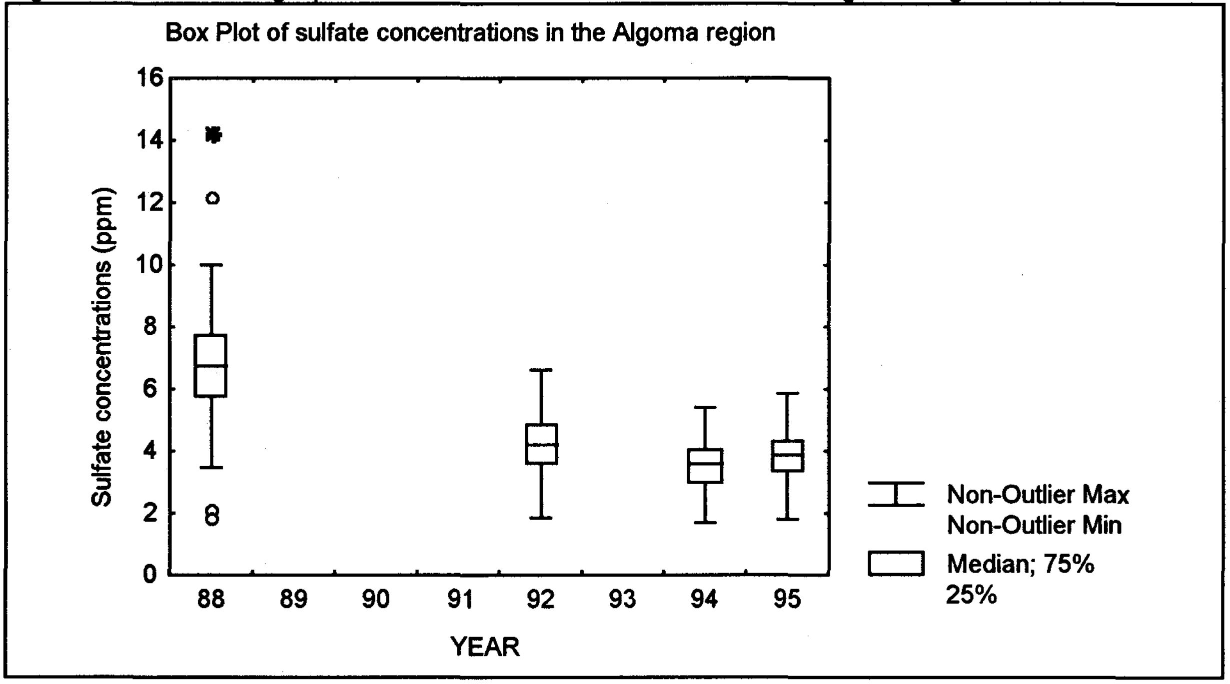
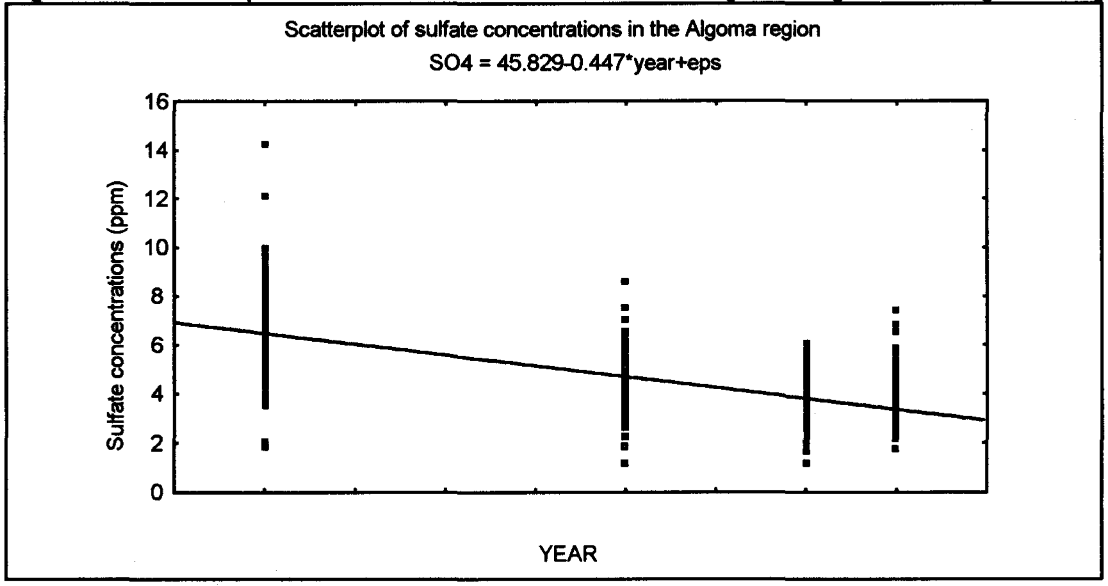


Figure 31 shows several very high values in 1988. These "outlier" values can affect significantly the regional regression. The "nonparametric" boxes and whiskers show a decreasing trend pattern in the sulfate concentrations particularly in the first three sampling years. The following results of the regional regression support this fact:

n	:	942
R^2	:	0.51
Intercept estimate (year 0)	:	45.83
Slope estimate	:	-0.45 ppm/year
Initial value estimate (1990)	:	5.60
Final value estimate (1995)	:	3.36

The regression is highly significant (p=0.0001). Figure 32 shows the regression line passing through the cloud of observations associated to each year, while figure 33 presents the normal probability plot of the regional regression residuals.

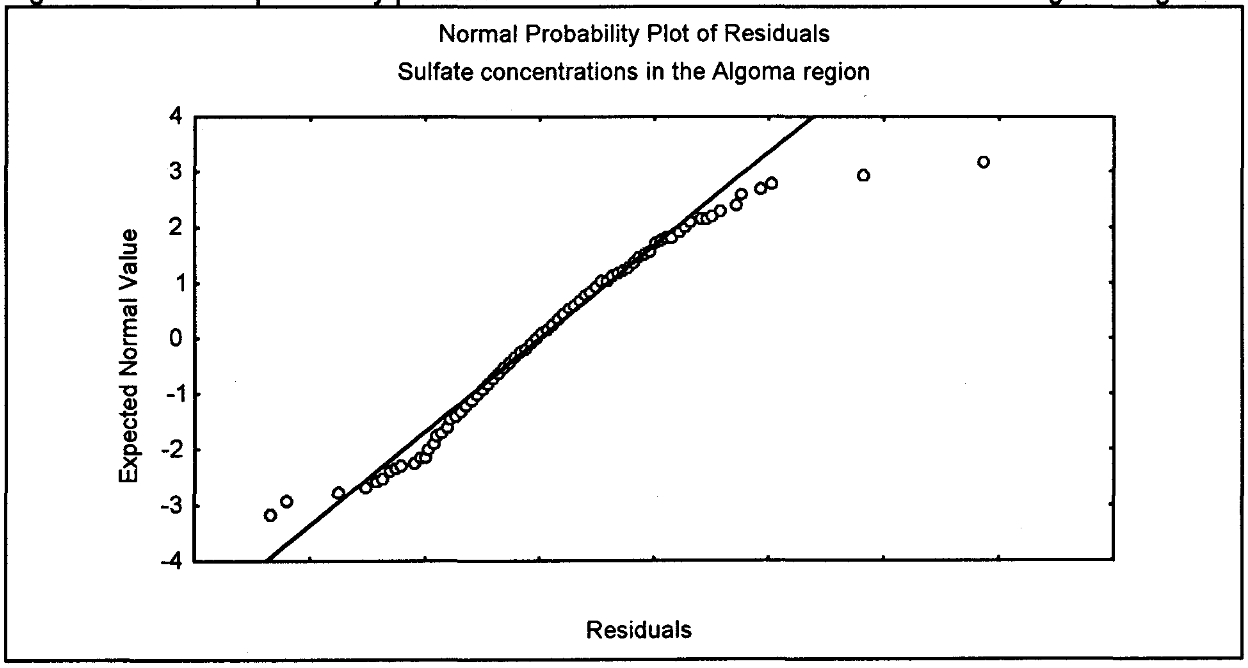
Figure 32 : Scatterplot of sulfate concentrations in theAlgoma region with regional regression line



The regional regression scatterplot clearly shows the significant decreasing trend of -0.45 ppm/year. Figures 31 and 32 show that like for the sulfate concentrations in the Muskoka region, the variability of sulfate concentrations between lakes seems to decrease in time in the Algoma region.

Figure 33 presents the normal probability plot of the regional regression residuals of the sulfate concentrations in the Algoma region. This graph shows the presence of possible high outliers, but except for a possible inflated trend slope, the results presented earlier should not be largely affected by these possible outliers.

Figure 33 : Normal probability plot of residuals for sulfate concentrations in the Algoma region



Sudbury region

For the Sudbury region, data are available for 160 lakes and 6 years (1990- 1995). Several missing values being present, only 755 observations are used for this regional trend detection analysis of sulfate concentrations.

Figure 34 : Box-Plot graph for the sulfate concentrations in the Sudbury region

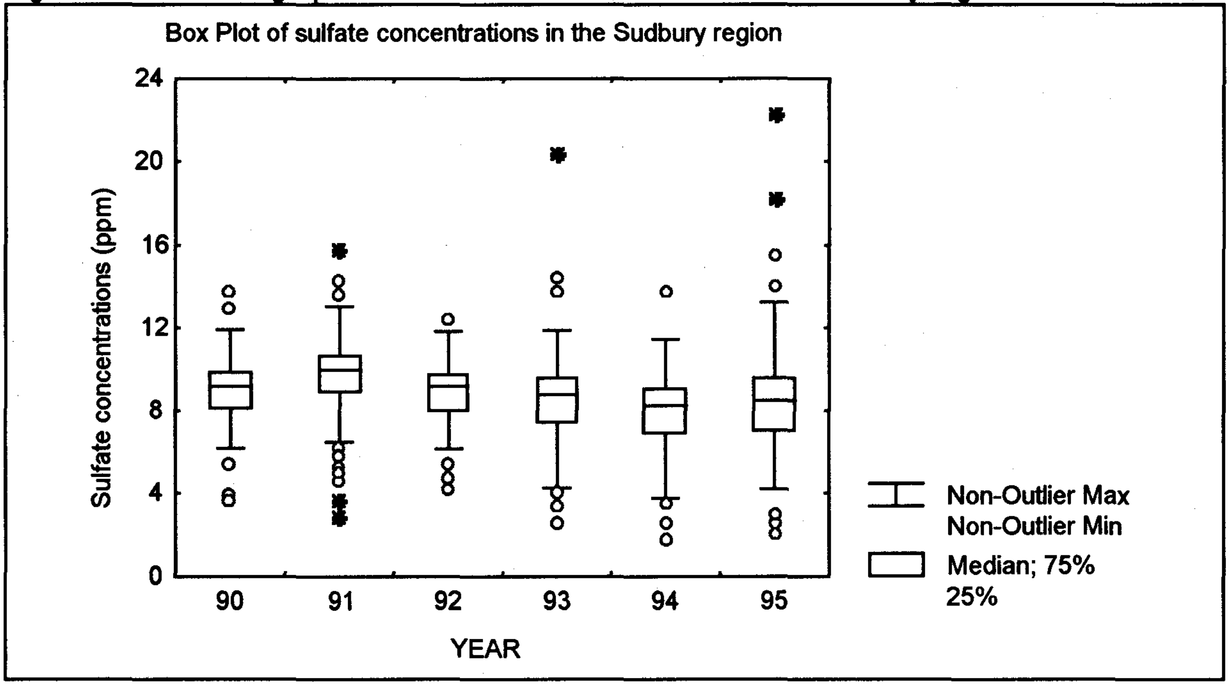
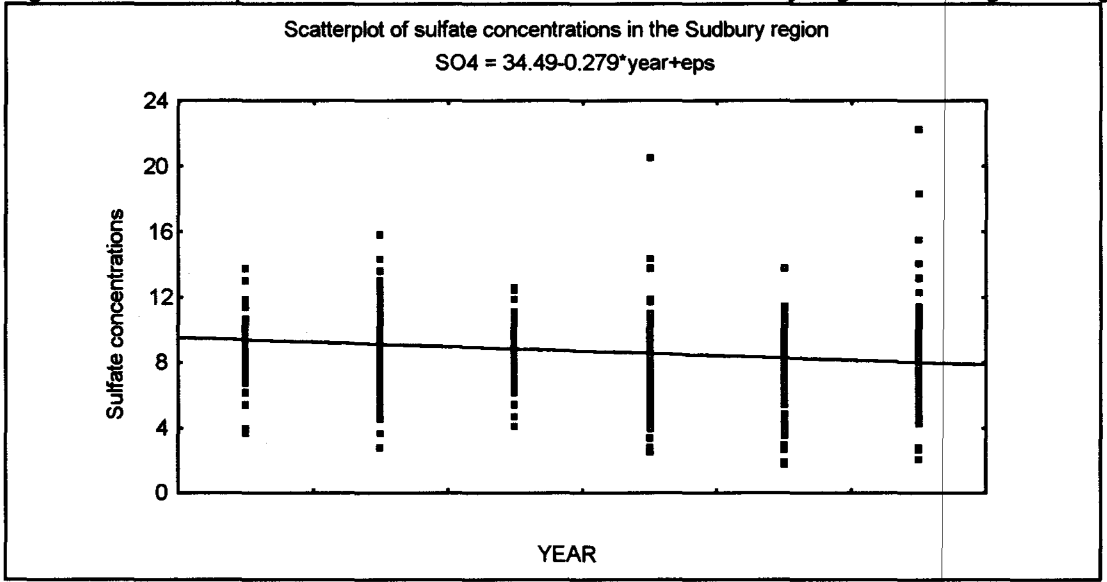


Figure 34 shows several very high and very low values for all years. These "outlier" values can affect significantly the regional regression. The "nonparametric" boxes and whiskers show a decreasing trend pattern in the sulfate concentrations particularly between 1991 and 1994. The following results of the regional regression support the presence of a significant trend:

n	:	755
R^2	:	0.05
Intercept estimate (year 0)	:	34.49
Slope estimate	:	-0.28 ppm/year
Initial value estimate (1990)	:	9.41
Final value estimate (1995)	:	8.01

The regression is highly significant (p=0.0001). Figure 35 shows the regression line passing through the cloud of observations associated to each year, while figure 36 presents the normal probability plot of the regional regression residuals.

Figure 35 : Scatterplot of sulfate concentrations in the Sudbury region with regional regression line



The regional regression scatterplot illustrates the significant decreasing trend of -0.28 ppm/year. Contrary to Muskoka and Algoma regions, figures 34 and 35 do not show a decrease in time of sulfate concentrations variability.

Figure 36 presents the normal probability plot of the regional regression residuals of the sulfate concentrations in the Sudbury region. This graph shows the presence of possible high outliers, but the inflated variability introduced do not mask the significance of the trend slope.

Figure 36 : Normal probability plot of residuals for sulfate concentrations in the Sudbury region

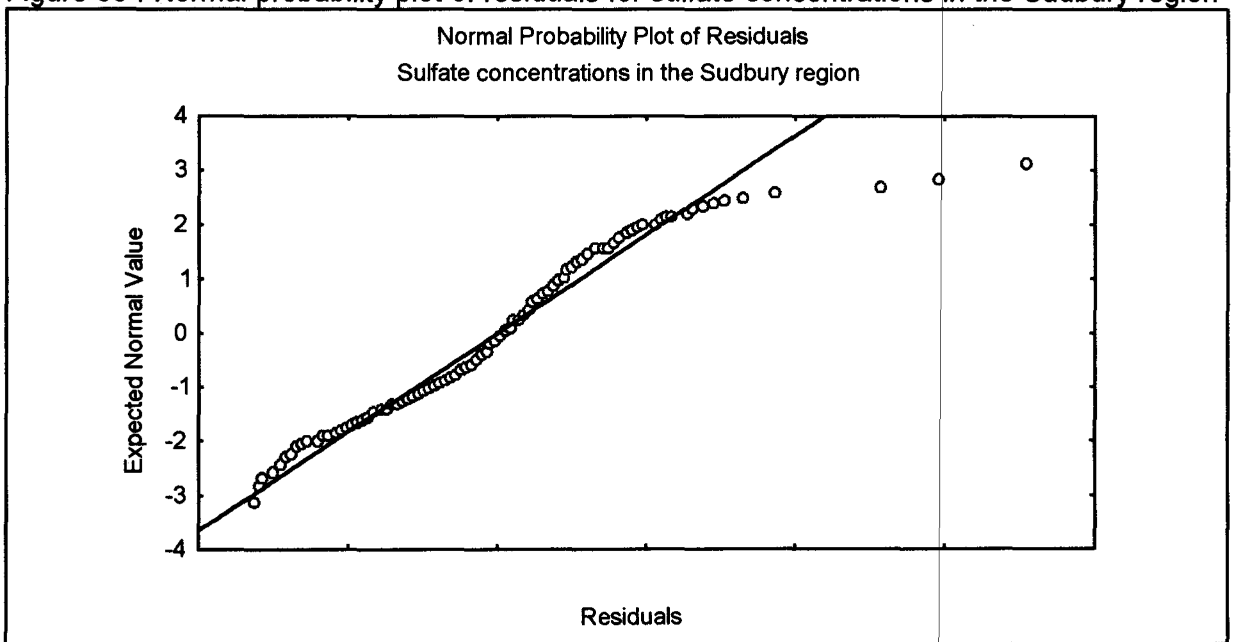


Table 1 : Regional regressions for pH values.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	782	Y	0.46	-2.67	0.09	5.57	6.02
12	935	Y	0.67	-0.00	0.06	5.77	6.09
37	755	Y	0.88	-3.09	0.09	5.42	5.89

Table 2 : Regional regressions for conductivity values.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	782	Y	7.80	141.09	-1.27	27.08	20.74
12	937	Y	8.22	116.54	-1.00	26.18	21.16
37	754	N	17.65	101.91	-0.70	38.49	34.96

Table 3 : Regional regressions for alkalinity values.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	772	N	29.00	-61.08	0.90	19.96	24.46
12	929	Y	73.15	-278.58	3.53	39.55	57.22
37	755	N	184.96	-388.71	4.92	54.34	78.96

Table 4 : Regional regressions for calcium concentrations.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	790	Y	0.55	13.31	-0.12	2.22	1.60
12	917	Y	1.55	11.13	-0.09	2.63	2.15
37	755	N	3.19	9.68	-0.07	3.68	3.35

Table 5 : Regional regressions for magnesium concentrations.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	790	Y	0.18	3.60	-0.033	0.67	0.51
12	917	Y	0.24	2.47	-0.021	0.54	0.43
37	755	N	0.61	1.63	-0.009	0.83	0.79

Table 6 : Regional regressions for potassium concentrations.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	790	N	0.13	0.57	-0.002	0.34	0.33
12	917	Y	0.08	0.40	-0.002	0.21	0.20
37	755	N	0.14	0.10	0.002	0.31	0.32

Table 7 : Regional regressions for sodium concentrations.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	790	N	0.92	3.67	-0.032	0.81	0.65
12	917	Y	0.17	3.30	-0.029	0.66	0.52
37	755	N	0.51	1.63	-0.009	0.83	0.78

Table 8 : Regional regressions for sulfate concentrations.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	790	Y	1.73	52.62	-0.51	6.93	4.39
12	942	Y	1.17	45.83	-0.45	5.60	3.36
37	755	Y	2.12	34.49	-0.28	9.41	8.01

Table 9 : Regional regressions for silicate concentrations.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	790	Y	1.22	-6.21	0.08	1.25	1.66
12	946	Y	1.61	12.55	-0.11	2.92	2.39
37	755	N	1.81	0.36	0.02	1.76	1.84

Table 10 : Regional regressions for chloride concentrations.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	790	N	1.54	3.08	-0.028	0.52	0.38
12	941	Y	0.11	1.86	-0.018	0.27	0.19
37	755	N	0.72	0.39	-0.002	0.24	0.24

Table 11 : Regional regressions for "TIC" concentrations.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	464	N	0.36	2.04	-0.015	0.65	0.58
12	711	N	0.79	2.26	-0.015	0.89	0.81
37	680	N	1.92	1.41	-0.003	1.12	1.10

Table 12 : Regional regressions for "DOC" concentrations.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	693	N	2.96	4.95	0.01	5.97	6.03
12	946	N	3.29	9.09	-0.02	7.55	7.46
37	755	N	2.95	-2.00	0.08	4.90	5.29

Table 13 : Regional regressions for "TKN" concentrations.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	688	Y	0.23	2.71	-0.02	0.47	0.35
12	711	Y	0.14	2.51	-0.02	0.48	0.36
37	544	Y	0.31	3.27	-0.03	0.48	0.33

Table 14 : Regional regressions for NO2NO3 concentrations.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	463	Y	0.02	-0.17	0.002	0.01	0.02
12	711	Y	0.03	-0.44	0.005	0.01	0.03
37	681	Y	0.01	0.10	-0.001	0.02	0.01

Table 15 : Regional regressions for total nitrogen concentrations.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	231	NA	0.16	0.40	0.000	0.40	0.40
12	474	N	0.12	-0.55	0.010	0.36	0.41
37	629	Y	0.28	6.44	-0.065	0.60	0.28

Table 16 : Regional regressions for ammoniac concentrations.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	464	N	36.55	98.93	-0.69	37.06	33.62
12	711	N	46.85	76.73	-0.40	41.14	39.17
37	681	N	107.42	-250.70	3.19	36.17	52.10

Table 17 : Regional regressions for total phosphorus concentrations.

Region	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	690	Y	11.48	118.68	-1.17	13.51	7.66
12	943	N	2.72	8.43	-0.02	6.48	6.38
37	703	Y	8.10	40.27	-0.35	8.46	6.69

Table 18 : Regional regressions for pH values: Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	N	0.50	1.51	0.05	5.62	5.85
1	1	143	Y	0.47	-3.15	0.10	5.45	5.92
1	2	73	Y	0.42	-5.57	0.12	5.28	5.88
1	3	118	Y	0.40	-4.63	0.11	5.44	5.99
1	4	119	Y	0.41	-0.57	0.07	5.73	6.08
1	5	115	Y	0.44	-5.45	0.12	5.48	6.09
1	6	135	Y	0.42	-1.61	0.08	5.78	6.19
12	0	109	Y	0.62	-0.08	0.06	5.74	6.06
12	1	185	Y	0.74	-0.36	0.07	5.73	6.07
12	2	123	Y	0.75	-0.18	0.07	5.77	6.10
12	3	179	Y	0.68	-0.32	0.07	5.67	6.01
12	4	138	Y	0.64	0.05	0.06	5.72	6.04
12	5	88	Y	0.46	1.52	0.05	6.00	6.25
12	6	113	Y	0.66	0.01	0.07	5.88	6.21
37	0	42	N	0.80	2.34	0.04	6.00	6.20
37	1	124	N	0.90	2.20	0.04	5.52	5.70
37	2	88	N	0.97	-5.06	0.12	5.30	5.87
37	3	149	Y	0.84	-2.38	0.09	5.36	5.79
37	4	129	Y	0.87	-3.75	0.10	5.25	5.75
37	5	99	Y	0.82	-3.79	0.10	5.35	5.86
37	6	124	Y	0.86	-5.82	0.13	5.59	6.22

Table 19 : Regional regressions for Conductivity : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	Y	7.67	151.14	-1.38	27.36	20.48
1	1	143	Y	6.96	132.21	-1.18	25.75	19.83
1	2	73	Y	4.43	128.57	-1.14	25.66	19.94
1	3	118	Y	15.30	169.43	-1.56	29.23	21.44
1	4	119	Y	4.39	139.78	-1.26	26.72	20.44
1	5	115	Y	4.36	125.39	-1.10	26.57	21.08
1	6	135	Y	4.27	136.47	-1.21	27.85	21.81
12	0	110	Y	7.50	82.63	-0.63	25.78	22.62
12	1	185	Y	11.13	135.13	-1.19	28.37	22.44
12	2	124	Y	8.01	121.92	-1.05	27.41	22.15
12	3	179	Y	8.74	123.62	-1.08	26.53	21.14
12	4	138	Y	6.61	127.31	-1.14	24.75	19.05
12	5	88	Y	4.07	97.68	-0.82	24.09	20.00
12	6	113	Y	5.85	102.31	-0.87	24.44	20.11
37	0	42	N	22.20	83.22	-0.44	43.30	41.08
37	1	124	N	28.73	253.01	-2.30	45.77	34.25
37	2	88	N	19.01	38.95	-0.02	37.59	37.51
37	3	149	N	14.02	79.51	-0.49	35.43	32.98
37	4	129	N	17.30	59.92	-0.26	36.55	35.25
37	5	99	Y	6.74	139.14	-1.13	37.72	32.09
37	6	124	N	7.71	94.21	-0.62	38.53	35.44

Table 20 : Regional regressions for Alkalinity : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	77	N	48.50	318.48	-3.15	35.12	19.37
1	1	142	N	23.73	-74.83	1.01	16.03	21.08
1	2	73	N	19.96	-173.55	2.04	10.13	20.34
1	3	115	N	21.16	-89.24	1.16	15.47	21.29
1	4	117	N	27.66	58.35	-0.35	26.86	25.11
1	5	115	Y	24.04	-255.37	2.97	12.04	26.90
1	6	133	N	31.79	-130.38	1.73	25.59	34.25
12	0	106	N	58.49	-329.26	4.08	38.12	58.53
12	1	184	N	99.30	-270.71	3.58	51.70	69.61
12	2	122	Y	75.59	-426.28	5.21	42.30	68.33
12	3	179	N	82.77	-225.20	2.96	41.25	56.05
12	4	138	Y	52.80	-276.16	3.36	26.10	42.89
12	5	87	N	36.28	-43.95	0.89	36.11	40.56
12	6	113	Y	55.75	-348.35	4.25	34.57	55.85
37	0	42	N	232.23	-630.93	8.49	132.73	175.15
37	1	124	N	321.46	1685.36	-16.86	167.54	83.21
37	2	88	N	217.97	-1423.50	16.37	49.59	131.43
37	3	149	N	120.00	-571.70	6.65	26.63	59.87
37	4	129	N	127.60	-653.17	7.46	18.23	55.53
37	5	99	N	81.97	-222.30	2.71	21.38	34.92
37	6	124	N	84.39	-533.19	6.41	43.78	75.84

Table 21 : Regional regressions for calcium concentrations : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	Y	0.85	10.88	-0.10	2.13	1.65
1	1	143	Y	0.64	10.55	-0.09	2.04	1.57
1	2	73	Y	0.36	11.06	-0.10	2.02	1.52
1	3	119	Y	0.56	13.76	-0.13	2.19	1.54
1	4	120	Y	0.46	15.20	-0.14	2.30	1.58
1	5	117	Y	0.45	13.65	-0.13	2.26	1.63
1	6	139	Y	0.44	15.77	-0.15	2.43	1.69
12	0	105	N	1.17	6.60	-0.05	2.50	2.27
12	1	180	N	2.12	12.50	-0.11	2.95	2.42
12	2	122	N	1.51	9.32	-0.07	2.70	2.33
12	3	179	Y	1.78	11.76	-0.10	2.68	2.18
12	4	136	Y	1.18	12.19	-0.11	2.31	1.76
12	5	83	Y	0.72	14.43	-0.13	2.59	1.93
12	6	112	Y	1.16	10.36	-0.09	2.45	2.01
37	0	42	N	3.85	26.46	-0.23	5.65	4.50
37	1	124	N	5.64	38.12	-0.37	5.22	3.39
37	2	88	N	3.37	-8.27	0.13	3.42	4.07
37	3	149	N	2.11	8.30	-0.06	3.16	2.87
37	4	129	N	2.25	4.30	-0.01	3.03	2.96
37	5	99	N	1.84	12.79	-0.10	3.46	2.94
37	6	124	N	1.64	6.97	-0.04	3.68	3.50

Table 22 : Regional regressions for magnesium concentrations : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	Y	0.24	3.49	-0.032	0.61	0.45
1	1	143	Y	0.19	3.17	-0.029	0.59	0.45
1	2	73	Y	0.11	2.90	-0.026	0.58	0.45
1	3	119	Y	0.18	3.88	-0.036	0.65	0.47
1	4	120	Y	0.17	4.03	-0.038	0.65	0.46
1	5	117	Y	0.17	3.20	-0.029	0.62	0.48
1	6	139	Y	0.18	3.91	-0.036	0.71	0.53
12	0	105	N	0.28	2.38	-0.020	0.60	0.50
12	1	180	Y	0.27	2.60	-0.023	0.57	0.45
12	2	122	Y	0.31	2.62	-0.023	0.57	0.46
12	3	179	Y	0.24	2.39	-0.021	0.53	0.42
12	4	136	Y	0.19	2.43	-0.021	0.50	0.39
12	5	83	Y	0.15	2.65	-0.024	0.54	0.42
12	6	112	Y	0.17	2.28	-0.020	0.50	0.40
37	0	42	N	0.78	3.44	-0.025	1.21	1.08
37	1	124	N	0.88	4.46	-0.039	0.99	0.80
37	2	88	N	0.80	-0.23	0.012	0.86	0.92
37	3	149	N	0.45	0.99	-0.003	0.73	0.72
37	4	129	N	0.58	0.77	-0.000	0.74	0.74
37	5	99	N	0.20	2.10	-0.015	0.72	0.64
37	6	124	N	0.40	2.75	-0.021	0.91	0.80

Table 23 : Regional regressions for potassium concentrations : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	N	0.23	0.84	-0.005	0.37	0.34
1	1	143	N	0.15	-0.51	0.009	0.28	0.33
1	2	73	N	0.13	-0.33	0.007	0.29	0.33
1	3	119	N	0.12	0.73	-0.004	0.34	0.32
1	4	120	N	0.10	0.89	-0.006	0.37	0.34
1	5	117	Y	0.09	1.18	-0.009	0.36	0.31
1	6	139	Y	0.08	0.98	-0.007	0.39	0.35
12	0	105	N	0.10	0.13	0.001	0.21	0.21
12	1	180	N	0.09	0.19	0.000	0.20	0.20
12	2	122	N	0.08	0.62	-0.004	0.23	0.21
12	3	179	N	0.07	0.25	-0.001	0.20	0.19
12	4	136	N	0.07	0.58	-0.004	0.22	0.20
12	5	83	N	0.06	0.55	-0.004	0.23	0.21
12	6	112	Y	0.07	0.68	-0.005	0.24	0.22
37	0	42	N	0.14	-0.19	0.006	0.33	0.36
37	1	124	N	0.18	0.97	-0.007	0.35	0.31
37	2	88	N	0.17	0.59	-0.003	0.31	0.29
37	3	149	N	0.16	-0.25	0.006	0.28	0.31
37	4	129	N	0.10	0.42	-0.001	0.29	0.28
37	5	99	N	0.12	-0.47	0.009	0.30	0.34
37	6	124	N	0.07	-0.07	0.004	0.32	0.34

Table 24 : Regional regressions for sodium concentrations : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	N	0.31	3.39	-0.029	0.80	0.65
1	1	143	Y	0.25	3.28	-0.028	0.74	0.60
1	2	73	Y	0.10	2.64	-0.022	0.66	0.55
1	3	119	N	2.32	6.95	-0.064	1.19	0.87
1	4	120	Y	0.22	3.61	-0.031	0.79	0.63
1	5	117	Y	0.15	2.69	-0.022	0.71	0.60
1	6	139	Y	0.17	2.84	-0.023	0.77	0.65
12	0	105	Y	0.18	2.71	-0.022	0.70	0.59
12	1	180	Y	0.23	4.28	-0.039	0.74	0.54
12	2	122	Y	0.18	3.52	-0.032	0.66	0.50
12	3	179	Y	0.15	2.86	-0.025	0.63	0.50
12	4	136	Y	0.17	3.97	-0.037	0.67	0.48
12	5	83	Y	0.12	2.58	-0.022	0.64	0.53
12	6	112	Y	0.11	2.54	-0.022	0.59	0.49
37	0	42	Y	0.21	5.16	-0.046	1.00	0.77
37	1	124	N	0.19	1.69	-0.010	0.76	0.70
37	2	88	Y	0.11	2.19	-0.016	0.79	0.71
37	3	149	N	0.45	1.02	-0.002	0.83	0.82
37	4	129	N	1.08	-0.77	0.018	0.86	0.95
37	5	99	Y	0.09	1.95	-0.013	0.76	0.69
37	6	124	Y	0.17	2.59	-0.019	0.86	0.77

Table 25 : Regional regressions for sulfate concentrations : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	Y	2.44	33.68	-0.31	5.86	4.32
1	1	143	Y	2.17	41.67	-0.40	5.94	3.95
1	2	73	Y	1.71	48.32	-0.46	6.59	4.27
1	3	119	Y	1.43	54.30	-0.53	6.90	4.27
1	4	120	Y	1.33	56.33	-0.55	7.21	4.48
1	5	117	Y	1.31	55.88	-0.54	7.53	4.84
1	6	139	Y	1.07	64.00	-0.62	7.83	4.71
12	0	109	Y	1.45	40.45	-0.39	5.42	3.48
12	1	187	Y	1.37	45.41	-0.44	5.52	3.31
12	2	122	Y	1.18	47.79	-0.47	5.55	3.20
12	3	181	Y	1.17	46.51	-0.45	5.69	3.42
12	4	139	Y	1.05	47.47	-0.47	5.62	3.29
12	5	87	Y	0.78	47.16	-0.46	5.69	3.39
12	6	116	Y	0.89	45.44	-0.44	5.67	3.46
37	0	42	N	3.66	76.87	-0.74	10.14	6.43
37	1	124	N	3.00	25.09	-0.19	8.34	7.41
37	2	88	Y	1.48	41.94	-0.36	9.40	7.59
37	3	149	Y	2.18	28.11	-0.21	8.89	7.83
37	4	129	Y	1.40	29.14	-0.22	9.59	8.51
37	5	99	Y	1.16	41.80	-0.35	10.11	8.34
37	6	124	Y	1.30	29.94	-0.22	10.08	8.97

Table 26 : Regional regressions for silicate concentrations : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	N	1.33	-10.63	0.14	1.53	2.21
1	1	143	Y	1.30	-8.49	0.11	1.40	1.95
1	2	73	Y	1.10	-11.70	0.14	1.11	1.82
1	3	119	N	1.46	-3.77	0.06	1.25	1.53
1	4	120	N	1.30	-3.59	0.05	1.34	1.61
1	5	117	N	0.94	-1.93	0.03	1.01	1.17
1	6	139	N	0.90	-3.07	0.05	1.20	1.44
12	0	110	N	1.83	12.79	-0.10	4.18	3.70
12	1	187	Y	1.68	19.62	-0.17	3.88	3.01
12	2	124	Y	1.39	12.01	-0.10	2.69	2.17
12	3	181	Y	1.53	10.62	-0.09	2.68	2.24
12	4	140	Y	1.36	11.88	-0.11	2.33	1.80
12	5	88	Y	1.00	10.44	-0.09	2.24	1.79
12	6	116	N	0.94	7.03	-0.06	2.05	1.77
37	0	42	N	2.06	27.11	-0.26	3.75	2.45
37	1	124	N	1.96	2.27	-0.00	2.23	2.22
37	2	88	N	1.12	6.31	-0.06	1.20	0.92
37	3	149	N	2.21	-3.54	0.06	1.64	1.93
37	4	129	N	1.28	-2.19	0.04	1.22	1.41
37	5	99	N	1.31	1.81	-0.00	1.44	1.42
37	6	124	N	1.83	3.06	-0.01	2.36	2.32

Table 27 : Regional regressions for chloride concentrations : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	N	0.18	-0.64	0.011	0.32	0.38
1	1	143	N	0.24	1.94	-0.017	0.39	0.30
1	2	73	Y	0.10	1.55	-0.013	0.34	0.27
1	3	119	N	3.93	8.51	-0.081	1.21	0.80
1	4	120	Y	0.08	2.35	-0.022	0.39	0.28
1	5	117	Y	0.10	2.76	-0.026	0.44	0.31
1	6	139	Y	0.12	3.24	-0.031	0.46	0.31
12	0	109	Y	0.12	1.42	-0.013	0.29	0.22
12	1	186	Y	0.13	2.07	-0.020	0.31	0.21
12	2	123	Y	0.10	1.86	-0.018	0.26	0.17
12	3	181	Y	0.11	1.47	-0.014	0.25	0.18
12	4	139	Y	0.12	2.72	-0.027	0.29	0.16
12	5	87	Y	0.08	1.97	-0.019	0.26	0.16
12	6	116	Y	0.08	1.45	-0.013	0.26	0.19
37	0	42	Y	0.16	3.30	-0.033	0.33	0.17
37	1	124	Y	0.14	1.61	-0.016	0.22	0.14
37	2	88	Y	0.08	1.79	-0.018	0.19	0.10
37	3	149	N	0.47	-1.92	0.023	0.15	0.27
37	4	129	N	1.65	-1.55	0.022	0.40	0.51
37	5	99	Y	0.07	1.30	-0.012	0.23	0.17
37	6	124	Y	0.07	0.92	-0.008	0.24	0.20

Table 28 : Regional regressions for "TIC" concentrations : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	51	N	0.35	0.36	0.003	0.59	0.60
1	1	92	N	0.38	-0.57	0.013	0.57	0.63
1	2	44	N	0.34	5.91	-0.057	0.80	0.52
1	3	69	N	0.35	4.40	-0.041	0.73	0.52
1	4	70	N	0.37	2.38	-0.019	0.67	0.58
1	5	60	N	0.34	1.54	-0.011	0.59	0.53
1	6	78	N	0.41	1.96	-0.014	0.68	0.61
12	0	83	N	0.63	1.37	-0.005	0.91	0.88
12	1	140	N	1.10	1.34	-0.003	1.02	1.01
12	2	93	N	0.77	1.49	-0.006	0.93	0.90
12	3	137	N	0.87	3.24	-0.026	0.91	0.78
12	4	105	N	0.54	3.75	-0.033	0.78	0.61
12	5	66	N	0.39	1.51	-0.008	0.76	0.71
12	6	87	N	0.64	2.96	-0.024	0.81	0.69
37	0	40	N	2.60	7.20	-0.053	2.45	2.19
37	1	114	N	3.38	10.38	-0.094	1.88	1.40
37	2	76	N	1.86	-5.73	0.075	0.99	1.37
37	3	131	N	1.33	0.93	-0.000	0.89	0.89
37	4	115	N	1.30	3.14	-0.025	0.89	0.76
37	5	90	N	0.86	2.78	-0.023	0.73	0.62
37	6	114	N	0.93	-0.64	0.018	0.99	1.08

Table 29 : Regional regressions for "DOC" concentrations : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	76	N	4.12	12.91	-0.06	7.75	7.46
1	1	137	N	3.27	16.67	-0.10	8.01	7.53
1	2	65	N	2.23	-5.36	0.13	6.40	7.06
1	3	103	N	2.94	1.45	0.05	6.19	6.45
1	4	105	N	2.03	-1.48	0.07	4.69	5.03
1	5	90	N	1.44	6.08	-0.02	4.46	4.37
1	6	117	N	1.49	0.79	0.04	4.36	4.56
12	0	110	N	4.06	14.55	-0.07	8.64	8.31
12	1	187	N	3.72	6.18	0.02	8.40	8.53
12	2	124	N	3.42	5.34	0.03	8.11	8.26
12	3	181	N	2.93	8.76	-0.01	7.67	7.61
12	4	140	N	2.64	10.35	-0.04	6.94	6.75
12	5	88	N	2.99	10.86	-0.04	6.88	6.65
12	6	116	N	1.44	10.91	-0.06	5.57	5.27
37	0	42	N	3.05	-11.92	0.22	7.94	9.04
37	1	124	N	3.36	-18.33	0.27	6.09	7.44
37	2	88	N	2.23	-5.49	0.12	5.13	5.72
37	3	149	N	3.00	17.24	-0.13	5.53	4.88
37	4	129	N	2.17	5.15	-0.01	4.04	3.98
37	5	99	N	2.49	4.56	0.00	4.94	4.96
37	6	124	N	1.51	1.02	0.02	3.08	3.19

Table 30 : Regional regressions for "TKN" concentrations : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	76	Y	0.39	9.97	-0.102	0.83	0.32
1	1	135	Y	0.26	4.90	-0.047	0.65	0.42
1	2	65	Y	0.15	2.35	-0.020	0.52	0.41
1	3	102	N	0.14	1.36	-0.010	0.44	0.39
1	4	105	N	0.14	1.16	-0.009	0.36	0.31
1	5	89	N	0.09	0.21	0.001	0.29	0.29
1	6	116	N	0.08	0.43	-0.002	0.27	0.26
12	0	83	Y	0.14	2.81	-0.026	0.47	0.34
12	1	140	Y	0.13	2.19	-0.019	0.48	0.39
12	2	93	N	0.12	1.07	-0.007	0.46	0.42
12	3	137	Y	0.14	2.81	-0.025	0.52	0.39
12	4	105	Y	0.11	2.63	-0.024	0.48	0.36
12	5	66	Y	0.22	5.15	-0.051	0.58	0.33
12	6	87	Y	0.07	1.69	-0.015	0.35	0.28
37	0	30	N	0.23	3.94	-0.036	0.68	0.50
37	1	90	N	0.48	4.85	-0.046	0.67	0.43
37	2	61	N	0.22	2.98	-0.028	0.50	0.36
37	3	104	Y	0.27	3.34	-0.032	0.49	0.33
37	4	92	Y	0.25	3.10	-0.030	0.44	0.29
37	5	72	Y	0.22	3.26	-0.031	0.42	0.27
37	6	95	Y	0.22	3.07	-0.030	0.35	0.20

Table 31 : Regional regressions for NO2NO3 concentrations : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	51	N	0.02	0.19	-0.002	0.025	0.017
1	1	92	N	0.02	-0.11	0.001	0.012	0.019
1	2	44	N	0.04	-0.52	0.006	0.002	0.031
1	3	69	N	0.02	-0.02	0.000	0.016	0.018
1	4	70	N	0.02	-0.04	0.001	0.016	0.019
1	5	59	N	0.02	-0.36	0.004	-0.002	0.018
1	6	78	Y	0.01	-0.36	0.004	-0.003	0.017
12	0	83	Y	0.02	-0.43	0.005	0.004	0.028
12	1	140	Y	0.03	-0.53	0.006	0.003	0.033
12	2	93	N	0.05	-0.65	0.007	0.005	0.041
12	3	137	Y	0.03	-0.38	0.004	0.008	0.030
12	4	105	N	0.04	-0.27	0.003	0.013	0.029
12	5	66	Y	0.02	-0.49	0.006	0.002	0.029
12	6	87	N	0.02	-0.31	0.004	0.014	0.031
37	0	40	N	0.03	0.69	-0.007	0.041	0.005
37	1	114	Y	0.02	0.30	-0.003	0.025	0.009
37	2	77	N	0.01	0.08	-0.001	0.013	0.009
37	3	131	N	0.01	0.12	-0.001	0.018	0.012
37	4	115	N	0.01	-0.03	0.000	0.009	0.011
37	5	90	N	0.01	-0.04	0.001	0.008	0.011
37	6	114	N	0.01	-0.03	0.000	0.012	0.014

Table 32 : Regional regressions for total nitrogen concentrations : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	24	NA	0.20	0.45	NA	NA	NA
1	1	46	NA	0.21	0.50	NA	NA	NA
1	2	22	NA	0.12	0.48	NA	NA	NA
1	3	35	NA	0.10	0.44	NA	NA	NA
1	4	35	NA	0.09	0.35	NA	NA	NA
1	5	30	NA	0.10	0.32	NA	NA	NA
1	6	39	NA	0.06	0.28	NA	NA	NA
12	0	54	N	0.12	6.51	-0.06	0.68	0.36
12	1	94	N	0.13	3.60	-0.03	0.58	0.41
12	2	62	N	0.13	-3.75	0.04	0.26	0.48
12	3	92	N	0.11	-2.73	0.03	0.28	0.44
12	4	70	N	0.11	-0.66	0.01	0.34	0.40
12	5	44	Y	0.06	-3.64	0.04	0.18	0.39
12	6	58	Y	0.06	-4.38	0.05	0.09	0.34
37	0	38	Y	0.23	5.98	-0.06	0.75	0.46
37	1	109	Y	0.43	10.42	-0.11	0.87	0.34
37	2	67	Y	0.19	7.52	-0.08	0.68	0.30
37	3	115	Y	0.25	6.53	-0.07	0.61	0.29
37	4	104	Y	0.23	6.42	-0.07	0.57	0.24
37	5	84	Y	0.20	5.22	-0.05	0.50	0.24
37	6	112	Y	0.20	4.61	-0.05	0.41	0.18

Table 33 : Regional regressions for ammonia concentrations : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	51	N	26.47	218.35	-2.01	37.70	27.67
1	1	92	N	47.26	439.83	-4.20	61.68	40.67
1	2	44	N	39.62	-345.91	4.14	26.77	47.48
1	3	69	N	40.72	-100.13	1.51	35.55	43.09
1	4	70	N	33.56	192.70	-1.70	39.53	31.02
1	5	60	N	33.35	-311.08	3.65	17.15	35.39
1	6	78	N	14.52	302.44	-3.04	28.81	13.61
12	0	83	N	40.60	290.70	-2.77	41.42	27.57
12	1	140	N	48.12	-279.01	3.36	23.05	39.83
12	2	93	N	46.68	-174.99	2.35	36.65	48.41
12	3	137	N	47.28	232.08	-1.97	55.20	45.38
12	4	105	N	68.94	87.70	-0.40	51.56	49.55
12	5	66	Y	18.74	429.89	-4.23	49.53	28.40
12	6	87	N	20.66	191.91	-1.76	33.78	24.99
37	0	40	N	149.66	-2351.08	26.12	-0.15	130.46
37	1	114	N	170.79	758.56	-7.41	92.07	55.05
37	2	77	N	72.18	122.79	-0.88	43.91	39.52
37	3	131	N	103.13	-678.06	7.86	29.72	69.04
37	4	115	N	106.30	-343.35	4.20	35.05	56.07
37	5	90	N	57.88	-364.16	4.21	15.03	36.09
37	6	114	N	24.77	67.44	-0.53	20.00	17.37

Table 34 : Regional regressions for total phosphorus concentrations : Classification #1

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	76	Y	16.16	415.95	-4.29	30.05	8.62
1	1	135	Y	13.21	211.79	-2.12	21.18	10.59
1	2	65	N	8.85	70.64	-0.63	13.97	10.83
1	3	103	N	4.64	34.65	-0.28	9.53	8.13
1	4	105	N	13.95	103.70	-1.03	10.99	5.84
1	5	90	N	2.50	17.84	-0.13	6.07	5.42
1	6	116	N	1.81	18.33	-0.14	5.28	4.56
12	0	109	N	3.23	-1.59	0.08	5.95	6.37
12	1	186	N	2.96	11.34	-0.05	6.91	6.66
12	2	124	N	2.76	7.65	-0.00	7.41	7.39
12	3	181	N	2.76	4.39	0.03	6.89	7.02
12	4	140	N	2.36	18.33	-0.13	6.52	5.87
12	5	87	N	2.22	12.30	-0.07	6.09	5.74
12	6	116	N	1.50	5.94	-0.01	4.94	4.89
37	0	40	N	6.49	15.54	-0.04	12.10	11.91
37	1	119	N	17.19	101.05	-0.96	14.70	9.91
37	2	78	N	2.90	29.91	-0.24	7.90	6.68
37	3	133	N	4.13	35.35	-0.30	8.25	6.75
37	4	118	Y	2.74	47.66	-0.45	7.16	4.91
37	5	93	Y	2.92	46.60	-0.44	7.33	5.15
37	6	122	Y	1.90	30.93	-0.29	5.27	3.84

Table 35 : Regional regressions for pH values: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	407	Y	0.41	-0.85	0.07	5.73	6.10
1	1	221	Y	0.45	-5.20	0.12	5.43	6.02
1	2	153	Y	0.47	-5.11	0.12	5.25	5.83
12	-9	1	NA	NA	4.57	0.00	4.57	4.57
12	0	350	Y	0.60	0.06	0.06	5.87	6.19
12	1	283	Y	0.66	-0.61	0.07	5.73	6.08
12	2	301	Y	0.74	0.66	0.06	5.71	5.99
37	-9	11	N	0.53	1.27	0.05	5.97	6.23
37	0	533	Y	0.96	-4.33	0.11	5.35	5.89
37	1	116	Y	0.66	-2.40	0.09	5.60	6.04
37	2	95	N	0.65	1.07	0.05	5.44	5.68

Table 36 : Regional regressions for conductivity values: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	408	Y	4.67	116.41	-1.01	25.94	20.91
1	1	221	Y	5.37	150.64	-1.37	27.25	20.40
1	2	153	Y	14.44	197.27	-1.86	30.10	20.81
12	-9	1	NA	NA	28.70	0.00	28.70	28.70
12	0	350	Y	5.92	103.71	-0.89	23.83	19.40
12	1	284	Y	9.41	115.80	-1.00	25.76	20.75
12	2	302	Y	8.55	131.53	-1.14	29.28	23.60
37	-9	11	N	17.39	432.81	-4.32	43.89	22.29
37	0	533	N	19.19	111.33	-0.79	40.66	36.74
37	1	116	N	13.29	-19.44	0.58	32.73	35.63
37	2	95	N	8.28	108.77	-0.87	30.64	26.30

Table 37 : Regional regressions for alkalinity values: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	406	N	27.21	-31.36	0.60	22.27	25.25
1	1	219	N	34.70	-44.67	0.72	19.99	23.58
1	2	147	Y	23.90	-178.66	2.13	13.09	23.74
12	-9	1	NA	NA	-32.50	0.00	-32.50	-32.50
12	0	347	Y	56.39	-297.59	3.69	34.12	52.55
12	1	282	N	89.27	-221.10	2.93	42.55	57.19
12	2	299	Y	73.65	-293.67	3.75	43.68	62.42
37	-9	11	N	206.02	3121.11	-33.09	142.95	-22.51
37	0	533	N	205.59	-416.18	5.30	60.63	87.12
37	1	115	N	143.47	-1076.11	12.29	29.77	91.21
37	2	95	N	62.29	31.23	-0.02	29.59	29.50

Table 38 : Regional regressions for calcium concentrations: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	415	Y	0.50	12.54	-0.12	2.19	1.61
1	1	222	Y	0.51	13.02	-0.12	2.21	1.61
1	2	153	Y	0.74	15.85	-0.15	2.30	1.55
12	-9	1	NA	NA	1.34	0.00	1.34	1.34
12	0	337	Y	1.23	10.81	-0.09	2.38	1.92
12	1	287	Y	1.87	11.40	-0.10	2.55	2.05
12	2	292	Y	1.46	11.58	-0.10	2.99	2.52
37	-9	11	N	3.21	64.31	-0.66	5.22	1.93
37	0	533	N	3.55	8.71	-0.05	3.76	3.49
37	1	116	N	2.26	-3.07	0.07	3.43	3.79
37	2	95	Y	1.46	20.29	-0.19	3.20	2.25

Table 39 : Regional regressions for magnesium concentrations: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	415	Y	0.18	3.46	-0.031	0.63	0.48
1	1	222	Y	0.17	3.52	-0.032	0.63	0.47
1	2	153	Y	0.22	4.07	-0.038	0.65	0.46
12	-9	1	NA	NA	0.33	0.000	0.33	0.33
12	0	337	Y	0.11	1.81	-0.015	0.43	0.36
12	1	287	Y	0.22	2.33	-0.020	0.51	0.41
12	2	292	Y	0.31	3.43	-0.030	0.70	0.54
37	-9	11	N	0.67	11.79	-0.118	1.20	0.61
37	0	533	N	0.68	1.24	-0.004	0.84	0.82
37	1	116	N	0.48	-0.15	0.011	0.81	0.86
37	2	95	Y	0.17	3.68	-0.033	0.74	0.57

Table 40 : Regional regressions for potassium concentrations: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	415	Y	0.11	1.31	-0.010	0.37	0.31
1	1	222	N	0.13	0.54	-0.002	0.33	0.32
1	2	153	Y	0.18	-1.34	0.018	0.30	0.39
12	-9	1	NA	NA	0.19	0.000	0.19	0.19
12	0	337	N	0.06	0.25	-0.000	0.21	0.20
12	1	287	N	0.09	0.47	-0.003	0.22	0.21
12	2	292	N	0.08	0.51	-0.003	0.21	0.20
37	-9	11	N	0.05	0.98	-0.007	0.35	0.32
37	0	533	N	0.14	0.27	0.000	0.31	0.31
37	1	116	N	0.14	0.42	-0.001	0.33	0.32
37	2	95	Y	0.13	-1.38	0.018	0.27	0.36

Table 41 : Regional regressions for sodium concentrations: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	415	Y	0.18	2.77	-0.023	0.73	0.62
1	1	222	Y	0.23	3.37	-0.029	0.76	0.62
1	2	153	N	2.05	7.55	-0.071	1.14	0.78
12	-9	1	NA	NA	1.03	0.000	1.03	1.03
12	0	337	Y	0.17	3.54	-0.032	0.62	0.46
12	1	287	Y	0.16	3.31	-0.029	0.66	0.51
12	2	292	Y	0.18	2.94	-0.025	0.71	0.59
37	-9	11	N	0.14	3.87	-0.033	0.92	0.76
37	0	533	N	0.59	1.14	-0.003	0.83	0.82
37	1	116	N	0.16	2.15	-0.015	0.82	0.74
37	2	95	Y	0.15	2.68	-0.021	0.76	0.66

Table 42 : Regional regressions for sulfate concentrations: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	415	Y	1.41	48.24	-0.46	7.15	4.86
1	1	222	Y	1.56	49.22	-0.47	6.75	4.39
1	2	153	Y	2.35	64.21	-0.64	6.50	3.29
12	-9	1	NA	NA	6.28	0.00	6.28	6.28
12	0	350	Y	0.90	44.71	-0.43	5.59	3.41
12	1	290	Y	1.18	46.75	-0.46	5.56	3.28
12	2	301	Y	1.43	46.30	-0.45	5.64	3.38
37	-9	11	N	1.39	84.99	-0.83	10.69	6.57
37	0	533	Y	1.76	30.00	-0.23	9.68	8.55
37	1	116	N	2.19	26.60	-0.20	9.04	8.06
37	2	95	Y	2.47	49.25	-0.46	7.72	5.41

Table 43 : Regional regressions for silicate concentrations: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	415	Y	0.98	-6.01	0.078	0.97	1.36
1	1	222	Y	1.10	-6.29	0.084	1.27	1.69
1	2	153	N	1.58	-2.20	0.048	2.11	2.35
12	-9	1	NA	NA	4.54	0.000	4.54	4.54
12	0	352	Y	1.18	10.67	-0.095	2.17	1.69
12	1	291	Y	1.36	12.04	-0.103	2.78	2.27
12	2	302	Y	1.78	15.25	-0.126	3.94	3.31
37	-9	11	N	1.35	0.41	0.028	2.95	3.09
37	0	533	N	1.89	1.85	-0.002	1.68	1.67
37	1	116	N	1.63	-0.46	0.024	1.72	1.84
37	2	95	N	1.40	-7.95	0.111	2.09	2.64

Table 44 : Regional regressions for cloride concentrations: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	415	Y	0.10	2.49	-0.023	0.41	0.29
1	1	222	Y	0.15	1.86	-0.016	0.37	0.29
1	2	153	N	3.47	8.44	-0.081	1.11	0.70
12	-9	1	NA	NA	0.51	0.000	0.51	0.51
12	0	350	Y	0.10	2.04	-0.020	0.27	0.17
12	1	290	Y	0.13	1.70	-0.016	0.27	0.19
12	2	300	Y	0.10	1.78	-0.017	0.29	0.21
37	-9	11	N	0.10	3.16	-0.032	0.32	0.16
37	0	533	N	0.86	-0.15	0.005	0.25	0.27
37	1	116	Y	0.10	1.90	-0.019	0.23	0.14
37	2	95	N	0.09	0.76	-0.006	0.19	0.16

Table 45 : Regional regressions for "TIC" concentrations: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	235	N	0.33	1.02	-0.005	0.56	0.53
1	1	132	N	0.32	2.71	-0.023	0.67	0.56
1	2	97	N	0.46	4.32	-0.038	0.88	0.69
12	0	264	N	0.61	2.44	-0.018	0.80	0.71
12	1	219	N	1.00	1.45	-0.006	0.90	0.86
12	2	228	N	0.73	2.76	-0.020	0.97	0.88
37	-9	11	N	2.50	42.37	-0.447	2.11	-0.13
37	0	477	N	2.10	1.80	-0.007	1.19	1.16
37	1	106	N	1.68	-6.03	0.076	0.82	1.20
37	2	86	N	0.66	0.29	0.005	0.77	0.79

Table 46 : Regional regressions for "DOC" concentrations: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	357	Y	1.34	11.49	-0.08	4.47	4.08
1	1	195	N	1.68	14.51	-0.09	6.74	6.31
1	2	140	N	3.55	-10.31	0.22	9.12	10.20
12	-9	1	NA	NA	9.66	0.00	9.66	9.66
12	0	352	N	1.15	7.05	-0.02	5.11	5.00
12	1	291	N	1.39	9.10	-0.02	6.87	6.75
12	2	302	N	3.29	12.06	-0.01	11.04	10.98
37	-9	11	N	4.31	-137.53	1.54	1.45	9.17
37	0	533	N	1.99	8.33	-0.05	4.14	3.90
37	1	116	N	2.30	-6.06	0.14	6.57	7.27
37	2	95	N	3.23	-8.80	0.19	8.65	9.62

Table 47 : Regional regressions for "TKN" concentrations: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	354	Y	0.18	2.30	-0.021	0.38	0.27
1	1	193	Y	0.27	4.03	-0.039	0.56	0.36
1	2	141	Y	0.22	2.61	-0.022	0.61	0.50
12	0	264	Y	0.10	1.62	-0.014	0.38	0.31
12	1	219	Y	0.14	3.09	-0.029	0.50	0.35
12	2	228	Y	0.14	2.94	-0.026	0.57	0.44
37	-9	10	N	0.20	2.78	-0.026	0.40	0.27
37	0	386	Y	0.24	3.23	-0.031	0.43	0.27
37	1	82	N	0.47	3.91	-0.037	0.62	0.44
37	2	66	Y	0.30	5.01	-0.048	0.70	0.46

Table 48 : Regional regressions for NO2NO3 concentrations: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	234	Y	0.02	-0.23	0.003	0.007	0.020
1	1	132	N	0.03	-0.28	0.003	0.008	0.025
1	2	97	N	0.01	0.14	-0.001	0.018	0.011
12	0	263	Y	0.04	-0.61	0.007	0.006	0.041
12	1	219	Y	0.03	-0.43	0.005	0.007	0.031
12	2	228	Y	0.02	-0.24	0.003	0.008	0.021
37	-9	11	N	0.06	1.48	-0.016	0.058	-0.021
37	0	478	N	0.01	0.06	-0.000	0.015	0.012
37	1	106	N	0.01	0.02	-0.000	0.011	0.010
37	2	86	N	0.01	0.16	-0.002	0.017	0.009

Table 49 : Regional regressions for total nitrogen concentrations: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	114	NA	0.08	0.31	0.000	0.31	0.31
1	1	67	NA	0.12	0.43	0.000	0.43	0.43
1	2	50	NA	0.21	0.56	0.000	0.56	0.56
12	0	177	Y	0.10	-3.48	0.040	0.16	0.37
12	1	146	N	0.09	-0.15	0.006	0.37	0.39
12	2	151	N	0.12	2.71	-0.024	0.58	0.46
37	-9	11	N	0.24	4.83	-0.048	0.47	0.23
37	0	442	Y	0.22	6.06	-0.061	0.54	0.23
37	1	97	Y	0.42	8.57	-0.086	0.79	0.36
37	2	79	Y	0.27	9.87	-0.100	0.89	0.39

Table 50 : Regional regressions for ammoniac concentrations: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	235	N	28.18	109.73	-0.88	30.88	26.50
1	1	132	N	39.83	-118.16	1.68	33.42	41.84
1	2	97	N	45.95	452.32	-4.35	60.59	38.82
12	0	264	N	47.22	140.85	-1.13	39.43	33.79
12	1	219	N	39.50	208.19	-1.82	44.80	35.72
12	2	228	N	52.17	-124.35	1.82	39.60	48.71
37	-9	11	N	4.83	67.49	-0.61	12.69	9.64
37	0	478	N	71.14	71.73	-0.36	39.29	37.49
37	1	106	N	180.50	-679.61	8.01	40.95	80.98
37	2	86	N	149.16	-1191.15	13.51	25.15	92.73

Table 51 : Regional regressions for total phosphorus concentrations: Classification #2

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	356	Y	11.19	107.41	-1.08	10.05	4.64
1	1	193	Y	9.69	132.44	-1.31	14.86	8.33
1	2	141	Y	11.37	156.21	-1.50	21.23	13.73
12	-9	1	NA	NA	6.35	0.00	6.35	6.35
12	0	352	N	2.00	11.22	-0.06	5.57	5.26
12	1	291	N	2.62	6.07	0.00	6.31	6.32
12	2	299	N	3.03	7.48	0.00	7.72	7.74
37	-9	11	N	5.26	-217.98	2.44	1.99	14.21
37	0	497	Y	3.06	42.66	-0.40	6.97	4.98
37	1	107	N	18.01	103.38	-0.99	14.43	9.48
37	2	88	N	4.91	24.40	-0.14	12.12	11.44

Table 52 : Regional regressions for pH values: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	Y	0.50	-0.40	0.07	5.64	5.98
1	1	90	Y	0.53	-5.83	0.12	5.29	5.91
1	2	154	Y	0.39	-1.76	0.08	5.69	6.11
1	3	459	Y	0.44	-2.72	0.09	5.56	6.02
12	0	80	Y	0.56	0.54	0.06	5.92	6.22
12	1	235	Y	0.77	0.07	0.06	5.73	6.04
12	2	121	N	0.43	3.59	0.03	6.15	6.30
12	3	499	Y	0.66	-0.97	0.07	5.67	6.04
37	-9	9	N	0.81	26.50	-0.23	5.98	4.84
37	0	73	N	0.83	1.30	0.05	6.05	6.31
37	1	145	N	0.93	0.84	0.05	5.27	5.52
37	2	211	Y	0.69	-3.56	0.10	5.78	6.29
37	3	317	Y	0.84	-3.95	0.10	5.16	5.66

Table 53 : Regional regressions for conductivity values: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	N	18.15	177.85	-1.62	31.96	23.86
1	1	90	Y	7.78	208.79	-1.99	29.37	19.40
1	2	154	Y	5.24	129.78	-1.14	27.14	21.44
1	3	459	Y	4.83	128.61	-1.14	25.86	20.15
12	0	80	Y	7.01	96.77	-0.77	27.26	23.40
12	1	236	Y	10.78	124.26	-1.07	27.76	22.40
12	2	121	Y	5.21	81.26	-0.63	24.90	21.77
12	3	500	Y	7.45	124.10	-1.09	25.56	20.09
37	-9	9	N	19.14	327.42	-3.14	44.82	29.12
37	0	73	N	14.82	100.88	-0.64	42.94	39.72
37	1	145	N	28.03	181.57	-1.53	43.56	35.89
37	2	211	N	9.98	74.96	-0.42	36.72	34.59
37	3	317	N	15.85	99.01	-0.69	36.77	33.31

Table 54 : Regional regressions for alkalinity values: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	78	N	31.23	-52.11	0.86	25.32	29.62
1	1	88	N	46.54	28.41	-0.07	22.41	22.08
1	2	152	N	21.98	-36.31	0.63	20.83	24.00
1	3	454	N	26.25	-83.93	1.14	18.38	24.06
12	0	77	N	60.27	-262.98	3.49	50.94	68.38
12	1	233	N	97.83	-280.29	3.70	52.36	70.84
12	2	121	N	45.49	-97.27	1.59	45.57	53.50
12	3	498	Y	65.73	-324.66	3.94	30.34	50.06
37	-9	9	N	234.19	3607.02	-38.37	153.72	-38.13
37	0	73	N	173.40	-676.78	8.59	96.76	139.74
37	1	145	N	286.54	398.71	-3.46	86.96	69.64
37	2	211	N	97.93	-387.74	4.92	55.08	79.68
37	3	317	N	170.05	-565.66	6.65	32.54	65.78

Table 55 : Regional regressions for calcium concentrations: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	Y	0.63	13.48	-0.12	2.35	1.73
1	1	91	Y	0.79	17.64	-0.17	2.34	1.49
1	2	155	Y	0.59	12.87	-0.12	2.28	1.69
1	3	465	Y	0.46	12.72	-0.12	2.15	1.56
12	0	75	N	1.20	11.06	-0.09	2.91	2.46
12	1	234	N	2.08	9.96	-0.08	2.78	2.38
12	2	119	Y	0.91	12.77	-0.11	2.76	2.20
12	3	489	Y	1.40	11.29	-0.10	2.48	1.99
37	-9	9	N	3.62	69.10	-0.71	5.33	1.79
37	0	73	N	2.76	13.85	-0.10	4.89	4.39
37	1	145	N	5.32	27.01	-0.25	4.40	3.15
37	2	211	N	1.82	9.76	-0.07	3.88	3.55
37	3	317	N	2.58	4.49	-0.02	3.07	2.99

Table 56 : Regional regressions for magnesium concentrations: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	Y	0.21	3.81	-0.035	0.69	0.52
1	1	91	Y	0.24	4.34	-0.041	0.65	0.45
1	2	155	Y	0.18	3.96	-0.036	0.68	0.50
1	3	465	Y	0.16	3.35	-0.030	0.61	0.46
12	0	75	Y	0.28	3.45	-0.031	0.69	0.54
12	1	234	Y	0.26	2.13	-0.018	0.52	0.43
12	2	119	Y	0.22	3.26	-0.029	0.61	0.47
12	3	489	Y	0.23	2.32	-0.020	0.51	0.41
37	-9	9	N	0.76	16.98	-0.175	1.27	0.40
37	0	73	N	0.58	1.58	-0.006	1.00	0.97
37	1	145	N	0.58	1.26	-0.006	0.71	0.68
37	2	211	N	0.37	2.73	-0.020	0.92	0.82
37	3	317	N	0.73	1.14	-0.004	0.79	0.77

Table 57 : Regional regressions for potassium concentrations: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	N	0.16	-0.39	0.008	0.34	0.38
1	1	91	N	0.15	0.17	0.002	0.31	0.32
1	2	155	N	0.13	0.79	-0.005	0.37	0.34
1	3	465	N	0.12	0.76	-0.005	0.34	0.32
12	0	75	N	0.09	0.28	-0.001	0.23	0.22
12	1	234	Y	0.08	0.58	-0.004	0.21	0.19
12	2	119	N	0.07	0.54	-0.003	0.26	0.24
12	3	489	N	0.07	0.31	-0.001	0.20	0.20
37	-9	9	Y	0.04	2.66	-0.026	0.37	0.24
37	0	73	N	0.10	1.09	-0.008	0.36	0.32
37	1	145	N	0.15	0.47	-0.002	0.30	0.29
37	2	211	N	0.10	0.08	0.003	0.33	0.34
37	3	317	N	0.16	-0.21	0.006	0.29	0.31

Table 58 : Regional regressions for sodium concentrations: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	N	2.82	10.76	-0.103	1.53	1.02
1	1	91	Y	0.35	4.71	-0.043	0.82	0.60
1	2	155	Y	0.20	3.23	-0.027	0.79	0.65
1	3	465	Y	0.19	2.92	-0.024	0.72	0.59
12	0	75	Y	0.17	2.66	-0.021	0.75	0.64
12	1	234	Y	0.21	3.92	-0.036	0.69	0.51
12	2	119	Y	0.12	2.12	-0.017	0.62	0.53
12	3	489	Y	0.16	3.38	-0.030	0.65	0.50
37	-9	9	N	0.17	6.84	-0.066	0.95	0.62
37	0	73	N	0.15	2.77	-0.021	0.89	0.78
37	1	145	N	1.03	0.68	0.002	0.84	0.85
37	2	211	N	0.20	2.17	-0.015	0.86	0.79
37	3	317	N	0.31	1.59	-0.009	0.79	0.74

Table 59 : Regional regressions for sulfate concentrations: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	Y	1.43	53.49	-0.52	6.91	4.32
1	1	91	Y	2.17	61.84	-0.61	6.90	3.85
1	2	155	Y	1.84	54.62	-0.53	7.32	4.69
1	3	465	Y	1.63	50.05	-0.48	6.81	4.41
12	0	80	Y	1.30	42.05	-0.40	5.73	3.71
12	1	237	Y	1.32	44.87	-0.44	5.47	3.28
12	2	123	Y	1.02	45.85	-0.45	5.80	3.57
12	3	502	Y	1.10	46.86	-0.46	5.58	3.29
37	-9	9	N	0.85	13.03	-0.03	10.26	10.11
37	0	73	Y	2.00	63.05	-0.59	10.31	7.38
37	1	145	Y	2.97	43.35	-0.37	9.62	7.74
37	2	211	Y	1.76	28.08	-0.21	9.54	8.51
37	3	317	Y	1.87	29.35	-0.23	9.05	7.92

Table 60 : Regional regressions for silicate concentrations: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	N	1.95	-6.34	0.09	1.96	2.42
1	1	91	N	0.98	0.20	0.02	1.57	1.64
1	2	155	Y	1.19	-9.15	0.12	1.29	1.87
1	3	465	Y	1.04	-5.77	0.08	1.07	1.45
12	0	80	N	1.87	16.12	-0.13	4.73	4.10
12	1	238	Y	1.56	14.07	-0.12	3.30	2.70
12	2	123	N	1.21	5.59	-0.04	2.06	1.86
12	3	505	Y	1.45	12.61	-0.11	2.66	2.11
37	-9	9	N	1.65	55.90	-0.58	3.31	0.38
37	0	73	N	1.89	-2.81	0.06	2.53	2.82
37	1	145	N	1.62	7.11	-0.06	1.68	1.38
37	2	211	N	2.21	-0.90	0.03	2.10	2.26
37	3	317	N	1.44	0.66	0.01	1.44	1.48

Table 61 : Regional regressions for chloride concentrations: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	79	N	4.78	14.23	-0.140	1.67	0.97
1	1	91	N	0.50	3.97	-0.038	0.55	0.36
1	2	155	Y	0.10	2.11	-0.019	0.40	0.31
1	3	465	Y	0.14	2.15	-0.020	0.39	0.29
12	0	80	Y	0.13	1.68	-0.015	0.34	0.26
12	1	237	Y	0.13	2.13	-0.021	0.29	0.18
12	2	123	Y	0.09	1.87	-0.018	0.29	0.20
12	3	501	Y	0.10	1.75	-0.017	0.26	0.17
37	-9	9	N	0.09	1.79	-0.017	0.29	0.21
37	0	73	Y	0.11	2.35	-0.023	0.28	0.16
37	1	145	N	1.56	-0.04	0.005	0.41	0.44
37	2	211	Y	0.08	1.33	-0.012	0.24	0.18
37	3	317	N	0.33	-0.18	0.004	0.17	0.19

Table 62 : Regional regressions for "TIC" concentrations: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	51	N	0.41	3.84	-0.033	0.84	0.67
1	1	51	N	0.41	7.22	-0.070	0.95	0.60
1	2	91	N	0.39	-1.39	0.021	0.51	0.61
1	3	271	N	0.33	1.98	-0.015	0.62	0.54
12	0	59	N	0.66	3.76	-0.030	1.08	0.93
12	1	179	N	1.09	0.67	0.004	1.00	1.02
12	2	93	N	0.49	2.91	-0.023	0.85	0.74
12	3	380	N	0.67	2.64	-0.020	0.81	0.71
37	-9	9	N	2.82	44.63	-0.471	2.22	-0.14
37	0	69	N	1.91	-0.54	0.025	1.72	1.85
37	1	132	N	2.93	4.69	-0.038	1.31	1.12
37	2	192	N	1.09	0.14	0.010	1.05	1.10
37	3	278	N	1.70	1.59	-0.007	0.93	0.89

Table 63 : Regional regressions for "DOC" concentrations: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	72	N	3.78	-3.23	0.11	6.78	7.33
1	1	76	N	3.34	7.11	0.00	7.29	7.30
1	2	137	N	2.43	10.87	-0.06	5.67	5.38
1	3	408	N	2.79	5.02	0.01	5.72	5.76
12	0	80	N	3.93	22.91	-0.16	8.62	7.83
12	1	238	N	3.67	5.57	0.02	7.51	7.62
12	2	123	N	2.86	8.09	-0.01	6.80	6.73
12	3	505	N	3.06	8.57	-0.01	7.56	7.51
37	-9	9	N	1.59	47.90	-0.50	2.86	0.36
37	0	73	N	3.99	-48.28	0.58	4.35	7.28
37	1	145	N	3.24	-4.09	0.10	5.07	5.58
37	2	211	N	2.18	9.94	-0.06	4.88	4.59
37	3	317	N	2.90	4.26	0.01	5.09	5.14

Table 64 : Regional regressions for "TKN" concentrations: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	72	Y	0.27	3.95	-0.038	0.53	0.34
1	1	76	N	0.22	2.52	-0.022	0.51	0.40
1	2	135	Y	0.31	4.62	-0.046	0.52	0.29
1	3	405	Y	0.20	1.93	-0.017	0.44	0.35
12	0	59	Y	0.10	2.88	-0.027	0.44	0.30
12	1	179	Y	0.13	2.61	-0.024	0.48	0.36
12	2	93	N	0.12	2.03	-0.018	0.44	0.36
12	3	380	Y	0.15	2.51	-0.022	0.49	0.38
37	-9	8	N	0.22	7.48	-0.078	0.42	0.03
37	0	52	N	0.19	0.45	-0.001	0.37	0.37
37	1	104	Y	0.33	4.93	-0.048	0.58	0.34
37	2	154	Y	0.23	3.32	-0.032	0.45	0.29
37	3	226	Y	0.36	3.06	-0.029	0.48	0.34

Table 65 : Regional regressions for NO2NO3 concentrations: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	51	N	0.02	0.10	-0.001	0.020	0.016
1	1	51	Y	0.01	-0.32	0.004	-0.004	0.014
1	2	91	N	0.02	0.12	-0.001	0.024	0.019
1	3	270	Y	0.02	-0.29	0.003	0.005	0.021
12	0	59	Y	0.02	-0.51	0.006	0.002	0.031
12	1	179	Y	0.04	-0.49	0.006	0.008	0.036
12	2	93	Y	0.03	-0.51	0.006	0.004	0.033
12	3	380	Y	0.03	-0.38	0.004	0.008	0.029
37	-9	9	N	0.07	0.86	-0.009	0.066	0.021
37	0	69	N	0.02	0.28	-0.003	0.026	0.012
37	1	132	N	0.01	0.13	-0.001	0.016	0.010
37	2	192	N	0.01	-0.03	0.000	0.010	0.012
37	3	279	N	0.01	0.06	-0.001	0.013	0.011

Table 66 : Regional regressions for total nitrogen concentrations: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	26	NA	0.14	0.40	0.000	0.40	0.40
1	1	26	NA	0.19	0.45	0.000	0.45	0.45
1	2	45	NA	0.10	0.35	0.000	0.35	0.35
1	3	134	NA	0.17	0.41	0.000	0.41	0.41
12	0	39	N	0.09	1.70	-0.014	0.41	0.34
12	1	119	N	0.11	0.05	0.004	0.39	0.40
12	2	62	N	0.12	-0.52	0.010	0.35	0.40
12	3	254	N	0.13	-1.31	0.018	0.33	0.42
37	-9	9	N	0.26	8.58	-0.090	0.49	0.04
37	0	66	N	0.18	2.22	-0.020	0.44	0.34
37	1	123	Y	0.30	9.47	-0.097	0.76	0.28
37	2	179	Y	0.22	5.24	-0.052	0.52	0.26
37	3	252	Y	0.33	7.10	-0.072	0.64	0.28

Table 67 : Regional regressions for ammoniac concentrations: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	51	N	35.97	579.50	-5.75	61.74	32.98
1	1	51	N	42.04	13.58	0.26	36.67	37.95
1	2	91	N	28.88	19.45	0.10	28.71	29.22
1	3	271	N	37.95	55.46	-0.22	35.49	34.38
12	0	59	N	14.96	-138.23	1.69	13.92	22.37
12	1	179	N	37.39	-57.66	1.02	34.43	39.55
12	2	93	N	67.26	630.23	-6.28	64.82	33.41
12	3	380	N	47.44	36.99	0.06	42.69	43.00
37	-9	9	N	11.24	-136.04	1.67	13.99	22.33
37	0	69	N	75.95	-838.55	9.49	15.66	63.12
37	1	132	N	164.25	-183.14	2.64	54.12	67.30
37	2	192	N	71.23	-168.51	2.18	27.88	38.79
37	3	279	N	102.41	-154.91	2.17	40.15	50.99

Table 68 : Regional regressions for total phosphorus concentrations: Classification #3

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	0	72	Y	11.84	159.00	-1.59	15.73	7.77
1	1	75	N	9.27	80.04	-0.74	13.03	9.31
1	2	135	Y	18.60	237.41	-2.44	17.92	5.72
1	3	407	Y	8.13	80.78	-0.77	11.79	7.96
12	0	80	N	2.49	10.98	-0.06	5.92	5.64
12	1	236	N	2.73	4.98	0.01	6.28	6.35
12	2	123	N	2.29	10.00	-0.04	6.14	5.92
12	3	504	N	2.83	9.33	-0.03	6.75	6.61
37	-9	9	N	1.55	72.46	-0.75	4.78	1.02
37	0	70	N	3.88	8.28	-0.01	7.35	7.30
37	1	136	N	4.86	22.30	-0.16	8.32	7.54
37	2	198	Y	3.28	37.95	-0.34	7.16	5.45
37	3	290	N	11.62	56.49	-0.52	9.71	7.11

Table 69 : Regional regressions for pH values: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	19	N	0.46	-5.33	0.12	5.22	5.81
1	0	314	Y	0.44	-3.17	0.09	5.38	5.85
1	1	161	Y	0.37	-3.83	0.10	5.51	6.03
1	2	288	Y	0.42	-2.12	0.09	5.79	6.23
12	-9	33	N	0.64	4.85	0.01	5.60	5.64
12	0	413	Y	0.68	-2.63	0.09	5.40	5.85
12	1	236	Y	0.53	1.05	0.05	5.97	6.24
12	2	253	Y	0.47	3.16	0.03	6.22	6.39
37	-9	3	NA	1.06	6.14	0.00	6.14	6.14
37	0	364	Y	0.79	-2.46	0.08	4.95	5.36
37	1	99	N	0.74	-0.40	0.07	6.05	6.41
37	2	289	Y	0.65	-4.61	0.12	5.79	6.37

Table 70 : Regional regressions for conductivity values: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	19	Y	2.31	111.99	-0.95	26.56	21.81
1	0	314	Y	5.79	134.29	-1.22	24.74	18.65
1	1	161	Y	3.53	131.30	-1.17	26.42	20.59
1	2	288	Y	10.47	153.51	-1.37	29.94	23.07
12	-9	34	Y	6.81	174.19	-1.63	27.77	19.64
12	0	413	Y	8.39	146.46	-1.35	25.11	18.37
12	1	237	Y	7.37	96.23	-0.78	26.30	22.42
12	2	253	Y	8.04	81.24	-0.60	27.65	24.67
37	-9	3	NA	33.17	49.43	0.00	49.43	49.43
37	0	364	Y	12.13	165.18	-1.41	37.83	30.76
37	1	99	N	29.52	99.37	-0.62	43.69	40.60
37	2	289	N	17.41	19.92	0.19	37.31	38.27

Table 71 : Regional regressions for alkalinity values: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	18	N	21.96	-218.86	2.54	9.31	21.98
1	0	311	N	22.26	-61.40	0.83	12.88	17.01
1	1	161	Y	15.64	-110.55	1.36	11.73	18.52
1	2	282	N	36.81	-50.26	0.92	32.30	36.89
12	-9	32	N	47.24	101.05	-0.81	27.92	23.86
12	0	409	Y	75.10	-402.81	4.69	19.10	42.54
12	1	236	N	61.69	-211.62	2.87	47.01	61.38
12	2	252	N	73.90	-173.99	2.69	67.94	81.38
37	-9	3	NA	390.31	230.87	0.00	230.87	230.87
37	0	364	N	119.10	-140.93	1.74	15.83	24.54
37	1	99	N	329.77	346.54	-1.81	183.85	174.81
37	2	289	N	161.58	-952.09	11.21	56.97	113.03

Table 72 : Regional regressions for calcium concentrations: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	19	Y	0.31	16.92	-0.16	2.45	1.65
1	0	318	Y	0.52	10.54	-0.10	1.92	1.44
1	1	162	Y	0.32	13.54	-0.13	2.20	1.57
1	2	291	Y	0.59	16.08	-0.15	2.54	1.79
12	-9	33	Y	1.32	21.49	-0.21	2.78	1.74
12	0	401	Y	1.64	10.14	-0.09	2.18	1.73
12	1	237	Y	1.20	10.18	-0.08	2.75	2.34
12	2	246	Y	1.51	12.85	-0.11	3.24	2.71
37	-9	3	NA	6.16	6.26	0.00	6.26	6.26
37	0	364	N	1.91	11.72	-0.10	2.73	2.23
37	1	99	N	5.97	24.00	-0.20	6.14	5.14
37	2	289	N	2.55	2.66	0.02	4.03	4.11

Table 73 : Regional regressions for magnesium concentrations: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	19	Y	0.06	3.12	-0.028	0.63	0.49
1	0	318	Y	0.15	2.81	-0.025	0.53	0.40
1	1	162	Y	0.12	3.51	-0.032	0.63	0.47
1	2	291	Y	0.20	4.45	-0.041	0.75	0.55
12	-9	33	Y	0.27	5.15	-0.050	0.67	0.42
12	0	401	Y	0.14	1.66	-0.014	0.40	0.33
12	1	237	Y	0.24	2.75	-0.024	0.62	0.51
12	2	246	Y	0.28	3.36	-0.030	0.69	0.54
37	-9	3	NA	1.24	1.49	0.000	1.49	1.49
37	0	364	N	0.63	2.52	-0.020	0.74	0.64
37	1	99	N	0.45	0.10	0.008	0.83	0.87
37	2	289	N	0.60	0.61	0.003	0.92	0.94

Table 74 : Regional regressions for potassium concentrations: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	19	N	0.22	-6.04	0.069	0.13	0.48
1	0	317	N	0.15	0.93	-0.007	0.33	0.30
1	1	162	N	0.08	0.34	-0.000	0.31	0.31
1	2	291	N	0.12	0.62	-0.003	0.38	0.36
12	-9	33	N	0.11	0.13	0.001	0.20	0.20
12	0	401	N	0.08	0.11	0.001	0.18	0.19
12	1	237	Y	0.08	0.80	-0.006	0.24	0.21
12	2	246	Y	0.06	0.54	-0.003	0.24	0.23
37	-9	3	NA	0.02	0.35	0.000	0.35	0.35
37	0	364	N	0.14	0.09	0.002	0.28	0.29
37	1	99	N	0.15	-0.23	0.006	0.33	0.36
37	2	289	N	0.13	0.24	0.001	0.34	0.34

Table 75 : Regional regressions for sodium concentrations: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	19	Y	0.08	3.99	-0.036	0.79	0.61
1	0	318	Y	0.18	2.69	-0.023	0.66	0.55
1	1	161	Y	0.16	2.84	-0.024	0.71	0.60
1	2	291	N	1.49	5.02	-0.044	1.04	0.82
12	-9	33	Y	0.16	3.07	-0.027	0.68	0.55
12	0	401	Y	0.17	3.75	-0.035	0.62	0.44
12	1	237	Y	0.16	3.01	-0.026	0.70	0.57
12	2	246	Y	0.16	2.91	-0.024	0.71	0.59
37	-9	3	NA	0.28	0.91	0.000	0.91	0.91
37	0	364	Y	0.18	2.43	-0.018	0.77	0.68
37	1	99	N	0.15	0.88	-0.002	0.73	0.72
37	2	289	N	0.77	0.72	0.002	0.92	0.93

Table 76 : Regional regressions for sulfate concentrations: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	19	Y	1.34	94.87	-0.96	8.27	3.46
1	0	318	Y	1.91	42.91	-0.41	6.09	4.04
1	1	162	Y	1.28	53.28	-0.51	7.37	4.82
1	2	291	Y	1.53	59.78	-0.58	7.54	4.64
12	-9	34	Y	1.26	46.47	-0.46	5.42	3.14
12	0	411	Y	1.12	47.02	-0.46	5.39	3.08
12	1	243	Y	1.29	46.44	-0.45	5.69	3.43
12	2	254	Y	1.03	43.15	-0.41	5.85	3.78
37	-9	3	NA	0.67	9.70	0.00	9.70	9.70
37	0	364	Y	2.34	37.78	-0.31	9.45	7.88
37	1	99	N	1.97	26.74	-0.21	8.14	7.11
37	2	289	Y	1.73	31.45	-0.24	9.73	8.52

Table 77 : Regional regressions for silicate concentrations: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	19	N	1.37	-0.89	0.031	1.93	2.08
1	0	318	N	1.10	-3.98	0.059	1.28	1.58
1	1	162	Y	0.83	-8.20	0.100	0.79	1.29
1	2	291	Y	1.43	-6.57	0.089	1.46	1.91
12	-9	34	Y	1.90	37.56	-0.358	5.30	3.50
12	0	414	Y	1.46	15.29	-0.137	2.93	2.24
12	1	243	N	1.65	7.64	-0.055	2.66	2.39
12	2	255	Y	1.64	11.30	-0.093	2.91	2.44
37	-9	3	NA	2.24	3.76	0.000	3.76	3.76
37	0	364	N	1.60	-3.26	0.051	1.32	1.57
37	1	99	N	2.05	7.41	-0.060	1.99	1.69
37	2	289	N	1.89	1.32	0.010	2.18	2.23

Table 78 : Regional regressions for chloride concentrations: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	19	N	0.13	0.77	-0.004	0.42	0.40
1	0	318	Y	0.13	1.66	-0.015	0.34	0.26
1	1	162	Y	0.12	1.94	-0.017	0.39	0.30
1	2	291	N	2.52	5.23	-0.049	0.80	0.55
12	-9	34	Y	0.10	2.08	-0.019	0.32	0.23
12	0	410	Y	0.11	2.04	-0.020	0.26	0.16
12	1	243	Y	0.11	1.65	-0.015	0.27	0.20
12	2	254	Y	0.11	1.79	-0.017	0.29	0.21
37	-9	3	NA	0.14	0.33	0.000	0.33	0.33
37	0	364	Y	0.09	1.27	-0.012	0.19	0.13
37	1	99	N	0.14	0.94	-0.008	0.22	0.18
37	2	289	N	1.15	-1.01	0.015	0.31	0.39

Table 79 : Regional regressions for "TIC" concentrations: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	17	N	0.69	-13.12	0.15	0.19	0.93
1	0	190	N	0.27	2.84	-0.02	0.60	0.48
1	1	91	N	0.25	2.98	-0.03	0.60	0.47
1	2	166	N	0.42	2.74	-0.02	0.81	0.70
12	-9	28	N	0.45	10.15	-0.10	1.00	0.49
12	0	309	N	0.81	3.32	-0.03	0.78	0.64
12	1	182	N	0.65	2.30	-0.02	0.93	0.85
12	2	192	N	0.84	-0.83	0.02	0.99	1.09
37	-9	3	NA	4.75	3.08	0.00	3.08	3.08
37	0	326	N	1.31	3.48	-0.03	0.78	0.63
37	1	90	N	3.47	-1.47	0.04	2.06	2.26
37	2	261	N	1.58	-1.70	0.03	1.14	1.29

Table 80 : Regional regressions for "DOC" concentrations: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	18	N	5.07	-102.18	1.19	4.89	10.84
1	0	288	N	3.37	14.36	-0.08	6.85	6.44
1	1	138	N	1.81	3.22	0.02	5.11	5.22
1	2	249	N	2.37	5.34	0.00	5.48	5.49
12	-9	34	N	3.87	45.60	-0.37	12.03	10.16
12	0	414	N	3.12	6.54	0.00	6.91	6.93
12	1	243	N	3.48	12.38	-0.04	8.45	8.24
12	2	255	N	2.83	9.02	-0.02	7.23	7.14
37	-9	3	NA	2.45	3.11	0.00	3.11	3.11
37	0	364	N	3.09	-4.46	0.10	4.49	4.99
37	1	99	N	3.16	18.13	-0.12	7.00	6.38
37	2	289	N	2.54	-2.87	0.09	4.82	5.25

Table 81 : Regional regressions for "TKN" concentrations: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	18	Y	0.16	-6.20	0.071	0.15	0.50
1	0	286	Y	0.30	4.59	-0.044	0.61	0.38
1	1	137	Y	0.15	2.24	-0.020	0.41	0.31
1	2	247	Y	0.12	1.13	-0.009	0.35	0.31
12	-9	28	Y	0.12	4.01	-0.038	0.59	0.40
12	0	309	Y	0.13	1.85	-0.016	0.43	0.35
12	1	182	Y	0.14	2.76	-0.025	0.51	0.39
12	2	192	Y	0.15	3.14	-0.029	0.50	0.35
37	-9	3	NA	0.29	0.47	0.000	0.47	0.47
37	0	261	Y	0.35	2.58	-0.024	0.44	0.32
37	1	71	Y	0.28	5.74	-0.056	0.66	0.38
37	2	209	Y	0.24	3.44	-0.033	0.47	0.31

Table 82 : Regional regressions for NO2NO3 concentrations: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	17	N	0.02	0.52	-0.005	0.038	0.011
1	0	190	N	0.02	-0.24	0.003	0.008	0.022
1	1	90	N	0.02	0.02	0.000	0.018	0.018
1	2	166	Y	0.01	-0.26	0.003	0.003	0.017
12	-9	28	N	0.01	-0.13	0.001	0.009	0.016
12	0	309	Y	0.04	-0.56	0.006	0.004	0.036
12	1	182	Y	0.02	-0.32	0.004	0.005	0.023
12	2	192	Y	0.03	-0.41	0.005	0.012	0.035
37	-9	3	NA	0.10	0.09	0.000	0.091	0.091
37	0	326	N	0.01	0.09	-0.001	0.016	0.012
37	1	90	N	0.01	-0.03	0.000	0.010	0.012
37	2	262	N	0.01	0.06	-0.001	0.013	0.010

Table 83 : Regional regressions for total nitrogen concentrations: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	10	NA	0.21	0.51	0.000	0.51	0.51
1	0	94	NA	0.20	0.47	0.000	0.47	0.47
1	1	44	NA	0.08	0.35	0.000	0.35	0.35
1	2	83	NA	0.09	0.34	0.000	0.34	0.34
12	-9	19	Y	0.10	11.67	-0.119	0.98	0.39
12	0	205	N	0.13	-1.05	0.015	0.32	0.40
12	1	122	N	0.11	0.29	0.001	0.41	0.42
12	2	128	N	0.10	-2.17	0.027	0.27	0.41
37	-9	3	NA	0.38	0.56	0.000	0.56	0.56
37	0	300	Y	0.33	5.91	-0.059	0.57	0.28
37	1	83	N	0.26	9.63	-0.098	0.80	0.31
37	2	243	N	0.22	6.12	-0.062	0.58	0.27

Table 84 : Regional regressions for ammoniac concentrations: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	17	N	23.04	273.93	-2.63	37.62	24.49
1	0	190	N	44.91	137.01	-0.99	47.70	42.74
1	1	91	N	30.67	120.55	-0.96	33.74	28.91
1	2	166	N	26.70	10.22	0.18	26.01	26.88
12	-9	28	N	28.90	214.47	-1.96	38.25	28.46
12	0	309	N	57.54	-134.81	1.90	36.30	45.81
12	1	182	N	41.04	60.62	-0.24	39.06	37.86
12	2	192	Y	32.46	404.31	-3.93	51.04	31.41
37	-9	3	NA	2.90	13.63	0.00	13.63	13.63
37	0	326	N	119.00	-20.64	0.75	47.01	50.77
37	1	90	N	94.08	-484.34	5.75	33.06	61.81
37	2	262	N	97.00	-411.91	4.86	25.57	49.87

Table 85 : Regional regressions for total phosphorus concentrations: Classification #4

Region	Classif #1	n	sig ?	RMSE	B0	B1	Value 1990	Value 1995
1	-9	18	N	4.89	-71.86	0.89	7.80	12.22
1	0	287	Y	14.08	202.51	-2.03	19.61	9.45
1	1	138	Y	12.46	115.74	-1.16	11.54	5.76
1	2	247	Y	3.40	30.11	-0.25	7.50	6.24
12	-9	34	N	2.72	16.17	-0.09	7.63	7.16
12	0	412	N	2.76	6.26	0.00	6.34	6.34
12	1	242	N	2.75	10.34	-0.04	6.76	6.56
12	2	255	N	2.62	10.06	-0.04	6.33	6.13
37	-9	3	NA	2.14	4.43	0.00	4.43	4.43
37	0	338	N	11.07	48.15	-0.43	9.29	7.13
37	1	92	N	3.64	44.17	-0.39	9.14	7.19
37	2	270	Y	3.43	32.48	-0.28	7.33	5.94

Section 3: Considerations for regional trend detection

The following developments are largely inspired from Larsen, Urquhart and Kugler (1995) who discussed a similar environmental monitoring program used by the U.S. EPA to measure human influence on valuable natural resources (lakes, wetlands, etc).

3.1 Establishment of a sound population survey design

Larsen, Urquhart and Kugler (1995) discuss the advantages of a random sampling design. They underscore the fact that random sampling designs lead to unbiased estimators for the levels and for the trends of the studied population. On the other hand the use of a non random sampling design, without an a-priori knowledge of the relationships between the sampled lakes can produce some biases in the estimators; thus the inaccuracy in the resulting statistical tests is very difficult to assess.
Also, according to Larsen, Urquhart and Kugler (1995), the establishment of a sound population survey design has several basic requirements:

- a formal recognition of the population of interest (set of lakes in a target region);
- an explicit identification of the members of the population;
- a frame that represents the population of interest (list, map) and
- probability methods for selecting lakes from the defined frame.

This approach exploiting a sampling design similar to a population survey seems to us quite appropriate and almost completely in lign with the philosophy favoured by the CWS. Our past visits and discussions let us believe that the CWS:
1) has a formal recognition of the population of interest in the three regions discussed in this report;
2) has an explicit identification of the members of the population and
3) has a frame that represents the population of interest (list, map).

However, the lakes do not appear to have been randomly selected. A non-random selection of the lakes forces the use of more complex statistical treatments in order to assess the possible biases induced by the non-random selection of the sample of lakes extracted from the possible population. The selection of a group of lakes from rather homogeneous sub-regions may induce an excessive spatial correlation causing a source of biases for the slope and for the variance. These effects will be discussed later in this report.

3.2 Choice of a regional trend detection method

For the detection of regional trends, many lakes are used simultaneously in order to increase the detection power that would otherwise be too small with only 4 to 10 years of data for a single lake. Several hundreds of lakes allowed to detect trends for many parameters in the three studied regions (Algoma, Muskoka et Sudbury). Nevertheless, the results of these regional studies must stay at the regional level: One can say, as an example, that the pH increased significatively as a combination in all of the three regions (with the hypothesis that the non-random sampling was nevertheless representative), but one may not conclude on an individual lake, unless one detects a trend on this particular site via the use of classical methods, despite the reduced length of such a series.

In certain cases, one may be interested to detect trends in sub-groups of lakes within a single region. In this case, the conclusions will be valid for these regional sub-groups. Results presented previously in this report allow to see the various possibilities of the simple linear regression to detect regional trends. Section 3.2 compares this method with other methods for regional trend detection. The following sections will allow to validate the use of simple linear regression in presence of possible temporal or spatial correlations. The power for trend detection of the simple linear regression will be studied as well as the effects of various types of variability.

Analysis of variance

The use of the analysis of variance may allow the detection of trends for all the lakes of a given region. Up to a point, this analysis may even appear more appropriate than linear regression, given the discrete character of the time variable. In fact, the detection of trends with data pertaining to only 4 years but many hundreds of lakes leads to simple linear regression lines through 4 clouds of vertically aligned points (one for each sampled year).

Nevertheless the monotonic aspect of the trends to be detected seems in contradiction with the use of the analysis of variance because a high value of the mean for a single year will lead to the rejection of the hypothesis of equality of means without being really associated with possible trends.

Lets suppose, as an example, that the values for years 1990, 1991 and 1995 are equal, but that year 1993 exhibits significantly higher values, the variance analysis will reject the equality of means, but it is difficult to conclude about the existence of a trend. With the analysis of variance, the rejection of the null hypothesis is not directly related to the presence or absence of trends.
One should also acknowledge that, for the detection of step trends (instantaneous changes of levels), the analysis of variance would be better adapted than simple linear regression.

Nonparametric methods

The use of nonparametric techniques could be envisioned in situations where the presence of outliers or abnormal values could affect the conclusions. The availability of a statistical software allowing simultaneous use of parametric and nonparametric analyses would be an advantage as it would allow to validate the possible effect of possible outliers on the results of the tests. In fact, if both techniques yield the same conclusions, then either there is no outlier or they don't affect the conclusions of the tests. If the techniques diverge in their conclusions, then an additional analysis is necessary to determine which technique should be favored; but in the presence of dubious data nonparametric techniques are recognized to be more appropriate most of the time.

One nonparametric technique that could be used is the simple linear regression on the ranks (Spearman correlation). In addition, one may also try to adapt the Mann-Kendall test for the detection of regional trends; this could be done by using the Hirsch, Slack and Smith (1982) extensions, substituting the lakes at the place of seasons. Such an use would need to be validated as it would be necessary to take into account the high correlation between the sampled lakes.

Even if these nonparametric methods are of a definite interest, they will not be discussed any more in this report. One should not forget also that one of the important weaknesses of the parametric methods is the difficulty to obtain good estimators for the level parameter and for the magnitude of the trends. For these reasons, the joint use of both techniques, parametric and nonparametric, seems to be the best approach.

3.3 Study of the presence of possible autocorrelation

In order to asses the possible effect of autocorrelation on the conclusions of the tests used for detecting regional trends, a short analysis was performed for data of the Muskoka region. This study deals with correlation between years for all the sampled lakes. Table 86 presents the results for each of the 17 studied parameters.

Table 86
Correlations between pairs of years for the lakes of the Muskoka region

Parameter	90 and 91	90 and 93	90 and 95	91 and 93	91 and 95	93 and 95
pH	.59 (n=89)	.23 (n=197)	.14 (n=195)	.56 (n=89)	.48 (n=92)	.64 (n=212)
Conductivity	.22 (n=59)	.09 (n=197)	.06 (n=195)	.46 (n=89)	.49 (n=92)	.19 (n=212)
Alkalinity	.46 (n=89)	.21 (n=196)	.25 (n=185)	.54 (n=89)	.59 (n=87)	.74 (n=204)
Calcium	.56 (n=95)	.18 (n=205)	.22 (n=203)	.49 (n=89)	.56 (n=92)	.44 (n=212)
Magnesium	.63 (n=95)	.26 (n=205)	.28 (n=203)	.52 (n=89)	.53 (n=92)	.63 (n=212)
Potassium	.55 (n=95)	.14 (n=205)	.06 (n=203)	.40 (n=89)	.21 (n=92)	.37 (n=212)
Sodium	.05 (n=95)	-.02 (n=205)	.00 (n=203)	.41 (n=89)	.49 (n=92)	.04 (n=212)
Sulfate	.57 (n=95)	-.02 (n=205)	.10 (n=203)	.00 (n=89)	.05 (n=92)	.36 (n=212)
Silicate	.13 (n=95)	.01 (n=205)	.14 (n=203)	.23 (n=89)	.27 (n=92)	.31 (n=212)
Chloride	.03 (n=95)	-.01 (n=205)	.00 (n=203)	.14 (n=89)	.15 (n=92)	.00 (n=212)
TIC	na	na	na	na	na	.44 (n=212)
DOC	na	.00 (n=205)	.12 (n=203)	na	na	.42 (n=212)
TKN	na	.07 (n=201)	.06 (n=201)	na	na	.31 (n=209)
NO2NO3	na	na	na	na	na	.01 (n=211)
TN	na	na	na	na	na	na
NH3	na	na	na	na	na	.03 (n=212)
TP	na	-.04 (n=202)	.03 (n=202)	na	na	.38(n=210)

This table shows that between-years correlation is not very important, maximal correlation values being of the order of 0.6 or 0.7. Furthermore this correlation contains a part related to the levels of the parameters for the lakes. A lake presenting, for a parameter such as pH, a level higher in 1990 than the bulk of the other lakes will probably have also higher values for the other years. This type of correlation should not affect the detection of regional trends. In view of this, it sounds logical to believe that temporal autocorrelation is low and should not affect significantly the detection of trends. To make sure that correlation has little effect on the conclusions given by the regressions with several observations for each lake, Table 87 presents regression results using only one observation per lake. For each lake, a single year was randomly chosen, discarding all other years for computational purposes.

Table 87
Regional trend detection results in the Muskoka region when only one observation is randomly selected for each lake

Parameter	Sig	n	RMSE	B0	B1	Value 1990	Value 1995
pH	Y	232	0.46	-3.88	0.10	5.48	6.00
Conductivity	Y	232	8.21	127.3	-1.12	26.78	21.20
Alkalinity	N	228	26.97	-92.24	1.21	16.93	23.00
Calcium	Y	235	0.65	12.22	-0.11	2.19	1.64
Magnesium	Y	235	0.20	3.23	-0.029	0.63	0.48
Potassium	N	235	0.12	0.33	-0.000	0.33	0.33
Sodium	N	235	0.94	2.14	-0.015	0.76	0.68
Sulfate	Y	235	2.01	55.09	-0.53	7.04	4.37
Silicate	Y	235	1.23	-8.38	0.11	1.20	1.74
Chloride	N	235	1.62	0.55	-0.001	0.46	0.46
TIC	Y	135	0.34	6.05	-0.058	0.83	0.54
DOC	N	204	3.13	2.64	0.037	6.00	6.19
TKN	Y	204	0.24	3.32	-0.031	0.49	0.33
NO2NO3	N	135	0.02	0.056	-0.0004	0.02	0.02
TN	NA	69	0.12	0.38	0.000	0.38	0.38
NH3	N	135	37.71	53.21	-0.24	31.83	30.64
TP	Y	204	9.14	108.49	-1.06	13.12	7.82

This table 87 shows results very similar to these presented in the first part of this report:
1/ The results related to significance are similar except for TIC;
2/ The RMSE and the location parameters (ordinate at the origin, slope, 1990 and 1995 values) are consistent with previous results with more observations.

This similarity in results allows the following important conclusions:
1/ The possible autocorrelation would have a negligible effect on trend detection conclusions if lakes of the Muskoka region are sampled annually or bi-annually. Then it seems adequate to use all the available data for regional trend detection purposes;
2/ Should a rationalisation in the sampling design be necessary, the similarity in results suggests that the number of lakes sampled each year could be reduced and that a good temporal trend detection power would be retained.

A sampling plan with "serially alternating design ", as proposed by Larsen, Urquhard and Kugler (1995) seems to be a good compromise between the regional trend detection power and the possibility to detect trends on some specific lakes. A possible sampling design could be to sample

80 different lakes each year within a 4-year cycle (the 80 lakes sampled at year 1 would be sampled again at year 5, and so on..) Such a plan would only need 320 lakes sampled within 4 years, rather than 520 actually (2 x 260 for the Muskoka region). This is only an example, and it would be essential to optimize the sampling plan according to the magnitudes of the different sources of variability and within the available budgets.

3.4 Study of the presence of possible spatial correlation

As a first step, it is important to note that correlation between individuals in a population is possible and that correlation between such individuals should not necessarily be considered as a source of bias for the estimators related to the trend detection techniques. In this report, the detection of regional trend is looking at he behaviour of lakes within a region. Within the studied population, some lakes might be highly correlated for a number of parameters, this correlation being only an image of what happens for the whole target population.

Spatial correlation becomes a source of bias for the estimators when lake selection is not representative of the distribution of lakes within the studied population. Random selection of lakes is a choice technique to ensure representativity. If this selection design was not used, then it is essential to make sure that the selected lakes have not induced any bias related to special situations, such as the selection of lakes part of a neighbouring group characterized by this special situation.

As the lake selection was not performed randomly in the 3 studied regions, this part deals with the possible effects of spatial correlation on the results of regional trend detection. The developments are performed for the Muskoka region which seems to have a sampling plan prone to biases from spatial correlation (First selection of plots, then selection of lakes within these plots).

In a first step, the presence of spatial correlation is evaluated by computing the mean correlation between lakes. This computation is realized with use of a SAS procedure, similar to the one presented in the 1995 report dealing with the new adapted DETECT version. To perform consistent calculations, only lakes with observations for the 4 years (1990,91,93 and 95) were used. In the Muskoka region, this reduced the number of lakes to 92. Computations were performed on raw and detrended data. The calculation for detrended data is necessary, because the presence of trends leads to an increase of correlation between lakes. Table 88 presents mean correlations between lakes in the Muskoka region for pH, conductivity, alkalinity, calcium, sodium, sulfate and silicate.

Table 88

Mean correlations between lakes in the Muskoka region

Parameter	Mean correlation of raw data	Mean correlation of detrended data
pH	0.63	0.22
Conductivity	0.81	0.51
Alkalinity	0.26	0.18
Calcium	0.81	0.39
Sodium	0.54	0.13
Sulfate	0.69	0.27
Silicate	0.15	0.13

One can note that the spatial correlation differs largely from one parameter to the other and that this correlation decreases if detrended data are used. Calcium and conductivity are the most correlated parameters, followed by pH, sulfate, then by alkalinity and silicates with the lowest correlations. Given the relationships between parameters, one may believe that magnesium should behave like calcium and chlorides like sodium.

In order to assess more accurately the possible effect of spatial correlation, this calculation was then performed between lakes of the same plot. This was realised for the 7 plots of the Muskoka region. The computation was again performed with a SAS procedure similar to the one presented in the 1995 report on the new DETECT version. In a similar way, this computation was performed for sulfates only with the lakes having observations for the same 4 years (1990,91,93,95). Correlations are given for detrended data on the Table 89, for the 7 Muskoka plots.

Table 89

Mean correlations between lakes concentrations within the 7 plots of the Muskoka region

Lake number	n	Mean correlation
< 200	28	0.52
>200 and < 300	30	0.35
>300 and < 400	7	0.92
>400 and < 500	7	0.62
>500 and < 600	5	0.52
>600 and < 700	5	0.28
>700	10	0.12

One can remark that the spatial correlations are superior within plots as these for all the lakes of the region (reference: Table 88. Mean correlation for detrended sulfate concentration = 0.27).
The higher spatial correlation within plots implies the possible presence of a local effect on the detection of regional trends. To assess this effect, three short Monte-Carlo simulations were performed to answer the following questions:

- Did the use of linear regression conserve the 5% significance level in presence of a sampling plan of several lakes at 4 different dates ?
- Should one use the noncentral t distribution to determine the power of the test of regional trend detection ?
- What is the effect of spatial correlations on the significance level of the regional trend detection test and on the estimators ?

For each of these questions, 500 series of 80 observations were simulated (20 lakes x 4 years: 90,91,93 and 95).
The first simulation studied the conservation of the significance level.

Significance level of regional trend detection

In this study, series consisted of 80 numbers drawn from a N(0,1) distribution, without trend. For each series a regression is established and a test on the slope of the regression is performed. To conserve the 5% significance level, a trend should be detected 5% of the time on the simulated series (without real trend) i.e (type I error consist of probability of rejecting the null hypothesis when the null hypothesis is true).

The mean slope for the 500 series is 0.001 (theoretical value is 0), the mean RMSE for the 500 series is 0.9995 (theoretical value is 1.0) and the mean standard deviation of the slope is 0.057 (theoretical value is $(\sigma/\Sigma(x_i-x_{mean})^2)^{0.5}$ = 1/(80(3.7))=0.058), where x_i=$year_i$=90, 91, 93 and 95 for i=1,2,3 and 4 and where x_{mean}=92.25. Given those results for the point estimators it's not surprising to have an empirical significance level (number of series with detected trend / number of simulated series) of 0.04 which is not significantly different from 5%.

Theoretical power of regional trend detection

In this second study, the same 80 numbers , drawn from a N(0,1) distribution are used, but a trend is added to each of the sampled years. To assess the power of the regional trend detection test, it would be very convenient to be able to relate to theoretical results obtained from classical regression analysis.
To test the slope, Neter et Wasserman (1974) have shown that the power of the test can be determined using the noncentral t distribution, with a noncentrality parameter δ defined by :

$$\delta^2=\Delta^2/\sigma^2\sum_{i=1}^{80}(x_1-\bar{x})^2 \qquad (1)$$

where Δ is the amplitude of the trend (slope) to be detected, σ is the standard deviation (estimated by the RMSE) and x_i=$year_i$=90, 91, 93 and 95 for i=1,2,3 and 4. The δ values are associated to different powers (probability of rejecting the null hypothesis when the null hypothesis is false) : 50%, 70%, 85% and 90% powers are respectively associated to, 2.5, 3.0 and 3.3. In order to validate the use of the theoretical power, a simulation is performed with δ value of 3.0. When replaced in equation (1), the values of δ, σ and x give a corresponding trend slope Δ=0.175/year. Thus the 500 series of 80 observations are simulated with means 0 in 1990, 0.175 in 1991, 0.525 in 1993 and 0.875 in 1995.

The mean annual slope for the 500 series is 0.173 (theoretical value is 0.175), the mean RMSE for the 500 series is 0.994 (theoretical value is 1.0) and the mean standard deviation of the slope is 0.059 (theoretical value is 0.058. Given those results for the point estimators it's not surprising to have an empirical power (number of series with detected trend / number of simulated series) of 0.85 which is not significantly different from 85%. These results validate the use of equation (1) for obtaining the amplitude of trend that can be detected with a known probability.

Significance level in presence of spatial correlation

In this third simulation study, again the simulated series consisted of 80 numbers without trend. A spatial dependance is introduced between observations using the structure implied by equation:

$$Lake_i = 0.80\ Lake_{i-1} + e_i \qquad (2)$$

Where the value for $Lake_i$ is obtained by summing 80% of the value for $Lake_{i-1}$ and the value of e_i (i.i.d with distribution N(0,1)). This structure will produce some pairs of lakes highly correlated while other pairs of lakes are less correlated (for example lakes #1 and #20). For each simulated series, a linear regression and a test on the slope are performed. Once again we want to evaluate the number of series with detected trends when the simulated series are created without trend (significance level=type I error, consist of probability of rejecting the null hypothesis when the null hypothesis is true).

The mean slope for the 500 series is -0.004 (theoretical value is 0), the mean RMSE for the 500 series is 1.45 (theoretical value is 1.0) and the mean standard deviation of the slope is 0.255 (theoretical value is 0.058. Given those results for the point estimators it's not surprising to have an empirical significance level (number of series with detected trend / number of simulated series) of 0.53 which is significantly higher than 5%.

Here is a brief explanation of this highly biased empirical significance level : the presence of high correlation between lakes introduces groups of lakes with very close values. These groups of lakes bring an increase in the variability by the presence of large values (a large value will rarely be isolated) which is reflected in the larger RMSE. However, the groups of lakes also introduced an important increase in the variability of the slopes (groups of lakes at one end of the series will largely affect the trend slope). The standard deviation used in the test for the slope is obtained by the equation $RMSE/(\Sigma(x_i-x_{mean})^2)^{0.5} = 1.45/(296)^{0.5} = 0.084$, while the real variability of the slope is associated to a standard deviation of 0.255. The important underestimation of the standard deviation of the slope introduces the high number of trends detected even if no trend is introduced in the simulated series. We thus conclude that groups of lakes tend to affect the slopes more largely than they affect the RMSE which is not surprising since the regression line should attempt to fit the groups of lakes even if they are aberrant and that does not necessarily mean that the RMSE will increase.

Given the results for the significance level in presence of spatial correlation, the study of the power is not necessary. We can transpose the results of the significance level study to conclude that in presence of spatial correlation, more than 85% of the series will conclude to a significant trend if a 0.175/year slope is introduced in the simulated series.

Regional trend detection in presence of spatial correlation

Now that we know a little more on the effect of spatial correlation on the regional trend detection test and on the possible presence of significant spatial correlation in the three regions studied, one important question arises : What can we do with it?

Regretfully, the answer to this question is neither simple nor documented in the literature, but the preceding developments allow us to derive a number of suggestions to validate the regional trend detection in the presence of spatial correlation.

As a first step, it is necessary to pass a judgement on the spatial representativity of the selected lakes, with regards to the lakes of the whole population. This step necessitates a good physical knowledge of the investigated population.
To obtain an unbiased estimation of the population characteristics, a random sampling is also necessary, what in the present case is not fully secured. Given these limitations, the representativity of the sampled lakes should be judged using an educated guessing.

In a second step it is possible to go further with the analyses of regional trend detection and to investigate if some grouping of spatially correlated lakes could lead to dubious conclusions.. In the Muskoka region, the selection of lakes within plots is very much adapted to this kind of supplementary study. Trend detection tests can be performed within each plot to identify plots able to largely influence the global trend detection. The representativity of the plots can also be briefly discussed.

The following section deals with an example of such complementary study: In this case, an analysis is performed with sulfate data within the Muskoka region.

Effect of spatial correlation on trend detection for sulfate concentrations in the Muskoka region

The first results for trend detection of sulfates within this region have shown that sulfates are decreasing significatively in the order of 0.50 ppm/year. This trend reduces concentrations from 6.91 ppm in 1990 to 4.40 in 1995; this result was obtained from 813 observations originating from 260 lakes during the years 1990, 1991, 1993 and 1995.
The lakes of the Muskoka region are subdivided into 7 plots for which it was remarked that the internal spatial correlation was higher than for the global region (Table 89). The Table 90 presents the lineal regression results obtained within each plot.

Table 90
Regional trend detection results for sulfate concentrations in the seven plots of the Muskoka region

Plot	Lake number	n	sig?	RMSE	B0	B1	Value 1990	Value 1995
1	< 200	129	Y	1.46	66.46	-0.65	7.96	4.71
2	>200 and <300	125	Y	1.72	54.84	-0.53	7.14	4.49
3	>300 and <400	112	Y	1.51	78.77	-0.79	7.62	3.67
4	>400 and <500	89	Y	1.27	19.36	-0.15	5.86	5.11
5	>500 and <600	113	Y	2.30	58.45	-0.58	6.25	3.35
6	>600 and <700	109	Y	1.20	49.74	-0.48	6.54	4.14
7	>700	113	Y	1.66	26.19	-0.22	6.39	5.29

Table 90 shows that trends are negative and significant for each of the 7 plots, but that the slopes have a large range, from -0.15 ppm/year to -0.79 ppm/year : Lakes from plots #4, #6 and #7 exhibit trends with lower amplitudes than for the region of Muskoka taken as a whole (-0.50 ppm/year). The RMSE for the whole region regression is 1.72. One can see that scatter around the regression line is generally lower than for the grouping of all the plots. Only plot #5, with an RMSE of 2.30 exhibits a higher variability than the Muskoka region as a whole.

The stability of the trends detected for the different plots allows us to believe that the trend obtained for the whole Muskoka region is not the artificial result of a strong spatial correlation within some extreme groupings. This kind of conclusion.should only be applied to a region which is not much larger than the area covered by the plots and remains subject to the representativity of the selected lakes.

Variance components decomposition

The following developments correspond to the variance decomposition technique proposed by Larsen, Urquhart and Kugler (1995). This decomposion allows to evaluate the magnitude of different variance components, and to assess their effect on the detection of regional trends.

As stated by the authors :

"Under ideal circumstances, a two-way, balanced, replicated design (with r observations on each lake during the index interval each year) would allow unambiguous estimation of the major components of variance".

However, the data sets available can't produce a replicated design but a two-way balanced design can be achieved if only the lakes with observations for all four years are used. The effects are then associated to the Population Variance (lakes), the Year Variance and the Lake*Year Interaction, while all other variance components can't be dissociated from the error term.

The authors suggest that :

"An ideal database with which to estimate variances would contain data (1) derived from a consistent sampling program, ... (2) including many lakes (more than 20 for effective variance estimation) across many years (more than five)..."

For the Muskoka and Algoma regions, 93 and 218 lakes are respectively available with four years of data. For the Sudbury region 144 lakes are available with at least 4 years of data. Since years 1990 and 1992 are missing for more than 50% of the 144 lakes, we have decided to ignore them for the variance component estimation. Nevertheless, these databases can certainly be used for obtaining a good idea of the variance components. Tables 91, 92 and 93 present respectively the variance components (mean square) for the first ten parameters in the Muskoka, Algoma and Sudbury regions.

Table 91

Variance components for the first ten parameters in the Muskoka region

Parameter	MS Year	MS Lake	MS Year*Lake	Total Variance
pH	7.2	0.81	0.06	0.30
Conductivity	1319.7	66.7	8.64	33.76
Alkalinity	4955.5	3581.8	397.7	1233.59
Calcium	11.08	0.84	0.053	0.34
Magnesium	0.57	0.12	0.004	0.039
Potassium	0.037	0.041	0.004	0.014
Sodium	0.63	0.14	0.016	0.052
Sulfate	147.4	4.9	0.87	3.08
Silicate	1.69	3.89	0.37	1.26
Chloride	0.63	0.26	0.016	0.08

N.B.: The shaded areas are associated with parameter with significant regional trends.

Table 92
Variance components for the first ten parameters in the Algoma region

Parameter	MS Year	MS Lake	MS Year*Lake	Total Variance
pH	10.1	1.64	0.05	0.48
Conductivity	2035.6	212.9	13.64	70.24
Alkalinity	48163.2	20332.9	462.7	5607.0
Calcium	16.0	9.4	0.10	2.55
Magnesium	0.85	0.22	0.005	0.063
Potassium	0.118	0.014	0.003	0.006
Sodium	1.83	0.09	0.011	0.037
Sulfate	413.5	2.59	0.61	2.53
Silicate	91.6	7.6	0.44	2.55
Chloride	1.03	0.02	0.007	0.014

N.B.: The shaded areas are associated with parameter with significant regional trends.

Table 93
Variance components for the first ten parameters in the Sudbury region

Parameter	MS Year	MS Lake	MS Year*Lake	Total Variance
pH	5.59	2.90	0.04	0.78
Conductivity	676.4	1221.3	26.6	327.1
Alkalinity	13498	134863	1586	34793
Calcium	7.5	39.5	0.45	10.2
Magnesium	0.24	1.48	0.03	0.39
Potassium	0.007	0.071	0.005	0.02
Sodium	0.30	1.29	0.005	0.33
Sulfate	64.5	11.3	1.71	4.42
Silicate	6.43	11.66	0.52	3.32
Chloride	0.24	2.62	0.03	0.68

N.B.: The shaded areas are associated with parameter with significant regional trends.

The last three Tables show that the Mean Squares associated with the interaction term **Lake*Year** are always much smaller than the Mean Squares associated with **Lakes** and **Years** effects. This result shows that the differences between years are "**concordant from lake to lake**". The variance components for years and lakes vary greatly from one parameter to another and from one region to another. Each of the ten parameters will be discussed in the following paragraphs.

pH values

In all three regions, the variance components associated to years are larger than the variance components associated to lakes and the difference is particularly important in the Muskoka and Algoma regions. This result characterizes the presence of a trend. Table 94 shows an increase of pH, in time, in all three regions for all years sampled supporting the conclusion obtained in the first part of the contract (positive regional trend detected in all three regions). The decomposition of variance components for pH values shows that all factors are favourable to trend detection : large variability between years, smaller variability between lakes and very small variability associated to interaction between lakes and years.

Table 94
Yearly means of pH values calculated for sampled years

Region	1988	1989	1990	1991	1992	1993	1994	1995
Muskoka			5.57	5.59		5.73		6.17
Algoma	5.68				5.80		6.09	6.12
Sudbury				5.51		5.67	5.73	5.98

Conductivity values

In the Muskoka and Algoma regions, the variance components associated to years are very large compared to the variance components associated to lakes. This result characterizes the presence of a trend. Table 95 shows a decrease of conductivity, in time, in these regions for all years sampled (except for a small increase in 1995) supporting the conclusion obtained in the first part of the contract (negative regional trend detected in these regions). For the Sudbury region, the variance component associated to lakes is much larger than the corresponding component in the Muskoka and Algoma regions while the variance component associated to years is two times smaller. Thus, the possible trend in years is smaller in the Sudbury region than in the two other regions while the lakes show a larger variability for conductivity values in the Sudbury region. These results explain the conclusion of no regional trend detected in the Sudbury region.

Table 95
Yearly means of conductivity values calculated for sampled years

Region	1988	1989	1990	1991	1992	1993	1994	1995
Muskoka			30.2	24.1		21.9		22.5
Algoma	28.4				23.2		21.6	22.5
Sudbury				39.4		35.6	34.3	36.6

Alkalinity values

The variance decompositions show highly different results from one region to another. For the Muskoka region the variance components associated to years and lakes are of similar amplitudes and are smaller than in the other two regions. The lakes in the Muskoka region show smaller increase in time and show smaller variability between themselves compared to the other two regions. In the Algoma region, the variance component associated to years is two times larger than the variance component associated to lakes. In the Sudbury region the alkalinity values show a variance component associated to lakes 10 times larger than the variance component associated to years. In addition, the Sudbury region show a much greater variability for the alkalinity values in comparison to the other two regions. The Sudbury region is thus characterized by lakes showing a large variability for alkalinity values and this large variability makes it more difficult to detect a regional trend even if the slope estimator is larger than in the Algoma region where a regional trend is detected. Table 96 shows the yearly means of alkalinity values. This table completes the variance component decomposition by showing the possible monotonic trend pattern.

Table 96
Yearly means of alkalinity values calculated for sampled years

Region	1988	1989	1990	1991	1992	1993	1994	1995
Muskoka			24.5	15.0		24.4		33.2
Algoma	32.4				43.6		68.0	50.2
Sudbury				61.0		64.6	71.9	82.9

Calcium concentrations

The variance decompositions show different results from one region to another. For the Muskoka region the variance component associated to years is much larger than the variance component associated to lakes. The lakes in the Muskoka region also show smaller variability between themselves compared to the other two regions. In the Algoma region, the variance component associated to years is two times larger than the variance component associated to lakes. In the Sudbury region the calcium concentrations show a variance component associated to lakes 5 times larger than the variance component associated to years. In addition, the Sudbury region show a much greater variability for the calcium concentrations in comparison to the other two regions. The Sudbury region is thus characterized by lakes showing a large variability for calcium concentrations and this large variability makes it more difficult to detect a regional trend. Table 97 shows the yearly means of calcium concentrations. This table completes the variance component decomposition by showing the possible monotonic trend pattern.

Table 97
Yearly means of calcium concentrations calculated for sampled years

Region	1988	1989	1990	1991	1992	1993	1994	1995
Muskoka			2.48	2.03		1.78		1.71
Algoma	2.80				2.49		2.28	2.16
Sudbury				3.84		3.36	3.38	3.41

Magnesium concentrations.

The results for magnesium concentration are quite similar to those of the calcium concentrations and will not be discussed in more details. Table 98 shows the yearly means of magnesium concentrations. This table completes the variance component decomposition by showing the possible monotonic trend pattern.

Table 98
Yearly means of magnesium concentrations calculated for sampled years

Region	1988	1989	1990	1991	1992	1993	1994	1995
Muskoka			0.69	0.58		0.55		0.51
Algoma	0.58				0.49		0.47	0.43
Sudbury				0.88		0.81	0.79	0.79

Potassium concentrations

The variance decompositions show different results from one region to another. For the Muskoka region the variance component associated to years and lakes are quite. In the Algoma region, the variance component associated to years is much larger than the variance component associated to lakes. In the Sudbury region the potassium concentrations show a variance component associated to lakes 10 times larger than the variance component associated to years. The Sudbury region is thus characterized by lakes showing a large variability for calcium concentrations and this large variability makes it more difficult to detect a regional trend. Table 99 shows the yearly means of potassium concentrations. This table completes the variance component decomposition by showing the possible monotonic trend pattern.

Table 99
Yearly means of potassium concentrations calculated for sampled years

Region	1988	1989	1990	1991	1992	1993	1994	1995
Muskoka			0.35	0.33		0.30		0.33
Algoma	0.23				0.18		0.22	0.21
Sudbury				0.32		0.31	0.32	0.33

Mean values for the Algoma region exhibit no definite trends So it is legitimate to question the results about significant regional trends obtained in the first part of this report ...The small component of the variance related to the lakes let to believe into a possible large similarity between lakes; In this case, the high spatial correlation could be the cause of the apparent significance of the global regional trend detected earlier. For whatever reason, this Algoma region and the validity of the detected trends should warrant a more in depth investigation because of the conflicting results obtained...,

Sodium concentrations.

The variance decompositions show different results from one region to another. For the Muskoka region the variance component associated to years is much larger than the variance component associated to lakes. In the Algoma region, the variance component associated to years is twenty times larger than the variance component associated to lakes. In the Sudbury region the sodium concentrations show a variance component associated to lakes 4 times larger than the variance component associated to years. In addition, the Sudbury region show a much greater variability for the calcium concentrations in comparison to the other two regions. The Sudbury region is thus characterized by lakes showing a large variability for sodium concentrations and this large variability makes it more difficult to detect a regional trend. Table 100 shows the yearly means of sodium concentrations. This table completes the variance component decomposition by showing the possible monotonic trend pattern.

Table 100
Yearly means of sodium concentrations calculated for sampled years

Region	1988	1989	1990	1991	1992	1993	1994	1995
Muskoka			0.78	0.66		0.72		0.58
Algoma	0.74				0.57		0.57	0.52
Sudbury				0.89		0.82	0.80	0.78

Sulfate concentrations

In all three regions, the variance components associated to years are larger than the variance components associated to lakes and the difference is particularly important in the Muskoka and Algoma regions. This result characterizes the presence of a trend. Table 101 shows a decrease of sulfate concentrations with in time, in all three regions for almost all years sampled supporting the conclusion obtained in the first part of the contract (negative regional trend detected in all three regions). The decomposition of variance components for sulfate concentrations shows that all factors are favourable to trend detection : large variability between years, smaller variability between lakes and very small variability associated to interaction between lakes and years. However, it should be noted that yearly means show an increase in 1995 for the Algoma and Sudbury regions. Could it be that the trend is stabilizing (or reversing) in these regions?

Table 101
Yearly means of sulfate concentrations calculated for sampled years

Region	1988	1989	1990	1991	1992	1993	1994	1995
Muskoka			7.79	6.27		5.25		5.01
Algoma	6.60				4.26		3.50	3.93
Sudbury				9.60		8.56	7.99	8.62

Silicate concentrations

In the Muskoka region, the variance component associated to years is smaller than the variance component associated to lakes. Even if this does not generally characterize the presence of a trend, the results in the first part of this report conclude to a significant positive trend. Table 102 shows that the means are almost the same for the years 1991, 1993 and 1995 after a large increase between 1990 and 1991. The means after 1990 suggests two comments : (1) can we really talk of a trend in this situation and; (2) the stability of these means explains the relatively small variance component for years. For the Algoma region, the variance component associated to years is much larger than the variance component for the lakes. For the Sudbury region the variance component associated to years is smaller than the variance component for the lakes. For the later two regions, the variance components decomposition is in lign with the trend detection results : significant trend in the Algoma region and nonsignificant trend in the Sudbury region. It should be noted that, like for the sulfate concentrations, yearly means show an increase in 1995 for the Algoma and Sudbury regions. Could it be that the trend is stabilizing (or reversing) in the Algoma region?

Table 102
Yearly means of silicate concentrations calculated for sampled years

Region	1988	1989	1990	1991	1992	1993	1994	1995
Muskoka			1.14	1.42		1.42		1.39
Algoma	3.21				2.65		1.76	3.04
Sudbury				2.08		1.71	1.58	1.76

Chloride concentrations

In the Muskoka and Algoma regions, the variance components associated to years are larger than the variance components associated to lakes and the difference is particularly important in the Algoma region. This result explains the presence of a trend in the Algoma region only. For the Sudbury region the varaince component associated to years is 10 times smaller than the variance component associated to lakes. Table 103 shows a decrease of chloride concentrations, in time, in all three regions for almost all years sampled. However a significant trend is detected for the Algoma region only. The variance component associated to lakes is much smaller in the Algoma region showing a possible high correlation in this region for the chloride concentrations. A more detailed trend detection analysis would be appropriate in order to validate the detected trend and insure that the trend is not caused by a very large spatial correlation. Once again, it should be noted that, like for the sulfate and silicate concentrations, yearly means show an increase in 1995 for the Algoma and Sudbury regions. Could it be that the trend is stabilizing (or reversing) in the Algoma region?

Table 103
Yearly means of chloride concentrations calculated for sampled years

Region	1988	1989	1990	1991	1992	1993	1994	1995
Muskoka			0.51	0.38		0.36		0.31
Algoma	0.33				0.19		0.17	0.23
Sudbury				0.31		0.23	0.22	0.27

General comments about the variance component decomposition

The variance component decomposition suggests the following comments :

1/ In the Algoma region, a significant trend is detected for all parameters. This may suggest a possible effect of spatial correlation. It would be appropriate to complete the trend detection analyses for this region in order to evaluate the possible effect of spatial correlation on the regional trend detection conclusions.

2/ In the Sudbury region, a large variability between lakes makes it difficult to detect significant trends. But the presence of high spatial correlation can be put aside.

3/ In the Muskoka region, the total variability of parameters is generally lower than in the Algoma region and the ratio of variance component for years with variance component for lakes is also generally lower in the Muskoka region. That could explain the presence of more detected trends in the Algoma region.

Detectable trend amplitudes with actual sampling plan

Given the actual sampling plan, we can evaluate trend amplitudes that can be detected 90% and 98% of the time. These results suppose that the observations are independent (no temporal or spatial correlation) and identically distributed N(0,1). Tables 104 through 120 present the detectable trend amplitudes for all 17 parameters in the Muskoka, Algoma and Subury regions. The detectable trend amplitudes are evaluated with the help of equation (1).

$$\delta^2 = \frac{\Delta^2}{\sigma^2} \sum_{i=1}^{n} (x_1 - \bar{x})^2$$

which can be rewritten as :

$$\Delta^2 = \frac{\delta^2 \sigma^2}{\sum_{i=1}^{n} (x_1 - \bar{x})^2} \tag{3}$$

where δ is 3.3 for power=90% and 4.0 for power=98%, σ is estimated by the RMSE and the denominator is calculated for all years and lakes measured in each region. The columns of tables 104 through 120 respectively present :

- the name of the region,
- the number of nonmissing observations,
- the significance of the regional trend according to a simple linear regression,
- RMSE for the simple linear regression,
- the trend slope estimator obtained by the simple linear regression,
- the denominator in equation (3),
- evaluated trend amplitude that is detected 90% of the time,
- evaluated trend amplitude that is detected 98% of the time.

These tables explain in part the reason why a lot more trends are detected in the Algoma region. In this region, more data are available in addition to the fact that data are available for the year 1988. These two facts bring a denominator much larger in the Algoma region, which allow the detection of smaller trend amplitudes. A brief description of trend power status for each parameter will now be presented.

pH values

The actual sampling plan is good enough to detect annual slopes of 0.03 unit/year in the Muskoka and Algoma regions and annual slopes of 0.06 unit/year (90%) or 0.08 unit/year (98%) in the Sudbury region. Trends are detected in all three regions.

Conductivity values

The actual sampling plan is good enough to detect 90% of the time annual slopes of 0.46 unit/year in the Muskoka region, 0.33 unit/year in the Algoma region and annual slopes of 1.27 unit/year in the Sudbury region. Trends are detected in the first two regions while the high variability and the smaller denominator associated to sampled years do not permit to detect a trend in the Sudbury region.

Alkalinity values

The actual sampling plan is good enough to detect 90% of the time annual slopes of 1.73 unit/year in the Muskoka region, 2.98 unit/year in the Algoma region and annual slopes of 13.30 unit/year in the Sudbury region. A trend is detected in the Algoma region. In the Muskoka region, the trend is much smaller than in the Algoma region which explains that no trend is detected even if a smaller trend could be detected in the Muskoka region. In the Sudbury region the high variability and the smaller denominator associated to sampled years do not permit to detect a trend in the Sudbury region even if the trend slope estimate is larger than in the Algoma region.

Calcium concentrations

The actual sampling plan is good enough to detect 90% of the time annual slopes of 0.03 ppm/year in the Muskoka region, 0.06 ppm/year in the Algoma region and annual slopes of 0.23 ppm/year in the Sudbury region. Trends are detected in the first two regions while the high variability and the smaller denominator associated to sampled years do not permit to detect a trend in the Sudbury region.

Magnesium concentrations

The actual sampling plan is good enough to detect 90% of the time annual slopes of 0.01 ppm/year in the Muskoka region, 0.01 ppm/year in the Algoma region and annual slopes of 0.04 ppm/year in the Sudbury region. Trends are detected in the first two regions while the high variability and the smaller denominator associated to sampled years do not permit to detect a trend in the Sudbury region.

Potassium concentrations

The actual sampling plan is good enough to detect 90% of the time annual slopes of 0.008 ppm/year in the Muskoka region, 0.003 ppm/year in the Algoma region and annual slopes of 0.010 ppm/year in the Sudbury region. A trend is detected in the Algoma region only, while an higher variability and a smaller denominator associated to sampled years do not permit to detect trends of the same amplitude in the Muskoka and Sudbury regions.

Sulfate concentrations

The actual sampling plan is good enough to detect 90% of the time annual slopes of 0.102 ppm/year in the Muskoka region, 0.047 ppm/year in the Algoma region and annual slopes of 0.152 ppm/year in the Sudbury region. Trends are detected in all three regions and it should be noted that trend slope estimates region is 5 times a 90% detectable amplitude in the Muskoka and almost 10 times a 90% detectable amplitude in the Algoma region. So not much doubt can be associated to the significance of the trend in those regions.

Silicate concentrations

The actual sampling plan is good enough to detect 90% of the time annual slopes of 0.071 ppm/year in the Muskoka region, 0.065 ppm/year in the Algoma region and annual slopes of 0.130 ppm/year in the Sudbury region. A trend is detected in the Algoma region only, while smaller trend amplitudes and smaller denominator associated to sampled years do not permit to detect trends in the Muskoka and Sudbury regions.

Chloride concentrations

The actual sampling plan is good enough to detect 90% of the time annual slopes of 0.090 ppm/year in the Muskoka, 0.005 ppm/year in the Algoma region and annual slopes of 0.052 ppm/year in the Sudbury region. A trend is detected in the Algoma region only. An higher variability and a smaller denominator associated to sampled years do not permit to detect a trend of the same amplitude in the Muskoka region while an higher variability, a smaller denominator associated to sampled years and a smaller trend amplitude do not allow to detect a trend of the same amplitude in the Sudbury region.

TIC concentrations.

The actual sampling plan is good enough to detect 90% of the time annual slopes of 0.056 ppm/year in the Muskoka region, 0.078ppm/year in the Algoma region and annual slopes of 0.168 ppm/year in the Sudbury region. No trend is detected in the three regions. A deficient sampling strategy for this parameter brings small denominators. The trend amplitudes estimated by the regression are still far from being detectable.

DOC concentrations

The actual sampling plan is good enough to detect 90% of the time annual slopes of 0.181 ppm/year in the Muskoka, 0.132 ppm/year in the Algoma region and annual slopes of 0.213 ppm/year in the Sudbury region. No trend is detected in the three regions. Relatively high variability compared to the trend amplitudes explain the absence of significant trends . The trend amplitudes estimated by the regression are still far from being detectable.

TKN concentrations

The actual sampling plan is good enough to detect 90% of the time annual slopes of 0.014 ppm/year in the Muskoka region, 0.014ppm/year in the Algoma region and annual slopes of 0.024 ppm/year in the Sudbury region. Trends are detected in all three regions.

NO_2NO_3 concentrations

The actual sampling plan is good enough to detect 90% of the time annual slopes of 0.003 ppm/year in the Muskoka region, 0.003 ppm/year in the Algoma region and annual slopes of 0.001 ppm/year in the Sudbury region. Trends are detected in all three regions.

Total nitrogen concentrations

The actual sampling plan is good enough to detect 90% of the time annual slopes of 0.036 ppm/year in the Algoma region and annual slopes of 0.025 ppm/year in the Sudbury region. In the Muskoka region no trend amplitude can de evaluated since data are available for 1995 only. No trend is detected in the three regions. A trend is detected in the Sudbury region. A deficient sampling strategy and a small trend amplitude do not permit to detect a trend for this parameter in the Algoma region.

Ammoniac concentrations

The actual sampling plan is good enough to detect 90% of the time annual slopes of 5.59 ppm/year in the Muskokaregion, 4.64 ppm/year in the Algoma region and annual slopes of 9.37 ppm/year in the Sudbury region. No trend is detected in the three regions. A deficient sampling strategy and a relatively high variability for this parameter explain this result. The trend amplitudes estimated by the regression are still far from being detectable in the Muskoka and Algoma regions.

Total phosphorus concentrations

The actual sampling plan is good enough to detect 90% of the time annual slopes of 0.70 ppm/year in the Muskoka, 0.11 ppm/year in the Algoma region and annual slopes of 0.59 ppm/year in the Sudbury region. Trends are detected in the Muskoka and Sudbury regions even if these regions show higher variability and smaller denominator associated to sampled years. A very small trend amplitude explains the absence of a significant trend in the Algoma region.

Detectable trend amplitudes with other sampling plan

Using equation (3), detectable trend amplitudes with other sampling plans can be evaluated. For example we can answer a question asked in last year contract concerning the number of years necessary for detecting a global trend of 0.5 σ with a 90% probability. For a single site, 523 years are necessary to obtain such a power. In a regional trend detection situation, the number of lakes may vary in addition to the number of years.

Equation (3) may be rewritten as :

$$D=\sum_{i=1}^{n}(x_1-\bar{x})^2=\frac{\delta^2\sigma^2}{\Delta^2}$$

where δ is always 3.3 when a 90% power is desired. A 0.5 σ global trend amplitude corresponds to a 0.1 σ annual trend for the 1990-1995 period and a 0.071 σ annual trend for the 1988-1995 period.

For the Sudbury and Muskoka regions, D must be greater than or equal to 1089 in order to detect a 0.1 σ trend 90% of the time. With the actual sampling strategy (90,91,93 and 95) in the Muskoka region and (90,91,92,93,94 and 95) in the Sudbury region, each lake contributes to D with a respective value of 14.75 and 17.5. Given these contributions we need approximately 74 lakes in the Muskoka region and 63 lakes in the Sudbury region in order to detect a 0.5 σ global trend in the 1990-1995 period.

In the Algoma region, D must be greater than or equal to 2160 in order to detect a 0.071 σ annual trend 90% of the time. With the actual sampling strategy (88,92,94 and 95) in the Algoma region each lake contributes to D with a value of 28.75. Given this contribution we need approximately 75 lakes in the Algoma region in order to detect a 0.5 σ global trend in the 1988-1995 period.

These results show that with the sampling of approximately 260 lakes in the Muskoka and Algoma regions and of approximately 160 lakes in the Sudbury regions, one can expect to easily detect global trends of 0.5 σ 90% of the time.

Similar study can be performed for fixed annual trend amplitudes. Suppose one want to know the number of lakes needed to detect 90% of the time an annual trend of 0.01 pH unit in the 1990-1995 period. In this case, the D value to reach depends on the RMSE (standard deviation estimator).

For the Muskoka region the value, of RMSE (0.46), δ (3.3) and trend slope (0.01) give a D value of 23043 to reach, in order to detect the desired trend 90% of the time. Given the actual sampling frequency (90,91,93 and 95) 23043/14.75=1563 lakes would be necessary. If a sample is added in

1997, the contribution of a lake to the D sum goes from 14.75 to 32.8 and 703 lakes would be necessary to detect a 0.01 pH unit trend amplitude. If another sample is added in 1999, the contribution of a lake to the D sum goes from 32.8 to 60.8 and 378.8 lakes would be necessary to detect a 0.01 pH unit trend amplitude. Finally, if another sample is added in 2001, the contribution of a lake to the D sum goes from 60.8 to 100.9 and 228 lakes would be necessary to detect a 0.01 pH unit trend amplitude. So the actual number of lakes sampled would be sufficient to detect a 0.01 unit of pH trend amplitude with three additionnal biannual samples. For the Algoma and Sudbury regions more samples would be necessary to detect the same trend amplitude.

The examples presented above illustrate how power analysis can be used to rationalize the monitoring network. In order to do that, several underlying hypotheses are done :

- The effect of temporal or spatial correlation is not important
- The RMSE does not change with additional samples : stationarity of the variance in time
- The trends are monotonic.

A rationalization of the monitoring network should consider all those underlying hypotheses.

Table 104 : Regional regression powers for pH values.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	782	Y	0.46	0.09	3105.5	0.03	0.03
Algoma	935	Y	0.67	0.06	6616.7	0.03	0.03
Sudbury	755	Y	0.88	0.09	2105.1	0.06	0.08

Table 105 : Regional regression powers for conductivity values.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	782	Y	7.80	-1.22	3105.5	0.46	0.56
Algoma	937	Y	8.22	-1.00	6631.3	0.33	0.40
Sudbury	754	N	17.65	-0.70	2102.3	1.27	1.54

Table 106 : Regional regression powers for alkalinity values.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	772	N	29.00	0.90	3042.5	1.73	2.10
Algoma	929	Y	73.15	3.53	6572.2	2.98	3.61
Sudbury	755	N	184.96	4.92	2105.1	13.30	16.13

Table 107 : Regional regression powers for calcium concentrations.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	790	Y	0.55	-0.12	3154.6	0.03	0.04
Algoma	917	Y	1.55	-0.09	6252.4	0.06	0.08
Sudbury	755	N	3.19	-0.07	2105.1	0.23	0.28

Table 108 : Regional regression powers for magnesium concentrations.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	790	Y	0.18	-0.033	3154.6	0.01	0.01
Algoma	917	Y	0.24	-0.021	6252.4	0.01	0.01
Sudbury	755	N	0.61	-0.009	2105.1	0.04	0.05

Table 109 : Regional regression powers for potassium concentrations.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	790	N	0.13	-0.002	3154.6	0.008	0.009
Algoma	917	Y	0.08	-0.002	6252.4	0.003	0.004
Sudbury	755	N	0.14	0.002	2105.1	0.010	0.012

Table 110 : Regional regression powers for sodium concentrations.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	790	N	0.92	-0.032	3154.6	0.054	0.066
Algoma	917	Y	0.17	-0.029	6252.4	0.007	0.009
Sudbury	755	N	0.51	-0.009	2105.1	0.036	0.044

Table 111 : Regional regression powers for sulfate concentrations.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	790	Y	1.73	-0.51	3154.6	0.102	0.123
Algoma	942	Y	1.17	-0.45	6723.5	0.047	0.057
Sudbury	755	Y	2.12	-0.28	2105.1	0.152	0.185

Table 112 : Regional regression powers for silicate concentrations.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	790	Y	1.22	0.08	3154.6	0.071	0.087
Algoma	946	Y	1.61	-0.11	6796.6	0.065	0.078
Sudbury	755	N	1.81	0.02	2105.1	0.130	0.158

Table 113 : Regional regression powers for chloride concentrations.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	790	N	1.54	-0.028	3154.6	0.090	0.110
Algoma	941	Y	0.11	-0.018	6723.4	0.005	0.005
Sudbury	755	N	0.72	-0.002	2105.1	0.052	0.063

Table 114 : Regional regression powers for "TIC" concentrations.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	464	N	0.36	-0.015	465.0	0.056	0.068
Algoma	711	N	0.79	-0.015	1108.3	0.078	0.095
Sudbury	680	N	1.92	-0.003	1426.2	0.168	0.203

Table 115 : Regional regression powers for "DOC" concentrations.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	693	N	2.96	0.01	2916.0	0.181	0.219
Algoma	946	N	3.29	-0.02	6796.6	0.132	0.160
Sudbury	755	N	2.95	0.08	2105.1	0.213	0.258

Table 116 : Regional regression powers for "TKN" concentrations.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	688	Y	0.23	-0.02	2907.1	0.014	0.017
Algoma	711	Y	0.14	-0.02	1108.3	0.014	0.017
Sudbury	544	Y	0.31	-0.03	1822.8	0.024	0.029

Table 117 : Regional regression powers for NO2NO3 concentrations.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	463	Y	0.02	0.002	464.0	0.003	0.004
Algoma	711	Y	0.03	0.005	1108.3	0.003	0.004
Sudbury	681	Y	0.01	-0.001	1431.0	0.001	0.002

Table 118 : Regional regression powers for total nitrogen concentrations.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	231	NA	0.16	0.000	0.0	NA	NA
Algoma	474	N	0.12	0.010	118.7	0.036	0.044
Sudbury	629	Y	0.28	-0.065	1351.8	0.025	0.031

Table 119 : Regional regression powers for ammoniac concentrations.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	464	N	36.55	-0.69	465.0	5.59	6.78
Algoma	711	N	46.85	-0.40	1108.3	4.64	5.63
Sudbury	681	N	107.42	3.19	1431.0	9.37	11.36

Table 120 : Regional regression powers for total phosphorus concentrations.

Region	n	sig ?	RMSE	B1	Denominator	Power=90%	Power=98%
Muskoka	690	Y	11.48	-1.17	2908.8	0.70	0.85
Algoma	943	N	2.72	-0.02	6783.1	0.11	0.13
Sudbury	703	Y	8.10	-0.35	2060.0	0.59	0.71

Conclusions and recommandations

The present study has clearly demonstrated that regional trend detection analysis is well suited to the databases provided by CWS. The use of simple linear regression allowed the detection of several logical trends. The limitations of regional trend detection compared to trend detection on a single site are largely associated to the kind of conclusion that can be drawn. In a regional trend detection analysis, the conclusion can only be attributed to the target region and nothing can be said about a particular lake. However, given the sampling strategy established by CWS, the study of regional trends appears natural.

This report also contains several sections on restrictive characteristics that could affect the regional trend detection analyses : autocorrelation, spatial correlation, outliers. In these sections, we tried to state the possible effects of these characteristics and presented examples to show how to performed regional trend detection when these characteristics appeared important in the CWS databases. However, it was impossible to completely close the subject of restrictive characteristics in the regional trend detection analyses. The treatments associated to spatial correlation, in particular, are highly time consuming and the study of all parameters in all three regions, although very important could not be completed in this contract.

The variance component decomposition show that : (1) In the Algoma region, a significant trend is detected for all first ten parameters and that the variance component associated to years is always much larger than the variance component associated to lakes; (2) In the Sudbury region, a large variability between lakes makes it difficult to detect significant trends and; (3) In the Muskoka region, the total variability of parameters is generally lower than in the Algoma region and the ratio of variance component for years with variance component for lakes is also generally lower in the Muskoka region. In all three region, the variance component associated to the interaction Year*Lake is generally quite small compared to the other variance components presented.

The power analyses allow to confirm that the actual sampling strategy can easily detect global trend amplitudes of 0.5 σ with a 90% probability. A similar power in a single site trend detection would be obtained after 523 years.

Finally, examples show how the equation used to evaluate the power can be used to rationalize the monitoring network. This section however should be completed after an explicit definition of the future objectives of the monitoring network. Concerning the monitoring network rationalization, we believe that several advantages could be gained by using a random lake selection with a serially alternating design as the one proposed by Larsen, Urquhart and Kugler (1995). However, several disadvantages could also arise: (1) if trend detection at single site is still desired (some lakes already chosen should then be kept in order to perform single site trend detection), (2) if the sampling strategy is used for other objectives (waterfowl). These questions show the necessity to specify the objectives and available budget in order to optimize (rationalize) the monitoring network in the future.