Water Quality in the Catfish Creek Watershed
A Summary of 1991-1995 Conditions and Trends

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EXECUTIVE SUMMARY

The purpose of this report is to characterize surface water quality and identify key water quality issues within the Catfish Creek watershed. This was accomplished through the analysis of data from the Provincial Water Quality Monitoring Network (PWQMN), and a review of existing literature.

Although Catfish Creek Conservation Authority has participated in the PWQMN for more than thirty years, a water quality report has never been produced for the watershed. To provide a benchmark indicative of the current water quality conditions found within the Kettle Creek watershed and to identify potential water quality issues, our analysis investigated the most recent five year contiguous set of data, 1991-1995, for which seven monitoring sites could be evaluated. The entire dataset (historical to current) for each of the seven sites was also assessed for preliminary long-term temporal trends where possible.

The watershed was divided into two major study areas: Upper Catfish Creek and Lower Catfish Creek (Figure 1). While each basin was evaluated and discussed on an individual basis, it is recognized that the areas are not autonomous.

Water quality sampling within the Catfish Creek Watershed occurred on a routine basis whereby flow was not always considered. Generally, sampling was performed across a range of flow events; however, peak events were missed for some years. This potential bias towards sampling at low to moderate flows indicates that the results from the monitoring data presented here has mainly characterized base-flow and likely has not captured the changes in water quality which occur during high flow events.

The upper main branch of Catfish Creek tends to be the area within the watershed where water quality is most impaired from which point the water quality appears to progressively improve as the creek flows downstream.

Nutrient levels, primarily nitrate, nitrite and phosphorus, were found to be the major water quality issue within the upper sub-basin. Catfish Creek drains over a clayey till plain which does not allow for a high degree of infiltration, thereby leading to an increase in the amount of run-off entering the creek. This natural phenomenon is then amplified by the agricultural land-use within the area (e.g. row cropping, tile drainage, livestock access) which facilitates the movement of water off the land.

Nitrate inputs are usually attributed to fertilizer application and sewage treatment plant effluent. Within the upper sub-basin these concentrations could be as a result of agricultural runoff entering the waterways from natural processes, via tile drains or from faulty septic systems within the villages of Springfield and Brownsville.

Nitrite inputs tend to be associated with livestock, septic or sewage treatment plant waste. High levels of nitrite can also be indicative of an ammonia input. However, given the low ammonia levels found within the Creek, this can not be determined.

The impact of the urban development throughout the Catfish Creek watershed is reflected by the increase in phosphorus levels downstream of Aylmer and the reported algae blooms and poor water colour downstream of the Aylmer sewage lagoons during times of discharge. These algal blooms may be indicating that the creek does not have the assimilative capacity for the bi-annual discharge from the sewage lagoons. However, further investigations are needed to determine if this is the case.

The Catfish Creek watershed has relatively low natural base-flows and areas within the upper portion of the watershed have intermittent flow during dry seasons. This phenomenon is amplified by the numerous tile and municipal drains and the impervious soils which do not allow for sufficient recharge within the region. Other land-use practices such as the increased number of dams and online ponds for irrigation found within the lower sub-basin could also be negatively affecting the natural base-flow in some creeks

(e.g. Silver Creek). In general, base flow within lower Catfish Creek is higher relative to the rest of the watershed. Therefore, the lower nutrient concentrations found within lower Catfish Creek could potentially be as a result of dilution from these higher base flows. Sampling during higher flow periods should be done to fully understand if this is a potential mechanism to explain the better water quality observed downstream.

Within the Catfish Creek watershed dissolved oxygen levels have rarely been observed to dip below 8 mg/L. While this value is considered to be adequate for aquatic life, samples were generally only taken during the day which would not have accounted for the diurnal fluctuation or the range of values an organism truly experiences. Thus, determining if dissolved oxygen within the Catfish Creek watershed was limiting to aquatic organisms could not be accurately assessed with the 1991-1995 sampling regime and diurnal monitoring should be employed as part of future monitoring programs.

Supersaturation of dissolved gases can also be potentially hazardous to aquatic life. Recently, dissolved oxygen (DO) levels have been reported as high as 12.66 mg/L (at site 502), which when converted to percent saturation was found to be supersaturated (130%). Supersaturation of gases within the water can lead to gas exchange problems in aquatic life such as blood gas trauma in fish (Fidler & Miller, 1994). However, there has yet to be a criteria set for the upper limit of DO for the protection of aquatic life.

Very little data characterizing bacteria and pathogen exists for the Catfish Creek watershed; however, it is evident from the available data that there is a high degree of variability within and between sites across the watershed. Therefore interpretation of the results presented here should be done so with this in mind. The elevated fecal coliform levels found within upper Catfish Creek between 1991 and 1995 were likely as a result of the high percentage of livestock operations adjacent to the creek and the faulty septic systems within the Village of Springfield. To address this problem, in the late 1990's Springfield was taken off septic and connected to the municipal sewage lagoons in Aylmer. This in conjunction with the current decline in livestock operations within the upper sub-basin has likely helped to decrease bacterial concentrations within the area. However, future investigations should be performed to identify if this is in-fact true.

Very little current information exists on the Springwater reservoir. However, local knowledge indicates that high phosphorus levels are a problem resulting in increased levels of algae. In 2005, an investigation into the application of alum as a potential method for reducing the phosphorus levels with the reservoir was carried out (Griffiths and CCCA in progress). Preliminary results from this analysis suggests that the alum treatment had a positive impact on the water quality by reducing phosphorus levels and subsequently decreasing plant growth and improving visibility (Griffiths and CCCA in progress).

Spills and wastewater treatment lagoon bypasses are a significant threat to downstream water users in the Catfish Creek watershed. They represent an acute and immediate impairment to water quality that can compromise recreational uses at Port Bruce. Therefore, it may be of use to have an effective spills response protocol to mitigate a timely response and notification of downstream users.

Preliminary trend assessment yields variable results with respect to whether nutrient levels are decreasing or increasing over time. Nitrate and nitrite concentrations appeared to be slightly decreasing across the watershed where as non-filterable residue appeared to be on the rise in the upper watershed. Total phosphorus concentrations have decreased since the 1970's at site 502, directly downstream of Aylmer, indicating that the removal of phosphates from household cleaners and wastewater effluent has had a marked effect in decreasing urban inputs of total phosphorus to the watershed. Re-assessing these trends in the future with current data would be beneficial in evaluating if new trends are emerging.

The primary recommendations from this report include: an increase in the number of samples taken at each of the PWQMN monitoring sites in order to improve statistical analysis; continue sampling at the current Source Water Protection (SWP) monitoring stations to ensure adequate spatial cover of the watershed; incorporation of diurnal and high flow monitoring in order to better assess the total range of conditions; conduct future investigations into the water quality conditions of Springfield Reservoir to build on existing baseline information; promote outreach programs such as ‘greencover’ to facilitate rehabilitation in the upper watershed; conduct future investigations into the connection between local soil conditions and ambient water quality to determine realistic water quality goals; and deploy continuous temperature loggers to identify if summer daily maximum water temperatures are increasing.

The analysis of physiochemical water quality data in this report is intended to be used as a benchmark against which future information can be compared. This will allow for the determination of whether water quality within the watershed is improving, degrading, or remaining the same. Similar reports are expected to be compiled at five year intervals as consecutive years of data are obtained

INTRODUCTION

The Catfish Creek watershed is home to approximately 24,071 people most of which live in rural areas. The major urban areas include the town of Aylmer (approximately 7,945 residents), a portion of St. Thomas (approximately 1,662 residents), the village of Springfield (approximately 800 residents) and the village of Port Bruce (approximately 200 residents). The tributaries and reservoirs within the Catfish Creek watershed support a variety of uses such as habitat for aquatic organisms, recreational use within Springwater Conservation Area, agricultural irrigation, livestock watering and waste assimilation. Although this watershed is relatively small in area, there is the potential for an increase in rural population and an intensification of current agricultural land-use. As the pressure on the waterways increases and the already highly agricultural area intensifies, there is the potential for the quality of the water within the watershed to decrease if proper precautionary and management measures are not implemented. These concerns along with the current water quality issues within this watershed highlight the need for baseline and continuous water quality assessment.

It is not only important to monitor water quality, but also to document and report on it so as to identify issues and recommend actions to improve the state of the waterways. Within Ontario the Provincial Water Quality Monitoring Network (PWQMN) provides an invaluable source of data and is the primary dataset employed by this report to determine the ambient water quality within the Catfish Creek watershed. Therefore, much of this report will focus on characterizing nutrients, non-filterable residue, metals, major ions, and bacteria at the three long-term monitoring sites within the watershed.

The purpose of this report is to characterize the chemical and physical aspects of surface water quality and identify the water quality issues which affect Catfish Creek through the analysis of historical data and a review of existing literature.

Watershed Characteristics

The Catfish Creek Watershed is located within Elgin County along the north shore of Lake Erie situated between the Kettle Creek Conservation Authority and Long Point Region Conservation Authority's jurisdictions. This watershed drains an area of approximately 490 km^2 of land starting in the north near Brownsville traveling approximately 25 km to the south where it empties into Lake Erie at Port Bruce. The total drop in elevation within the watershed from near Brownsville to Port Bruce is approximately 146 meters with an average gradient of 5.8 meters per kilometer.

For the purpose of this analysis the drainage network has been separated into two sub-basins, Upper Catfish and Lower Catfish (Figure 1). The upper portion of the watershed is drained via three main tributaries, West Catfish Creek, East Catfish Creek and the upper portion of the Main Catfish Creek Channel. The lower sub-basin is primarily drained by the main Catfish Creek channel.

These headwaters, which are separated in the West from the Kettle Creek watershed by the St. Thomas moraine, are located in a succession of low clay till ridges known as the Mount Elgin Ridges (St. Thomas and Norwich Moraines), which were deposited during the recession of the Wisconsin glacier (Figure 2). Near New Sarum these watercourses unite to form the lower portion of the main Catfish Creek channel. From there the water flows in a deep, steep-sided, flat-floored valley south, through the Norfolk Sand Plain, to Port Bruce at Lake Erie.

Land use in the watershed is primarily agriculture, with a small percentage (< 11%) classified as forested or marginal (Elgin County Landscape Strategy, Elgin County Stewardship Council/MNR- Aylmer, 2004) (Figure 3). The Town of Aylmer and the Villages of Springfield and Port Bruce are the primary urban centers and comprise approximately 2% of the land cover. The watershed contains some of the best agricultural land in Ontario (Barnes, 1966), and as such feels the effects associated with intensive agriculture. It has been suggested that several of the water quality problems facing Catfish Creek are directly related to land use and the inherent geology and topography of the area (Johnston, 1983). Within the southern half of the watershed, south of Aylmer on Bradley Creek is Springwater Reservoir, which is primarily used for recreation but is also equipped with a dam to mitigate flood control (Figure 1).

Currently, about 44% of the residents within the Catfish Creek watershed receive their drinking water from Lake Erie through the Elgin Area Primary Water Supply System, located 2 km East of Port Stanley, with an intake pipe approximately 1290 m off the Lake Erie shore. The remainder receives their water from either privately owned wells within the region, or the municipal well system servicing the village of Brownsville.

Historically, the town of Aylmer was the only urban area serviced by a municipal sewage lagoon wastewater treatment facility, which discharged twice a year (spring and fall) into the main branch of Catfish Creek just downstream of Aylmer. The remainder of the watershed was serviced via private septic systems. However, in the late 1990's the Village of Springfield was taken off septic and connected to the Aylmer municipal sewage lagoon system.

A combination of the land-use, intrinsic geology and anthropogenic sources (e.g. wastewater treatment plants, agricultural runoff) all contribute to the water quality issues present in the Catfish Creek watershed.

Major Water Uses

Water quality is generally evaluated according to the primary use of the water body. Some of the common designated uses within a watershed include drinking water supplies, habitat for aquatic life, industrial/commercial uses, agricultural uses or contact and non-contact recreational uses.

The tributaries within the Catfish Creek watershed are primarily used for agricultural irrigation, waste assimilation and as habitat for aquatic life. Although aquatic recreation does occur within the watershed it is limited (e.g. Springwater CA, and the beach at Port Bruce) and therefore is not seen as a primary use throughout. Water quality is generally evaluated with respect to provincial objectives, Canadian guidelines, or other criteria for a particular water use. Since there are no such criteria for waste assimilation, evaluation of water quality will be against criteria for the protection of aquatic life. It also important to point out that while there are no direct drinking water intakes within the watershed, the regions drinking water is taken from Lake Erie into which Catfish Creek drains. Therefore it is also important to evaluate the influence Catfish Creek's water quality may have on Lake Erie.

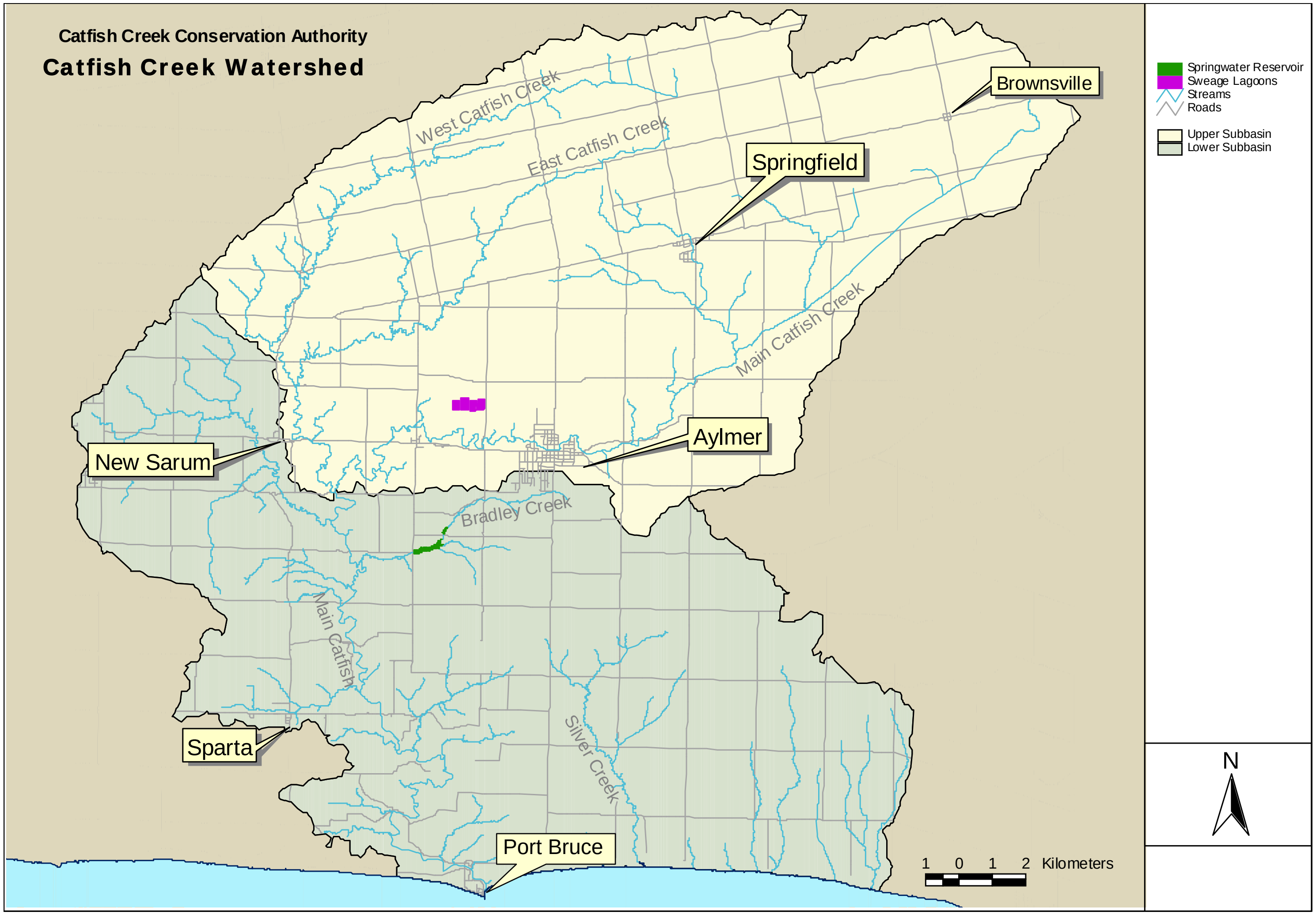


Figure 1. Catfish Creek watershed characteristics illustrating location of; urban centres, industrial areas, wastewater treatment plants, drinking water intakes, streams, & reservoirs

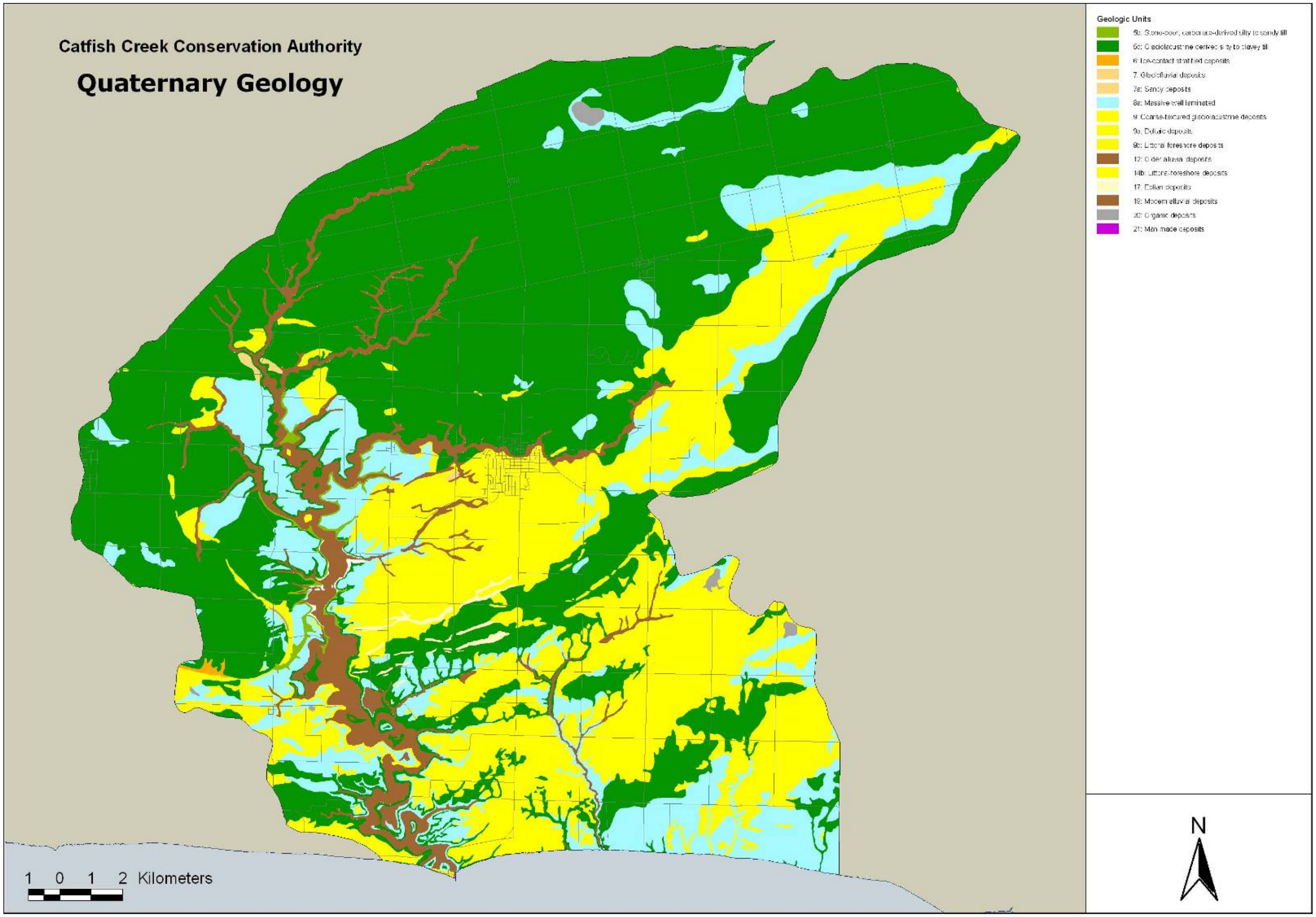


Figure 2. Surficial Geology of the Catfish Creek Watershed

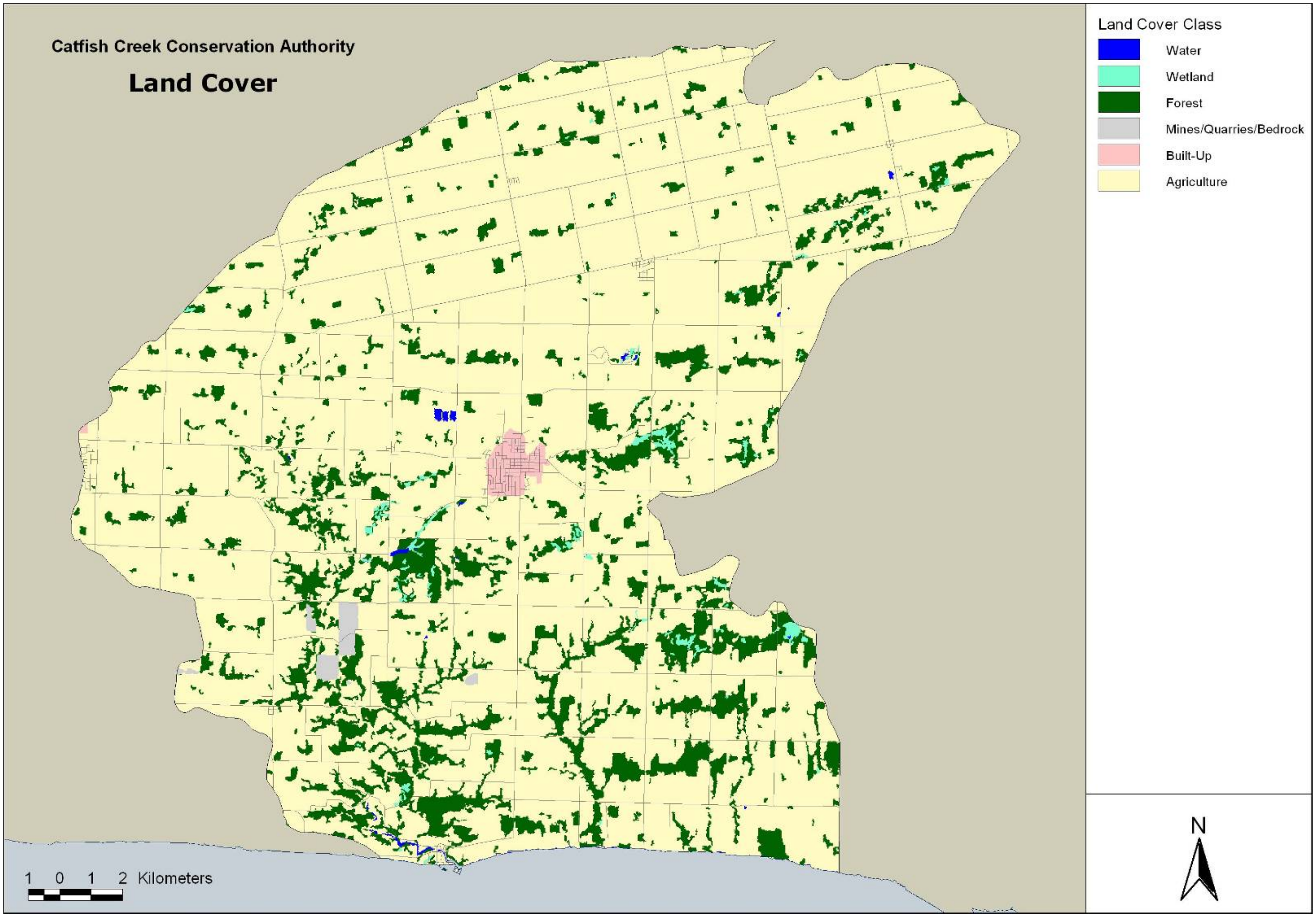


Figure 3. Land cover in the Catfish Creek watershed

METHODS

Dataset Selection

Surface water quality monitoring has historically focused on characterizing the chemical and physical attributes of the creeks and rivers within a watershed. The Provincial Water Quality Monitoring Network (PWQMN) is an important long-term monitoring program for Ontario which facilitates the characterization of the chemical and physical aspects of water quality. However, financial cutbacks by the province over the last decade, along with limited capacity at conservation authorities, have resulted in a decrease in the number of sites monitored and the frequency at which they are sampled.

As part of the partnership in the PWQMN program the Ontario Ministry of the Environment (MOE) is responsible for the laboratory analysis while the Conservation Authorities are responsible for collecting the samples. There are seven historic monitoring sites within the Catfish Creek watershed that were at some point part of the Provincial Water Quality Monitoring Network (PWQMN). Appendix A describes the location of the active and inactive PWQMN sampling sites and the period for which samples were taken at each site. In the Catfish Creek watershed, the number of monitoring sites fell from a high of 9 in 1975 to a low of zero from 1996 to 2002. In 1996 when the MOE cut funding to the PWQMN program, Catfish Creek Conservation Authority (CCCA) did not have the internal capacity to continue monitoring on its own leaving a seven year data gap for watershed wide sampling from 1996 to 2002. However, in 2003 a year after the MOE started re-building the PWQMN, CCCA resumed sampling. This data gap resulted in the 1991-1995 sampling period being the most recent 5 year contiguous set of data. This report will focus on the three sites which were sampled during the five year period from 1991 to 1995, illustrated in Figure 4.

The number of annual samples taken per site has also declined over the years. Under the PWQMN program the MOE is responsible for the laboratory analysis while CCCA is responsible for collecting the samples. Currently the MOE allows for eight samples per year to be taken at each of the PWQMN sites; however, historically a total of 12 samples per year were taken at each of the sites. During the 1991-1995 sampling period, the number of samples taken generally ranged between six and ten samples per year.

To provide a benchmark indicative of the current water quality conditions found within the Kettle Creek watershed, our analysis investigated the most recent five year contiguous set of data, 1991-1995, for which seven monitoring sites could be evaluated. The entire dataset (historical to current) for each of the seven sites was also assessed for preliminary long-term temporal trends where possible.

Summarizing the most recent contiguous five years of data helps to increase the likelihood of characterizing the full range of flow and climatic conditions. This approach also reduces the strong year-to-year variability from extremes in climate (e.g. wet and dry periods).

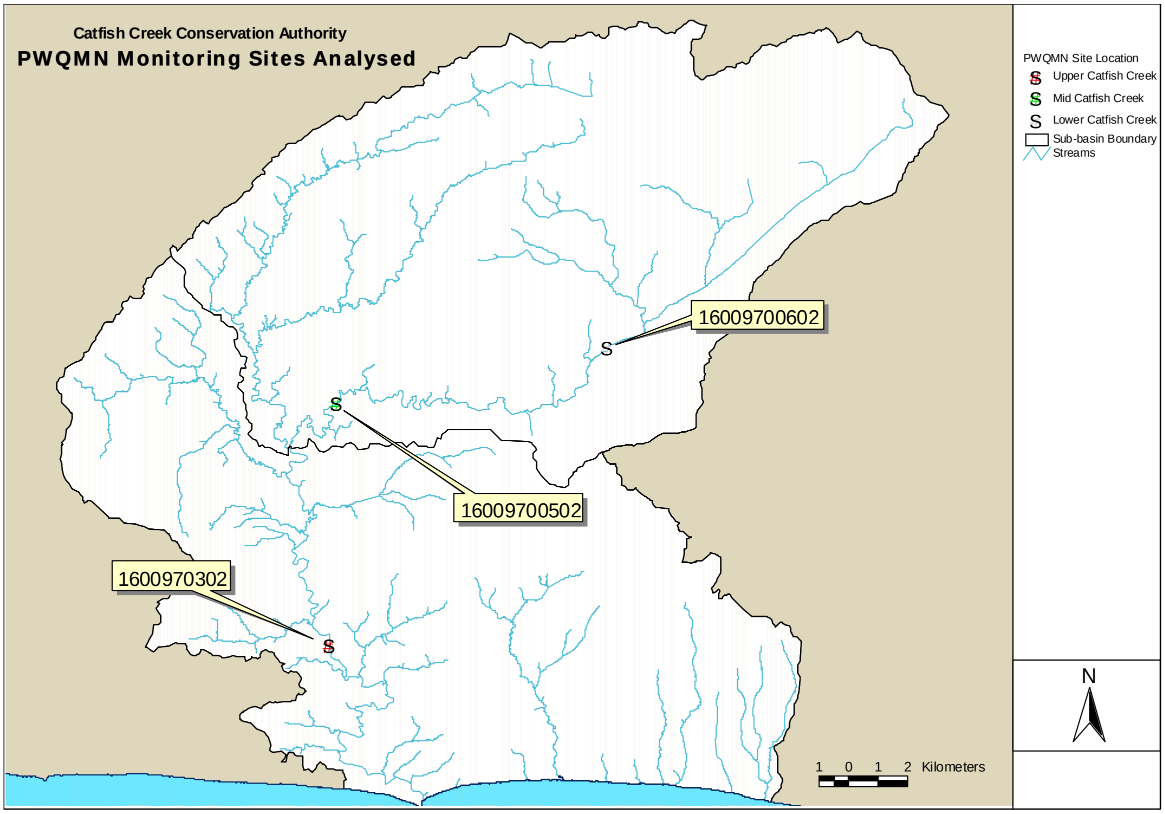


Figure 4. Location of the 3 sites within the Provincial Water Quality Monitoring Network that were analysed in this study.

Parameters Analysed

Routine Chemistry, Nutrients, Metals and Pesticides

Water quality samples were analyzed for routine chemistry, nutrients and metals (Table 1). For more information on laboratory methods and detection limits refer to MOE (1994) and Appendix B. Water samples were collected using standard sampling procedures depending on access type. Sites with easy access were sampled directly from the stream with the sample bottle upstream of where they were standing. Sites with bank access were sampled from the shore with a stainless steel bucket attached to an extension rod. Finally, sites with only bridge access were sampled by lowering a stainless steel pail from the bridge into stream. Sample bottles were rinsed three times on site with the sample water prior to filling. Samples were preserved if necessary, stored on ice and couriered to the MOE laboratory.

Pesticides were only monitored for twice in 1981 at PWQMN site 16009700302 (Sparta Line East of Sparta). These samples were also collected using the procedure previously described.

Dissolved Oxygen, conductivity, pH and temperature were monitored in the field at the time of sample collection using a titration kits and/or a handheld data sonde.

Table 1. List of water quality variables analyzed in PWQMN stream/river samples.

Water Quality Variable Category	Water Quality Variables
Nutrients	Dissolved Nutrients: ammonia, nitrate, nitrite; phosphate Total Nutrients: Total phosphorus, Total Kjeldahl nitrogen
Solids	Non-filterable residue; Total dissolved solids
Major Ions/Anions	Calcium; Magnesium, Sodium, Potassium; Hardness; Chloride
Routine Chemistry	pH; Alkalinity; Conductivity
Metals	Aluminum; Barium, Beryllium; Cadmium; Chromium, Copper; Iron; Manganese; Molybdenum; Nickel; Lead; Strontium; Titanium; Vanadium; Zinc
Routine Physical	Turbidity; Temperature

Bacteria and Pathogens

Generally samples for bacteria or pathogens were not routinely collected as part of the long-term PWQMN monitoring program. However, for the three sites reviewed in this report, Fecal Coliform was sampled for from 1976-1994 where as, *E. Coli* was only sampled during the 1994 and 1995 sampling seasons. Other projects apart from the PWQMN have also investigated the presence of bacteria and/or pathogens within the Catfish Creek watershed (e.g. Depuydt, 1994; Hayman, 1989) which can provide insight into the potential bacterial issues within the region. Relevant results from these investigations will be referred to in the discussion of this report in an attempt to fill in gaps and further substantiate results from our analysis.

Benthic Macroinvertebrates

Historically, no routine monitoring of the benthic macroinvertebrate assemblages within the Catfish Creek watershed has been performed. However, there have been some projects outside the PWQMN undertaken by CCCA and others (Johnston, 1983; Mackenzie, 2001) that have investigated the presence of benthic macroinvertebrates assemblages within specific locations along Catfish Creek. The discussion of this report will elaborate on the results of these analyses as they relate to water quality within the Catfish Creek watershed.

Reservoirs

Historically, no routine monitoring of the major reservoirs within the Catfish Creek watershed has been carried out. However, recently the CCCA in cooperation with Dr. Griffiths (Griffiths & CCCA in progress) examined the water quality within the Springwater reservoir with an emphasis on decreasing the level of phosphorus present in the reservoir. Relevant results from this investigation will be elaborated on within the discussion of this report.

Data Analysis

Streamflow

Streamflow was analyzed to help characterize the study period since water quality in rivers is strongly influenced by the amount and timing of rainfall and snowmelt. There are two gauge stations located within the Catfish Creek watershed (Figure 6). Station 02GC030 is located on upper Catfish Creek at Aylmer and station 02GC018 is located further downstream on Catfish Creek near the village of Sparta. Data from these stations were provided by the Water Survey of Canada (Environment Canada, http://www.wsc.ec.gc.ca/).

The historical long-term average annual flow was calculated and compared with the annual average flows for each year from 1991-1995. This comparison indicated whether stream levels were rising or falling signifying a wetter or dryer period than normal.

The strength of the relationship between water quality parameters and streamflow was investigated using the non parametric Kendall Correlation Coefficient (Kendall tau statistic).

Summary Statistics

Box and whisker plots were used to present the data graphically. Box and whisker plots can illustrate the distribution and statistics of a dataset. The box in the box-whisker plot shows the 25th and 75th percentiles of the dataset, called the lower and upper quartiles, and the median (50th percentile) (Figure 5). The whiskers represent the range of the data set to the 90th and 10th percentiles (Sigma Plot 8.0 2002). The circles illustrate outliers beyond the 10th and 90th percentiles (values more than 2 standard deviations from the mean).

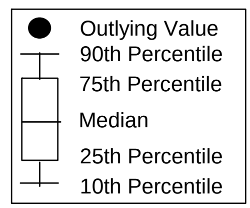


Figure 5. Box and whisker plot illustrating the 5th 25th, 50th (median) 75th and 95th percentiles and outliers of the 1991-1995dataset.

A summary of the descriptive statistics, (including the minimum, maximum, mean, and median values), for each water quality parameter analyzed from the 1991-1995 dataset are included in Appendix C.

Comparative Statistics

Statistical methods for detecting spatial and temporal changes in water quality have greatly improved throughout the years (Hirsch, R.M et al 1991). Nonparametric statistical methods can accommodate data that are not normally distributed, are robust against outliers, and have missing data (Hrynkiw et al 2003). These characteristics are typical of water quality data (Trkulja 1997).

Nonparametric regression analyses were carried out, using Mann-Whitney or Kruskal-Wallis tests (Analyse-it Software, 2003), to identify differences between PWQMN sites for each water quality parameter (nutrients, non-filterable residue and chloride). Sites were considered to be significantly different if the *p* value resulting from these tests were < 0.05. However, it is cautioned that finding a statistically significant result does not necessarily imply that one has found an environmentally significant result (Griffiths et al 2001; Trkulja 1997).

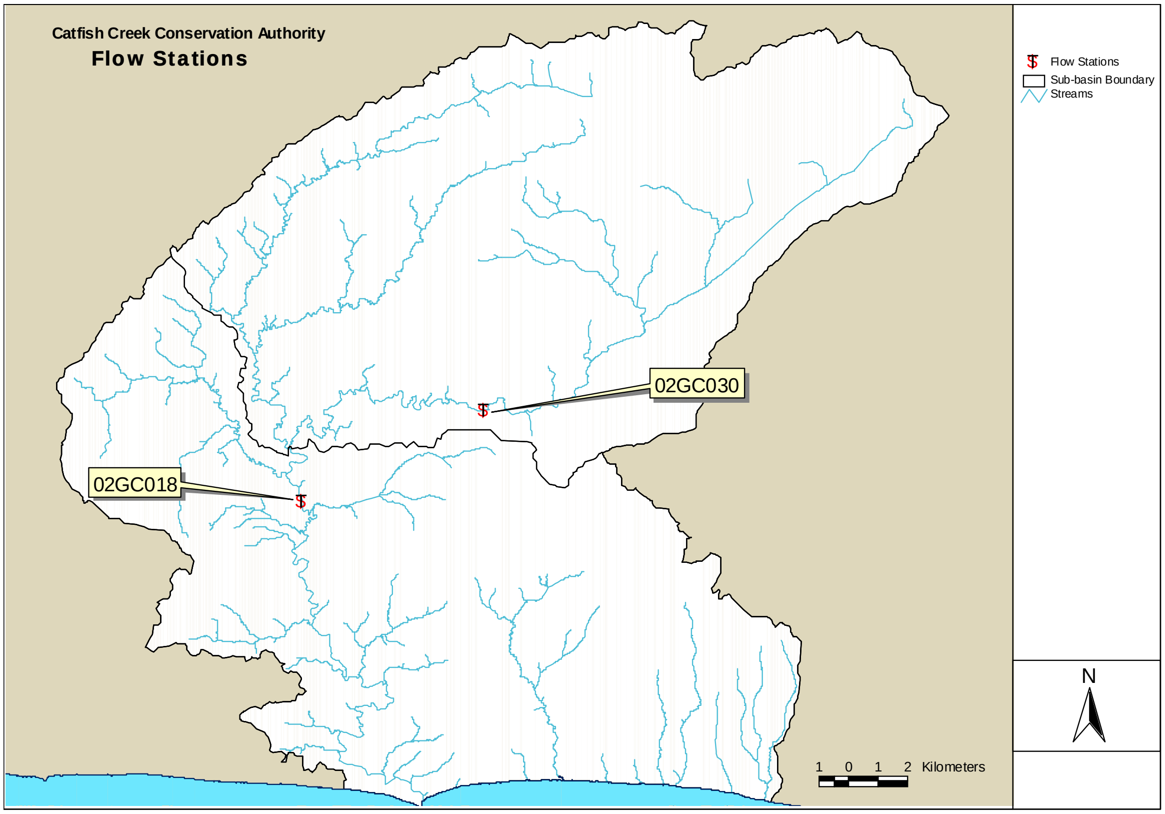


Figure 6. Location of flow stations monitored by the Water Survey of Canada within the Catfish Creek watershed.

Compliance with Guidelines

Provincial Water Quality Objectives (PWQO), Federal Guidelines and other relevant criteria were used to evaluate whether stream water quality within the region was meeting the specified levels for protection of aquatic life (Table 2). The level of compliance was determined at each site for each water quality parameter by calculating the percentage or frequency of samples above the objective, guideline or criteria for the data collected between 1991 and 1995. For presentation purposes and relative comparison of compliance levels between sites, results of this analysis were subsequently classed into 5 percentage groups (0%, 1-25%, 26-50%, 51-75%, 76-100%) and each group was assigned a representative colour. Actual values for the percentage of samples above the objective, guideline or criteria for each water quality parameter measured can be found in Appendix D. Results for each sampling site were then graphically represented on maps of the watershed region as coloured dots corresponding to the percentage group previously mentioned. These maps along with similar maps representing the 75th percentile value at each site for each parameter were developed to be used as communication tools for illustrating where the areas for improvement likely are (actual 75th percentile values can be found in Appendix E).

Trend analysis (LOWESS)

Although sampling frequency has fluctuated over the years, the long-term nature of the PWQMN warrants the evaluation of long-term monotonic trends to determine whether conditions are improving or deteriorating. Furthermore, this is one of the objectives of the network (A. Todd, pers. Communication).

Time series plots were created for each parameter at each of the seven PWQMN sites for the entire period of record, to explore the data for temporal variability and preliminary trends. A LOWESS (LOcally WEighted Scatterplot Smoothing) smoothing algorithm was then applied, which are helpful in visually inspecting the data for potential trends. However, the results from the LOWESS analysis to not represent a statistical trend analysis and as such are only considered preliminary. With the aforementioned sampling frequency and timing there is the potential for these trend estimates to be incorrect. Trkulja (1997) suggested that trend estimates based on monthly sampling are less reliable than estimates based on daily and weekly sampling schemes. Consequently, more detailed analyses are required to accurately evaluate statistical trends.

Table 2. Water quality parameters and corresponding Federal Guideline or Provincial Objective.

Water Quality Parameters	Objective or Criteria Used	Jurisdiction
Nitrate	2.93 mg/L	Canadian Environmental Quality Guidelines
Nitrite	0.06 mg/L	Canadian Environmental Quality Guidelines
Total Ammonia	pH and temperature dependant	Ontario Ministry of the Environment
Total Phosphorus	0.030 mg/L	Ontario Ministry of Environment
Non-filterable residue	25.0 mg/L	General criteria
Chloride	250 mg/L	Benchmark identified in Environment Canada report[1]; Drinking Water Quality Guideline
pH	6.5- 8.5	Ontario Ministry of Environment
Dissolved Oxygen	Temperature dependant	Ontario Ministry of Environment
Temperature	Natural thermal regime shall not be altered	Ontario Ministry of Environment

1. Environment Canada. 2001. Priority Substances List Assessment Report: Road Salt. Environment Canada, Health Canada, Ottawa, Ontario, 165p.

RESULTS

Streamflow

Streamflow for the 5 year period between 1991 and 1995 was higher within lower Catfish Creek near Sparta than within upper Catfish at Aylmer (Figure 7).

To give an indication of how wet or dry a particular year was relative to a long-term average (40 year from 1965-2004), the average annual flow was calculated for each year during the period from 1965 to 2004, for station 02GC018 on Lower Catfish Creek near Sparta and then plotted with the 40 year long-term average (Figure 8). Average annual flows within Catfish Creek near Sparta were very close to the long-term average in 1995, above the long-term average in 1992, and below in 1991, 1993 and 1994 (Figure 8).

Sampling Frequency

Historic sampling occurred on a routine basis where by flow in the stream was not considered. This is evident when the date of sampling event was graphed against stream flow (Figure 9). This was likely a result of limited manpower and logistical challenges associated with sampling high flow events. However, recently there has been an attempt to characterize high flow events.

Water quality in Catfish Creek and its tributaries is significantly influenced by climate and the amount of rainfall or snow pack that runs off the land. High stream flows can contribute to high contaminant levels by mobilizing land-based contaminants into the stream (e.g. phosphorus or suspended sediment). On the other hand, high flows can help reduce some negative impacts by cooling in-stream temperatures which can, subsequently increase dissolved oxygen levels. Therefore, it is important to sample both high and low stream flows when characterizing stream water quality.

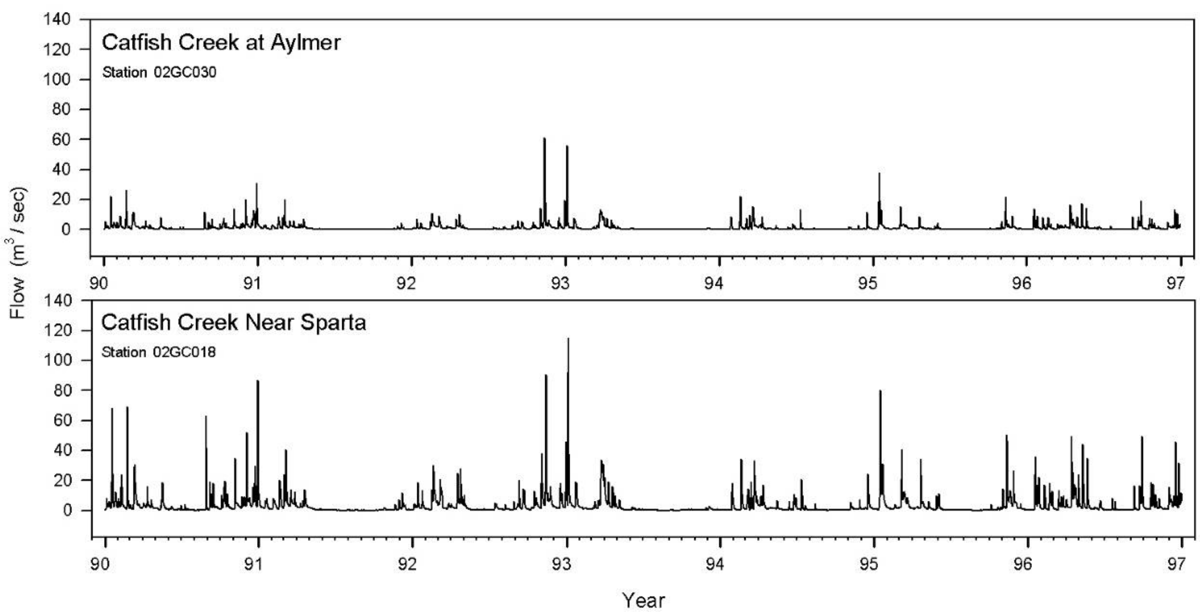


Figure 7. Flow rates at the two Water Survey of Canada gauge stations for the period form 1991-1995 within Catfish Creek Watershed.

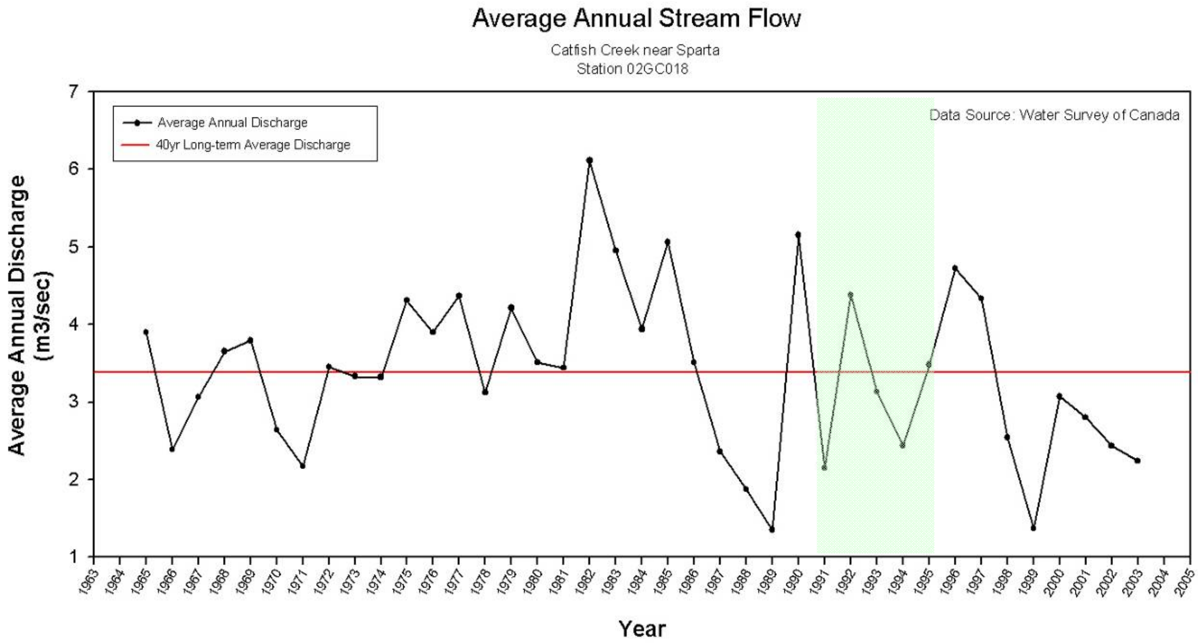


Figure 8. Average annual stream flow from 1965-2004 for station 02GC018 on Catfish Creek near Sparta.

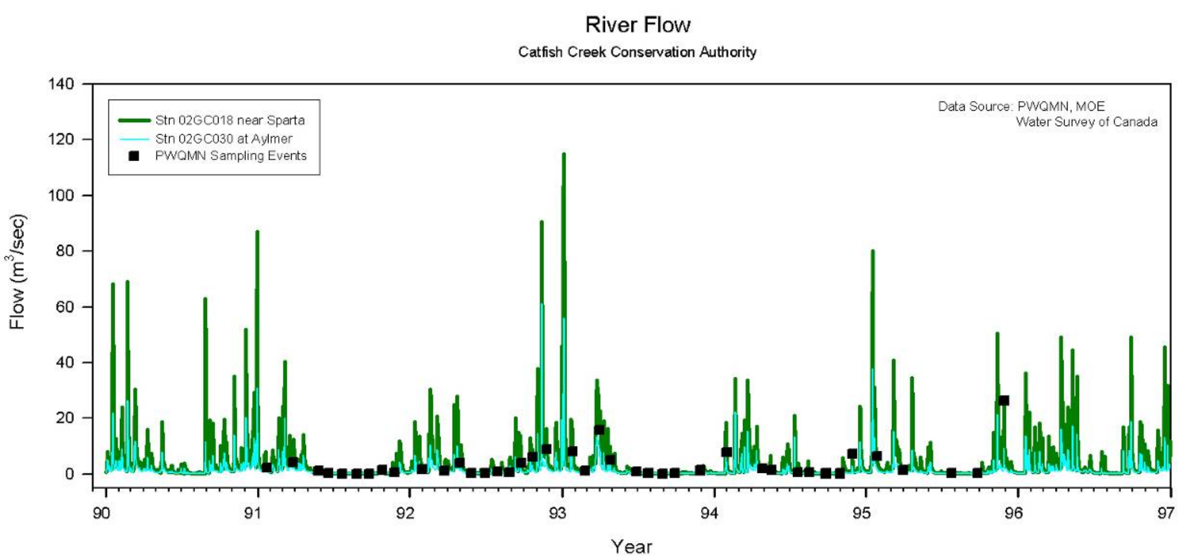


Figure 9. Stream flow rates at three locations within Catfish Creek watershed plotted with the time of sampling events.

Water Quality Conditions 1991-1995

Upon first inspection of the nutrient, suspended sediment, and major ion data there appeared to be several outliers (data more than 2 standard deviations from the mean as evident from a visual inspection of the box and whisker plots shown below). To account for this characteristic of the data when describing the data range we will be reporting on the 95th percentiles from each PWQMN site (Appendix F). Actual min and max values can be found in the descriptive statistics table in Appendix C. Results, including *p* values, from the Kruskal-Wallis and Mann-Whitney tests are listed in Appendix G. For the purposes of describing the results and subsequent sections PWQMN sites will be referred to by the last 3 digits of the site number or their location along Catfish Creek (i.e. site 16008700602 will be referred to as 602 or upper Catfish; site 16008700502 will be referred to as 502 or mid Catfish; and site 16008700302 will be referred to as site 302 or lower Catfish).

Nitrate

<u>Range within watershed:</u>
Nitrate levels within the region ranged from 0.20 mg/L, on lower and mid Catfish Creek (sites 302 and 502), to 9.8 mg/L on upper Catfish just above Aylmer (site 602) and 7.70 mg/L midway along Catfish Creek downstream of Aylmer (site 502).

<u>Relationship between sites:</u>
In general, median nitrate concentrations appeared to be higher on upper Catfish Creek compared to the rest of the watershed (Figure 10). When median values for the three PWQMN sites were statistically analyzed using a Kruskal-Wallis test a significant difference was found ($p = 0.0467$). To spatially determine where within the watershed these differences occurred, a series of Mann-Whitney tests were carried out. No significant difference was found between sites 602 and 502 (upstream and midway along Catfish Creek) or between sites 302 and 502 (downstream and midway along Catfish Creek). However, a significant difference was found between the upper (site 602) and lower (site 302) sites on Catfish Creek ($p = 0.0129$).

<u>% samples exceeding objective:</u>
The number of times a sample did not meet the Canadian Guideline for nitrate, (2.93 mg NO_3/L), was highest midway along Catfish Creek (site 502) where 68% of the samples were above the guideline (Appendix D). Site 302 within lower Catfish Creek had the lowest number of samples with values above the guideline (52%) compared with the sites at mid or upper Catfish Creek.

Nitrite

<u>Range within watershed:</u>
Nitrite levels within the watershed ranged from 0.01 mg/L, observed midway (site 502) and downstream (site 302) along Catfish Creek, to 0.263 mg/L along upper Catfish Creek (site 602). It should be noted that there was a higher degree of variation within sites for nitrite concentrations than the other parameters tested, likely due to the methods for detection (Figure 11).

<u>Relationship between sites:</u>
In general, nitrite concentrations progressively decreased from upstream to downstream along Catfish Creek (Figure 11). Site 602 on upper Catfish had a significantly higher median concentration than either of the other two sites ($p = 0.0101$ for site 502 and $p = 0.0009$ for site 302). However, no significant

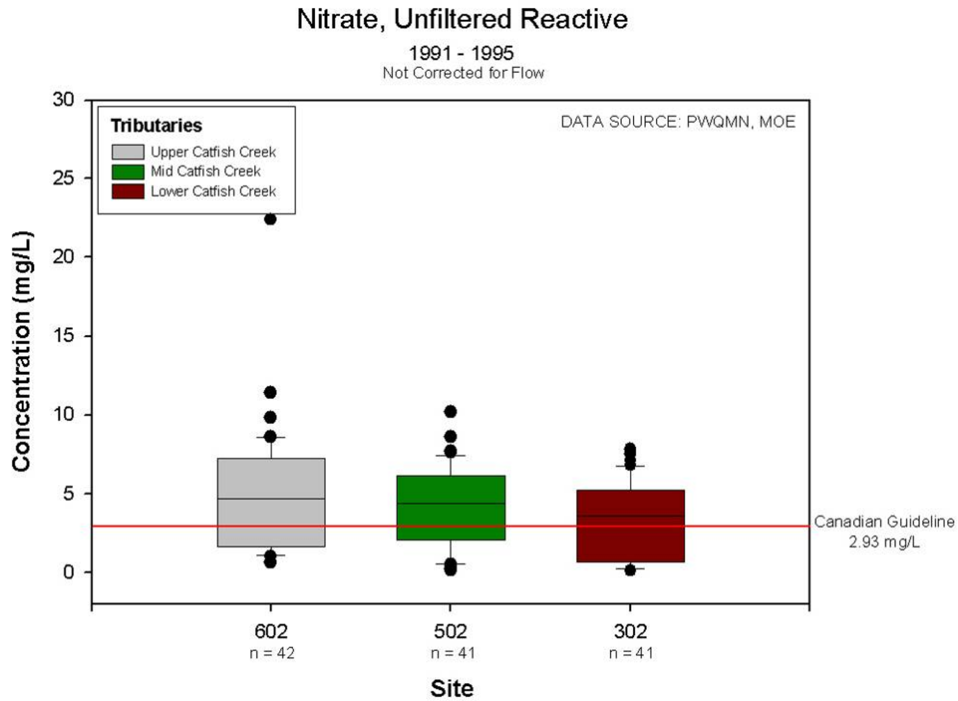


Figure 10. Total Nitrate concentrations at 3 PWQMN monitoring sites in the Catfish Creek watershed from 1991-1995

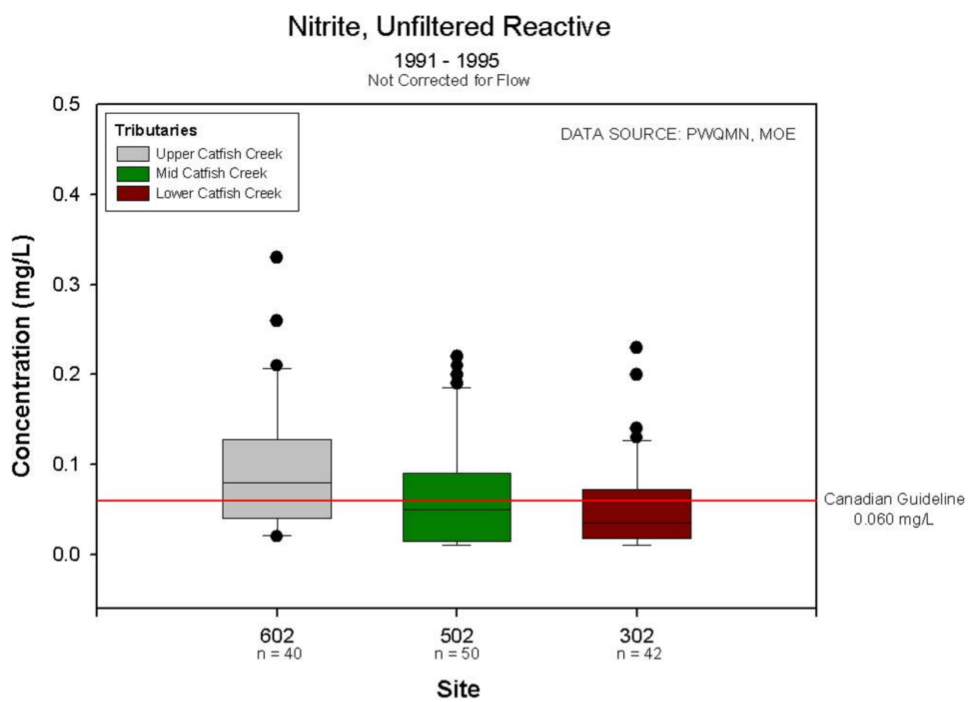


Figure 11. Total Nitrite concentrations at 3 PWQMN monitoring sites in the Catfish Creek watershed from 1991-1995

difference was found between site 502, midway along Catfish Creek, and site 302 on lower Catfish Creek (p = 0.4702).

<u>% samples exceeding objective:</u>
Across the watershed the number of times a sample for a given site was above the Canadian Guideline (0.06 mg/L) decreased from upstream to downstream (Appendix D). Site 602, along upper Catfish Creek, exhibited the greatest number of samples above the guideline (55%) whereas site 302, along lower Catfish Creek, exhibited the fewest (28%) (Appendix D).

Ammonia

<u>Range within watershed:</u>
Within the watershed total unionized ammonia ranged from below the detection limit (Appendix B) at all sites to 0.0086 mg/L at site 602, furthest upstream on Catfish Creek.

<u>Relationship between sites:</u>
In general, median unionized ammonia concentrations did not vary widely from site to site (Figure 12). In fact, when concentrations for all of the PWQMN sites were compared using a Kruskal-Wallis test no significant differences were found (p = 0.7390)

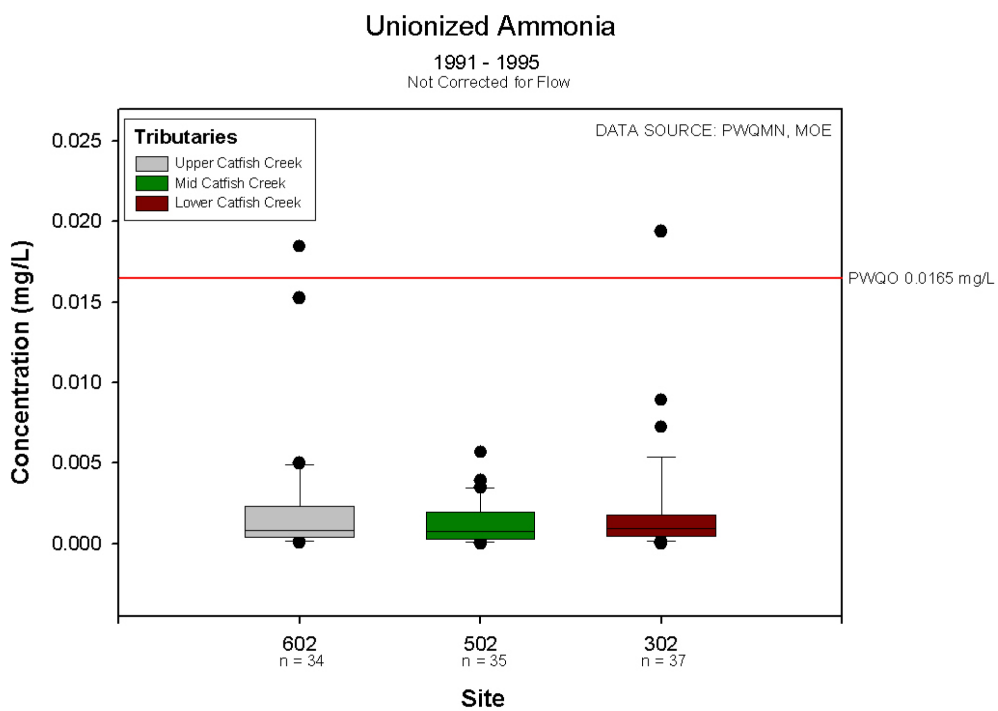


Figure 12. Unionized Ammonia concentrations at 3 PWQMN monitoring sites in the Catfish Creek watershed from 1991-1995

% samples exceeding objective:
Generally, sites within the Catfish creek watershed do not exceed the Provincial Water Quality Objective (PWQO) of 0.0165 mg/L (Figure 12). However, two sites did have a small number of samples with values higher than the objective. Both site 602 (on upper Catfish) and site 302 (on lower Catfish) had close to 3% of the samples taken with concentrations reported above the objective (Appendix D).

Total Kjeldhal Nitrogen (TKN)

Range within watershed:
Total kjeldhal nitrogen (TKN) concentrations varied from 0.47 mg/L furthest downstream on Catfish Creek (site 302) to 2.5 mg/L on upper Catfish Creek (site 602) (Appendix F).

Relationship between sites:
In general, higher total kjeldhal nitrogen values were found upstream on Catfish Creek relative to the rest of the sites within the watershed (Figure 13). Median TKN values within upper and mid Catfish Creek were found to be statistically similar and significantly higher than that found at site 302 along lower Catfish Creek.

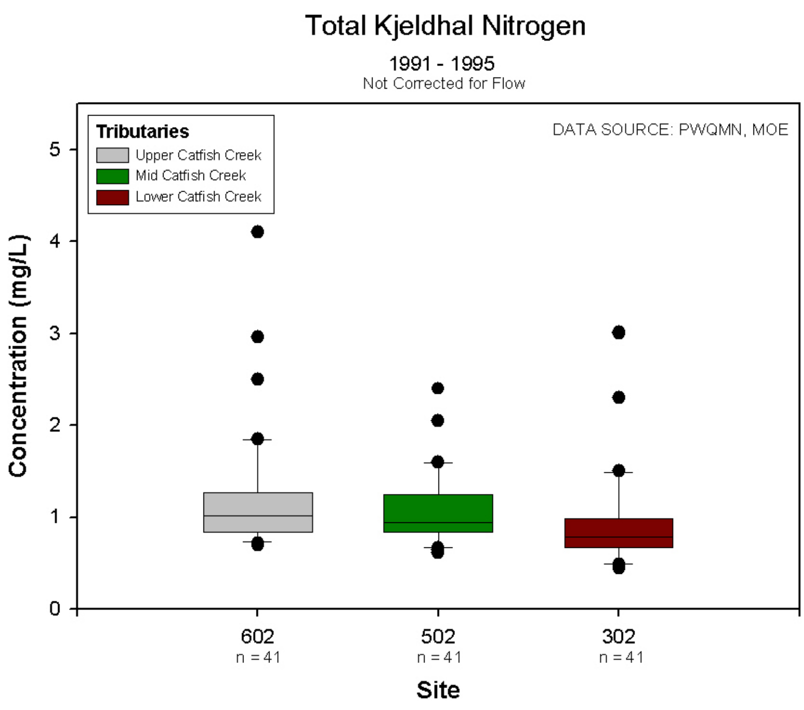


Figure 13. Total Kjeldahl Nitrogen concentrations at 3 PWQMN monitoring sites in the Catfish Creek watershed from 1991-1995

Total Nitrogen (Nitrate + Nitrite + Kjeldahl Nitrogen)

Total Nitrogen is made up of three constituents; nitrate, nitrite and total kjeldahl nitrogen (TN = NO_3 + NO_2 + TKN) (TKN = NH_4 + Organic N). On Average nitrates tend to make up greater than 60% of the total nitrogen pool at all PWQMN sites analysed within the watershed (Figure 14). Organic nitrogen levels ranged from 32% on lower Catfish to 24% on upper Catfish above Aylmer. Unionized ammonia levels made up less than 1% of the total nitrogen pool at all three sites along Catfish Creek.

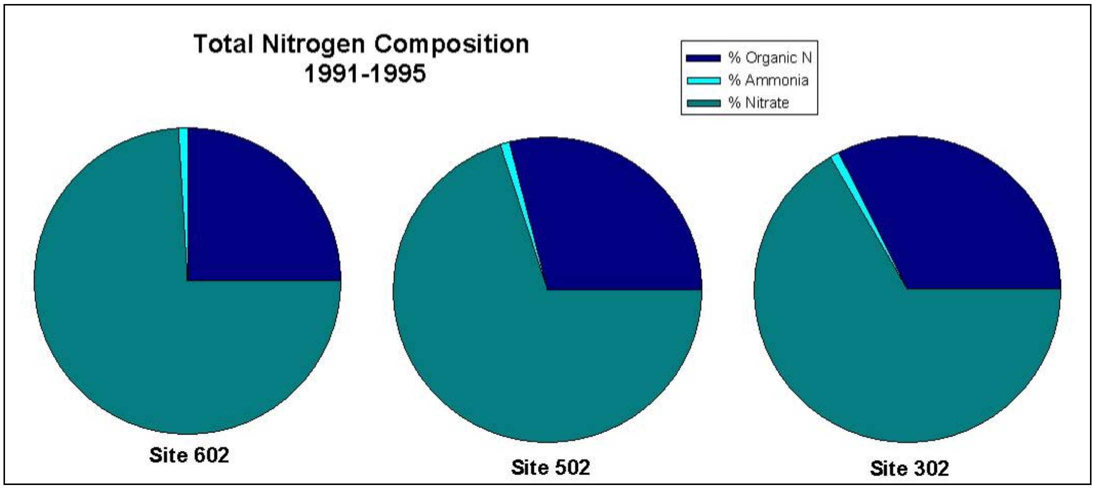


Figure 14. Total Nitrogen Composition at 3 PWQMN monitoring sites in the Catfish Creek watershed from 1991-1995

Phosphorus

<u>Range within watershed:</u>
Phosphorus levels within the region were quite high and ranged from 0.032 mg/L along lower Catfish Creek (site 302) to 0.3750 mg/L midway along Catfish downstream of Aylmer (site 502) (Appendix F).

<u>Relationship between sites:</u>
Both of the sites within the upper Catfish sub-basin (site 502 & 602) appear to have higher concentrations than site 302 within the lower sub-basin (Figure 15). When sites were compared using a Kruskal-Wallis test a significant difference was found between all three sites (p = 0.0031). When investigating the spatial trends within the region, there were no significant differences in median values found between those sites situated along mid and upper Catfish Creek (p = 0.2226). However, median phosphorus concentrations within lower Catfish Creek at site 302 were significantly lower relative to the other sites within the watershed (502 & 602) (p = 0.0012 and p = 0.0217 respectively) (Appendix G).

<u>% samples exceeding objective:</u>
Phosphorus samples throughout the Catfish Creek watershed are routinely above the provincial objective of 0.03 mg/L. Samples from the mid and upstream sites along Catfish Creek (sites 502 and 602) had

recorded concentrations above the objective 100% of the time while site 302 on lower Catfish Creek had 95% of the samples taken higher than the objective (Appendix D).

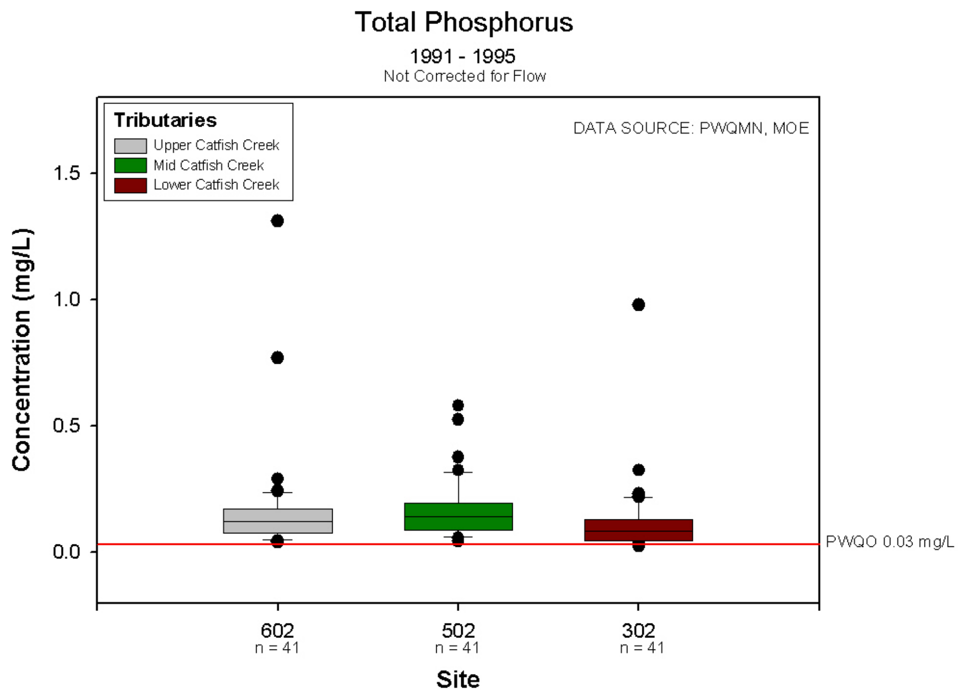


Figure 15. Total Phosphorus concentrations at 3 PWQMN monitoring sites in the Catfish Creek watershed from 1991-1995

Non-filterable residue (NFR)

<u>Range within watershed:</u>
Non-filterable residue levels within the region were quite variable and ranged from 9.2 mg/L, at both the lower (site 302) and upper (site 602) sites along Catfish Creek, to 76.8 mg/L at site 602 just above the town of Aylmer (Appendix F).

<u>Relationship between sites:</u>
In general, median concentrations for NFR did not appear to vary within Catfish Creek (Figure 16). This was substantiated by the Kruskal Wallis test returning a p value of 0.4933.

<u>% samples exceeding objective:</u>
Although there is no PWQO for NFR, a benchmark of 25 mg/L is usually used (CCME, 1999). Occurrences of samples with concentrations above this benchmark appear to be more of an issue along Catfish Creek downstream of Aylmer. Site 602 along upper Catfish, upstream of Aylmer, had samples with recorded concentrations above the benchmark 34% of the time (Appendix D). Downstream of Aylmer the percent of samples with concentrations above the benchmark were higher and ranged from 52% midway along Catfish Creek downstream of Aylmer (site 502), to 52 % on lower Catfish (site 302).

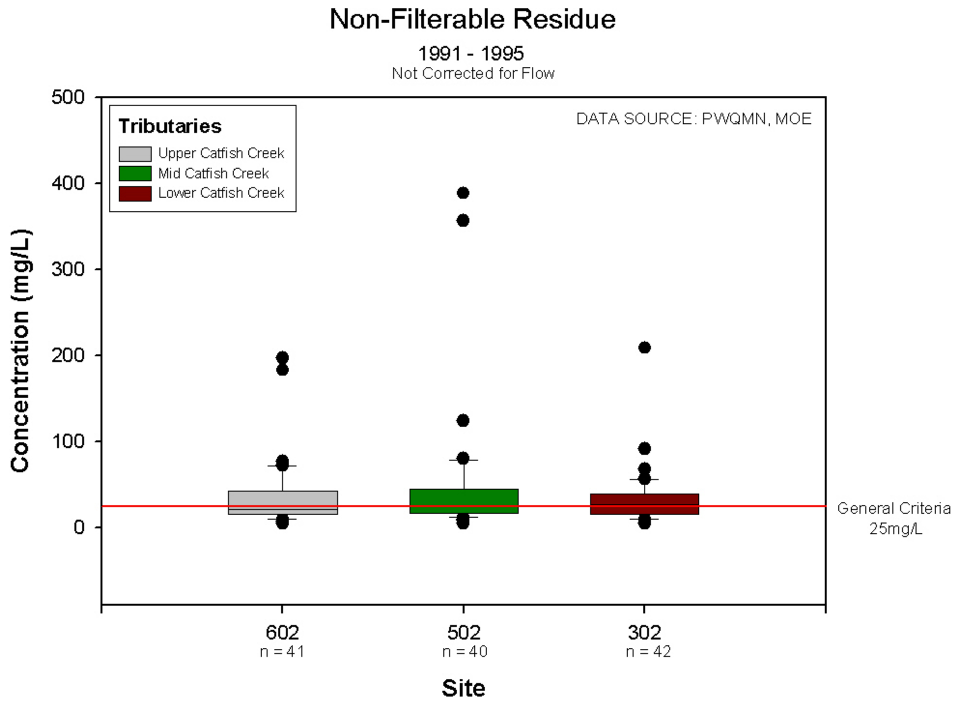


Figure 16. Non-filterable residue concentrations at 3 PWQMN monitoring sites in the Catfish Creek watershed from 1991-1995

Chloride

<u>Range within watershed:</u>
Across the entire Catfish Creek watershed, chloride levels were low ranging from 20.5 mg/L on lower Catfish (site 302) to 68.50 mg/L on upper Catfish and 63.20 mg/L directly downstream of Aylmer (site 502) (Figure 17; Appendix F).

<u>Relationship between sites:</u>
In general, chloride concentrations were highest at site 502, situated midway along Catfish Creek and directly downstream of Aylmer. Median Chloride levels were found to be significantly higher at site 502 than either the upper or lower Catfish sites (p <0.0001 and p = 0.0007 respectively). No significant difference was found between upper of lower Catfish Creek (p = 0.3252).

<u>% samples exceeding objective:</u>
Total chloride levels within the watershed do not appear to be a problem. Although there are no federal or provincial criteria set for chloride levels, a benchmark of 250 mg/L has been identified by Environment Canada (Environment Canada, 2001). None of the PWQMN sites examined had samples with concentrations above the Environment Canada benchmark (Appendix D).

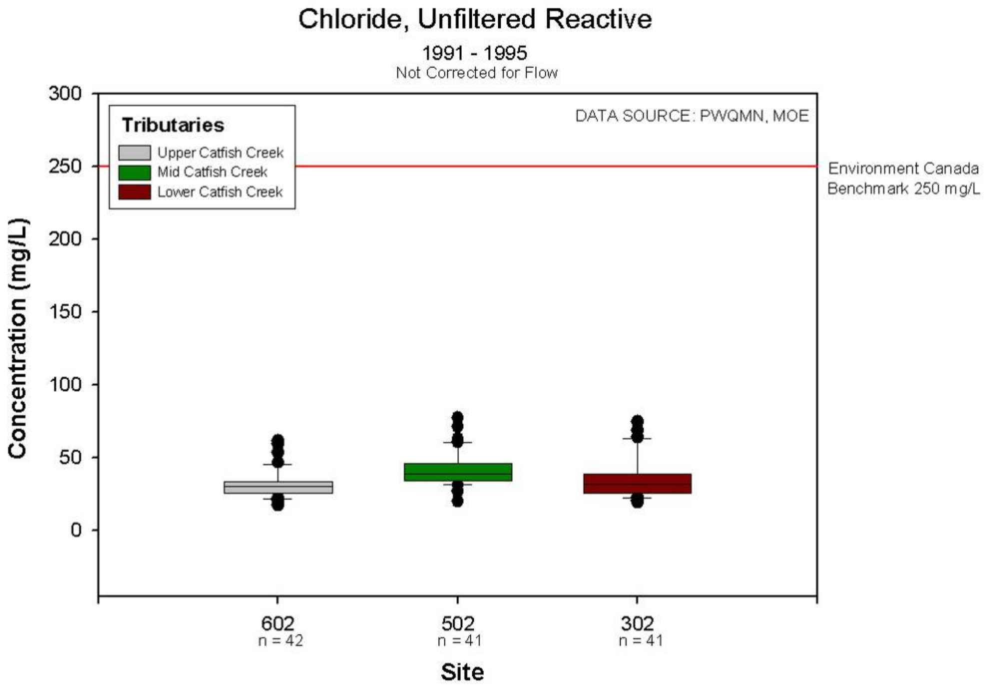


Figure 17. Total Chloride concentrations at 3PWQMN monitoring sites in the Catfish Creek watershed from 1991-1995

PH

The Provincial Water Quality Objective for aquatic health indicates that pH should be maintained between 6.5 and 8.5. The pH values throughout the Catfish Creek watershed appeared to be closer towards the upper end of this range. The pH values varied between all three PWQMN sampling sites ranging from 7.09 to 8.44 and significantly increased as the creek flowed from upstream to downstream (Figure 18) (Appendix D).

Dissolved Oxygen

Dissolved Oxygen (DO) levels during the period from 1991-1995 were not observed below the critical 4 mg/L threshold for cold water biota (Figure 19). In fact, all samples reported values between 8.0 and 9.5 mg/L. However, sampling generally occurred during the day (between 9am and 1pm) and as a result the data presented here does not represent diurnal fluctuations in DO levels. Current DO levels taken in 2004 reported a much wider range of values (5.92 to 12.66 mg/L) within Catfish Creek downstream of Aylmer indicating that aquatic organisms may be experiencing larger extremes than historically reported. However, more data is needed to accurately comment on this issue.

Temperature

Temperature fluctuates depending on the time of day the sample was taken. Historically temperature was taken during the day (between 9am, and 1pm) at the same time all other sampling was performed. This bias should be accounted for when interpreting the data in this report. Ambient water temperatures within the Catfish Creek watershed tend to follow a seasonal pattern ranging form 0 degrees in the winter to 26 degrees in the summer. Very little variation was found between the three PWQMN sites.

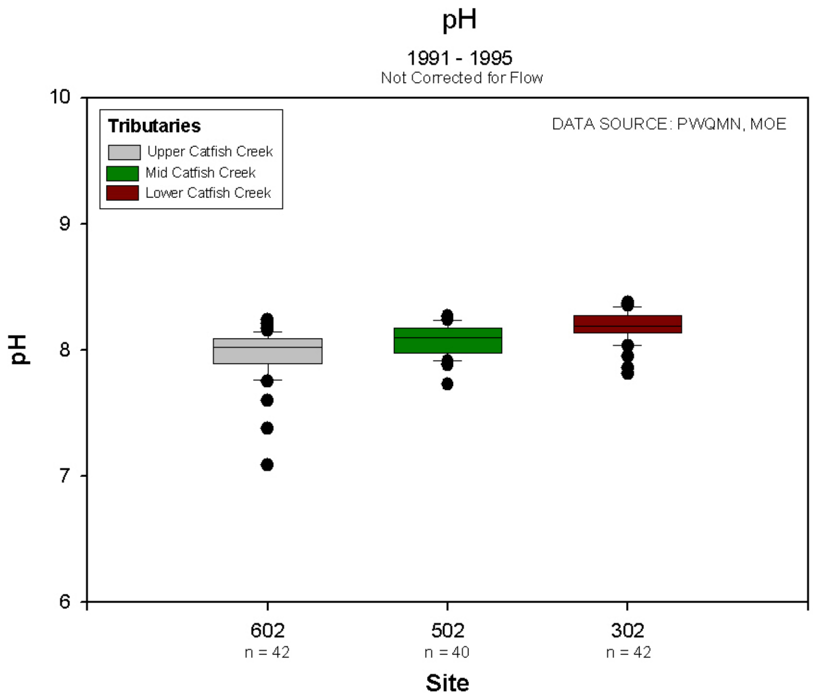


Figure 18. pH at 3 PWQMN monitoring sites in the Catfish Creek watershed from 1991-1995

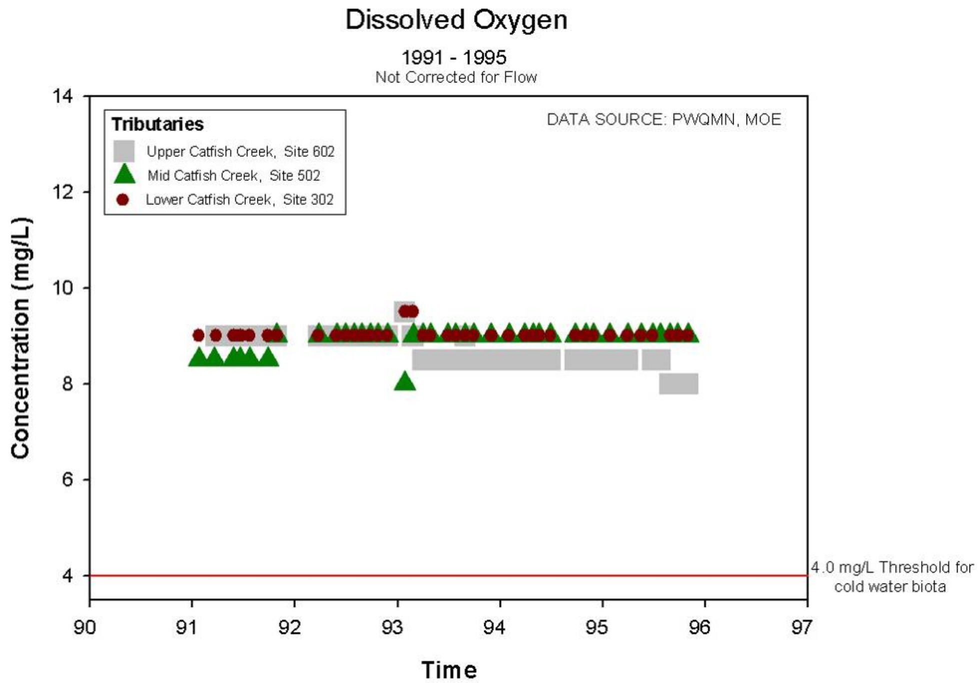


Figure 19. Dissolved Oxygen concentrations from 1991-1995, samples taken during the day.

Metals

Metals data were not fully analyzed in this report due to concerns with historical laboratory detection methods. In 1997 the Ministry of the Environment replaced the historical method for detecting metals in surface water, MET33386 with MET3080. This change replaced the digestion step with an ultrasonic nebulizer to reduce contamination problems previously found (Rusty Moody at MOE personal communication).

Pesticides

Water samples collected at PWQMN site 16009700302 (near Sparta) were monitored for pesticides twice during 1981. Unfortunately, the concentrations within the samples were below the detection limit and thus no measurable response could be obtained. Detection limits for the pesticides sampled don't allow for trace amounts to be identified and thus comparison of levels to the PWQO for aquatic health could not accurately be assessed.

Bacteria and Pathogens

Fecal coliform data was collected at all PWQMN sites from 1972-1994. Other bacteria such as *Escherichia coli* were only monitored during the 1994 and 1995 sampling seasons.

Given the inherent variability in sampling and analyzing bacteria in surface waters, as well as the small sample size for *E. coli* (8-11 samples per site), we felt that no statistical analyses could be carried out and have only commented on general characteristics in the data.

A general decreasing trend from upstream to downstream along Catfish Creek was found for both fecal coliform and *E. coli*. Fecal coliform levels between 1991 and 1995 were highly variable and ranged from 4 counts / 100ml at site 302 on lower Catfish, to 194,000 counts / 100ml at site 602 on upper Catfish (Figure 20). A similar trend in the range of values was also observed for *E. coli* counts ranging from 20 to 2800 counts / 100ml at site 302 (Figure 21). High levels of fecal coliforms were not only found directly downstream of Aylmer (site 502) but also further upstream at site 602. This could potentially be an indication that the Aylmer STP is not the only contributing source of bacterial loading and there is likely a major source somewhere upstream of site 602.

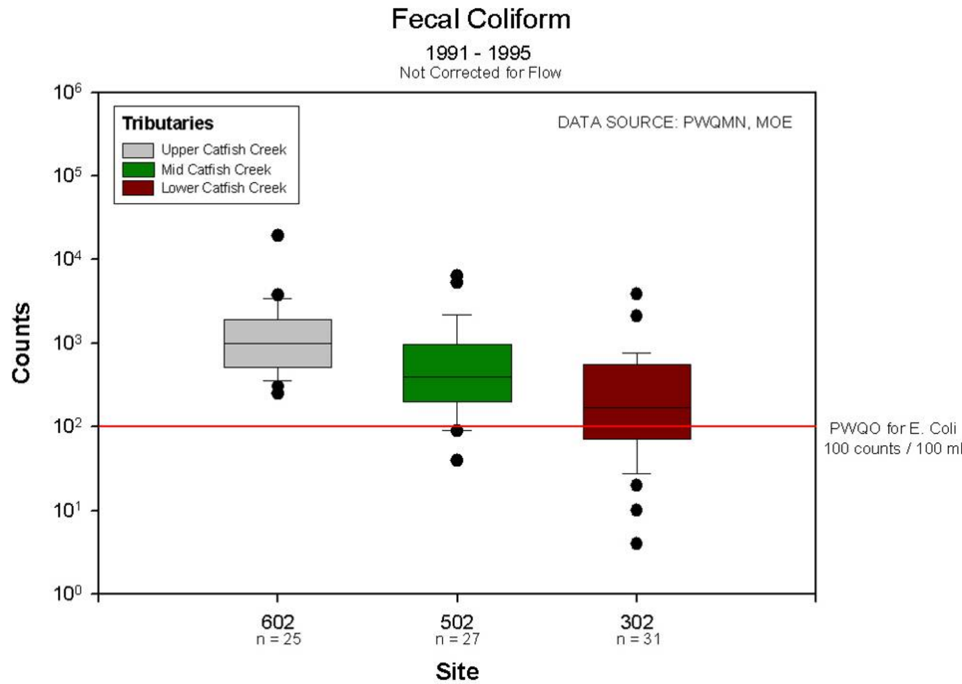


Figure 20. Total Fecal Coliform counts at 3 PWQMN monitoring sites in the Catfish Creek watershed from 1991-1994.

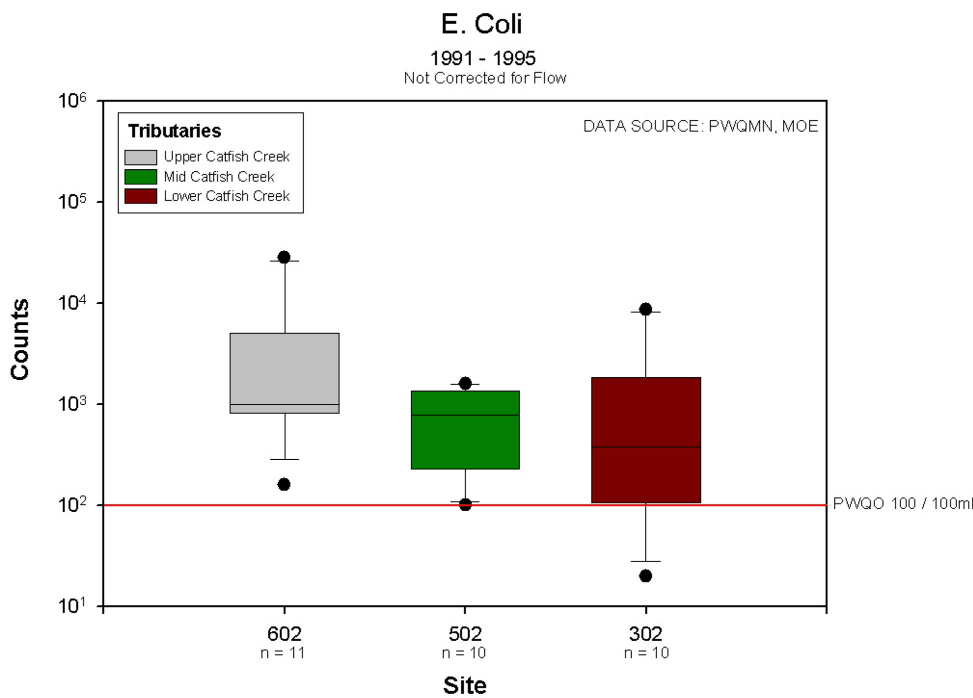


Figure 21. Total *E. coli* counts at 3 PWQMN monitoring sites in the Catfish Creek watershed from 1994-1995.

Preliminary Trend Analysis (LOWESS Plots)

Due to the low sampling frequency for the 1991-1995 sampling period and the fact that there are only a handful of samples that have currently been collected (2003-2005), statistical trend analysis was not undertaken. It was decided that there was not enough confidence in the historic data or statistical power in the current data to adequately report on statistical trends over time. Therefore, only a preliminary analysis to explore the data for temporal variability is provided.

Time series plots were created for each water quality parameter at each of the three PWQMN sites for the period of record (Appendix H). A LOWESS (LOcally WEighted Scatterplot Smoothing) smoothing algorithm was then applied to visually assess preliminary trends (Appendix H). Most of the parameters did not exhibit any discernable trends over time. Since the late 1980's, nitrate concentrations appeared to be slightly decreasing within all locations along Catfish Creek (Figure 22). Preliminary trends in total phosphorus concentrations were only evident within upper Catfish Creek at site 502 (just downstream of Aylmer), where levels appeared to have been decreasing since the mid 1970's (Figure 23). The occurrence of extremely high non-filterable residue concentrations appears to have decreased since the early 1980's within lower Catfish Creek (Figure 24). Chloride concentrations appeared to be slightly increasing over time within both upper and lower Catfish Creek (Figure 25).

Although summer temperatures did not appear to increase within the study time period (1991-1995), the current data for 2004-2005 indicates there has been an increase in summer temperatures, namely August (Figure 28).

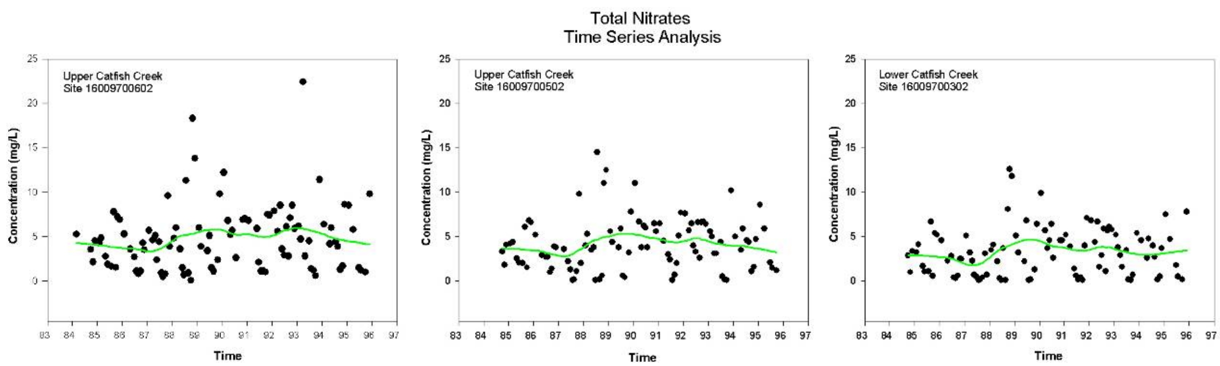


Figure 22. Time series plots for total nitrate concentrations from 1984-1996 at three PWQMN locations within Upper and Lower Catfish Creek. Lowess plots (green line) were applied to visually smooth the data and facilitate interpretations.

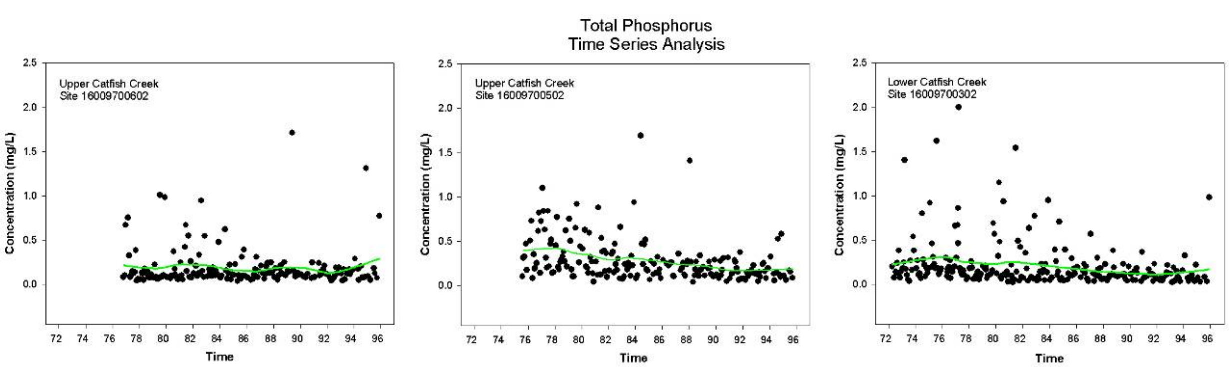


Figure 23. Time series plots for total phosphorus concentrations from 1976-1996 at three PWQMN locations within Upper and Lower Catfish Creek. Lowess plots (green line) were applied to visually smooth the data and facilitate interpretations.

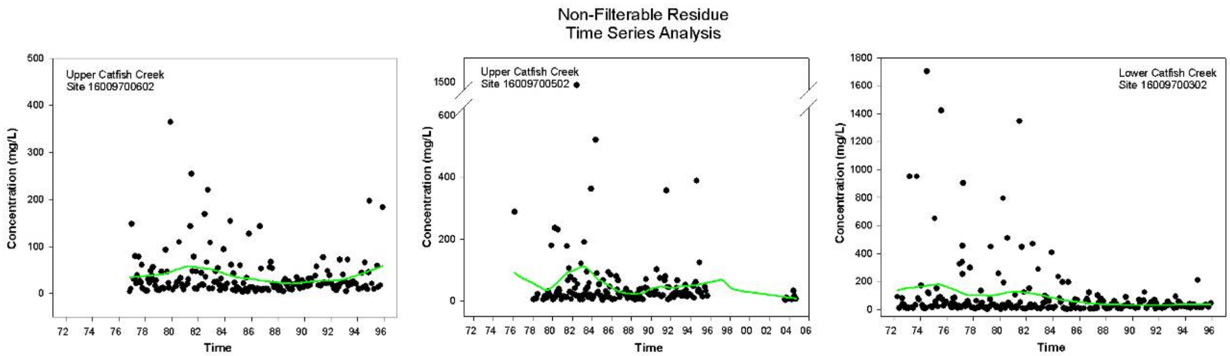


Figure 24. Time series plots for non-filterable residue concentrations from 1976-1996 at PWQMN sites 602 & 302 and from 1976-2004 at PWQMN site502 located within Upper and Lower Catfish Creek. Lowess plots (green line) were applied to visually smooth the data and facilitate interpretations.

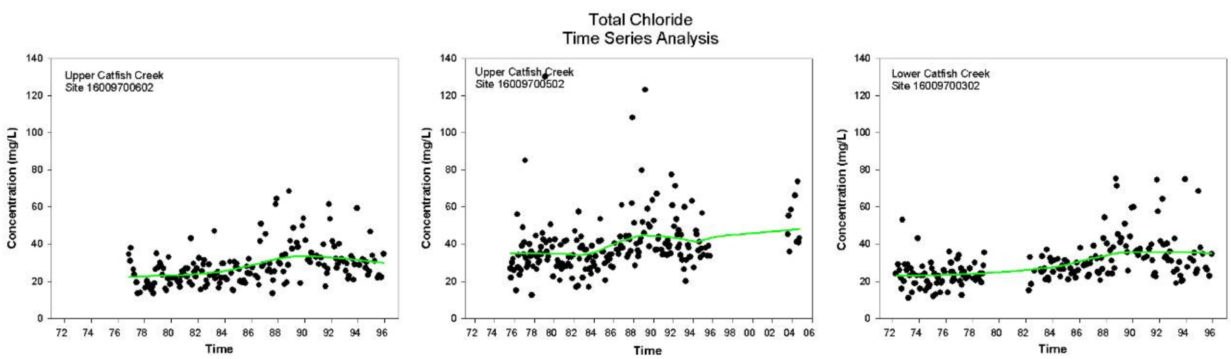


Figure 25. Time series plots for chloride concentrations from 1976-1996 at PWQMN sites 602 & 302 and from 1976-2004 at PWQMN site502 located within Upper and Lower Catfish Creek. Lowess plots (green line) were applied to visually smooth the data and facilitate interpretations.

Discussion

Data Limitations

Environmental monitoring is imperative to good environmental decision-making (ECO 1997). However, the interpretation of results from monitoring programs can be strongly influenced by the quality of data gathered. Therefore, it is important to be transparent about the limitations of the data used in decision-making. This is not to say that we should hold-off investigating an issue until better data presents itself. In contrast, using the best available data at the time of investigation allows gaps in our existing datasets to be identified and thus better direct future data gathering expeditions.

Two of the most common data limitations found in environmental studies are the quantity (number of samples taken spatially and temporally) and quality (time and location of sampling event) of the data available.

Data Quantity Limitations

Historically, the Catfish Creek Conservation Authority (CCCA) carried out water quality sampling at a variety of scales including site specific (such as the water quality studies within Silver Creek) and watershed wide (such as the PWQMN) to understand different water quality issues within Catfish Creek's watershed. Due to financial cutbacks by the province and limited internal capacity of the conservation authority, there has been a drastic reduction in water quality monitoring since 1996 until 2005. Across Ontario the PWQMN currently monitors at 350 stream sites (A.Todd pers. communication), which is down from a high of 730 sampling sites in 1995 but up from the 240 sites monitored in 2000 (ECO, 2000). The decrease in spatial coverage of the PWQMN within the Catfish Creek Watershed (from a high of 9 sites to the current 3 sites) and the reduction of yearly samples taken at each site (from 12 to 8) has limited the ability to conduct comprehensive spatial and temporal analyses at the watershed scale.

Water quality is highly variable and is sensitive to season, time of day, temperature, flow-stage, spills, soil types, basin topography and many other factors. Due to this, water quality samples must be collected over the range of stream-flows that are representative of the stream at the sample-collection site (ECO, 2002; Painter *et al* 2000). Consequently, many samples are required to adequately characterize water quality over a range of environmental conditions. Painter *et al* (2000) recommends that at least 10 samples be taken per year to adequately characterize ambient surface water quality in streams, while Maybeck *et al* (1996) suggest 12 samples per year for a multipurpose monitoring program, such as the PWQMN. The current eight samples per year per site limits the network's ability to characterize water quality over a full range of environmental conditions such as low and high flows or the effects of seasonality (e.g. under ice conditions).

Data Quality Limitations

Generally, water quality samples collected at sites in the Kettle Creek watershed were collected during low to moderate flows (Figure 9). This was likely a result of limited manpower and of the logistical challenges of sampling high flow events.

The determination of contaminant loads or 'fluxes' is critical to understand the contribution of nonpoint sources of contaminants to a waterbody since most of these contaminants are mobilized during runoff events. It is not uncommon for 80-90% of the annual load to be delivered during 10% of the time when the highest discharges are occurring (Richards 2002). As a result, it is important that water quality sampling be targeted to characterize both high and low flows. Painter *et al* (2000) suggested that as few as 30 to as many as 75 or more samples may be required to estimate river loads using various estimator techniques (e.g. statistical or regression approaches etc) however, censored data must be kept to a minimum of 50 percent.

Since only eight samples per year are collected at the PWQMN sites and generally at low to moderate flows, accurate annual loads cannot be made with any certainty. More frequent and targeted sampling of both high and low flows over the long-term is required to adequately characterize both ambient water quality and contaminant fluxes within sub-basins.

The approached used in this report whereby the most recent contiguous five years of data is summarized helps to increase the likelihood of characterizing the full range of flow and climatic conditions. This approach also reduces the strong year-to-year variability from extremes in climate (e.g. wet and dry periods).

The use of non-parametric statistics to anlayse the data also allowed our analysis to accommodate for the inherent characteristics of water quality data (i.e. non-normal distribution, outliers, missing data) (Hrynkiw et al 2003; Trkulja, 1997). However a numerical statistical difference does not always translate into an ecological significant difference.

Water Quality Conditions in the Catfish Creek Watershed

Generally, water quality conditions are described according to chemical and physical characteristics of stream water. However, biological indicators such as benthic macroinvertebrates and fish species should also be used in conjunction with chemical and physical characteristics to further describe the overall health of a watershed. Currently the Catfish Creek Conservation Authority is in the process of re-evaluating their surface water quality monitoring program. It is anticipated that the new program will take a more integrative approach to water quality monitoring and will hopefully begin in 2006. This program will include a combination of physiochemical sampling for both surface water (PWQMN) and ground water (PGMN) as well as benthic macroinvertebrate sampling.

The following sections describe the chemical and physical conditions for the period between 1991 and 1995 found within the major sub-basins (Figure 1) of the Catfish Creek watershed.

General Physiochemical Conditions within both Sub-basins

Dissolved oxygen and temperature levels were consistent throughout the Catfish Creek watershed. Both parameters are important indicators of stress on aquatic organisms. Not only is it important to watch for the upper or lower thresholds tolerable but also the range of values an organism experiences to determine if the conditions within an area are limiting.

Within the Catfish Creek watershed dissolved oxygen levels have rarely been observed to dip below 8 mg/L (well above the 4 mg/L lower threshold for cold water biota). While this value is considered to be adequate for aquatic life, samples were generally only taken during the day which would not have accounted for the diurnal fluctuation or the range of values an organism truly experiences. Thus, determining if dissolved oxygen within the Catfish Creek watershed was limiting to aquatic organisms could not be accurately assessed with the 1991-1995 sampling regime. Supersaturation of dissolved gases can also be potentially hazardous to aquatic life. Recently, dissolved oxygen (DO) levels have been reported as high as 12.66 mg/L (at site 502), which when converted to percent saturation was found to be supersaturated (130%). Supersaturation of gases within the water can lead to gas exchange problems in aquatic life such as blood gas trauma in fish (Fidler & Miller, 1994). However, there has yet to be a criteria set for the upper limit of DO for the protection of aquatic life.

Twenty four degrees is generally the temperature threshold between cool and warm water fish species (Stoneman and Jones 1996). Prolonged periods of time for which temperatures are above 24°C creates stress for cold or cool water species thus limiting the ability for them to inhabit these areas of the creek. For the period between 1991 and 1995 summer temperatures were consistently above 20°C and reached as high as 26°C. Although temperature within Catfish Creek does not appear to be of immediate concern there is a warming trend currently evident. This is of particular concern for those streams within the watershed which support cold water fisheries (e.g. Silver Creek, Bradley Creek). Increased water temperatures can also impact oxygen saturation of freshwaters thereby impacting metabolic rates, growth and reproduction of freshwater fish (Gordon et al 1994).

The pH within the Catfish Creek watershed significantly increased as the creek flowed from upstream to downstream (Appendix G). Median values reported ranged from 8.02 to 8.19, which could be of potential concern as pH levels greater than 8.5 can indicate high levels of photosynthesis (Wurts & Durborow, 1992).

Unionized ammonia concentrations did not differ significantly from upstream to downstream within Catfish Creek. Concentrations were shown to rarely exceed the PWQO and thus did not appear to be a water quality issue within Catfish Creek.

Conditions Specific to the Upper Catfish Creek Sub-basin

The upper Catfish Creek sub-basin extends from the Village of Brownsville, in the Northeast corner of the watershed, to near the Village of New Sarum, slightly Southwest of Aylmer, and drains over a succession of low clay till ridges (the Mount Elgin Ridges). Land-use across this region is mainly agricultural. During the 1991-1995 sampling period a high percentage of the agricultural practices within this region were comprised of livestock operations within close proximity to a waterway. Due to the inherent geology found within this sub-basin, numerous tile drains have been employed to mitigate flooding of agricultural fields. There are three main urban areas that could potentially have an influence on water quality within this sub-basin, the Town of Aylmer, the Village of Springfield and the Village of Brownsville.

Generally, the upper Catfish sub-basin tends to be the area within the watershed where water quality is most impaired and progressively improves as the creek flows from upstream to downstream along Catfish Creek. This unexpected trend is likely due to the underlying geology and the land-use within the upper sub-basin. Catfish Creek drains over a clayey till plain which does not allow for a high degree of infiltration, thereby leading to an increase in the amount of run-off entering the creek. This natural phenomena is then exacerbated by the agricultural land-use within the area (e.g. tile drains, livestock access and/or fertilization)

Nitrogen and phosphorus loading are the major nutrient loading issues within the upper sub-basin. The highest median values for nitrate, nitrite, ammonia, and kjeldhal nitrogen were found at site 602, furthest upstream along Catfish Creek.

Results from the Mann-Whitney pair-wise comparisons indicated that nitrate and nitrite levels were significantly higher within upper Catfish (site 602)) compared to lower Catfish (site 302). Since no significant difference was found between sites 502 (midway) and 302 (lower), the potential source of the nitrate and nitrite loading is likely somewhere upstream of site 602.

Nitrate loading is usually attributed to fertilizer application and sewage treatment plant effluent. Within the upper sub-basin this loading could be as a result of agricultural runoff entering the waterways from natural processes, via tile drains or faulty septic systems within Springfield and Brownsville.

Nitrite loading tends to be associated with livestock, septic or sewage treatment plant waste. The high nitrite levels (median value = 0.08 mg/L) found within site 602 (upstream) is of concern due to the fact that nitrite is highly toxic to aquatic life. Since there does not appear to be a limited supply of dissolved oxygen, these results indicate there is likely an input of ammonia input somewhere near site 602 and the nitrite is the resulting intermediate product of nitrification. Potential sources of ammonia within the area could be from the known faulty septic systems within Springfield (Deputy, 1983), agricultural run-off from livestock operations or direct input from livestock waste where stream access occurs.

Considering total ammonia (NH_4) levels within upper Catfish are fairly low, it is likely that the elevated TKN levels found at sites 602 and 502 are as a result of high levels of organic nitrogen. Organic nitrogen can either be used directly by plants or converted to nitrite and nitrate. Therefore high levels of TKN could also be a major contributing factor to the increased productivity found within upper Catfish Creek.

Phosphorus loading is a serious concern across the entire watershed with samples exceeding the provincial guideline 95 to100% of the time at all PWQMN sites monitored. Compared to the rest of the watershed phosphorus levels within upper Catfish are significantly higher than those found within the lower sub-basin. Elevated median concentrations were found downstream of Aylmer at site 502, indicating the possibility of an urban loading source.

Median total suspended solid (NFR) concentrations within the upper basin were either at or just slightly above (26.65 mg/L) the Environment Canada benchmark of 25 mg/L. Although there were no significant differences found between any of the sites monitored, higher median concentrations were found at site 502 just downstream of Aylmer. This could potentially be as a result of the discharge Catfish Creek receives from the Aylmer sewage lagoons twice a year or the historically high non-filterable residue levels found within East and West Catfish Creeks (CCCA, 1983).

E. Coli and Fecal Coliform counts progressively decrease from upstream to downstream, indicating that the major source is likely upstream of site 602. Depuydt (1994) found that the high bacterial loads within the upper Catfish Creek sub-basin were as a result of the prominent number of livestock farms and the faulty septic systems within the region. However, given the error associated with the methods for assessing bacterial counts in natural systems, further analysis is required to determine if bacteria within this area is of real concern.

Conditions Specific to the Lower Catfish Creek Sub-basin

Only one long-term monitoring site exists in the lower Catfish Creek sub-basin. This sub-basin extends from the confluence of the East, West and Main branches of Catfish Creek (just South of Aylmer) and travels south through the Norfolk sandplain where it eventually empties into Lake Erie at Port Bruce. The drop in elevation from the Northern part of this sub-basin South to Lake Erie is quite dramatic resulting in steep sided flat floored creeks. Land-use across this region is primarily row and cash crop agriculture which requires intensive irrigation due to the underlying sandplain. During the 1991-1995 sampling period the major crop within the eastern half of the lower sub-basin was tobacco. The Town of Aylmer (which straddles both basins) is the major urban influence within this sub-basin.

Generally, water quality within lower Catfish Creek tends to be better relative to that found upstream. This could be as a result of the underlying geology (i.e. sandplains have a lower run-off potential); increased flow (dilution factor); or as a result of other tributaries (e.g. East and West Catfish Creeks) emptying water of better quality into the main Catfish channel. A few historical studies (CCCA, 1983; MOE 1978) have suggested that the water within East and West Catfish Creeks is generally of better quality (excluding NFR concentrations) relative to the rest of the watershed. However, for the 1991-1995 sampling period the potential for East and West Catfish Creeks to have a positive influence on the main channel is only speculative as there were no monitoring sites within either of these tributaries.

Phosphorus loading is of concern within lower Catfish Creek. Although median concentrations are significantly lower than either of the upper basin sites, samples collected at this site between 1991 and 1995 were above the PWQO 95% of the time. These levels are likely as a result of the cumulative impact of the upstream concentrations.

Although there were no significant differences found in median NFR concentrations throughout the watershed, the highest median value was found at site 302 within lower Catfish Creek. This could potentially be as a result of the cumulative impact from upstream inputs, such as the Aylmer lagoon discharge and/or the historically high NFR levels found within East and West Catfish Creeks (CCCA, 1983). Although there was no long-term sampling of NFR at Port Bruce, in 1994, Triton Engineering attempted to determine potential sources for the sediment loading occurring within the Port Bruce harbour. Triton Engineering (1994) found that a proportion of the sedimentation was as a result of the high degree of stream bank erosion occurring within the lower Catfish Creek sub-basin South of Hwy 3. It was also suggested that this erosion was due to the topography of the area as well as the speed with which the watershed drains during high flow events.

Chloride is an important ion to metabolic processes of aquatic organisms as it influences osmotic balance and ion exchange. Chloride levels throughout the entire watershed are not of concern as levels were never above the guideline. However, it is important to note that the median value found downstream of Aylmer (site 502), was significantly higher relative to the other sites sampled. This indicated that urban road salting is likely contributing to an increase in chloride levels within nearby waterways.

Bacteria and Pathogens are of concern within the recreational areas of the Catfish Creek watershed including Springwater reservoir and the beach at Port Bruce. In general, bacterial loads within these swimming areas have not been an issue as they have rarely been closed by the public health department. However, McCarron and McCoy (1992) found high bacterial counts within Silver Creek which could potentially be attributing to the beach closures occurring at Port Burwell, situated along Lake Erie East of Catfish Creek. It was suggested that faulty septic systems, agricultural run-off and the occurrence of trash dumping into Silver Creek could be potential sources of these bacterial loads (McCarron & McCoy, 1992).

Unfortunately, none of the PWQMN sites analysed in this report were situated directly downstream of the Springwater reservoir to accurately assess its influence on Catfish Creek. However, local knowledge indicates that high phosphorus levels are a problem resulting in increased levels of algae. In 2005, an investigation into the application of alum as a potential method for reducing the phosphorus levels with the reservoir was carried out (Griffiths and CCCA in progress). Preliminary results from this analysis suggests that the alum treatment had a positive impact on the water quality by reducing phosphorus levels and subsequently decreasing plant growth and improving visibility (Griffiths and CCCA in progress).

Trends in Water Quality

To determine whether water quality conditions are improving or deteriorating proves to be particularly difficult as there are confounding variables that must be considered before statistically analyzing the data (Helsel and Hirsch 2002). For example, water quality time series data tend to be non-normally distributed, have large variability, are influenced by season, and have covariate effects (e.g. flow) (Trkulja 1997). Water quality data collected for the Provincial Water Quality Monitoring program are routinely affected by these confounding variables. The preliminary trend analysis performed here, to explore the temporal variability, was biased by the high occurrence of sampling during low flow periods. This in fact could have had an influence on whether a trend was discernable or if the one displayed was in fact true. Therefore, a more detailed analysis is required in the future following a change in the sampling regime which will encompass higher flows to accurately comment on temporal trends.

Spills

Spills can be defined as releases of pollutants into the natural environment originating from a structure, vehicle, or other container, and that are abnormal in light of all circumstances. All spills must be reported to the Ministry of the Environment so the necessary remedial actions and protection measures can be taken. Relatively few spills have been reported within the Catfish Creek watershed which is likely due to the lack of industrial land-use within the region.

Although spills are not considered to be a chronic water quality problem they can still have a tremendous impact on aquatic health. Currently, CCCA does not have a separate spills protocol.

SUMMARY & CONCLUSIONS

Water quality monitoring has historically focused on characterizing the chemical and physical attributes of the watershed. The Provincial Water Quality Monitoring Network is an important long term monitoring program for Ontario which facilitates the characterization of the chemical and physical aspects of water quality. However, financial cutbacks by the province over the last decade, along with limited capacity at Conservation Authorities, have compromised the utility of the data. For example, estimating mass loads, completing thorough trend analyses and characterizing the full range of variability in chemical and physical aspects of water quality within streams and rivers in Ontario is significantly limited by the number of samples taken each year and the timing at which samples are taken. Nonetheless, the data provide for a preliminary assessment of the conditions and trends that may be occurring in stream water quality. Currently CCCA monitors four sites under the PWQMN program and is proposing to monitor two sites under Source Water Protection with the intention of increasing the sampling coverage to represent the water quality across the entire watershed more effectively.

Generally, nitrogen and phosphorus concentrations are high within the Catfish Creek watershed. The upper reach of Catfish Creek tends to be the area within the watershed where water quality is most impaired. Land-use including intensive agricultural production, urban development, wastewater treatment plant effluents, the underlying geology and topography in Catfish Creek likely all contribute to the degradation in water quality.

Several studies (McTavish, 1986; Wilcox, 2005) indicate that there is a strong relationship between land-use practices and surface water quality. Within the Catfish Creek watershed most of the region is designated as agricultural land of which a high percentage is row cropped & tile drained. Land-use of this type can result in waterways becoming enriched through runoff of fertilizers and erosion of soils.

Although there were low levels of ammonia sampled throughout the watershed, this may not be an accurate representation of the levels entering the watercourse as ammonia is quickly converted into nitrite, which in turn is rapidly converted to nitrate. Therefore, the high levels of nitrite found within upper Catfish may be more indicative of an ammonia input rather than a lack of dissolved oxygen. Regardless, both ammonia and nitrite are highly toxic to aquatic life and while ammonia concentrations gathered from the PWQMN may not have been of concern during 1991-1995 within Catfish Creek, an investigation into current data should be performed to determine if ammonia loading is currently occurring.

The warming trend in summer temperature values across the entire watershed is of obvious concern. High temperatures can limit the diversity of aquatic species present as well as impact dissolved oxygen saturations. Within the Catfish Creek watershed there are a few cold water streams that currently support fisheries (e.g. Bradley, Silver and Burnt Mill Creeks). Future investigations into possible ways in which to manage and maintain these areas as suitable habitat for these fisheries should be examined.

Bacteria and pathogens in the Catfish Creek watershed tend to be highly variable likely as a result of the land-use within the watershed. Dorner (2004) identified both agricultural and urban watersheds as areas that have a high occurrence of pathogens. The elevated upstream fecal coliform levels were likely as a result of the high percentage of livestock operations adjacent to the creek and the faulty septic systems within the Village of Springfield. To address this problem, in the late 1990's Springfield was taken off septic and connected to the municipal sewage lagoons in Aylmer. This in conjunction with the current decline in livestock operations within the upper sub-basin have most likely helped to decrease bacterial loads within the area. However, future investigations should identify if this is in-fact true.

The Catfish Creek watershed has relatively low natural base-flows and areas within the upper portion of the watershed have intermittent flow during dry seasons. This phenomenon is amplified by the numerous tile and municipal drains and the impervious soils which do not allow for sufficient recharge within the region. Other land-use practices such as the increased number of dams and online ponds for irrigation purposes found within the lower sub-basin could also be negatively affecting the natural base-flow in some creeks (e.g. Silver Creek). In general, base flows within lower Catfish Creek are higher relative to the rest of the watershed. The lower concentrations found within lower Catfish Creek could potentially be as a result of dilution from these higher base flows. Sampling during higher flow periods should be done to fully understand if this is a potential mechanism for the better water quality observed downstream.

Also associated with low base flow is the potential for the creek to have poor assimilative capacity. Although no studies have examined the assimilative capacity of Catfish Creek, residents situated downstream of the sewage lagoons have reported algae blooms and poor water colour at the time of discharge. Future studies should be employed to determine if the creek has the assimilative capacity for the bi-annual discharge from the sewage lagoons.

Spills and wastewater treatment lagoon bypasses are a significant threat to downstream water users in the Catfish Creek watershed. They represent an acute and immediate impairment to water quality that can compromise recreational uses at Port Bruce. Therefore, it may be of use to have an effective spills response protocol and accurate river information for timely response and notification of downstream users.

The Catfish Creek and its tributaries are improving with respect to some nutrients but deteriorating with respect to others. Nitrate and nitrite concentrations appeared to be slightly decreasing at all three sites where as NFR appears to be on the rise. Total phosphorus concentrations have dramatically decreased since the 1970’s at site 502, directly downstream of Aylmer, indicating that the removal of phosphates from household cleaners and wastewater effluent has had a marked effect in decreasing urban inputs of total phosphorus to the watershed. Re-assessing these trends in the future with current data would be beneficial in evaluating if new trends are emerging. Ultimately improved wastewater treatment and targeted implementation of agricultural beneficial management practices is needed to maintain and hopefully improve surface water quality within the Catfish Creek watershed.

Although the characterization of the water quality within this analysis focused mainly on chemical and physical data from the PWQMN other sources and types of data should ideally be incorporated to create a more integrative approach to monitoring and assessing water quality within a watershed. Biological indices as water quality assessment tools should ideally be used in conjunction with traditional chemical and physical water quality monitoring. An integrative approach such as this is far more powerful than either alone and can act as a ‘quality assessment’ of these variables as surrogates to describe surface water quality.

RECOMMENDATIONS

To improve our understanding of the water quality conditions within the Catfish Creek watershed, the following recommendations are made:

Sampling Regime

1. At a minimum, 12 samples per year should be taken at each long term monitoring site to characterize ambient water quality conditions. However, this will require additional financial resources.
2. The sampling regime should be designed so that the range of flow conditions is sampled. For example, additional high flow samples should be targeted during spring runoff and summer rainfall events. This will characterize the range of environmental conditions that exist in the watershed.
3. Diurnal sampling of dissolved oxygen, pH and temperature should be carried out to adequately capture the range of values organisms are truly experiencing within a day.

Monitoring

1. Continue monitoring chemical and physical parameters within the watershed. However, an evaluation of the current surface water monitoring program to determine if the location of sampling sites adequately captures the water quality issues within the watershed should be performed.
2. Additional long term monitoring sites are needed to gain better spatial coverage, at the watershed scale, so that upstream/downstream and tributary comparisons can be made. Additional recommended sites include:
    i. Nineteenth Creek at the confluence with lower Catfish Creek
    ii. Bradley Creek downstream of the reservoir
3. Development of an integrative monitoring program that combines chemical, physical and biological (e.g. benthic macroinvertebrate, fish community) data.
4. Monitor for pesticide contamination pre and post application and target high flow events within smaller agricultural tributaries of the upper sub-basin.
5. Although bacteria and pathogen monitoring is fraught with difficulties and should remain in the research forum, a preliminary investigation, similar to the CURB report (Depuydt, 1994), into the variability of *Escherichia coli* in Catfish Creek and the newly developed Silver Creek would increase our understanding of the range of concentrations seen in the watershed.

Reporting

1. Identify specific long term indicators that can be used for progress measurement. Target monitoring activities so that these indicators will be collected annually. Incorporate these indicators into the monitoring design.
2. Annual high-level reporting of current conditions to report on progress should be carried out
3. Future analysis of data should be corrected for flow to determine if this is a confounding variable that is resulting in a misinterpretation of the water quality results such as bacterial loads.
4. Every five years, prepare an in-depth technical report.
5. Future statistical trend analyses should be carried out upon completion of a current 5 year set of sampling data. This is to properly assess if areas within the watershed are improving or deteriorating over time.

Future Investigations

1. Investigate the linkage between an areas underlying geology and ‘ambient’ nutrient concentrations to predict basin specific natural benchmarks (however current land-use practices and alterations must be taken into consideration as these may have amplified the natural relationship)
2. Investigate the linkage between land-use and water quality to help modify best practices for agriculture and pasture lands (for example the introduction of buffer or riparian zones to decrease sedimentation).
3. Investigate potential point and non-point sources of nutrient and sediment loading within the Catfish Creek watershed. This could include a mass load analysis to estimate loads from both point and non-point sources (e.g. sediment budget analysis to determine where the loading within Port Bruce is coming from).
4. Conduct an analysis characterizing the current water quality conditions within the Springwater Reservoir and its ability to assist in flow augmentation / supplementation during low flow seasons should be investigated.
5. Investigate the potential to protect recharge areas through reforestation and redesign of a more efficient municipal drainage system which could decrease the number of active drains.
6. Conduct site specific investigation(s) evaluating the potential for maintaining or rehabilitating cold water creeks currently supporting native fisheries (e.g. Bradley Creek, Silver Creek or Burnt Mill Creek).
7. Investigate the potential risk to water quality associated with the pesticide barrels dumped within Silver and Burnt Mill Creeks.
8. Investigate the potential for liquid manure injected into the ground to reach nearby surface waters during high flow events.
9. Conduct future outreach initiatives, such as the current ‘Greencover’ program, should be promoted to facilitate rehabilitation of the upper watershed (e.g. rural outreach for implementation of waterway fencing and buffer zones to decrease nutrient loading and sediment loading through erosion).

REFERENCES

Analyse-it Software, Ltd. 2005. Analyse-it statistical analysis software for Microsoft Excel. (http://www.analyse-it.com)

CCCA. 1983. Catfish Creek Conservation Authority Drainage Report CCCA publication 43 p.

CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment, Winnipeg.

Crook P. Engineering and Consulting Services. 1997. Port Bruce Harbour Flood Control Project Design Report and Project Plan Private Publication 40 p. & appendices.

Depuydt, D. 1994. Clean Up Rural Beaches (CURB) Plan. Kettle Creek and Catfish Creek Conservation Authorities, Ontario.

Dorner, S.M. 2004. Waterborne pathogens: Sources, Fate, and Transport in a Watershed used for Drinking Water Supply. PhD Thesis, University of Waterloo, Waterloo, Ontario, 343p.

Environment Canada. 2001. Priority Substances List Assessment Report: Road Salt. Environment Canada, Health Canada, Ottawa, Ontario, 165p.

Environmental Commissioner of Ontario. 1997. Open Doors- Ontario's Environmental Bill of Rights. 1997 Annual Report. Environmental Commissioner of Ontario, Toronto, Ontario. 100p.

Environmental Commissioner of Ontario (ECO). 2002. Developing Sustainability. 2001-2002 Annual Report. Environmental Commissioner of Ontario, Toronto, Ontario. 191p.

Fidler, LE & SB Miller. 1994. British Columbia Water Quality Guidelines for Dissolved Gas Supersaturation. Report for BC Environment. Aspen Applied Sciences Ltd., Valemount BC. Pgs. 110.

Helsel, D.R. and R.M. Hirsch. 2002. Techniques in Water Resources Investigations of the United States Geological Survey. Book 4 Hydrologic Analysis and Interpretation. Chapter A3. Statistical Methods in Water Resources. U.S. Department of the Interior, United States Geological Survey. (http://water.usgs.gov/pubs/twri/twri4a3/)

Hirsch, R.M, R.B. Alexander, and R.A. Smith. 1991. Selection of Methods for the Detection and Estimation of Trends in Water Quality. Technical Memorandum. (http://water.usgs.gov/admin/memo/BSA/BSA91.01.pdf)

Hrynkiw, T., T. Viraraghavan, and G. Fuller. 2003. Analysis of Trends in Water Quality of Buffalo Pound Lake. Canadian Water Resources Journal 28:3:337-357.

Johnston, M. 1983. Watershed Plan for the Catfish Creek Conservation Authority Privately published 58 p.

Letterhos, J. and Vincent, J. 2004. Lake Erie LaMP 2004 Report. Upper Thames River Conservation Authority, London, Ontario.

McCarron J. & McCoy K. 1992. Silver Creek Water Quality Inventory CCCA publication 37 p.

Mackenzie, H. 2001. Mill Creek Subwatershed Study Publisher CCCA 40+ p.

Maybeck, M, V. Kimstach, and R. Helmer. 1996. Chapter 2. Strategies for water quality assessment. In Water Quality Assessments – A guide to use of biota, sediments and water in Environmental Monitoring. Second Edition, UNESCO/WHO/UNEP (http://www.who.int/water_sanitation_health/resourcesquality/wqachapter2.pdf)

McTavish, D.A 1976. Kettle Creek Watershed, Surface Water Quality and Waste Loading Guidelines. Ministry of the Environment Southwestern Region Technical Support Section, Ontario.

McTavish, D.A. 1986. Relationships between Land Use and Water Quality in Southwestern Ontario. Gartner Lee and Associates and Ministry of the Environment Southwestern Region Technical Support Section, Ontario.

Ministry of the Environment. 1978. Catfish Creek Drainage Basin Study MOE Publication 72 p.

Painter, S., D.N. Myers, J. Letterhos. 2000. Lake Erie Lakewide Management Plant (LaMP) Technical Report Series. Characterization of Data and Data Collection Programs for Assessing Pollutants of Concern to Lake Erie. Lake Erie Lakewide Management Plan. Environment Canada, Burlington. 62p.

Richards, P.R. 2002. Estimation of pollutant loads in rivers and streams: A guidance document for NPS programs. Report to the U.S. Environmental Protection Agency-Region VIII. Heidelberg College Water Quality Laboratory, Tiffin, Ohio. 134p.

Sigma Plot 8.0. 2002. Users Guide. SPSS, Chicago Il.

Snowsell M., & CCCA. 1984. Burnt Mill Creek Stream Study CCCA published 19p.

Stoneman, C. L. and M. L. Jones. 1996. A simple method to classify stream thermal stability with single observations of daily maximum water and air temperatures. N. Am. J. Fisheries Management 16:728-737.

Triton Engineering. 1994.

Trkulja, J. 1997. Stochastic modeling and trend analysis of phosphorus in the Grand River. Maters of Science, University of Guelph, Guelph, Ontario. 156p.

Wall, G.J., A.W. Bos and A.H. Marshall. 1996. The Relationship Between Phosphorus and Suspended Sediment Loads in Ontario Watersheds. Journal of Soil and Water Conservation. 51(6):504-507.

Wurts, W.A. and Durborow, R.M. 1992. Interactions of pH, Carbon Dioxide, Alkalinity and Hardness in Fish Ponds. Southern Regional Aquaculture Centre. Publication no. 469. Stoneville Mississippi. 4p.

APPENDICES

Appendix A. Table of Provincial Water Quality Monitoring Network (PWQMN) Sites within Catfish Creek Watershed.

STATION	NAME	LOCATION	FIRST YR	LAST YR	TOTAL YRS	STATUS
16009700102	Catfish Creek	Imperial Rd, Elgin Cnty Rd 73, Port Bruce	1964	1971	8	Historic
16009700202	Catfish Creek	Rogers Rd, N of Hwy 3, W of Aylmer	1971	1975	5	Historic
16009700302	Catfish Creek	Sparta Ln, E of Sparta	1972	1995	24	Historic
16009700402	Catfish Creek West	Helkaa Line, confluence of East and West branches	1975	2003	6	Current
16009700502	Catfish Creek	Hwy 3, Talbot Ln, W of Orwell	1975	2003	22	Current
16009700602	Catfish Creek	Glencolin Ln, Glencolin	1976	1995	20	Historic
16009700702	Catfish Creek	Culloden Ln, Cnty Rd 10, Brownsville Station	1976	1980	5	Historic
16009700802	Catfish Creek	Rush Creek Ln, upstrm Port Bruce	2003	2003	1	Current
16009900102	Silver Creek	Nova Scotia Ln, Elgin Rd 42, E of Port Bruce	2003	2003	1	Current
0	Nineteen Creek		0	0	0	Proposed
0	Salter Creek		0	0	0	Proposed

Appendix B. Current method detection limit at MOE laboratory for various water quality variables.

Variable	Detection Limit	Units
Alkalinity - TFE	0.2	mg/L as CaCO3
Ammonia nitrogen	0.002	mg/L as N
Calcium	0.05	mg/L
Conductivity, 25C	1	mS/cm
Copper	0.0002	mg/L
Dissolved Solids	2	mg/L
Hardness	0.2	mg/L
Lead	0.0005	mg/L
Magnesium	0.02	mg/L
Nickel	0.0005	mg/L
Nitrate + Nitrite Nitrogen	0.005	mg/L as N
Nitrite nitrogen	0.001	mg/L as N
Potassium	0.01	mg/L
Reactive Phosphorus	0.0005	mg/L as P
Sodium	0.02	mg/L
Non-filterable residue	1	mg/L
Total Kjeldahl Nitrogen	0.02	mg/L as N
Total Phosphorus	0.002	mg/L as P
Total Solids	2	mg/L
Zinc	0.0005	mg/L

SOURCE:

Appendix C. Summary statistics for the 1991-1995 dataset for all the water quality parameters at the 7 long term PWQMN monitoring sites in the Catfish Creek watershed.

Nitrate	Site 302	Site 502	Site 602
Mean	3.3071	4.1537	5.1537
Std err	0.3718	0.3931	0.6243
Median	3.6000	4.4000	4.7000
Std dev	2.4093	2.5170	3.9977
Min	0.1000	0.1000	0.6000
Max	7.8000	10.2000	22.4000
N	42	41	41
% Exceed	52.38	68.29	63.41
10th	0.2000	0.7000	1.1000
25th	0.8000	2.1000	1.7000
75th	5.2000	5.9000	7.1000
90th	6.6400	6.7000	8.5000

Nitrite	Site 302	Site 502	Site 602
Mean	0.0536	0.0649	0.1000
Std err	0.0081	0.0086	0.0138
Median	0.0350	0.0450	0.0800
Std dev	0.0523	0.0606	0.0874
Min	0.0100	0.0070	0.0200
Max	0.2300	0.2200	0.4300
N	42	50	40
% Exceed	28.57	42.00	55.00
10th	0.0100	0.0100	0.0290
25th	0.0200	0.0170	0.0400
75th	0.0700	0.0800	0.1225
90th	0.1200	0.1702	0.1830

Ammonia	Site 302	Site 502	Site 602
Mean	0.0020	0.0013	0.0023
Std err	0.0006	0.0002	0.0007
Median	0.0009	0.0008	0.0008
Std dev	0.0035	0.0013	0.0040
Min	0.0000	0.0000	0.0000
Max	0.0194	0.0057	0.0185
N	37	35	34
% Exceed	2.70	0.00	2.94
10th	0.0003	0.0001	0.0002
25th	0.0005	0.0003	0.0004
75th	0.0017	0.0018	0.0020
90th	0.0037	0.0033	0.0046

Kjeldhal	Site 302	Site 502	Site 602
Mean	0.9632	1.0754	1.1939
Std err	0.0909	0.0658	0.1026
Median	0.7800	0.9400	1.0200
Std dev	0.5822	0.4210	0.6570
Min	0.4400	0.6100	0.6900
Max	3.0100	2.4000	4.1000
N	41	41	41
% Exceed	n/a	n/a	n/a
10th	0.5000	0.6800	0.7600
25th	0.6800	0.8400	0.8400
75th	0.9800	1.2400	1.2600
90th	1.4200	1.5600	1.8400

Total Nitrogen	Site 302	Site 502	Site 602
Mean	5.1942	5.5224	5.5949
Std err	0.4350	0.6414	0.6242
Median	4.7800	5.7200	5.5700
Std dev	2.7852	4.1071	3.9971
Min	0.5800	0.7200	0.6700
Max	9.8100	24.9500	21.3000
N	41	41	41
% Exceed	n/a	n/a	n/a
10th	1.5700	1.1500	1.7200
25th	3.0500	2.4800	2.5000
75th	7.6500	7.2000	6.7800
90th	8.6900	7.7600	9.4300

Phosphorus	Site 302	Site 502	Site 602
Mean	0.1218	0.1678	0.1685
Std err	0.0237	0.0181	0.0338
Median	0.0840	0.1430	0.1220
Std dev	0.1520	0.1159	0.2163
Min	0.0240	0.0450	0.0420
Max	0.9800	0.5800	1.3100
N	41	41	41
% Exceed	95.12	100.00	100.00
10th	0.0360	0.0620	0.0510
25th	0.0480	0.0940	0.0780
75th	0.1200	0.1940	0.1720
90th	0.2180	0.2880	0.2100

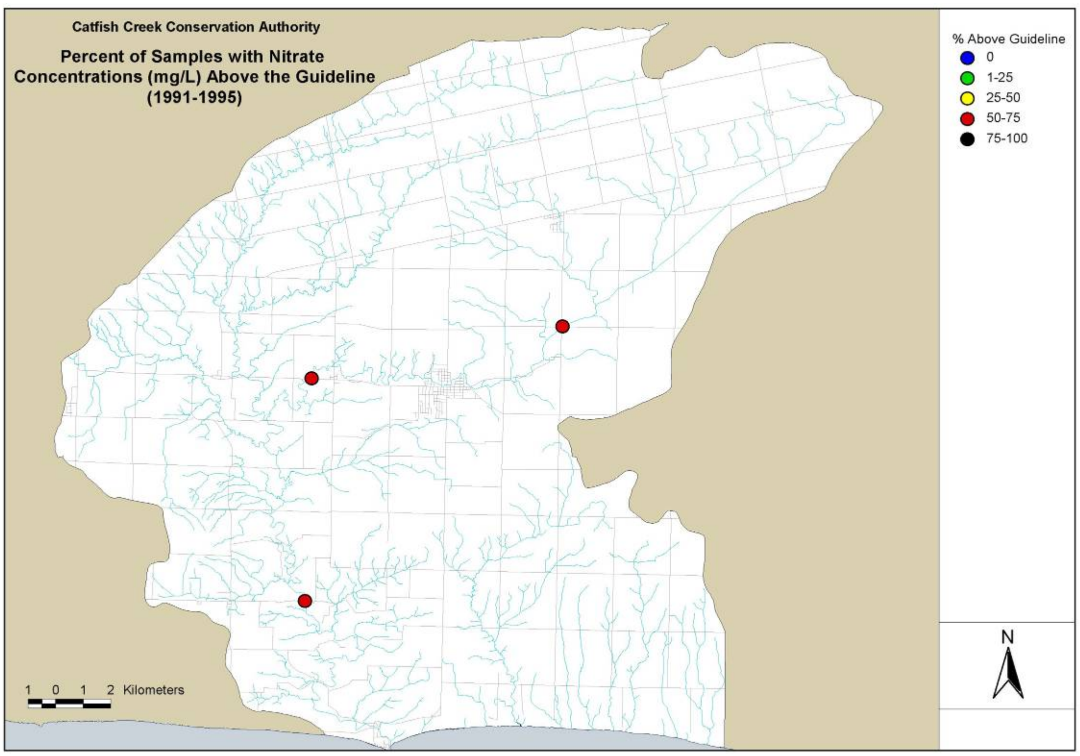
NFR	Site 302	Site 502	Site 602
Mean	33.3833	49.4500	35.1537
Std err	5.0841	12.4358	6.2837
Median	26.6500	25.4000	21.3000
Std dev	32.9486	78.6508	40.2355
Min	5.0000	5.0000	5.0000
Max	209.0000	389.0000	197.0000
N	42	40	41
% Exceed	52.38	52.50	34.15
10th	10.7300	13.2800	9.7000
25th	15.7250	17.0500	16.1000
75th	38.0250	45.1250	40.4000
90th	54.7900	67.7500	72.0000

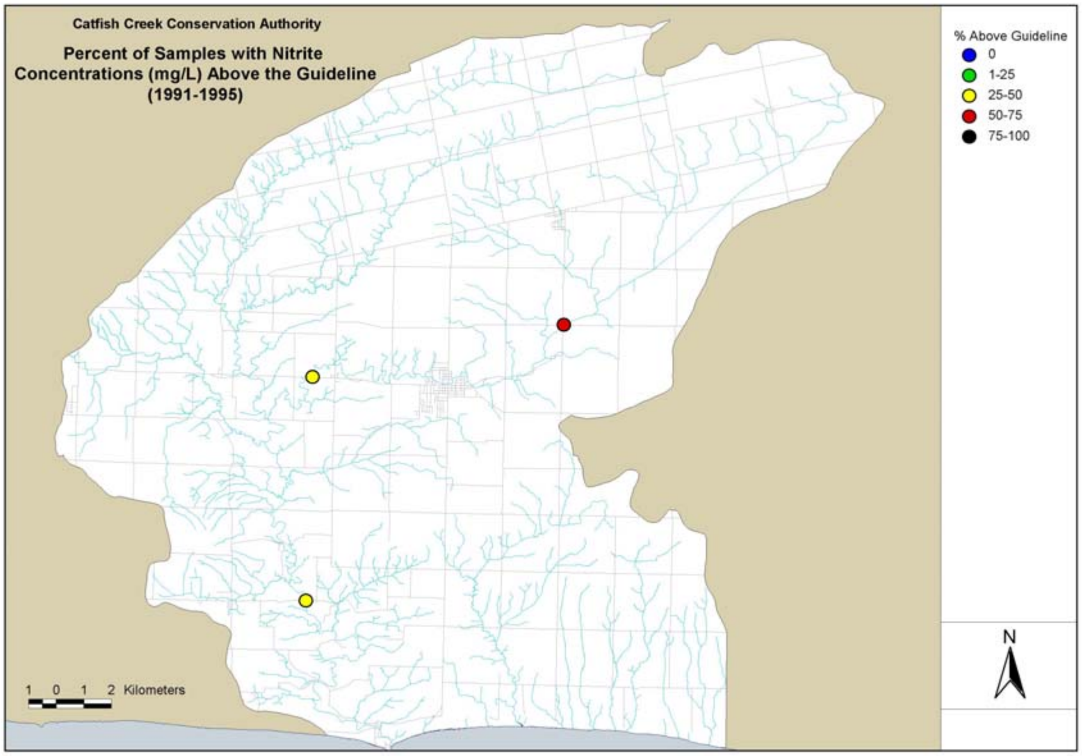
Chloride	Site 302	Site 502	Site 602
Mean	35.0537	41.6098	31.7667
Std err	2.1927	1.8603	1.4748
Median	31.7000	38.5000	30.4500
Std dev	14.0403	11.9118	9.5581
Min	19.0000	20.1000	17.2000
Max	74.8000	77.4000	61.6000
N	41	41	42
% Exceed	0.00	0.00	0.00
10th	22.8000	31.6000	22.2800
25th	26.1000	34.0000	25.9250
75th	38.1000	45.2000	33.3750
90th	57.6000	59.9000	41.3600

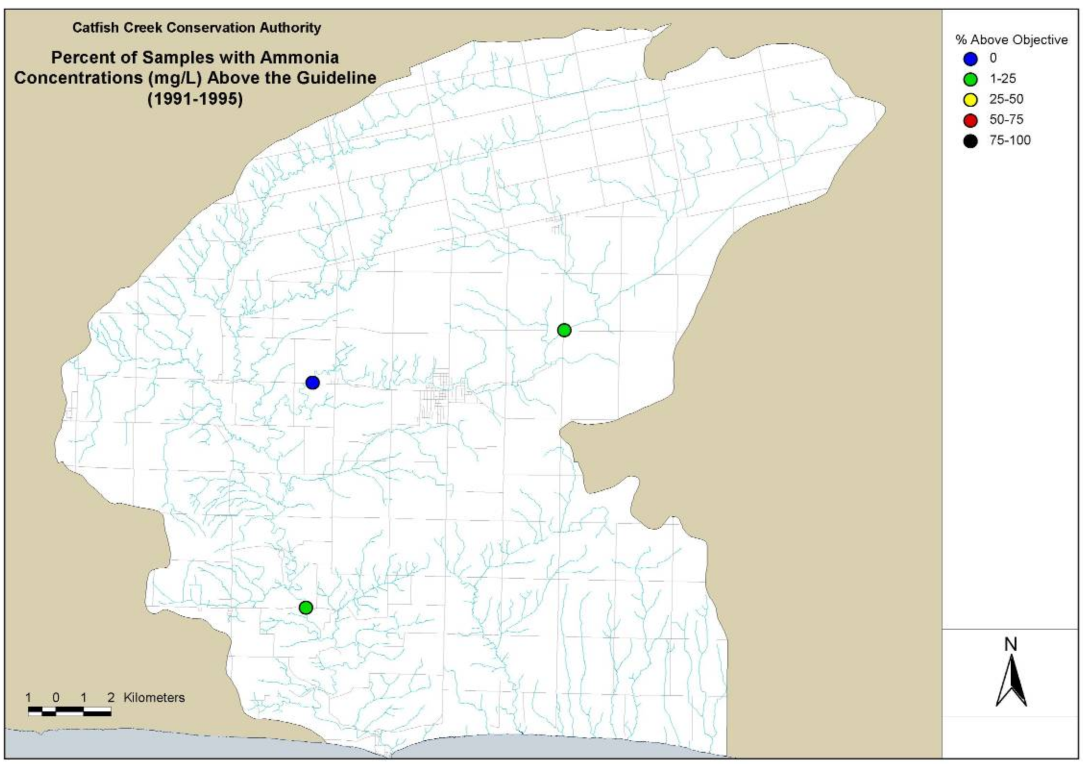
Appendix D. Percentage of samples per site with values greater than the provincial objective or Canadian guideline.

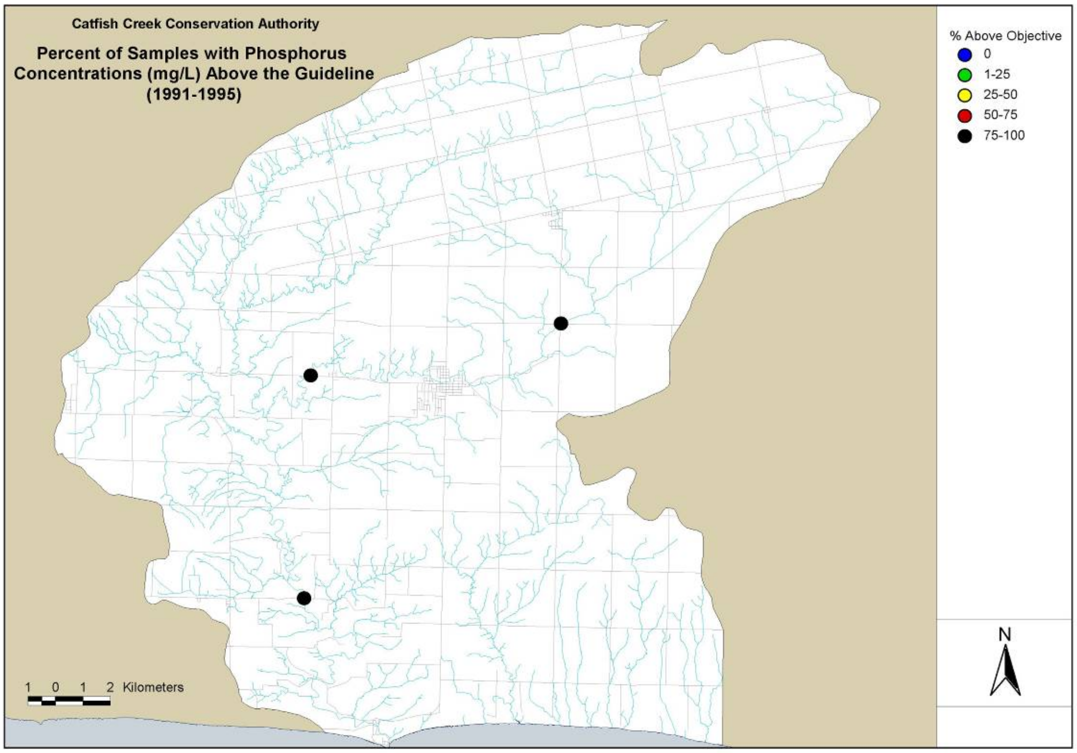
Site	Tributary	Nitrates	Nitrite	Unionized Ammonia	Kjeldhal Nitrogen	Total Phosphorus	Non-filterable residue	Chloride
	Objective:	2.93 mg/L	0.060 mg/L	0.0165 mg/L	N/A	0.030 mg/L	25.0 mg/L	250.0 mg/L
16009700302	Catfish Creek	52.38	28.57	2.70	N/A	95.12	52.38	0.00
16009700502	Catfish Creek	68.29	42.00	0.00	N/A	100.00	52.50	0.00
16009700602	Catfish Creek	63.41	55.00	2.90	N/A	100.00	34.15	0.00

Maps of the Catfish Creek watershed illustration the percent of times samples taken at one of the 7 PWQMN sites does not meet the Provincial water quality objective or the Canadian Guideline for the 1991-1995 dataset.

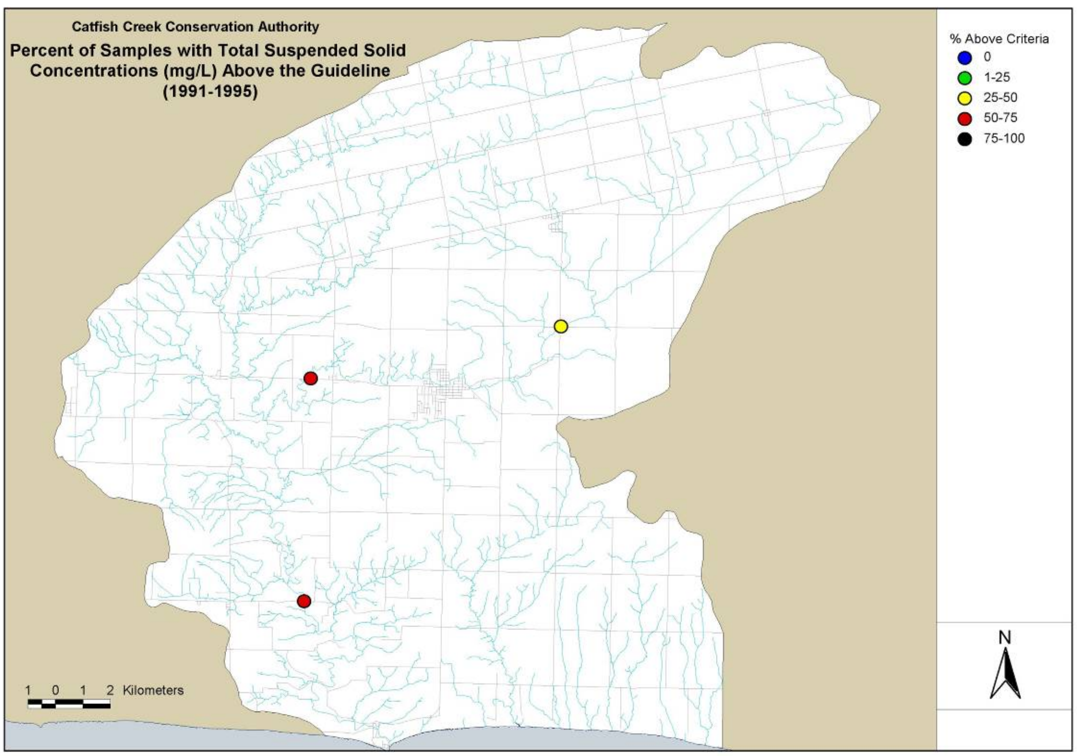



Catfish Creek Conservation Authority
Percent of Samples with Nitrite Concentrations (mg/L) Above the Guideline (1991-1995)
% Above Guideline
0
1-25
25-50
50-75
75-100
N
1 0 1 2 Kilometers

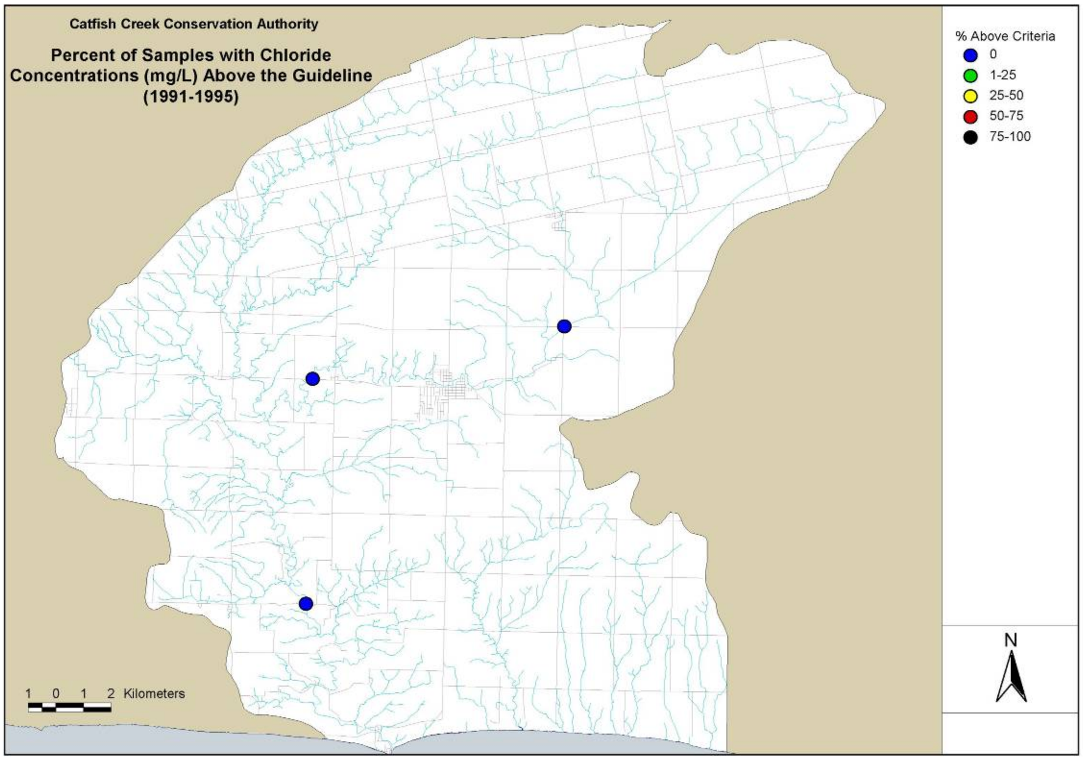

Catfish Creek Conservation Authority
Percent of Samples with Ammonia Concentrations (mg/L) Above the Guideline (1991-1995)
% Above Objective
0
1-25
25-50
50-75
75-100
N
1 0 1 2 Kilometers



Catfish Creek Conservation Authority
Percent of Samples with Phosphorus Concentrations (mg/L) Above the Guideline (1991-1995)
% Above Objective
0
1-25
25-50
50-75
75-100
N
1 0 1 2 Kilometers



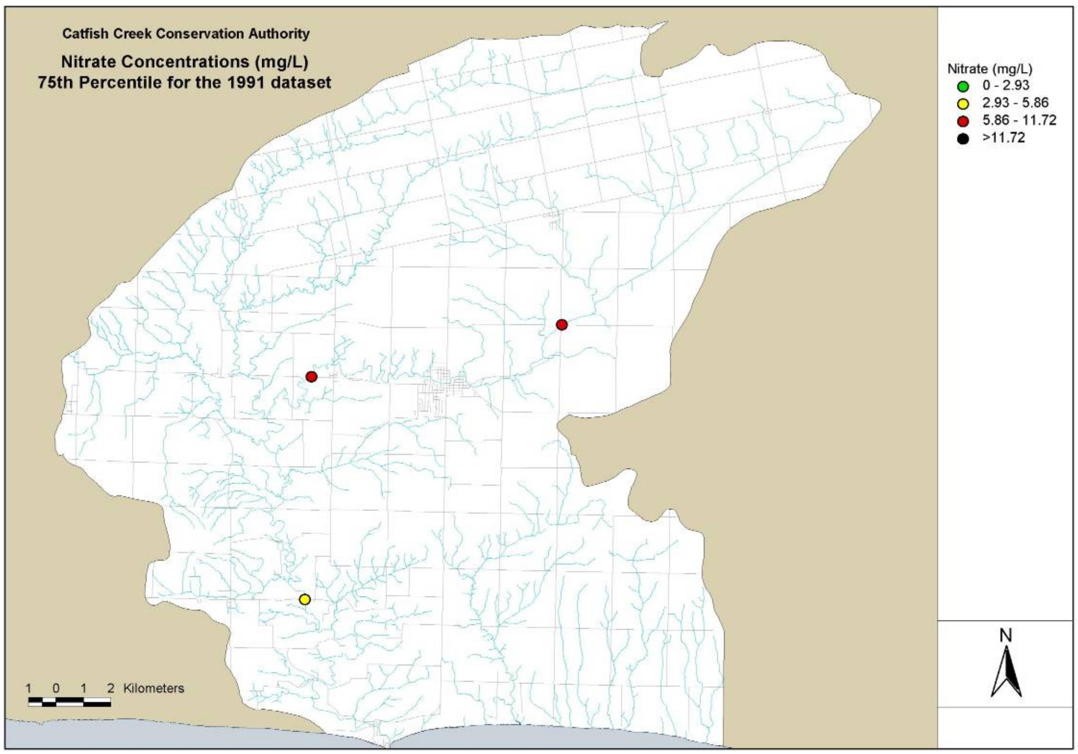
Catfish Creek Conservation Authority
Percent of Samples with Total Suspended Solid Concentrations (mg/L) Above the Guideline (1991-1995)
% Above Criteria
0
1-25
25-50
50-75
75-100
N
1 0 1 2 Kilometers

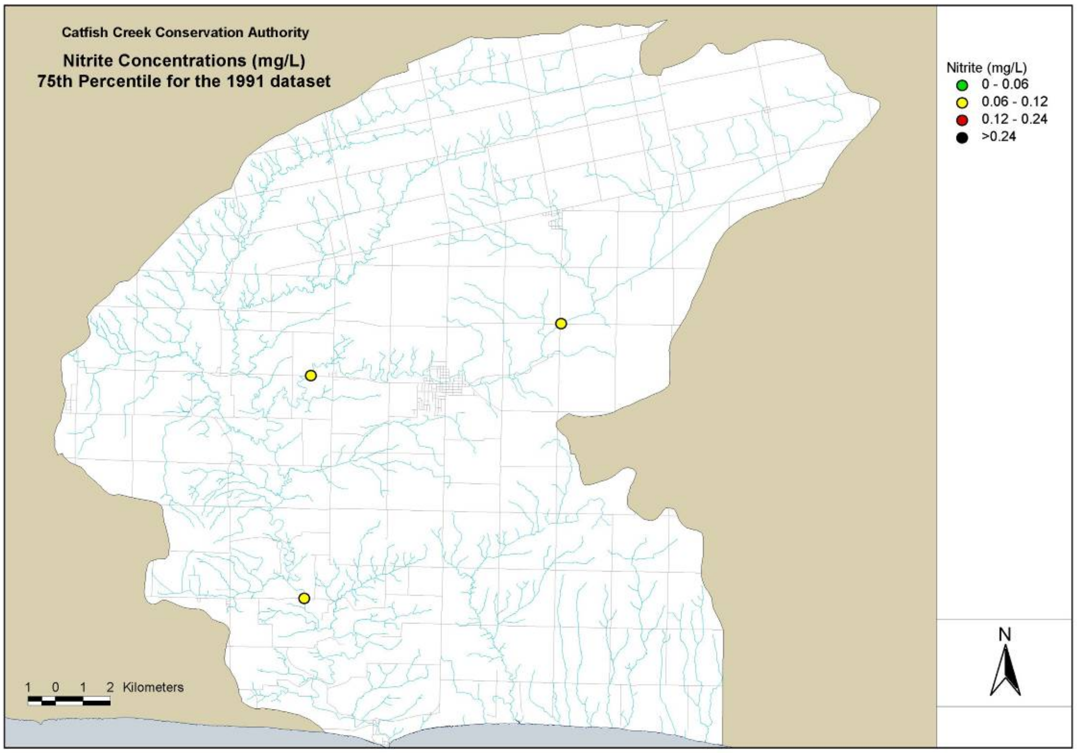

Catfish Creek Conservation Authority
Percent of Samples with Chloride Concentrations (mg/L) Above the Guideline (1991-1995)
% Above Criteria
0
1-25
25-50
50-75
75-100
N
1 0 1 2 Kilometers

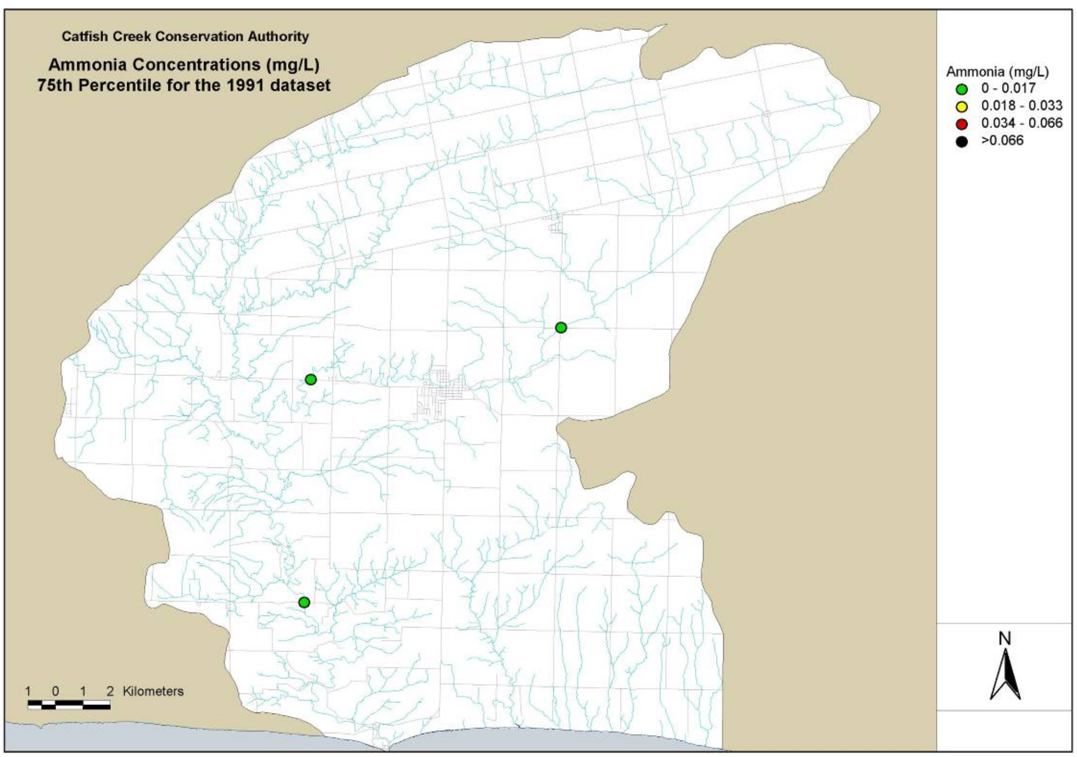
Appendix E. 75th percentile values at each of the 7 PWQMN sites for each water quality parameter analysed.

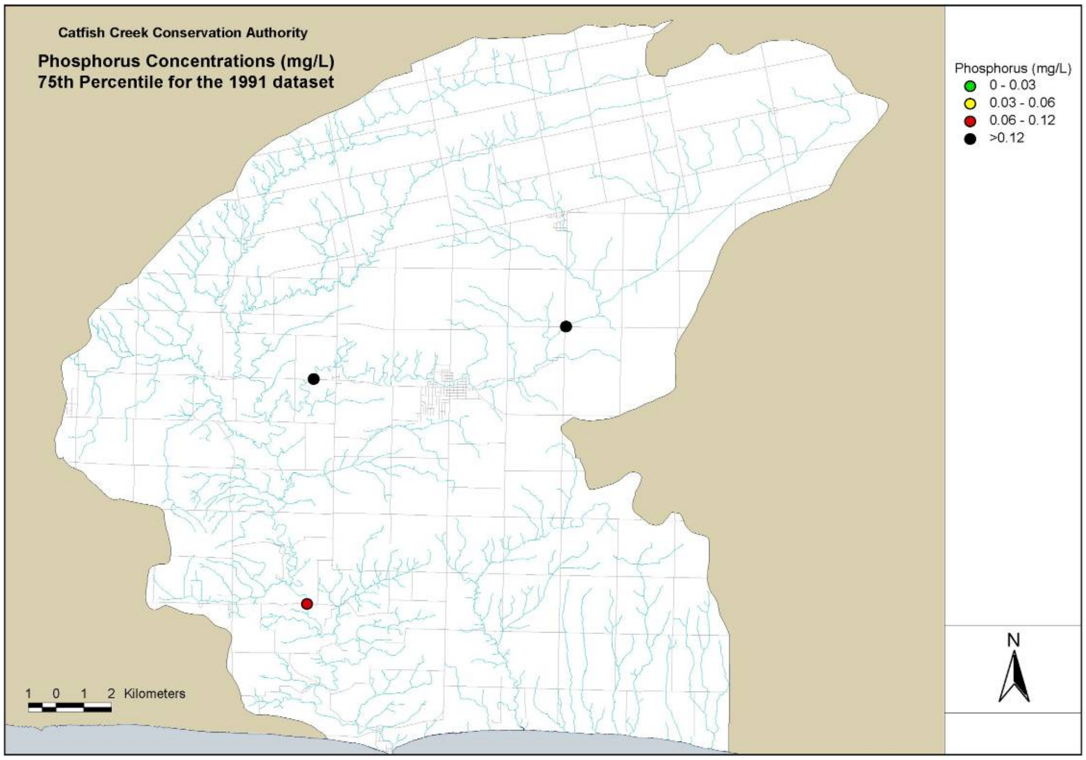
Site	Tributary	Nitrates	Nitrite	Unionized Ammonia	Kjeldhal Nitrogen	Total Nitrogen	Total Phosphorus	Non-filterable residue	Chloride
16009700302	Catfish	5.2	0.07	0.0017	0.98	7.65	0.12	38.02	38.1
16009700502	Catfish	5.9	0.08	0.0018	1.24	7.2	0.194	45.12	45.2
16009700602	Catfish	7.1	0.12	0.002	1.26	6.78	0.172	40.4	33.37

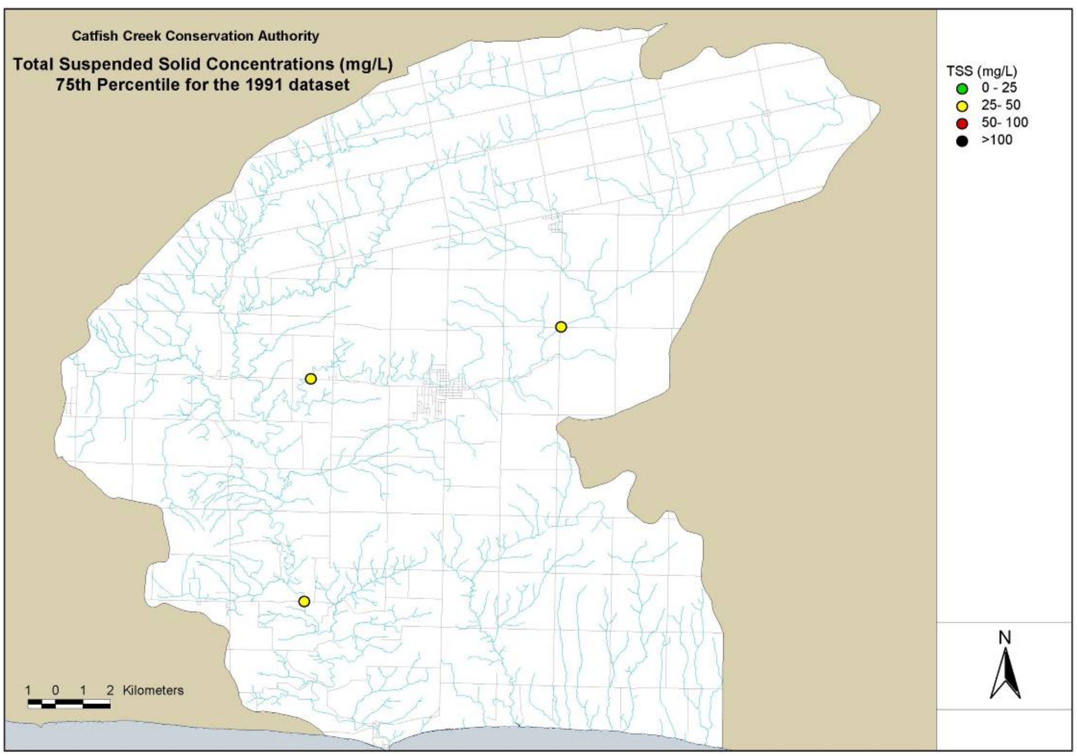
Maps of the Catfish Creek watershed illustrating how the 75th percentile value for each site ranks against the provincial water quality objective or Canadian Guideline.

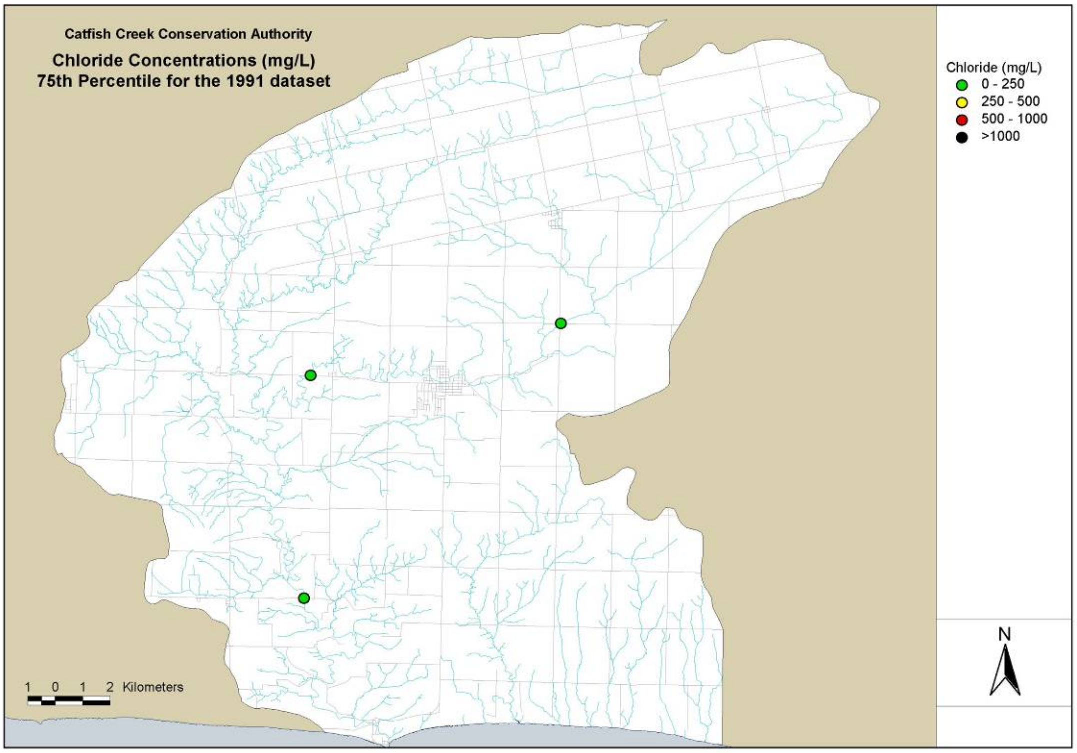



Catfish Creek Conservation Authority
Nitrite Concentrations (mg/L)
75th Percentile for the 1991 dataset
Nitrite (mg/L)
0 - 0.06
0.06 - 0.12
0.12 - 0.24
>0.24
N
1 0 1 2 Kilometers


Catfish Creek Conservation Authority
Ammonia Concentrations (mg/L)
75th Percentile for the 1991 dataset
Ammonia (mg/L)
0 - 0.017
0.018 - 0.033
0.034 - 0.066
>0.066
N
1 0 1 2 Kilometers


Catfish Creek Conservation Authority
Phosphorus Concentrations (mg/L)
75th Percentile for the 1991 dataset
Phosphorus (mg/L)
0 - 0.03
0.03 - 0.06
0.06 - 0.12
>0.12
N
1 0 1 2 Kilometers


Catfish Creek Conservation Authority
Total Suspended Solid Concentrations (mg/L)
75th Percentile for the 1991 dataset
TSS (mg/L)
0 - 25
25- 50
50- 100
>100
N
1 0 1 2 Kilometers


Catfish Creek Conservation Authority
Chloride Concentrations (mg/L)
75th Percentile for the 1991 dataset
Chloride (mg/L)
0 - 250
250 - 500
500 - 1000
>1000
N
1 0 1 2 Kilometers

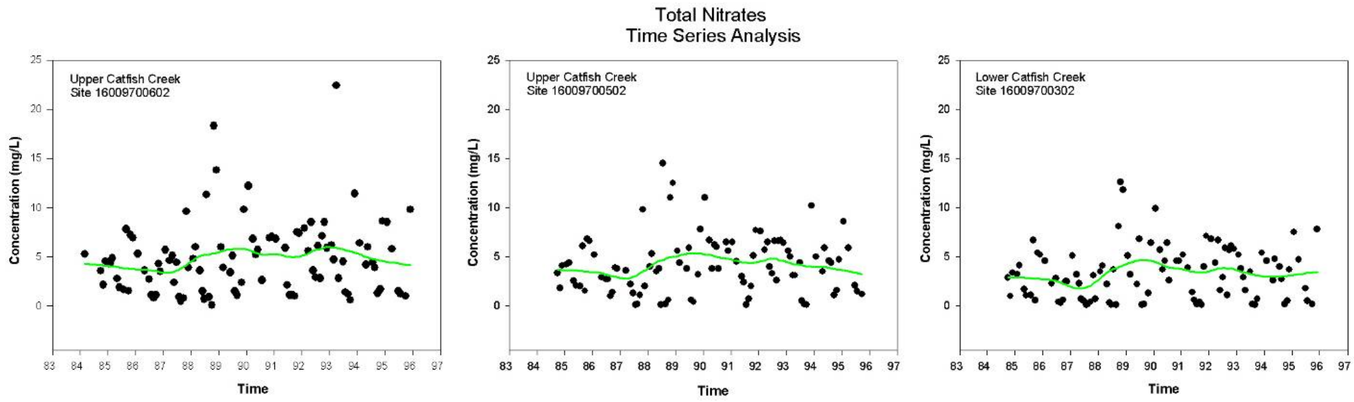
Appendix F. Table of 95th confidence limits for each nutrient for each site.

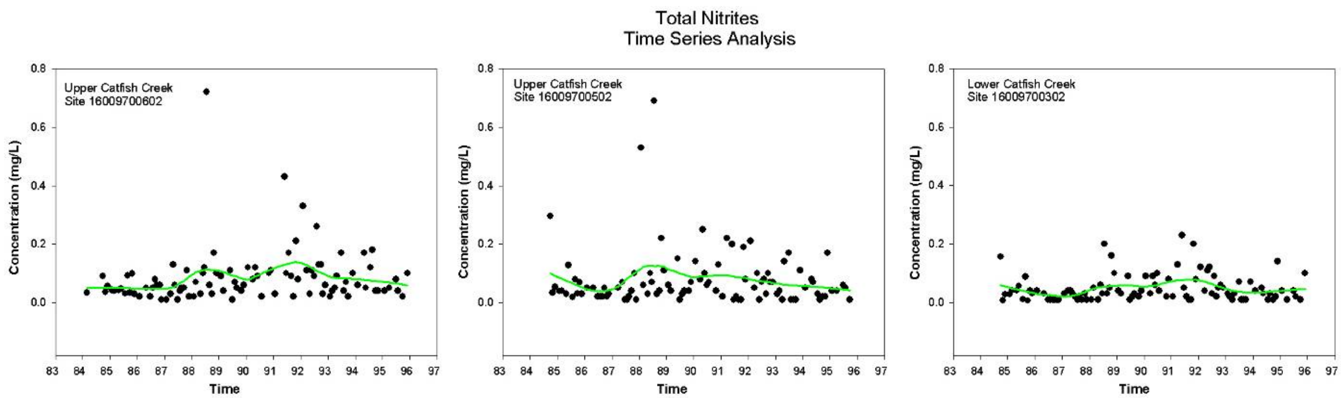
Site	Percentile	Nitrates	Nitrite	Unionized Ammonia	Kjeldhal Nitrogen	Total Nitrogen	Total Phosphorus	Non-filterable residue	Chloride
16009700302	5th	0.2000	0.0100	0.0001	0.47	1.2200	0.0320	9.2050	20.5000
	95th	7.0850	0.1395	0.0076	2.3	9.5600	0.2300	67.2300	68.5000
16009700502	5th	0.2000	0.0100	0.0001	0.66	0.8900	0.0620	9.6450	27.4000
	95th	7.7000	0.1955	0.0036	2.05	9.4400	0.3750	67.7500	63.2000
16009700602	5th	1.0000	0.0200	0.0001	0.7000	1.0400	0.0510	9.2000	21.2350
	95th	9.8000	0.2635	0.0086	2.5000	12.8600	0.2900	76.8000	53.1600

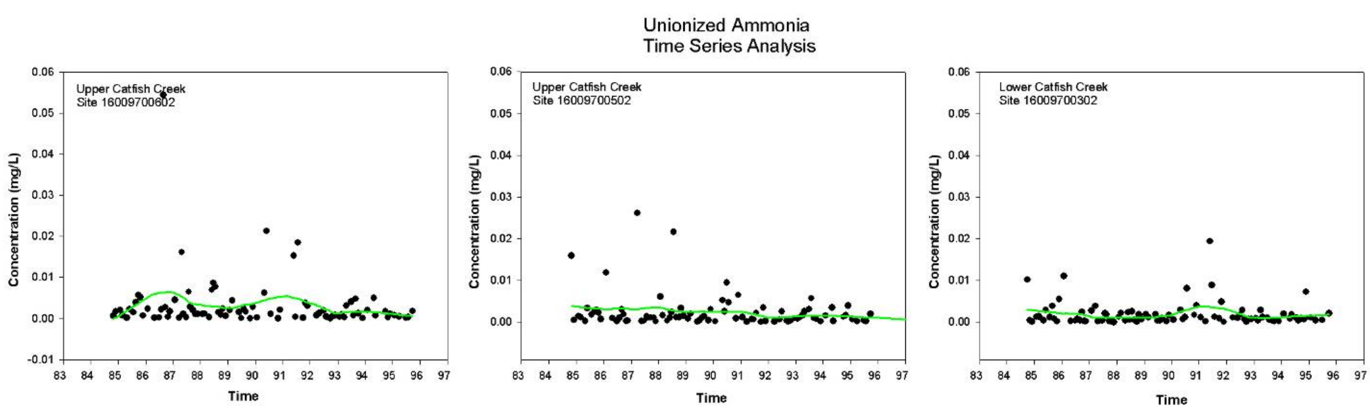
Appendix G. Nonparametric regression statistics for comparison of each water quality parameter between the 7 PWQMN sites within Catfish Creek watershed.

Parameter		Total Nitrate	Total Nitrite	Unionized Ammonia	Total Kjeldahl Nitrogen	Total Phosphorus	Total Suspended Sediment	Chloride	pH
All Sites									
602, 502 & 302	*p*	**0.0467**	**0.0027**	0.7390	**0.0036**	**0.0031**	0.4933	**<0.0001**	**<0.0001**
Upper Catfish Creek Sites									
602 vs 502	*p*	0.3347	**0.0101**	NA	0.5403	0.2226	NA	**<0.0001**	**0.0036**
Lower Catfish Creek Sites									
302 vs 502	*p*	0.1552	0.4702	NA	**0.0092**	**0.0012**	NA	**0.0007**	**0.0003**
302 vs 602	*p*	**0.0129**	**0.0009**	NA	**0.0020**	**0.0217**	NA	0.3252	**<0.0001**

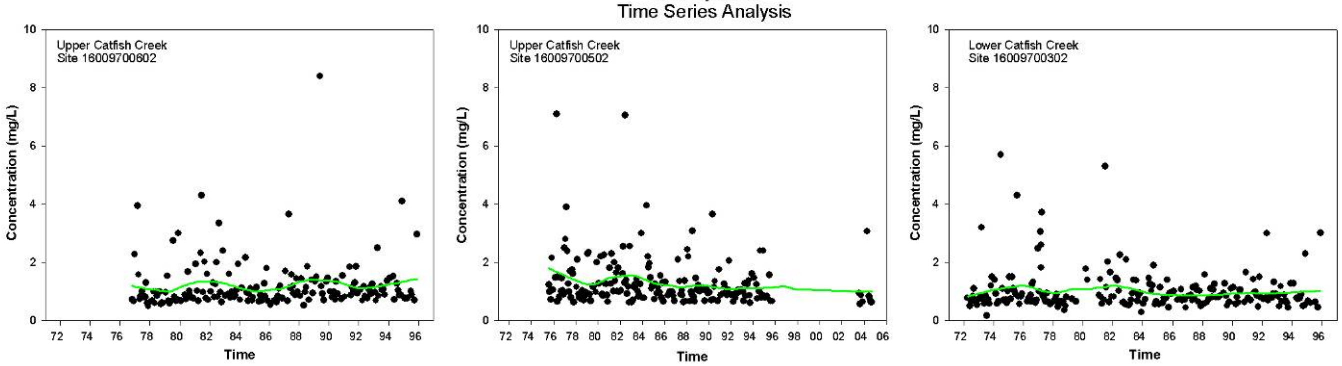
Appendix H. Time Series Analysis at each of the 3 PWQMN sites for each of the water quality parameters tested.



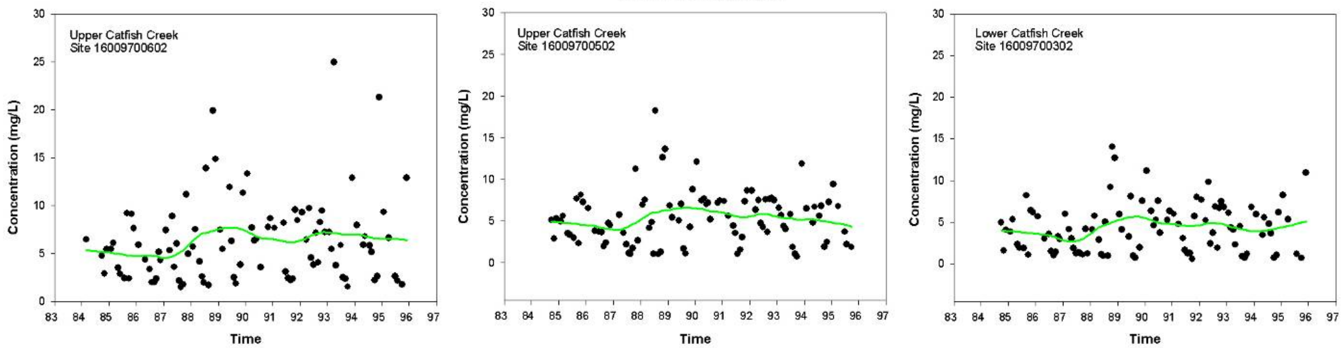




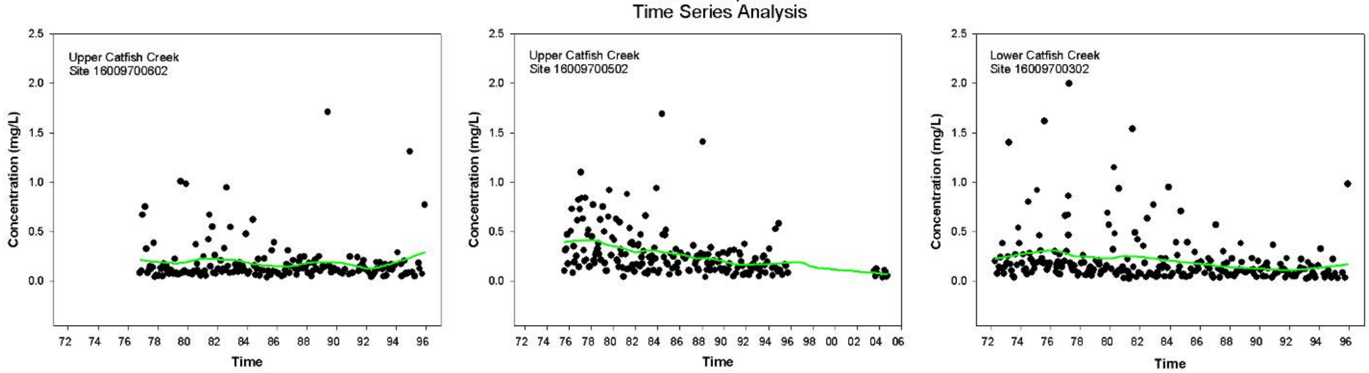
Total Kjeldhal
Time Series Analysis



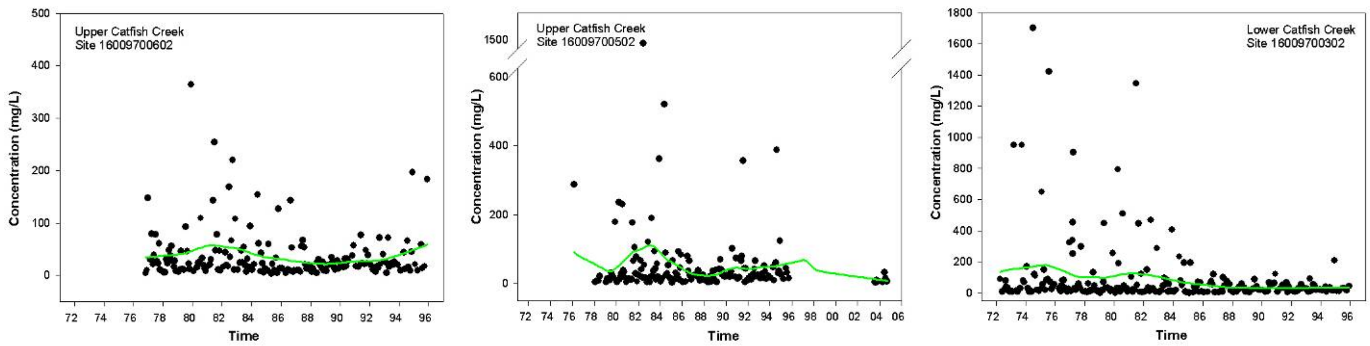
Total Nitrogen
Time Series Analysis



Total Phosphorus
Time Series Analysis



Non-Filterable Residue
Time Series Analysis



Total Chloride
Time Series Analysis