NPCA WATER QUALITY MONITORING PROGRAM:

2009 ANNUAL REPORT

APRIL 2010

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EXECUTIVE SUMMARY

The Niagara Peninsula Conservation Authority (NPCA) Water Quality Monitoring Program was implemented in 2001 and is operated in partnership with the Ontario Ministry of the Environment, Regional Municipality of Niagara, and the City of Hamilton. Through these partnerships the NPCA collects water quality samples at 68 surface water stations and 13 groundwater stations located throughout the NPCA watershed. The NPCA utilizes both chemical and biological approaches to evaluate the surface water quality. Surface water quality samples are analysed for several indicators such as nutrients, ***E. coli***, suspended solids, and metals. Surface water results are used to calculate the Canada Council of Ministries of Environment (CCME) Water Quality Index. This index is a Canada-wide standard for reporting water quality information. The NPCA also evaluates water quality in the watershed by sampling the aquatic animals at most of the NPCA surface water quality stations using the BioMAP protocol. The density and diversity of animals living in the watercourse provides a biological snapshot of the water quality. Groundwater samples are evaluated by comparing monitoring results to the Ontario Ministry of the Environment's Drinking Water Standards.

For surface water, the biological and chemical monitoring results indicate that most of Niagara's watersheds have poor or impaired water quality. Total phosphorus, ***E.coli***, suspended solids, and chlorides from non-point sources such as agricultural runoff, faulty septic systems, poor manure storage facilities and urban stormwater continue to be the major causes of impairment in the NPCA watershed. Twelve Mile Creek continues to have the best water quality rating in the NPCA watershed owing to its high forest cover and limited agricultural and rural development.

For groundwater, results indicate that water quality generally meets Ontario Drinking Water Standards. Reported groundwater quality exceedances were generally related to naturally occurring bedrock conditions; however, two groundwater monitoring stations were found to have elevated nitrate concentrations. These nitrate exceedances are likely attributed to surrounding agricultural landuse and/or faulty septic systems.

The Water Quality Monitoring Program continues to provide valuable information about the health of the NPCA watershed. Often the way the land is managed is reflected in the health of our water resources. The water quality is generally poor in the NPCA watershed and this has been caused by decades of environmental degradation. However, water quality improvement programs that target nutrient management, increase riparian buffers, and improve forest cover will address the significant water quality concerns in the NPCA watershed. The progress of these water quality improvement programs can be offset by the unknown amounts of environmental degradation in NPCA watershed. Therefore, this degradation needs to be quantified in order to properly assess the progress of watershed restoration. Consequently, it will likely take several years to restore the NPCA watershed to meet federal and provincial water quality guidelines and objectives. The NPCA will continue to monitor both surface water and groundwater resources to ensure there is current, scientifically defensible water quality information available for the NPCA watershed.

NPCA WATER QUALITY MONITORING PROGRAM: 2009 ANNUAL REPORT

1.0 INTRODUCTION

The NPCA Water Quality Monitoring Program was initiated in the summer of 2001. Previous to 2001, the NPCA was involved in numerous water quality related initiatives but did not have a dedicated monitoring program. The NPCA has since established an extensive network of monitoring stations located throughout the watershed with the purpose of gathering long-term water quality data for both surface and groundwater. This network represents the largest and most comprehensive water quality monitoring program in the Niagara Peninsula. The NPCA monitoring network is operated in partnership with the Ontario Ministry of the Environment (MOE), Regional Municipality of Niagara, and City of Hamilton. The main objective of the NPCA Water Quality Monitoring Program is to assess water quality in local watersheds using a network of chemical and biological monitoring stations. The purpose of the 2009 Annual Report is to summarize the water quality data collected from these monitoring stations and provide recommendations for future monitoring and restoration initiatives.

2.0 SURFACE WATER QUALITY MONITORING PROGRAM

2.1 CHEMICAL MONITORING

The NPCA currently monitors surface water quality at 68 stations covering 40 watersheds. Grab samples are collected monthly during the ice-free season and analyzed for several parameters including nutrients, metals, bacteria, suspended solids, and general chemistry.

2.1.1 NIAGARA RIVER AOC TRIBUTARY MONITORING PROGRAM

The Niagara River Remedial Action Plan Stage 2 Report released in 1995 by Environment Canada and the MOE outlines 37 recommended remedial actions to restore the health of the watershed. Recommendation #29 is to develop and implement a Welland River and Niagara River tributaries monitoring program to monitor rural non-point sources of pollution and track the effectiveness of restoration efforts (MOE and Environment Canada 1995). In order to fulfill this recommendation, the Niagara River Area of Concern (AOC) Tributary Monitoring Program was implemented in 2003 through a partnership between the NPCA and the MOE. The objectives of the program are to establish baseline water quality conditions at selected tributaries and track changes in water quality over time. Monitoring stations for the Niagara River AOC Tributary Monitoring Program were selected as specified in the funding agreement and sampling was initiated in 2003. Stations were selected to both overlap with historic stations and fill data gaps where required. Annual monitoring reports for this program were completed in both 2004 and 2005 (NPCA 2004, 2005).

2.1.2 PROVINCIAL WATER QUALITY MONITORING NETWORK

In 2003 a partnership was established with the MOE through the Provincial Water Quality Monitoring Network (PWQMN) whereby NPCA staff collect monthly water samples at six stations located within the NPCA watershed and the MOE provides laboratory services. The PWQMN was established in 1964 to collect surface water quality information from rivers and streams at strategic locations throughout Ontario. Over time, stations have been added and discontinued in response to changing MOE and program-specific needs. The six NPCA PWQMN stations established in 2003 are

located on the Welland River, Twenty Mile Creek, Four Mile Creek, and upper Twelve Mile Creek.

2.1.3 OTHER WATER QUALITY MONITORING PROGRAMS

Several watersheds are monitored through other water quality monitoring programs. In 2002 a monitoring agreement was established with the City of Hamilton whereby NPCA staff collect monthly water samples at eleven stations located within the City of Hamilton's municipal boundaries and the City of Hamilton provides laboratory services. Monitoring stations were selected based on existing water quality information and local landuse issues. The headwaters of the Welland River and Twenty Mile Creek are located in the former Township of Glanbrook in the City of Hamilton. The Welland River and Twenty Mile Creek are the largest watersheds in the NPCA jurisdiction, covering a combined drainage area of 1,325 km^2. In 2003 a similar monitoring agreement was established with the Regional Municipality of Niagara whereby NPCA staff collect water samples at ten stations located within the NPCA watershed and the Region provides laboratory services.

In 2004 the NPCA began monitoring tributaries of Twenty Mile Creek as part of the Twenty Mile Creek Watershed Plan (NPCA 2006a). In 2006 the NPCA began monitoring additional stations in upper Twelve Mile Creek, Fifteen, Sixteen and Eighteen Mile Creeks, and South Niagara Falls creeks (Grassy Brook, Tee Creek, Bayer Creek) as part of their respective watershed plans. In 2007 the NPCA began monitoring creeks and municipal drains located along Lake Erie as part of the Lake Erie North Shore Watershed Plan. In 2008 the NPCA began monitoring Shriners Creek and Beaverdams Creek as part of the watershed plan that is currently under development for these watersheds.

2.2 BIOLOGICAL MONITORING

The NPCA also monitors surface water quality using benthic invertebrates as indicators of stream health. Water quality monitoring has historically relied heavily upon chemical testing as a means of measuring the quality of water but the advantages of biological monitoring using benthic invertebrates as indicators of water quality are well documented (Griffiths 1999, Jones ***et al.*** 2005). Due to their restricted mobility and habitat preferences benthic invertebrates usually remain in a localized area. As a result they are continuously subjected to the effects of all pollutants and environmental stream conditions over time, and as such can provide a broad overview of water quality related problems. They are abundant in all types of aquatic systems and can be easily collected and identified.

2.2.1 BIOLOGICAL MONITORING AND ASSESSMENT PROGRAM

The NPCA has been using benthic invertebrates as indicators of water quality since 1995 and is a leader in the field of biological monitoring in the Niagara Peninsula. Benthic invertebrate samples are collected annually during the spring and fall seasons using the Biological Monitoring and Assessment Program (BioMAP) developed by Dr. Ron Griffiths (Griffiths 1999). BioMAP water quality assessments have been completed at over 100 sites located throughout the NPCA watershed. BioMAP monitoring projects are also completed annually and biennially by the NPCA for Hamilton International Airport and the City of Hamilton Glanbrook Landfill to evaluate environmental management practices.

2.2.2 ONTARIO BENTHOS BIOMONITORING NETWORK

The NPCA is also involved in the development of the Ontario Benthos Biomonitoring Network (OBBN). The OBBN is a biomonitoring research initiative that was launched in 2002 and is jointly led by the MOE and Environment Canada. The goal of the OBBN is to provide a standardized benthic invertebrate sampling protocol for the province of Ontario. A secondary goal of the OBBN is to provide a biological complement to the chemistry-based PWQMN. The NPCA is an active participant in the development of the OBBN, and is providing on-going research support in the upper Twelve Mile Creek watershed. It is anticipated that the NPCA will use the OBBN protocol to collect benthic invertebrate samples once the network has been firmly established and the protocol can be applied to warm water clay-based watercourses such as the Welland River. In the interim, MOE has indicated that the BioMAP protocol is an acceptable method of collecting and analyzing benthic invertebrate data until the OBBN protocol has been finalized (Jones, personal communication 2006).

3.0 SURFACE WATER QUALITY INDICATOR PARAMETERS

The indicator parameters described in the following sections best reflect the range of water quality issues that are likely encountered in the watershed and are most useful in assessing relative stream quality. These indicator parameters and their respective surface water quality objectives are summarized in **Table 1**.

Table 1: Summary of surface water quality indicator parameters

CATEGORY	INDICATOR PARAMETER	OBJECTIVE	REFERENCE
Nutrients	Total phosphorus	0.03 mg/L	PWQO (MOE 1994)
Nutrients	Nitrate	13 mg/L	CWQG (CCME 2007)
Metals	Copper	0.005 mg/L	PWQO (MOE 1994)
Metals	Lead	0.005 mg/L	PWQO (MOE 1994)
Metals	Zinc	0.02 mg/L	PWQO (MOE 1994)
Microbiological	***Escherichia coli***	100 counts/100 mL	PWQO (MOE 1994)
Other	Chloride	100 mg/L	CWQG (CCME 2005)
Other	Suspended solids	25 mg/L	BC MOE (2001)
Biological	Benthic invertebrates	Unimpaired	BioMAP (Griffiths 1999)

3.1 CHLORIDE

Chloride is a naturally occurring substance found in all waters. Chloride can be toxic to aquatic organisms with acute toxic effects at high concentrations and chronic effects on growth and reproduction at lower concentrations. Chloride ions are conservative, which means that they are not degraded in the aquatic environment and tend to remain in solution. Chloride is extensively used in the form of sodium chloride and calcium chloride for salting of roadways and ice removal during the winter season. Other anthropogenic or human-derived sources of chloride include sewage, animal waste, storm and irrigation drainage, fertilizers, and industrial effluent. Due to natural variability there is currently no guideline for chloride in surface water. The Canadian Water Quality Guidelines (CWQG) for the Protection of Agricultural Water Uses indicate that the lower limit for chloride concentrations in irrigation water is 100 mg/L for certain crop types, including some tender fruit crops (CCME 2005).

3.2 NITRATE

Nitrate is the most common form of nitrogen that occurs in surface water. In aerobic or oxygen-rich water, bacteria convert ammonium and nitrite to nitrate through a process known as nitrification. In anaerobic or oxygen-depleted water, the process is reversed through denitrification. The nitrate ion is the most stable form of nitrogen in water and does not tend to combine with other ions in solution. Nitrate can be toxic to aquatic organisms and elevated concentrations contribute to excessive plant and algae growth in surface water. Anthropogenic sources of nitrate include sewage discharges, animal waste, fertilizers and pesticides. The province of Ontario is currently developing a surface water quality objective for nitrate. The interim Canadian Water Quality Guidelines for the Protection of Aquatic Life recommend that nitrate concentrations should not exceed 13 mg/L in surface water (CCME 2007).

3.3 TOTAL PHOSPHORUS

Phosphorus is a natural element found in rocks, soils and organic material and is an essential nutrient for plant growth. Phosphorus clings tightly to soil particles and is often associated with suspended sediment. Excessive phosphorus concentrations stimulate the overgrowth and decomposition of plants and algae. The decomposition of organic matter in turn depletes dissolved oxygen concentrations and stresses aquatic organisms such as fish and benthic invertebrates. Total phosphorus is a measure of all forms of phosphorus in a water sample, and includes biologically accessible phosphates. Anthropogenic sources of phosphorus include fertilizers, pesticides, and sewage discharges. The interim Ontario Provincial Water Quality Objective (PWQO) for total phosphorus in streams and rivers is 0.03 mg/L (MOE 1994).

3.4 SUSPENDED SOLIDS

Suspended solids are a measure of undissolved solid material in surface water and usually consist of silt, clay, plankton, and fine particles of organic and inorganic matter. Sources of suspended solids include soil erosion, stormwater, wastewater, and industrial effluent. Fine particles are significant carriers of phosphorus, metals and other contaminants. Concentrations of suspended solids vary seasonally and often peak during rain events. Due to natural variability in surface water there is currently no water quality guideline for suspended solids in Ontario. High concentrations of suspended solids in surface water can negatively impact aquatic organisms. Water quality guidelines for the protection of aquatic life from the British Columbia Ministry of the Environment recommend that the maximum concentration of suspended solids in surface water should not exceed 25 mg/L when background concentrations are between 25 and 250 mg/L (BC MOE 2001).

3.5 COPPER

Copper is an essential trace element that is toxic to aquatic organisms at elevated concentrations. In surface water copper tends to bind with organic matter and accumulate in streambed sediment. Anthropogenic sources of copper include industrial wastewater, sewage discharges and pesticides. The interim PWQO for copper is 0.005 mg/L (MOE 1994).

3.6 LEAD

Lead is a non-essential trace element that is toxic to aquatic organisms at elevated concentrations. Lead tends to bioaccumulate and can affect the central nervous system. Anthropogenic sources of lead include industrial wastewater, sewage discharges, municipal waste incineration, fertilizers and pesticides. The interim PWQO for lead is 0.005 mg/L (MOE 1994).

3.7 ZINC

Zinc is an essential trace element that is toxic to aquatic organisms at elevated concentrations. In surface water zinc tends to bind with organic matter and accumulate in streambed sediment. Anthropogenic sources of zinc include industrial wastewater, sewage discharges and stormwater runoff. The interim PWQO for zinc is 0.02 mg/L (MOE 1994).

3.8 *ESCHERICHIA COLI*

Escherichia coli (***E. coli***) is a type of fecal coliform bacteria that is commonly found in the intestines of warm-blooded animals and humans. ***E. coli*** is used as an indicator for the presence of sewage or animal waste in surface water, and the possible presence of pathogens (Tchobanoglous & Schroeder 1987). The PWQO for ***E. coli*** is 100 counts per 100 mL (MOE 1994).

3.9 BENTHIC INVERTEBRATES

Benthic invertebrates are the larger organisms inhabiting the substrate of watercourses for at least part of their life cycle. As a general rule, benthic invertebrates include those species whose body width exceeds 500 microns. Examples of benthic invertebrate species that are commonly found in the NPCA watershed include clams, snails, leeches, worms, and the larval stages of dragonflies, stoneflies, caddisflies, mayflies, and beetles.

Benthic invertebrate samples are collected during the spring and fall seasons using the BioMAP protocol developed by Dr. Ron Griffiths (1999). Once collected, counted and preserved, the benthic invertebrates are identified to genus level. Each genus is assigned a sensitivity value which is used to determine if sample water quality is ***impaired*** or ***unimpaired***. ***Unimpaired*** water quality is recognized by the occurrence of organisms whose environmental requirements and tolerances match those which would be expected at the site without the input of environmental stresses. At sites where water quality is ***impaired***, the organisms found are less sensitive and therefore more tolerant to environmental stresses than organisms which would have historically occurred. The benthic population at an impaired site would typically be dominated by these more tolerant species, and as a result biodiversity at the site would be quite low. The g***rey zone*** category indicates that results are inconclusive and that further assessment is required to determine whether water quality is ***impaired*** or ***unimpaired***.

4.0 SURFACE WATER QUALITY MONITORING RESULTS

The Water Quality Index (WQI) was used to summarize the indicator parameter data collected from NPCA surface water quality monitoring stations between 2002 and 2009. The WQI was developed by a sub-committee established under the Canadian Council for Ministers of the Environment (CCME) Water Quality Guidelines Task Group to provide a convenient means of summarizing complex water quality information and

communicating it to the public (CCME 2001). The WQI incorporates the number of parameters where water quality objectives have been exceeded, the frequency of exceedances within each parameter, and the amplitude of each exceedance. The index produces a number between 0 and 100 which represents the worst and best water quality, respectively. These numbers are divided into five descriptive categories that range from ***poor*** to ***excellent*** (**Table 2**). The CCME WQI has been used extensively by other agencies, including conservation authorities and provincial ministries, as a means of reporting water quality data.

Table 2: CCME Water Quality Index categories (CCME 2001)

CATEGORY	WATER QUALITY INDEX	DESCRIPTION
Excellent	95-100	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.
Good	80-94	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
Fair	65-79	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
Marginal	45-64	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
Poor	0-44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

The calculation of the WQI is dependent on the water quality parameters and objectives selected for analysis. The indicator parameters and objectives summarized in **Table 1** were used to determine the WQI for NPCA monitoring stations. Benthic invertebrate data is not included in the WQI and is presented separately. It is important to note that the water quality information presented in this report is limited by the size of the dataset which represents 1 to 8 years of data, depending on the station. The reliability of the data will increase over time as more data is collected and a wider range of water quality conditions is captured in the dataset.

4.1 WELLAND RIVER WATERSHED

The Welland River is the largest watershed in the NPCA jurisdiction with a total drainage area of 1,023 km^2. The watershed covers eleven local municipalities, originating in the Town of Ancaster and spanning the center of the Niagara Peninsula to its physical outlet in the City of Niagara Falls at the Niagara River (**Figure 1**). Over 70% of the watershed is classified as rural. The Welland River is part of the Niagara River Area of Concern (AOC) and is targeted for restoration through the Remedial Action Plan. As shown in **Appendix A**, 23 of the 68 surface water quality monitoring stations are located in the Welland River watershed, and ten of these 23 stations are located on the Welland River.

4.1.1 Welland River: Water Quality Index

As shown in **Table 3**, the calculated Water Quality Index (WQI) for the Welland River ranges from ***poor*** to ***marginal***. Based on the data collected to date, nine of ten Welland River stations have ***poor*** water quality and one station (WR010) was rated as ***marginal***. WQI results are illustrated in **Appendix A**. Index results and water quality monitoring data collected from the Welland River between 2002 and 2009 are summarized as follows:

- Water quality at headwater stations WR00A and WR000 are rated as ***poor***. Both headwater stations are impacted by elevated concentrations of ***E. coli*** and total phosphorus, which resulted in lower index values. Phosphorus concentrations

are particularly elevated at station WR00A when compared to other Welland River stations (**Figure 2**). Sources of phosphorus and bacteria include runoff from agricultural landuse, animal waste, soil erosion, and sewage discharges. Baseflow at both stations is influenced by groundwater discharge; however, summer observations indicate that baseflow at station WR00A is sustained entirely by groundwater discharge. Upstream alterations to hydrology and landuse may be impacting water quality at this site and continued monitoring is recommended.

- Water quality at headwater stations WR001 and WR002 is ***poor*** due to elevated concentrations of chloride, phosphorus, ***E. coli***, copper and zinc. Zinc concentrations at these stations were found to exceed the provincial objective in almost all samples collected and it may be caused by zinc leaching from galvanized roofing material from the airport complex. The Ontario Ministry of Environment has been notified by these exceedances and there will be an investigation of the zinc source. Chloride concentrations in excess of 1000 mg/L were observed at station WR002. Stormwater and glycol discharges from Hamilton International Airport are sources of impairment at these stations. In June of 2007 NPCA water quality staff observed a spill at station WR002 and reported this incident to the MOE Spills Action Centre. Subsequent cooperation between the NPCA, MOE and Hamilton International Airport resulted in further investigation by the MOE and the drafting of a Certificate of Approval to regulate and monitor stormwater discharges to the Welland River and Twenty Mile Creek originating from airport property. In 2010 the airport will be relocating its salt storage facility in order to eliminate potential salt storage impacts to station WR002; it is anticipated that this move will reduce the amount of chloride reaching this station. The NPCA will continue to monitor water quality at these stations in 2010.

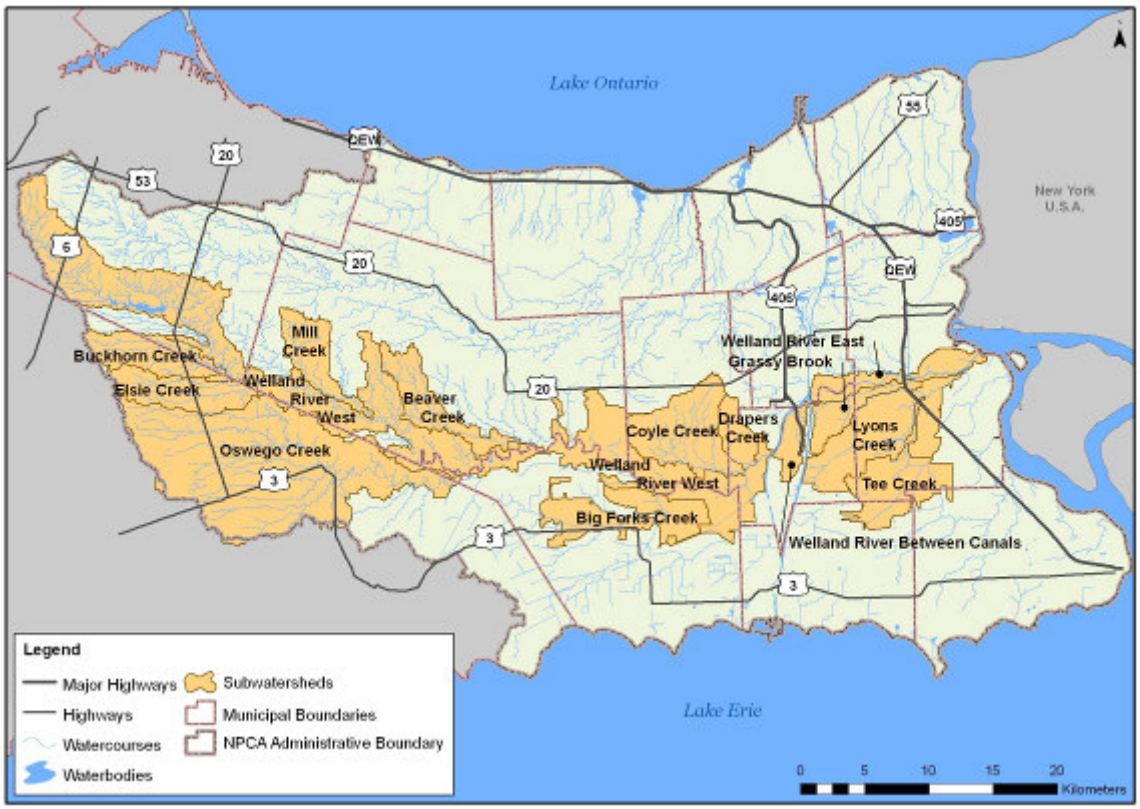

Figure 1: Map of the subwatersheds monitored for water quality within the Welland River watershed

- Based on current data, elevated concentrations of total phosphorus are a widespread cause of water quality impairment in the Welland River. 100% exceedance is observed at stations WR003 through to WR007, with total phosphorus concentrations up to 20 times greater than the provincial objective. As shown in **Figure 2**, mean total phosphorus concentrations at all stations greatly exceed the provincial objective. Manure from livestock operations, sewage discharges, soil erosion, fertilizers, and pesticides are sources of total phosphorus in the Welland River.

Table 3: Summary of NPCA water quality data for the Welland River (2001-2009)

STATION	WQI RATING	BIOMAP RATING	FACTORS AFFECTING WATER QUALITY
WR00A	Poor	Impaired	• Exceedances of ***E. coli*** and total phosphorus • Site has continuous baseflow due to sustained groundwater discharge but hydrology has been altered upstream • Inadequate upstream forest and riparian buffer
WR000	Poor	Impaired	• Exceedances of ***E. coli*** and total phosphorus • Site is vulnerable to intermittent baseflow due to seasonal fluctuations in groundwater discharge • Adequate upstream forest and riparian buffer • This section of the watercourse supports some sensitive taxa such as stoneflies and mayflies
WR001	Poor	Impaired	• Exceedances of chloride, ***E. coli***, total phosphorus and zinc • Watercourse is contaminated by runoff from airport property • Sedimentation caused by erosion and stormwater runoff
WR002	Poor	Impaired	• Exceedances of chloride, ***E. coli***, total phosphorus and zinc • Watercourse is contaminated by runoff from airport property • Sedimentation caused by erosion and stormwater runoff
WR003	Poor	Impaired	• Exceedances of chloride, copper, total phosphorus, suspended solids and zinc • Inadequate upstream forest and riparian buffer • Sedimentation caused by upstream agricultural runoff • Evidence of nutrient enrichment
WR004	Poor	Grey Zone	• Exceedances of copper, ***E. coli***, total phosphorus, suspended solids and zinc • Adequate upstream forest and riparian buffer • Site supports some sensitive taxa such as stoneflies and mayflies • Sedimentation caused by upstream agricultural runoff • Evidence of nutrient enrichment
WR005	Poor	Impaired	• Exceedances of nitrate, total phosphorus and suspended solids • Sedimentation caused by upstream agricultural runoff • Evidence of nutrient enrichment
WR006	Poor	Impaired	• Exceedances of nitrate, total phosphorus and suspended solids • Sedimentation caused by upstream agricultural runoff • Evidence of nutrient enrichment
WR007	Poor	Impaired	• Exceedances of nitrate and total phosphorus • Algae observed during summer months • Site is invaded by non-native Zebra Mussels
WR010	Marginal	n/a	• Exceedances of total phosphorus and ***E. coli***

- Water quality in the mid to lower reaches of the Welland River (i.e. stations WR003 to WR007) is rated as ***poor***. These stations are most impacted by nutrient enrichment and elevated concentrations of suspended solids. Sources of nutrients and suspended solids include runoff from agricultural landuse, soil erosion, sewage discharges, and animal waste.
- The best water quality rating for the Welland River is observed at station WR010 where water quality is rated as ***marginal***. Water quality at this location is improved by direct mixing with inflow from the Niagara River as it is redirected up the Welland River as part of the hydroelectric operations.

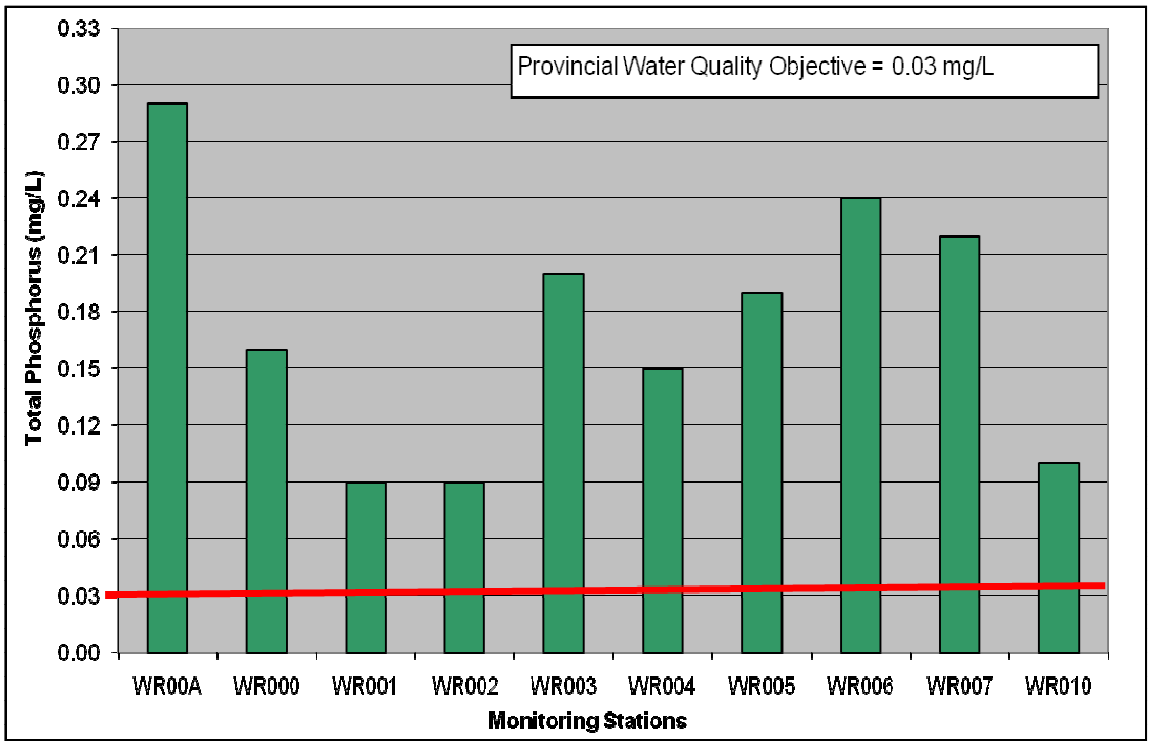

Figure 2: Mean total phosphorus concentrations in the Welland River 2002-2009

4.1.2 WELLAND RIVER: BIOMAP RESULTS

BioMAP results indicate that water quality is ***impaired*** at most stations in the Welland River (**Table 3**). Results from BioMAP assessments completed between 2001 and 2009 are illustrated in **Appendix B**. Benthic invertebrates at stations WR001 and WR002 are negatively impacted by stormwater and glycol discharges from Hamilton International Airport (HIA). The NPCA has completed annual BioMAP assessments for Hamilton International Airport since 1998 (NPCA 2009a). Recent NPCA reports recommend that HIA review its stormwater and glycol management practices in order to improve water quality in the upper Welland River. The NPCA also completes biennial BioMAP assessments of the Glanbrook Landfill for the City of Hamilton. BioMAP assessments completed between 1998 and 2008 indicate that water quality is impaired; however, there is no additional impairment resulting from the landfill (NPCA 2009b).

Station WR004 falls into the ***grey zone*** BioMAP category meaning the animal community at this site does not indicate a clear impairment nor does it fully match unimpaired conditions. The ***grey zone*** designation indicates that future BioMAP sampling will be planned in the future for this site to collect additional benthos information to determine the site's impairment status. The continuous flow from the Binbrook Reservoir and improved habitat are likely causes for the higher BioMAP rating at this station. Sediment loading, lack of in-stream habitat, and nutrient enrichment are the primary causes of impairment at all stations. A BioMAP assessment was not completed for WR010 due to high water depth and channel morphology. This station is located at the siphon where the Welland River flows beneath the Welland Canal and will require boat access for sample collection.

4.2 WELLAND RIVER TRIBUTARIES

Eleven tributaries of the Welland River are monitored through the NPCA Water Quality Monitoring Program. These tributaries include: Buckhorn Creek, Elsie Creek, Mill Creek, Oswego Creek, Beaver Creek, Big Forks Creek, Coyle Creek, Drapers Creek, Grassy Brook, Tee Creek, and Lyons Creek (**Figure 1**). Tributaries were selected based on drainage area, landuse, restoration projects, and watershed plans.

4.2.1 WELLAND RIVER TRIBUTARIES: WATER QUALITY INDEX

Based on the results of the Water Quality Index (WQI) ten of thirteen Welland River tributary stations have water quality that is rated as ***poor*** (**Table 4**). Stations CO001, LY003, and GR001 were found to have water quality rated as ***marginal***. WQI results are illustrated in **Appendix A.** Index results and water quality monitoring data collected from these tributaries between 2002 and 2009 are summarized as follows:

- ***E. coli*** concentrations frequently exceed the provincial objective in Buckhorn Creek, Big Forks Creek, Beaver Creek, Coyle Creek, Drapers Creek, Elsie Creek, Mill Creek, and Oswego Creek. Sources of ***E. coli*** in these tributaries include runoff from urban and agricultural landuse, sewage discharges, and the presence of waterfowl.
- Chloride concentrations frequently exceed the guideline for irrigation water in Elsie Creek, Buckhorn Creek, and Oswego Creek. Sources of chloride in these tributaries include stormwater runoff, de-icing salt applied to roads, and sewage discharges.
- Elevated concentrations of suspended solids are impacting water quality in Oswego Creek. Sources of suspended solids in this tributary include runoff from agricultural landuse and soil erosion.
- The ***marginal*** water quality rating for Lyons Creek station LY003 may be attributed in part to the influence of Lake Erie water pumped in from the Welland Canal at the headwaters of Lyons Creek.
- ***Marginal*** water quality ratings were again obtained at stations CO001 and GR001 in 2009. Station GR001 was added to the network in 2006 as part of the South Niagara Falls Watershed Plan and currently has very limited data. As a result this index rating may change as additional data is collected. Water quality at Coyle Creek station CO001 is improved by increased forest cover.
- Similar to the Welland River, water quality in all tributaries monitored is impacted by elevated concentrations of total phosphorus. High concentrations of phosphorus are a widespread cause of water quality impairment in these tributaries. 100% exceedance is observed at most stations with total phosphorus concentrations up to three orders of magnitude higher than the provincial objective. As shown in **Figure 3**, mean total phosphorus concentrations at all stations greatly exceed the provincial objective, particularly at stations BV001, BF001 and OS001. Of the 68 NPCA surface water quality monitoring stations, Beaver Creek station BV001 again has the highest mean concentration of total phosphorus in 2009. Manure from livestock operations, sewage discharges, soil erosion, fertilizers, and pesticides are likely sources of total phosphorus in these tributaries.

Table 4: Summary of NPCA water quality data for Welland River tributaries (2001-2009)

STATION	WATERSHED	WQI RATING	BIOMAP RATING	FACTORS AFFECTING WATER QUALITY
BF001	Big Forks Creek	Poor	Impaired	• Exceedances of nitrate, ***E. coli*** , total phosphorus and suspended solids • Algae observed during summer months
BU000	Buckhorn Creek	Poor	Impaired	• Exceedances of ***E. coli***, chloride and total phosphorus • High sediment loading evident from upstream erosion and runoff • Evidence of nutrient enrichment • Low baseflow conditions in summer • Adequate upstream forest and riparian buffer
BU001	Buckhorn Creek	Poor	Impaired	• Exceedances of ***E. coli***, chloride, and total phosphorus • High sediment loading evident from upstream erosion and runoff • Evidence of nutrient enrichment • Low baseflow conditions in summer • Adequate upstream forest and riparian buffer
BV001	Beaver Creek	Poor	Impaired	• Exceedances of ***E. coli*** and total phosphorus • Algae observed during summer months
CO001	Coyle Creek	Marginal	Impaired	• Exceedances of ***E. coli***, total phosphorus and suspended solids • High sediment loading evident from upstream erosion and runoff • Evidence of nutrient enrichment • Site invaded by non-native Zebra Mussels • Adequate upstream forest and riparian buffer
DR001	Drapers Creek	Poor	Impaired	• Exceedances of ***E. coli*** and total phosphorus • High sediment loading evident from upstream runoff • Site vulnerable to contaminants in runoff from urbanized sections of the watercourse and urban encroachment • Algae observed during summer months
EL001	Elsie Creek	Poor	Impaired	• Exceedances of chloride, ***E. coli*** and total phosphorus • High sediment loading evident from upstream erosion and runoff • Nutrient enrichment from upstream agricultural areas • Algae observed during summer months
GR001	Grassy Brook	Marginal	Impaired	• Exceedances of total phosphorus • Algae observed during summer months
TE001	Tee Creek	Poor	Impaired	• Exceedances of total phosphorus and ***E. coli***
LY003	Lyons Creek	Marginal	Impaired	• Exceedances of total phosphorus • Site is invaded by non-native Zebra mussels
MI001	Mill Creek	Poor	Impaired	• Exceedances of total phosphorus and ***E. coli***
OS001	Oswego Creek	Poor	Impaired	• Exceedances of ***E. coli***, total phosphorus and suspended solids
OS002	Oswego Creek	Poor	Impaired	• Exceedances of chloride, ***E. coli***, total phosphorus and suspended solids • Sediment loading evident from upstream erosion or runoff • Nutrient enrichment from upstream agricultural areas

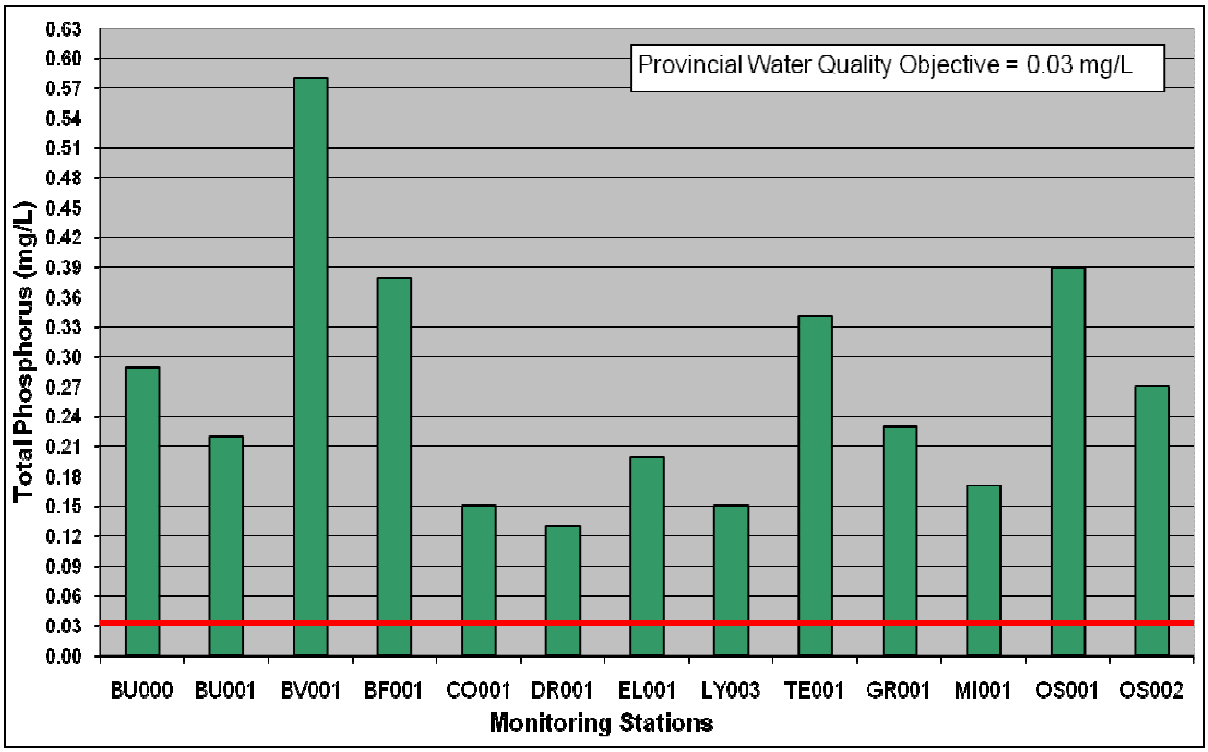

Figure 3: Mean total phosphorus concentrations in Welland River tributaries 2002-2009

4.2.2 WELLAND RIVER TRIBUTARIES: BIOMAP RESULTS

BioMAP results indicate that water quality is ***impaired*** at all Welland River tributary stations currently monitored (**Table 4**). Results from BioMAP assessments completed between 2001 and 2009 are illustrated in **Appendix B**. Sediment loading, lack of in-stream habitat, and nutrient enrichment are the primary causes of impairment at all stations. Buckhorn Creek BioMAP assessments are completed biennially by the NPCA for the City of Hamilton as part of the Glanbrook Landfill monitoring plan. BioMAP assessments completed between 1998 and 2008 indicate that water quality is impaired; however, there is no additional impairment resulting from the landfill (NPCA 2009b). BioMAP assessments were completed at Beaver Creek station BV001 and Mill Creek station MI001 for the first time in 2009. Water quality at these stations was found to be impaired. Sediment loading, lack of in-stream habitat, and nutrient enrichment are the primary causes of impairment at all stations.

4.3 TWENTY MILE CREEK WATERSHED

The Twenty Mile Creek watershed is the second largest watershed in the NPCA jurisdiction with a total drainage area of 302 km^2. Eight of 68 NPCA surface water quality monitoring stations are located within the Twenty Mile Creek watershed. There are five stations on the main channel and three stations for each of the subwatersheds which include Spring Creek, North Creek and Gavora Ditch (**Figure 4**). There is no surface water monitoring station for Sinkhole Creek since flow in this subwatershed is highly intermittent due to low baseflow and karst topography.

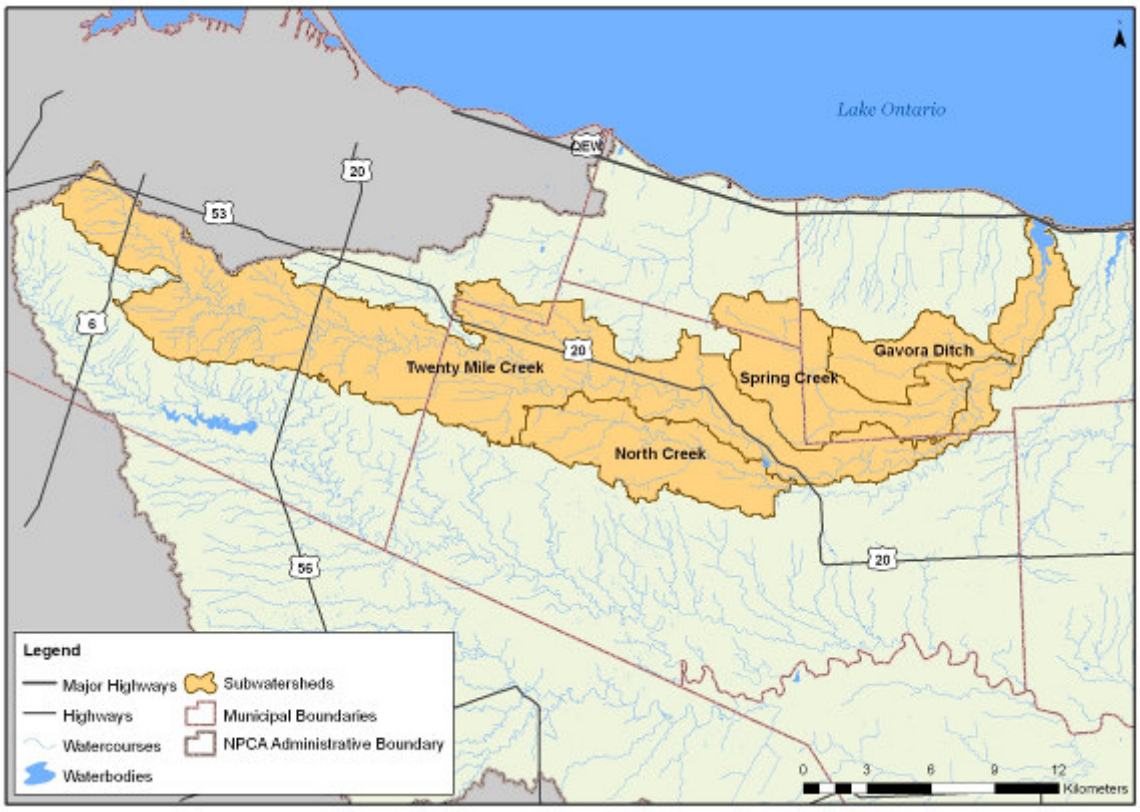

Figure 4: Map of the subwatersheds monitored for water quality within the Twenty Mile Creek watershed

4.3.1 TWENTY MILE CREEK WATERSHED: WATER QUALITY INDEX

Based on the results of the Water Quality Index (WQI) seven of eight Twenty Mile Creek watershed stations have water quality that is rated as ***poor*** (**Table 5**). Water quality at Gavora Ditch station GV001 is rated as ***marginal***. WQI results are illustrated in **Appendix A**. Index results and water quality monitoring data collected from the Twenty Mile Creek watershed between 2002 and 2009 is summarized as follows:

- Water quality at all monitoring stations is impacted by elevated concentrations of total phosphorus. Total phosphorus is a widespread cause of water quality impairment in the Twenty Mile Creek watershed, and frequent exceedances of the provincial objective occur at all stations. As shown in **Figure 5**, mean total phosphorus concentrations for the Twenty Mile Creek watershed greatly exceed the provincial objective at all stations, particularly stations TN004, GV001 and NC001. Manure from livestock operations, sewage discharges, soil erosion, fertilizers, and pesticides are likely sources of total phosphorus in this watershed.
- ***E. coli*** concentrations frequently exceed the provincial objective throughout the Twenty Mile Creek watershed. Sources of ***E. coli*** include runoff from urban and agricultural landuse, animal waste, sewage discharges, and the presence of waterfowl.
- Chloride concentrations frequently exceed the guideline for irrigation water at stations TN001, TN003, TN004 and TN006. Sources of chloride at these stations include runoff from urban and agricultural landuse, de-icing salt from roads, and sewage discharges.
- Copper and zinc concentrations exceed the provincial objective in the mid to upper reaches of Twenty Mile Creek. Sources of copper and zinc in upper reaches include runoff from urban and agricultural landuse.

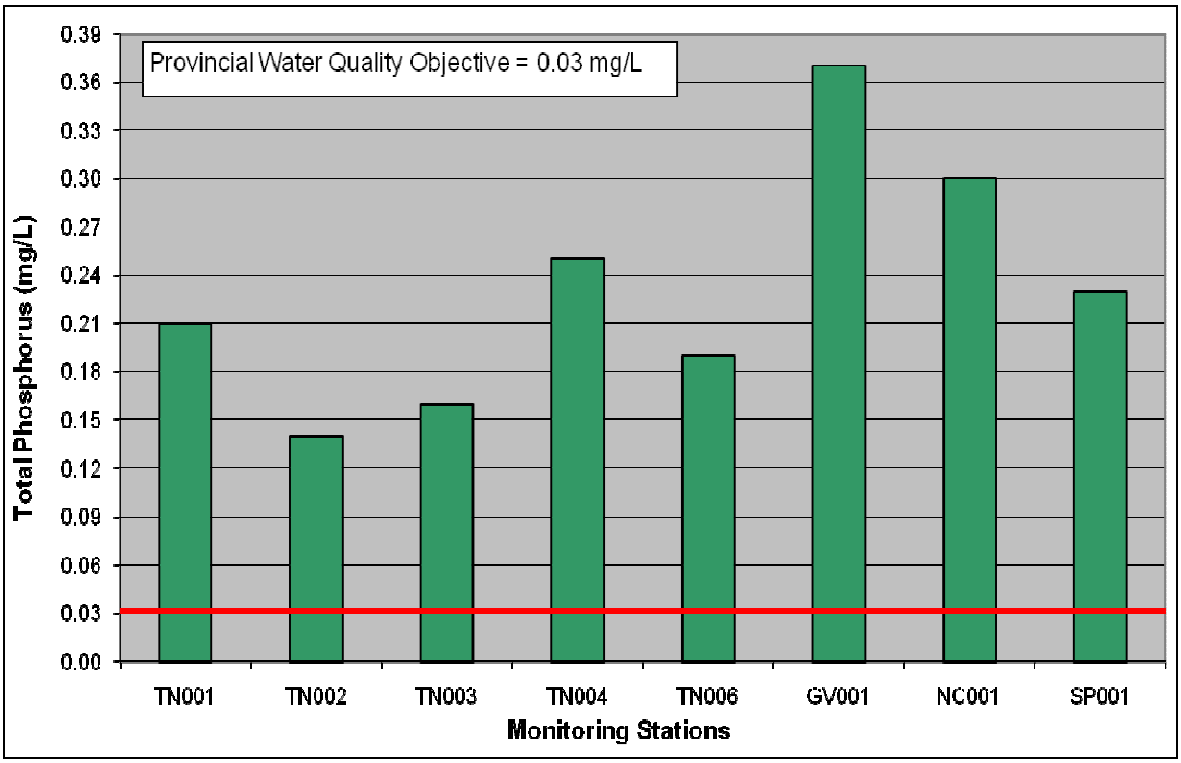

Figure 5: Mean total phosphorus concentrations in the Twenty Mile Creek watershed 2002-2009

- Elevated concentrations of suspended solids are impacting water quality throughout the watershed, particularly in the upper reaches. TN001 receives stormwater from upstream retention ponds and accelerated sedimentation is observed at this site. Sources of suspended solids include runoff from urban and agricultural landuse and soil erosion.
- A ***marginal*** water quality rating was again obtained at Gavora Ditch station GV001 in 2009. This station was added to the network in 2005 as part of the Twenty Mile Creek Watershed Plan (NPCA 2006a); however, the dataset for this station is very limited due to the intermittent nature of the watercourse and the presence of karst topography. This index rating will likely decrease over time as additional data is collected due to high total phosphorus concentrations.

4.3.2 Twenty Mile Creek Watershed: BioMAP Results

BioMAP results indicate that water quality is ***impaired*** at most Twenty Mile Creek stations currently monitored (**Table 5**). Results from BioMAP assessments completed between 2001 and 2009 are illustrated in **Appendix B**. Reduced baseflow, high sediment loading due to erosion, lack of in-stream habitat, and nutrient enrichment are primary causes of impairment at these stations. The benthic invertebrate community at station TN001 is also negatively impacted by a non-native invasive snail species. Outlet station TN006 is in the ***grey zone*** BioMAP category which indicates that water quality is neither ***impaired*** nor ***unimpaired*** and that further sampling is required. Continuous flow, groundwater discharge from the Niagara Escarpment, and improved habitat are likely causes for the ***grey zone*** BioMAP rating obtained at this station.

Table 5: Summary of NPCA water quality data for the Twenty Mile Creek watershed (2001-2009)

STATION	WATERSHED	WQI RATING	BIOMAP RATING	FACTORS AFFECTING WATER QUALITY
TN001	Twenty Mile Creek	Poor	Impaired	• Exceedances of chloride, ***E. coli***, total phosphorus, suspended solids, copper and zinc • High sediment loading from upstream stormwater retention ponds • Benthic community consists mainly of worms and is consistent with nutrient enrichment • Site invaded by the non-native Chinese Mystery Snails • Algae observed during the summer months
TN002	Twenty Mile Creek	Poor	Impaired	• Exceedances of ***E. coli***, total phosphorus, copper and zinc • Nutrient enrichment from upstream agricultural areas • Sediment loading evident from upstream erosion and runoff • Lack of adequate riparian buffer • Algae observed during the summer months
TN003	Twenty Mile Creek	Poor	Impaired	• Exceedances of chloride, ***E. coli***, total phosphorus, copper and zinc • Algae observed during the summer months
TN004	Twenty Mile Creek	Poor	Impaired	• Exceedances of chloride, ***E. coli***, total phosphorus, suspended solids and zinc • Algae observed during the summer months
TN006	Twenty Mile Creek	Poor	Grey Zone	• Exceedances of chloride, total phosphorus and ***E. coli*** • Adequate upstream forest buffer • Some severe erosion noted along sample reach • Site supports sensitive taxa such as caddisflies and water pennies • Algae observed during the summer months
NC001	North Creek	Poor	Impaired	• Exceedances of ***E. coli***, total phosphorus and suspended solids • Nutrient enrichment from upstream agricultural areas • Watercourse lacking adequate upstream forest and riparian buffer • Algae observed during the summer months
SP001	Spring Creek	Poor	Impaired	• Exceedances of ***E. coli*** and total phosphorus • Nutrient enrichment from upstream agricultural areas • Site is vulnerable to intermittent baseflow and water stagnation • Algae observed during the summer months
GV001	Gavora Ditch	Marginal	Impaired	• Exceedances of total phosphorus • This section of the watercourse supports sensitive taxa such as caddisflies • Low baseflow conditions in summer (intermittent due to karst) • Nutrient enrichment from upstream agricultural areas • Algae observed during summer months

4.4 LAKE ONTARIO TRIBUTARIES

Twelve tributaries discharging to Lake Ontario are monitored through the NPCA Water Quality Monitoring Program. These tributaries include: Forty Mile Creek, Eighteen Mile Creek, Sixteen Mile Creek, Fifteen Mile Creek, Twelve Mile Creek, Eight Mile Creek, Six Mile Creek, Four Mile Creek, Two Mile Creek, One Mile Creek, Shriners Creek, and Beaver Dam Creek (**Figure 6**). Outlet stations on Eight, Six and One Mile Creeks in Niagara-On-The-Lake were added to the network in 2009 as part of the NPCA Niagara-On-The-Lake Watershed Restoration Program. Twenty Mile Creek is also a tributary of Lake Ontario but is presented separately due to the relatively large size of the watershed.

4.4.1 LAKE ONTARIO TRIBUTARIES: WATER QUALITY INDEX

As shown in **Table 6**, the calculated Water Quality Index (WQI) for Lake Ontario tributaries ranges from ***poor*** to ***fair***. Upper Twelve Mile Creek station TW006 again achieved a rating of ***fair***, eleven stations are rated as ***marginal,*** and ten stations are rated as ***poor*** in 2009. WQI results are illustrated in **Appendix A**.

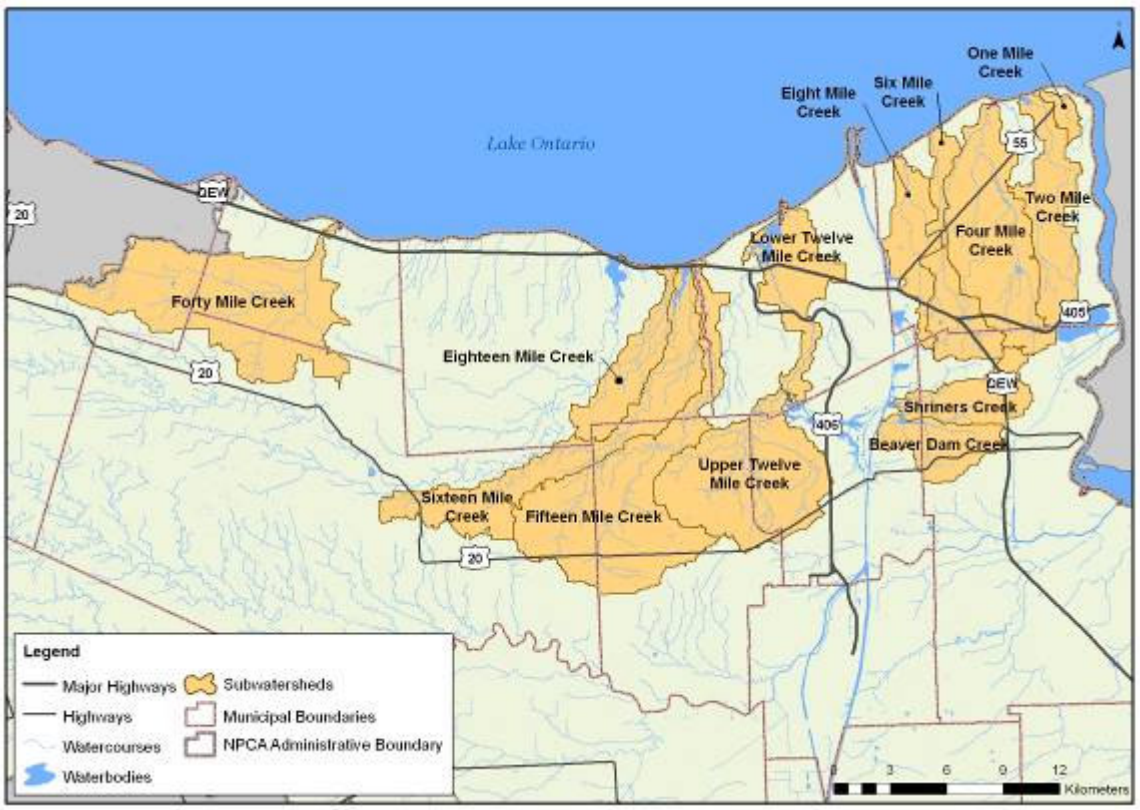

Figure 6: Map of the subwatersheds draining to Lake Ontario that are monitored for water quality

Index results and water quality monitoring data collected from Lake Ontario tributaries between 2003 and 2009 are summarized as follows:

- Water quality at Forty Mile Creek station FM001 is impacted by groundwater discharge from upstream quarry operations. Chloride concentrations frequently exceed the guideline for irrigation quality; however, this is largely attributed to groundwater input. Other potential sources of chloride include road salt applied for de-icing and sewage discharges. Runoff from urban and agricultural landuse results in frequent exceedances of ***E. coli*** and total phosphorus at this station.
- Four Mile Creek and Two Mile Creek are agricultural watersheds that are primarily impacted by high nutrient concentrations. Nitrate and total phosphorus concentrations routinely exceed water quality objectives. Two Mile Creek is also impacted by high concentrations of chloride and ***E. coli***. Sources include sewage discharges, animal waste, and runoff from surrounding landuse. As shown in **Figure 7**, mean total phosphorus concentrations greatly exceed the provincial objective at all stations, particularly Four Mile Creek station FU004.
- Eighteen, Sixteen, and Fifteen Mile Creeks are primarily agricultural watersheds and are impacted by elevated concentrations of chloride and total phosphorus. As shown in **Figure 7**, phosphorus concentrations are especially elevated at Fifteen Mile Creek station FF001 and Sixteen Mile Creek station SX001. Erosion

and sediment loading also result in elevated concentrations of suspended solids at Fifteen Mile Creek station FF001.

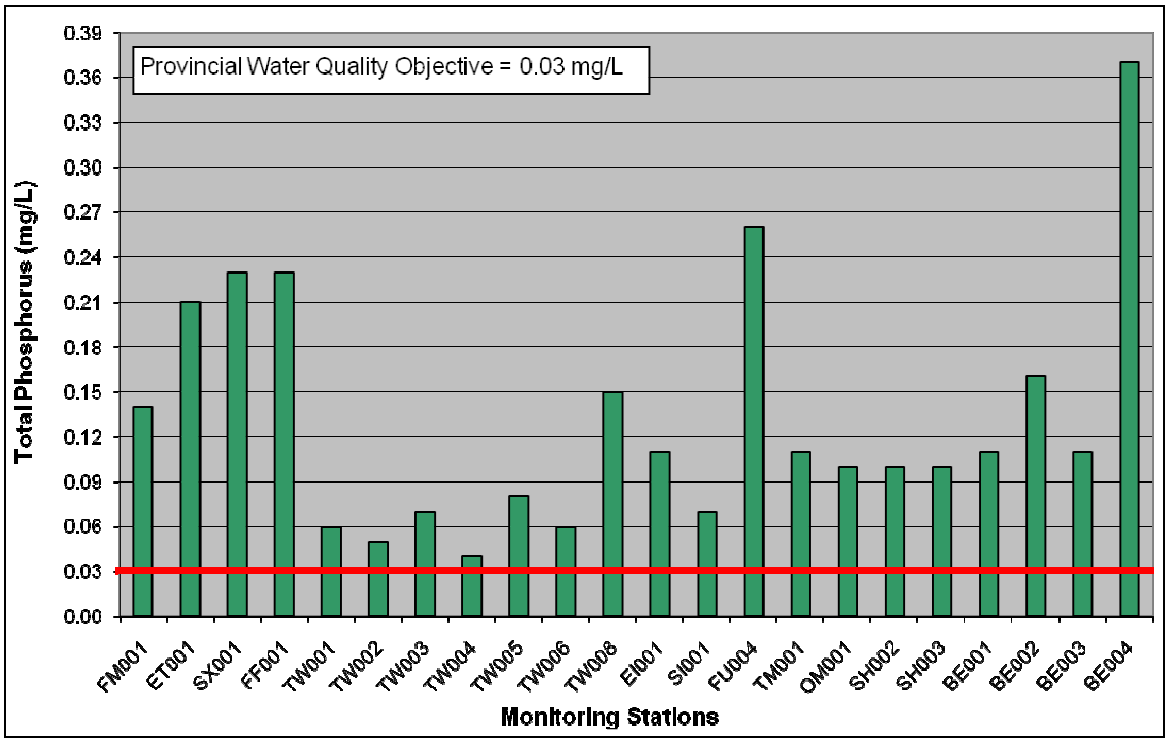

Figure 7: Mean total phosphorus concentrations in Lake Ontario tributaries 2003-2009

- Upper Twelve Mile Creek stations TW001 through TW006 represent some of the best water quality in the Niagara Peninsula; however, they are impacted by frequent exceedances of total phosphorus, ***E. coli***, and suspended solids due to high flows, erosion, and runoff from urban and agricultural landuse. These stations are also impacted by high summer water temperatures which exceed the optimal thermal range for brook trout (Michaud and Diamond 2006, 2007).
- Shriners Creek stations SH002 and SH003 are rated as ***marginal***; however, there is limited data for these stations since they were added to the network in 2008. These index ratings are expected to change over time as additional data is collected.
- Beaver Dam Creek stations BE001-BE004 were also added to the monitoring network in 2008 and as a result there is limited data available. Index ratings range from ***poor*** to ***fair***; however, these ratings are expected to change over time as additional data is collected. Elevated total phosphorus concentrations were again observed at all Beaver Dam Creek stations in 2009; however, concentrations were notably higher at station BE004 with a mean concentration of 0.37 mg/L.
- Stations EI001 and SI001 on Eight and Six Mile Creeks in Niagara-On-The-Lake also achieved ratings of ***marginal***, however, these stations were added to the network in 2009 and as a result there is limited data available. Index ratings are expected to change over time as additional data is collected.

4.4.2 LAKE ONTARIO TRIBUTARIES: BIOMAP RESULTS

BioMAP results indicate that water quality is ***impaired*** at most Lake Ontario tributary stations (**Table 6**). Results from BioMAP assessments completed between 2001 and 2009 are illustrated in **Appendix B**. Sediment loading, nutrient enrichment, and the lack of in-stream habitat are the primary causes of impairment at these stations. G***rey zone*** results were obtained at stations FM001 and TW005, indicating that water quality assessments are inconclusive and that further sampling is required. Upper Twelve Mile Creek stations TW002, TW004, and TW006 located on the Effingham tributary are rated as ***unimpaired***. The Effingham tributary of upper Twelve Mile Creek is the only watercourse in the NPCA watershed that consistently achieves this rating. These sites are able to support several sensitive taxa such as mayflies and stoneflies due to cooler water temperatures, excellent riparian buffer and in-stream habitat, and suitable water quality.

BioMAP assessments were completed for the first time at Beaver Dam Creek stations BE001, BE003 and BE004, Shriners Creek station SH003, Eight Mile Creek station EI001, and Six Mile Creek station SI001. All stations achieved BioMAP ratings of ***impaired***. Beaver Dam Creek station BE002 was not sampled due to poor accessibility.

Table 6: Summary of NPCA water quality data for Lake Ontario tributaries (2001-2009)

STATION	WATERSHED	WQI RATING	BIOMAP RATING	FACTORS AFFECTING WATER QUALITY
FM001	Forty Mile Creek	Poor	Grey Zone	• Exceedances of chloride, ***E. coli***, and total phosphorus • Adequate upstream forest cover • This section of the watercourse supports some sensitive taxa such as stoneflies and mayflies • Vulnerable to contaminants from upstream urban and agricultural areas • Receives highly mineralized groundwater discharge from an active quarry • Algae observed during summer months
ET001	Eighteen Mile Creek	Poor	Impaired	• Exceedances of chloride, total phosphorus and ***E. coli*** • Vulnerable to contaminants from upstream agricultural areas • Very low density of benthic invertebrates despite a relative abundance of habitat indicates that degraded water quality is impacting the benthic community
FF001	Fifteen Mile Creek	Poor	Impaired	• Exceedances of chloride, total phosphorus and suspended solids • Algae observed during summer months
SX001	Sixteen Mile Creek	Poor	Impaired	• Exceedances of chloride, total phosphorus, suspended solids, and ***E.coli*** • Sedimentation caused by upstream erosion • Vulnerable to contaminants from upstream agricultural areas
EI001	Eight Mile Creek	Marginal	Impaired	• Exceedances of total phosphorus and ***E. coli*** • Vulnerable to contaminants from upstream agricultural areas
SI001	Six Mile Creek	Marginal	Impaired	• Exceedances of chloride, total phosphorus and ***E. coli*** • Vulnerable to contaminants from upstream agricultural areas
FU004	Four Mile Creek	Poor	Impaired	• Exceedances of nitrate, total phosphorus, suspended solids, and ***E. coli*** • Lack of adequate riparian buffer • Algae observed during summer months • Vulnerable to contaminants from upstream urban and agricultural areas
TM001	Two Mile Creek	Poor	Impaired	• Exceedances of chloride, ***E. coli***, nitrate and total phosphorus • High proportion of shredders indicating an overabundance of aquatic vegetation and suggestive of nutrient enrichment • Vulnerable to contaminants from upstream urban and agricultural areas • Algae observed during summer months
OM001	One Mile Creek	Poor	Impaired	• Exceedances of chloride, total phosphorus and ***E. coli*** • Vulnerable to contaminants from upstream residential and agricultural areas

TW001	Twelve Mile Creek	Marginal	Impaired	• Exceedances of total phosphorus, suspended solids and ***E. coli*** • Benthic invertebrate community impacted by lack of adequate riparian buffer and in-stream habitat
TW002	Twelve Mile Creek	Poor	Unimpaired	• Exceedances of total phosphorus, suspended solids and ***E. coli*** • Excellent upstream forest and riparian buffer • This section of the watercourse supports sensitive taxa such as stoneflies and mayflies
TW003	Twelve Mile Creek	Marginal	Impaired	• Exceedances of total phosphorus and ***E. coli*** • Good upstream forest and riparian buffer • Benthic invertebrate community impacted by lack of in-stream habitat • Vulnerable to contaminants from upstream urban and agricultural areas
TW004	Twelve Mile Creek	Marginal	Unimpaired	• Exceedances of total phosphorus, nitrate and ***E. coli*** • Excellent upstream forest and riparian buffer • Vulnerable to contaminants from upstream agricultural areas and golf course • This section of the watercourse supports sensitive taxa such as stoneflies and mayflies
TW005	Twelve Mile Creek	Marginal	Grey Zone	• Exceedances of total phosphorus, ***E. coli***, and suspended solids • Excellent upstream forest and riparian buffer • Sedimentation caused by upstream erosion • Vulnerable to contaminants from upstream urban and agricultural areas
TW006	Twelve Mile Creek	Fair	Unimpaired	• Exceedances of total phosphorus, ***E. coli***, and suspended solids • Excellent upstream forest and riparian buffer • This section of the watercourse supports sensitive taxa such as stoneflies and mayflies • Channel morphology indicative of conditions that are in equilibrium with • stream flow and sediment discharge
TW008	Twelve Mile Creek	Poor	Impaired	• Exceedances of chloride, total phosphorus and ***E.coli*** • Low baseflow conditions in summer • Vulnerable to contaminants from upstream agricultural areas
SH002	Shriners Creek	Marginal	Impaired	• Exceedances of chloride, total phosphorus and ***E.coli*** • Located immediately downstream of NPCA constructed wetland designed or stormwater management • Algae observed during summer months • Vulnerable to contaminants from upstream urban areas
SH003	Shriners Creek	Marginal	Impaired	• Exceedances of chloride, total phosphorus, ***E.coli*** and suspended solids • Adequate upstream forest and riparian buffer in some reaches • Vulnerable to contaminants from upstream urban and agricultural areas
BE001	Beaver Dam Creek	Marginal	Impaired	• Exceedances of chloride, total phosphorus and ***E.coli*** • Algae observed during summer months • Vulnerable to contaminants from upstream agricultural areas
BE002	Beaver Dam Creek	Fair	n/a	• Exceedances of total phosphorus and suspended solids • Stream channel flows into large on-line pond at this station resulting in dilution • Vulnerable to contaminants from upstream agricultural areas and golf course
BE003	Beaver Dam Creek	Poor	Impaired	• Exceedances of chloride, total phosphorus, ***E. coli***, suspended solids and metals • Lack of adequate riparian buffer • Algae observed during summer months • Vulnerable to contaminants from upstream urban areas
BE004	Beaver Dam Creek	Marginal	Impaired	• Exceedances of total phosphorus and ***E. coli*** • Adequate riparian buffer • Vulnerable to contaminants from upstream industrial areas

4.5 NIAGARA RIVER TRIBUTARIES

Four tributaries discharging to the Niagara River are monitored through the NPCA Water Quality Monitoring Program. These tributaries include: Bayer Creek, Black Creek, Frenchman's Creek, and Usshers Creek (**Figure 8**).

4.5.1 NIAGARA RIVER TRIBUTARIES: WATER QUALITY INDEX

Based on the results of the Water Quality Index (WQI) most Niagara River tributary stations are rated as having ***poor*** water quality (**Table 7**). Bayer Creek station BA001 is rated as having ***marginal*** water quality. WQI results are illustrated in **Appendix A**. Index results and water quality monitoring data collected from Niagara River tributaries between 2003 and 2009 are summarized as follows:

- Water quality is negatively impacted by high concentrations of total phosphorus with 100% exceedance observed at all stations. As shown in **Figure 9**, mean total phosphorus concentrations exceed the provincial objective at all stations, particularly at Usshers Creek station US001. Sources of phosphorus at these stations include runoff from urban and agricultural landuse, sewage discharges, and soil erosion.

Figure 8: Map of the subwatersheds monitored for water quality in the Niagara River watershed outside of the Welland River

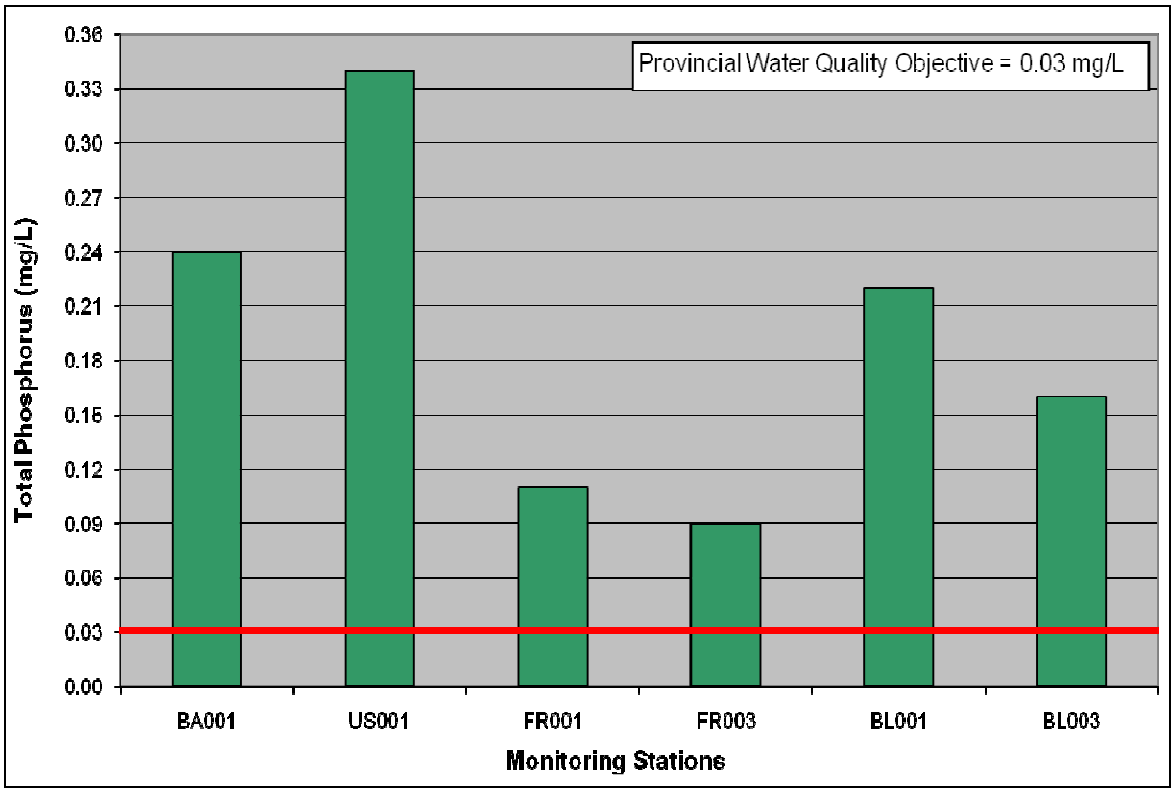

Figure 9: Mean total phosphorus concentrations in Niagara River tributaries 2003-2009

- Elevated concentrations of ***E. coli*** are frequently observed at stations BL001, FR001 and FR003. Sources of ***E. coli*** at these stations include sewage discharges, animal waste, and runoff from urban and agricultural landuse.
- Water quality at Frenchman's Creek station FR003 is influenced by discharge from an upstream retention pond which collects stormwater and washwater from a horse racing facility. Runoff from surrounding landuse may also contribute to elevated concentrations of chloride and nutrients at this station.
- A ***marginal*** water quality rating was again obtained at Bayer Creek station BA001 in 2009. This station was added to the network in 2006 as part of the South Niagara Falls Watershed Plan and as a result the dataset for this station is limited. This index rating may change as additional data is collected.

4.5.2 Niagara River Tributaries: BioMAP Results

BioMAP results indicate that water quality is ***impaired*** at all Niagara River tributary stations (**Table 7**). Results from BioMAP assessments completed between 2001 and 2009 are illustrated in **Appendix B**. Sediment loading, reduced baseflow, lack of in-stream habitat, and nutrient enrichment are primary causes of impairment at these stations. BioMAP samples have not been collected from station BL003 due to high water depth, channel morphology, and access restrictions.

Table 7: Summary of NPCA water quality data for Niagara River tributaries (2001-2009)

STATION	WATERSHED	WQI RATING	BIOMAP RATING	FACTORS AFFECTING BIOMAP RATING
BA001	Bayer Creek	Marginal	Impaired	• Exceedances of chloride, total phosphorus and ***E. coli*** • Nutrient and chloride enrichment from upstream urban and agricultural areas • Lack of riparian buffer
BL001	Black Creek	Poor	Impaired	• Exceedances of ***E. coli***, total phosphorus and suspended solids • Benthic community indicative of warm water conditions • Nutrient enrichment from upstream agricultural areas • Site is vulnerable to low baseflow and water stagnation
BL003	Black Creek	Poor	n/a	• Exceedances of total phosphorus
FR001	Frenchman's Creek	Poor	Impaired	• Exceedances of ***E. coli***, total phosphorus and suspended solids • Sediment loading due to upstream erosion and runoff • Vulnerable to contaminants from upstream urban and agricultural areas • Algae observed during summer months
FR003	Frenchman's Creek	Poor	Impaired	• Exceedances of chloride, ***E. coli*** and total phosphorus • Site receives discharge from upstream retention pond • Vulnerable to contaminants from upstream urban and agricultural areas • Algae observed during summer months
US001	Usshers Creek	Poor	Impaired	• Exceedances of total phosphorus and chloride • Benthic community consists mainly of worms that are consistent with nutrient enrichment • Site is vulnerable to low baseflow and stagnation • Algae observed during summer months

4.6 LAKE ERIE TRIBUTARIES

Eight tributaries discharging to Lake Erie are monitored through the NPCA Water Quality Monitoring Program. These tributaries include: Beaver Dam Creek, Casey Drain, Eagle Marsh Drain, Krafts Drain, Low Banks Drain, Point Abino Drain, Six Mile Creek, and the Wignell Drain (**Figure 10**). These stations were added as part of the Lake Erie North Shore Watershed Plan, which was initiated by the NPCA in 2007. Water quality is also monitored at the Wainfleet Wetlands Conservation Area, which is a large abandoned quarry that is owned by the NPCA.

4.6.1 LAKE ERIE TRIBUTARIES: WATER QUALITY INDEX

Based on the results of the Water Quality Index (WQI) three of nine Lake Erie tributary stations are rated as having ***poor*** water quality, four stations are rated as ***margina***l, station PA001 is rated as ***fair***, and station WW001 is rated as ***good*** (**Table 8**). WQI results are illustrated in **Appendix A**.

Index results and water quality monitoring data collected from Lake Erie tributaries between 2007 and 2009 are summarized as follows:

- Water quality is negatively impacted by high concentrations of total phosphorus with exceedances observed at all stations. As shown in **Figure 11**, mean total phosphorus concentrations exceed the provincial objective at all stations, particularly at Wignell Drain station WD001 and Casey Drain station CD001.

Sources of phosphorus at these stations include runoff from urban and agricultural landuse, sewage discharges, and soil erosion. Wainfleet Wetlands Conservation Area station WW001 again has the lowest mean total phosphorus concentration of all stations monitored in 2009.

Figure 10: Map of the subwatersheds monitored for water quality along the north shore of Lake Erie

- Elevated concentrations of ***E. coli*** are frequently observed at most stations. Sources of ***E. coli*** at these stations include sewage discharges, animal waste, and runoff from urban and agricultural landuse.
- Water quality at Eagle Marsh Drain station EM001 and Wignell Drain station WD001 is influenced by discharge from bedrock quarries located upstream. Chloride concentrations frequently exceed the guideline for irrigation quality at station EM001; however, this is largely attributed to groundwater input. Other potential sources of chloride include road salt applied for de-icing and sewage discharges.
- Wainfleet Wetlands Conservation Area station WW001 has achieved the highest water quality index rating for the second year in a row. Water quality at this station is improved by inflow from groundwater and Lake Erie.
- Generally, the WQI ratings obtained at Lake Erie tributary stations are higher than other parts of the NPCA watershed; however, it is important to note that these stations were recently added to the network in 2007. As such, the datasets for these stations are limited and these index ratings may change as additional data is collected.
- Nickel is not included in the WQI calculation; however, nickel concentrations were found to frequently exceed the Provincial Water Quality Objective at Beaver Dam Creek station BD001 and Wignell Drain station WD001.

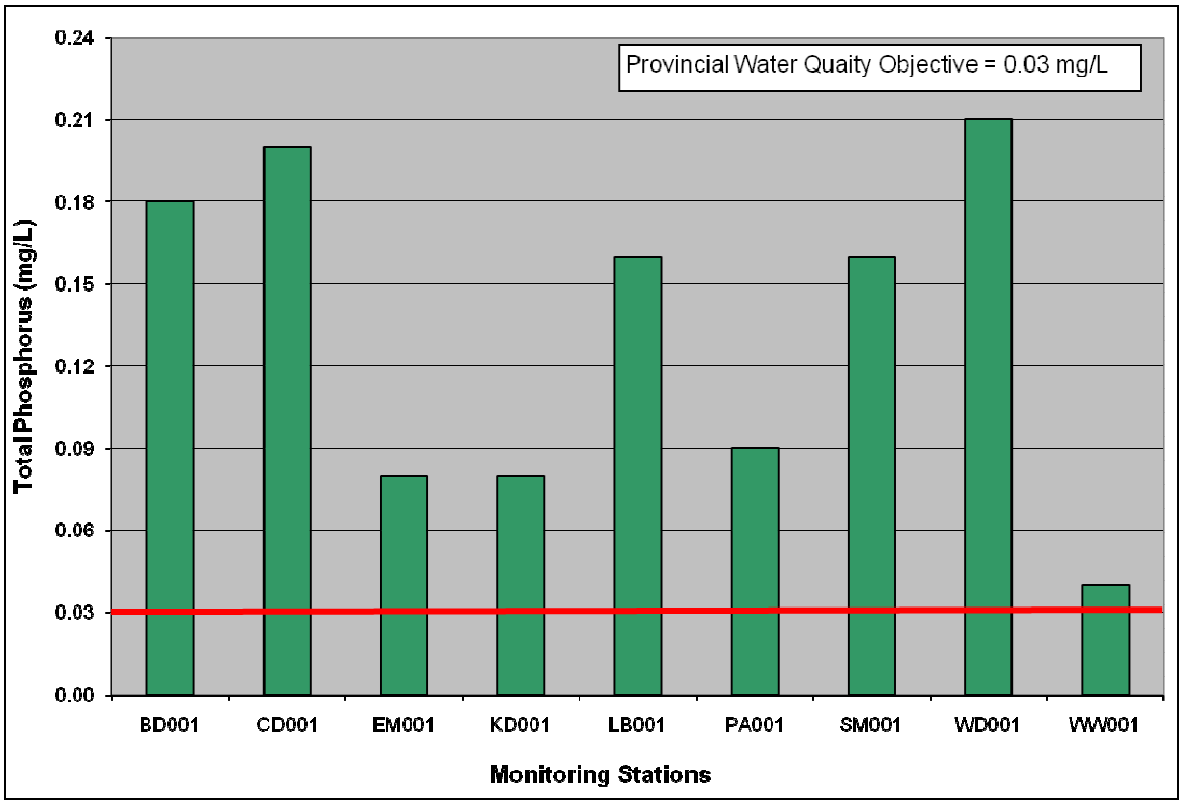

Figure 11: Mean total phosphorus concentrations in Lake Erie tributaries 2009

4.6.2 LAKE ERIE TRIBUTARIES: BIOMAP RESULTS

BioMAP results indicate that water quality is ***impaired*** at most Lake Erie tributary stations (**Table 8**). Results from BioMAP assessments for these stations are illustrated in **Appendix B**. Sediment loading, reduced baseflow, lack of in-stream habitat, and nutrient enrichment are primary causes of impairment at these stations. BioMAP samples have not been collected from stations SM001 and WW001 due to high water depth, channel morphology, and access restrictions.

Table 8: Summary of NPCA water quality data for Lake Erie tributaries (2001-2009)

STATION	WATERSHED	WQI RATING	BIOMAP RATING	FACTORS AFFECTING WATER QUALITY
BD001	Beaver Dam Drain	Poor	Impaired	• Exceedances of copper, total phosphorus and ***E. coli*** • Frequent nickel exceedances • Nutrient enrichment from upstream urban and agricultural areas • Lack of riparian buffer
CD001	Casey Drain	Marginal	Impaired	• Exceedances of ***E. coli***, total phosphorus and suspended solids • Nutrient enrichment from upstream urban and agricultural areas • Site is vulnerable to low baseflow and water stagnation • Algae observed during summer months • Lack of riparian buffer
EM001	Eagle Marsh Drain	Poor	Impaired	• Exceedances of chloride, ***E. coli***, total phosphorus and suspended solids • Nutrient enrichment from upstream urban and agricultural areas • Site is influenced by groundwater discharge from upstream bedrock quarry

KD001	Krafts Drain	Poor	Impaired	• Exceedances of ***E. coli***, total phosphorus and suspended solids • Nutrient enrichment from upstream urban and agricultural areas • Algae observed during summer months
LB001	Low Banks Drain	Marginal	Impaired	• Exceedances of ***E. coli*** and total phosphorus • Nutrient enrichment from upstream urban and agricultural areas • Site is vulnerable to low baseflow and water stagnation • Severe algae growth observed during summer months • Lack of riparian buffer
PA001	Point Abino Drain	Fair	Impaired	• Exceedances of total phosphorus • Nutrient enrichment from upstream urban and agricultural areas • Site is influenced by backflow from Lake Erie
SM001	Six Mile Creek	Marginal	n/a	• Exceedances of ***E. coli*** and total phosphorus • Nutrient enrichment from upstream urban and agricultural areas
WD001	Wignell Drain	Marginal	Grey Zone	• Exceedances of copper, ***E. coli*** and total phosphorus • Frequent nickel exceedances • Nutrient enrichment from upstream urban and agricultural areas • Site is influenced by groundwater discharge from upstream bedrock quarry
WW001	Wainfleet Wetlands Conservation Area	Good	n/a	• Exceedances of total phosphorus • Nutrient enrichment from upstream urban and agricultural areas

5.0 OTHER PROJECTS

5.1 HAMILTON INTERNATIONAL AIRPORT

Since 1998 the NPCA has completed annual biological assessments of water quality for Hamilton International Airport (HIA). The goal of the annual assessment is to determine if stormwater runoff and de-icing fluids such as propylene glycol are impacting surface water quality in two headwater tributaries of the Welland River. The annual biomonitoring is part of the airport's commitment to fulfilling a recommendation in the Niagara River Remedial Action Plan to improve degraded water quality in the Welland River. Data collected by the NPCA since 1998 indicates that water quality in the upper Welland River is impaired due to stormwater runoff and propylene glycol management practices at HIA, and improvements to these practices are strongly recommended in order to improve water quality. The NPCA will continue its annual monitoring for HIA in 2010.

5.2 GLANBROOK LANDFILL

Since 1996 the NPCA has completed bi-ennial biological assessments of water quality for the Glanbrook Landfill. The Glanbrook Landfill is owned and operated by the City of Hamilton, and is designed to receive domestic, commercial, and non-hazardous solid industrial waste. The purpose of the bi-ennial assessments is to determine if stormwater runoff and leachate from the landfill are negatively impacting water quality and aquatic biota in the Welland River and Buckhorn Creek. Results from NPCA assessments indicate that water quality in these watercourses has improved since 1996, with limited landfill impacts observed in 1996 and no impacts observed from 1998 through to 2008. The NPCA will continue its bi-ennial monitoring for the Glanbrook Landfill in 2010.

5.3 INTERNAL PROJECTS

The NPCA Water Quality Program is currently involved with several internal monitoring projects completed jointly with other NPCA programs. Joint internal projects that were active in 2009 are summarized in **Table 9**.

Table 9: Summary of joint projects completed between the NPCA Water Quality Program and other NPCA programs

PROJECT DESCRIPTION	NPCA PROGRAMS INVOLVED
Nitrate investigation at PGMN monitoring well # W0000361-2	Water Quality Monitoring, Source Water Protection
Monthly stream flow monitoring at water quality monitoring stations on the Welland River, upper 12-Mile Creek, and Niagara-On-The-Lake watersheds	Water Quality Monitoring, Restoration, Regulation, Source Water Protection

5.4 WELLAND RIVER EUTROPHICATION STUDY

The Welland River Eutrophication Study was initiated by the NPCA in 2008 in partnership with the MOE and Environment Canada as part of the Niagara River Remedial Action Plan (RAP). Eutrophication and nuisance algae are listed in the Niagara River RAP as a Beneficial Use Impairment for the Welland River. The objectives of the Welland River Eutrophication Study are to gather missing data about how the Welland River ecosystem is responding to nutrient inputs, set delisting criteria for key parameters in the river, and set targets for tributary loads to meet the delisting criteria. The completion date for the Study is 2010.

5.5 LAKE ONTARIO COLLABORATIVE STUDY

The NPCA Water Quality Monitoring Program is participating in the Lake Ontario Collaborative Drinking Water Study lead by Environment Canada. The objective of this program is to gather hydrologic and water quality data to determine pollutant loadings which will be used to evaluate risks to drinking water intakes located along the Lake Ontario shoreline. Pollutant loadings will also be used to evaluate changes in the nearshore ecology of the lake. This data will also be used for the calibration of the Soil and Water Assessment Tool (SWAT) watershed model that Environment Canada is planning to use for its future projects. The NPCA's role in this study is to monitor the water quality of Twenty Mile Creek using an ISCO auto-sampler with the goal of sampling wet-weather events that occur in this watershed. The NPCA captured a total of 14 and 23 sampling events in 2008 and 2009, respectively. The study is now complete and the auto-sampler has been removed from Twenty Mile Creek for use in other projects. A final report outlining the results of the study is currently being prepared by Environment Canada.

6.0 GROUNDWATER QUALITY MONITORING PROGRAM

6.1 PROVINCIAL GROUNDWATER MONITORING NETWORK

The Provincial Groundwater Monitoring Network (PGMN) is a province-wide groundwater monitoring initiative designed to collect long-term baseline data on groundwater quantity and quality in special areas of interest. Groundwater is monitored through a network of monitoring wells located throughout the NPCA watershed in locally

significant hydrogeologic areas. The NPCA currently operates 15 monitoring wells in partnership with the MOE as part of the PGMN (**Table 10**). Monitoring wells are instrumented with datalogging equipment which record hourly groundwater levels at all stations. Groundwater quality samples are collected twice yearly from 13 of the 15 wells during the spring and fall, and analyzed for nutrients, metals, bacteria, and general chemistry. Refer to **Appendix C** for NPCA groundwater monitoring locations.

The first round of groundwater quality samples were collected by the NPCA and MOE between 2002 and 2004 and analyzed by the MOE laboratory for a wide range of parameters including metals, nutrients, volatile organic compounds (VOCs), pesticides and general chemistry. Results from the first round of sampling generally indicate that water quality is good relative to natural bedrock conditions. VOCs and pesticides were not detected in any first round samples.

Routine groundwater quality sampling was initiated in 2006, and samples are collected annually by the NPCA during the spring and fall seasons. Groundwater quality samples are analyzed for bacteria, nutrients, metals, and general chemistry. Trends in groundwater quality are difficult to interpret at this time due to the limited size of the dataset; however, preliminary data collected to date indicates the following:

- Elevated concentrations of boron, fluoride, and selenium observed in bedrock wells may be attributed to natural groundwater conditions.
- Elevated sodium concentrations may be attributed to natural groundwater conditions; however, they may also be attributed to urban landuse and road de-icing in some areas.
- Elevated nitrate concentrations observed at monitoring wells W0000384 and W0000361-2 are likely attributed to agricultural landuse and/or faulty septic systems.

Table 10: NPCA Provincial Groundwater Monitoring Network stations

STATION	HYDROGEOLOGIC AREA OF INTEREST	MUNICIPALITY
W0000073	Guelph-Lockport Formation	Town of Grimsby
W0000080	Guelph-Lockport Formation	Township of West Lincoln
W0000287	Salina Formation	Haldimand County
W0000288	Guelph-Lockport Formation	City of Hamilton (Glanbrook)
W0000289	Onondaga Formation	City of Port Colborne
W0000290	Salina Formation	City of Niagara Falls
W0000341	Irondequoit Formation	Town of Lincoln
W0000356-2	St. David's Buried Gorge	City of Niagara Falls
W0000356-3	St. David's Buried Gorge	City of Niagara Falls
W0000357	Fonthill Kame-Delta Complex	Town of Pelham
W0000361-2	Fonthill Kame-Delta Complex	Town of Pelham
W0000361-3	Fonthill Kame-Delta Complex	Town of Pelham
W0000362-2	Fonthill Kame-Delta Complex	Town of Pelham
W0000362-3	Fonthill Kame-Delta Complex	Town of Pelham
W0000384	Iroquois Sandplain	Town of Niagara-On-The-Lake

Exceedances of the Ontario Drinking Water Standards (MOE 2003) are flagged by the MOE and are reported to the NPCA, Region of Niagara Public Health Department, and local municipalities. Wells with reported exceedances are subsequently re-sampled by the MOE to confirm the initial exceedance. Confirmed exceedances of the Ontario Drinking Water Standards (MOE 2003) at NPCA PGMN wells sampled between 2002 and 2009 are summarized in **Table 11**.

Table 11: Summary of confirmed exceedances of Ontario Drinking Water Standards at NPCA PGMN wells

STATION	PARAMETER EXCEEDED	PROBABLE SOURCE(S)
W0000080	Fluoride, Sodium	Natural groundwater conditions
W0000287	Sodium	Natural groundwater conditions
W0000288	Sodium	Natural groundwater conditions
W0000290	Boron, Sodium, Selenium	Natural groundwater conditions
W0000341	Sodium, Selenium	Natural groundwater conditions
W0000361-2	Nitrate	Agricultural landuse, faulty septic systems
W0000361-3	Sodium	Natural groundwater conditions
W0000362-2	Sodium	Urban landuse, road de-icing
W0000384	Nitrate, Sodium, Selenium	Agricultural landuse

6.2 NITRATE INVESTIGATION AT PGMN WELL W0000384

Additional groundwater sampling was completed by the NPCA in partnership with the Region of Niagara Public Health Unit in October 2008. The purpose of the additional sampling was to determine the extent of nitrate contamination in the vicinity of PGMN well W0000384, and notify affected residents of potential health concerns related to elevated nitrate concentrations in drinking water. Eleven private wells were sampled from residences located in close proximity to well W0000384 and analyzed for several parameters, including nitrate. Sampling results indicate that none of the private wells tested exceed the Ontario Drinking Water Standard for nitrate (MOE 2003). Isotopic analysis completed by the NPCA at well W0000384 in October 2008 suggests that the source of nitrate at this site is animal manure rather than faulty septic systems.

6.3 NITRATE INVESTIGATION AT PGMN WELL W0000361-2

Additional groundwater sampling was completed by the NPCA in partnership with the Region of Niagara Public Health Unit in November 2009. The purpose of the additional sampling was to determine the extent of nitrate contamination in the vicinity of PGMN well W0000361-2, and notify affected residents of potential health concerns related to elevated nitrate concentrations in drinking water. A total of 61 residents living within a 1 km radius of well W0000361-2 were invited to participate in this voluntary water well survey and 39 residents agreed to participate.

In the first phase of the investigation, 44 wells from 39 private residences were sampled and analyzed for nitrate in the field using an inexpensive nitrate test kit. Results from this first phase of sampling indicated that ten of the 44 wells (23%) had detectable concentrations of nitrate (i.e. > 2 mg/L). The ten wells identified in the first phase as having detectable concentrations of nitrate were subject to secondary testing and laboratory analysis in the second phase of the investigation. Laboratory analysis

confirmed that these wells had detectable concentrations of nitrate, and one well was found to exceed the Ontario Drinking Water Standard of 10 mg/L (MOE 2003). This well is a shallow dug well with poor construction, and is likely not related to the nitrate exceedance at PGMN well W0000361-2. The average nitrate concentration from the second round of confirmatory testing was found to be 6 mg/L. Letter notifications were mailed to participating residents to provide them with their testing results and also provide additional information regarding well testing.

6.4 WATER WELL DECOMMISSIONING PROGRAM

In 2007 the NPCA implemented the Water Well Decommissioning Program to provide grants to watershed residents interested in properly decommissioning abandoned water wells on their property. The grant program offers a 90% subsidy for water well decommissioning to a maximum of $2,000 per well. Grant applications are prioritized in areas designated as highly susceptible to groundwater contamination in the NPCA Groundwater Study (Waterloo Hydrogeologic Inc. 2005), areas where there is a high density of private wells used for domestic purposes, and areas where a watershed plan has been completed or is underway. Numerous improperly abandoned water wells are known to exist in the NPCA watershed, and these wells can serve as a direct pathway between potential contaminants at ground surface and deeper aquifers. The implementation of this program will reduce the risk of groundwater contamination and fulfills a recommendation made in the Groundwater Management Strategy of the NPCA Groundwater Study (Waterloo Hydrogeologic Inc. 2005).

6.5 NPCA GROUNDWATER STUDY

The NPCA Groundwater Study was completed in 2005 and contains several recommendations aimed at improving the management and protection of local groundwater resources. Since 2005, a number of these recommendations have been addressed through various NPCA programs. Three of the outstanding recommendations from 2008 were addressed in 2009, and include:

- Laying the groundwork for determining cistern use in Niagara,
- Completing the Tier 1 Water Budget and delineating sensitive groundwater recharge areas (SGRAs), and
- Identifying and geo-referencing managed lands and livestock density. Managed lands are defined as areas where fertilizers, non-agricultural source material and manure are applied and may include areas where livestock is present.

A summary of the NPCA Groundwater Study recommendations and follow-up actions is provided in **Tables 12** and **13** (Waterloo Hydrogeologic Inc. 2005).

7.0 CONCLUSIONS

The NPCA Water Quality Monitoring Program was implemented in 2001 and is operated in partnership with the Ministry of the Environment, Regional Municipality of Niagara, and City of Hamilton. Through these partnerships the NPCA collects water quality samples and the partnering agencies provide laboratory analysis. Surface water quality samples are collected monthly at 68 monitoring stations located throughout the NPCA watershed and analyzed using several indicator parameters including: chloride, nitrate, total phosphorus, suspended solids, copper, lead, zinc, and ***E. coli***. These indicator parameters were used to calculate the CCME Water Quality Index (WQI), which provides a descriptive water quality rating for each station. Benthic invertebrate samples

are collected annually throughout the watershed during the spring and fall seasons to assess stream health using the BioMAP protocol.

In general, water quality monitoring data collected between 2001 and 2009 is summarized as follows:

- Based on the results of the 2009 WQI, 65% of the NPCA surface water monitoring stations have water quality rated as ***poor***, 30% are rated as ***marginal***, 4% are rated as ***fair***, and 1% are rated as ***good***. None of the stations were able to achieve a WQI rating of ***excellent***.
- Based on the results of the 2009 BioMAP assessments, 81% of the NPCA BioMAP stations have water quality rated as ***impaired***, 7% are rated as ***grey zone***, 5% are rated as ***unimpaired***, and 7% have not been assessed.
- The Effingham tributary of upper Twelve Mile Creek continues to achieve one of the highest water quality ratings in the NPCA watershed, with a WQI rating of ***fair*** and BioMAP rating of ***unimpaired***.
- Total phosphorous concentrations frequently exceed the provincial objective at all 68 monitoring stations. Based on the data collected to date, elevated concentrations of total phosphorus are the most frequent and widespread cause of water quality impairment in the NPCA watershed. The relative high frequency and magnitude of these exceedances was a driving factor in lowering the WQI at all stations.
- Exceedances of nitrate are observed at some stations, most notably Two Mile Creek, Four Mile Creek, and portions of upper Twelve Mile Creek and the Welland River.
- Exceedances of chloride and copper are observed at some stations; however, they are relatively infrequent. Exceedances of lead are rare.
- Exceedances of zinc are frequently observed in the upper Welland River in the vicinity of Hamilton International Airport. The NPCA is currently working with the MOE and the airport to improve water quality.
- Exceedances of suspended solids and ***E. coli*** are frequently observed at several stations throughout the watershed.
- WQI and BioMAP results generally match up well at most stations (i.e. where the WQI rating is ***poor*** the BioMAP rating is ***impaired***) indicating that the benthic invertebrate data supports the chemical data. Instances where the WQI and BioMAP ratings did not match up may be attributed to factors which are beyond the scope of this analysis such as the availability of in-stream habitat, size of the dataset used to calculate the WQI, and influence of parameters not monitored by the NPCA.
- Data collected from PGMN monitoring wells indicates that groundwater quality generally meets Ontario Drinking Water Standards (MOE 2003). Exceedances of boron, selenium, sodium and fluoride are attributed to natural bedrock conditions. Nitrate exceedances are attributed to agricultural landuse or faulty septic systems.
- A nitrate investigation completed in the vicinity of PGMN well W0000361-2 determined that 98% of private wells in the study area meet the Ontario Drinking Water Quality Standard for nitrate. 1 well out of 44 wells tested exceeded the drinking water standard; however, this well is shallow and poorly constructed and is likely not related to the nitrate exceedance at PGMN well W0000361-2.

Table 12: Summary of NPCA Groundwater Study watershed-wide recommendations and follow-up actions

Study Recommendations	Follow-up Action(s) by NPCA
Ensure that the database created as part of the NPCA Groundwater Study be consistently maintained and regularly updated centrally.	• This recommendation is difficult to fulfill since: 1) updates to the database are contingent on updates to the MOE Water Well Information System and 2) WHI did not provide clear documentation of the digital information provided. However: • Groundwater quality data is housed in a central Access database, • Hydrogeoanalyst software was recently purchased for storing borehole data, and • All NPCA datapoints are georeferenced.
Update water well information for approximately 6500 water well records that could not be used in this study due to high uncertainty related to location and/or elevation by providing UTM coordinates and/or elevation information where possible.	• None
Develop a geology and hydrogeology reference package for use by local drillers during water well drilling and borehole logging to improve the quality of water well record information.	• None
Perform regular detailed reviews of permitted groundwater withdrawals with emphasis on the large users' maximum permitted rates in order to track total groundwater use in the watershed.	• The NPCA completes reviews of Permits To Take Water when circulated by MOE. • Groundwater reviews are completed by the NPCA for site specific projects (e.g. supplying MOE with local information which may affect their review including wetlands, sensitive recharge areas and stressed subwatersheds).
Investigate groundwater use and water budgets on a sub-watershed level to provide additional information on recharge areas that supply baseflow discharge and estimates of aquifer yield to aid in the evaluation of Permit to Take Water applications and review of development applications.	• The Tier 1 Water Budget and delineation of SGRAs have been completed by the NPCA at the watershed planning area level through the Source Water Protection Program.
Better define areas of naturally poor groundwater quality relative to private potable supplies.	• Ambient groundwater quality monitoring in hydrogeologic areas of interest through the PGMN, and • Investigative sampling of private wells in areas surrounding PGMN nitrate exceedances in partnership with Region of Niagara Public Health Unit.
Determine cistern use in order to produce a more accurate estimate of total domestic groundwater use in the watershed.	• The NPCA has developed a database for storing information regarding rural water use. • Water well surveys completed as part of the nitrate investigations at PGMN wells provide accurate information regarding domestic groundwater use in those areas.
Update the potential contaminant sources inventory database and mapping by completing the following tasks: 1) Geo-reference biosolids spreading locations permitted by the MOE within the City of Hamilton and Haldimand County, 2) Identify and geo-reference the other types of potential contaminant sources listed in Section 5.4.18: urban point sources such as unreported spills, residential heating oil tanks, fertilizer, pesticide, and herbicide storage and distribution centres, and snow dumps, and 3) Develop a water well decommissioning program that identifies and geo-	1) None 2) Developed mapping of managed lands and livestock density. Managed lands are defined as areas where fertilizers, non-agricultural source material and manure are applied and may include areas where livestock is present. 3) Watershed-wide water well decommissioning grant program developed and implemented by the NPCA in 2007. Decommissioned wells are georeferenced and housed in NPCA database.

references improperly abandoned wells, and offers incentives to landowners for proper water well decommissioning.	
Improve understanding of local hydrogeology through long-term monitoring of groundwater quality and quantity.	• Long-term monitoring of groundwater quality and quantity in hydrogeologic areas of interest through the PGMN

Table 13: Summary of NPCA Groundwater Study recommendations for hydrogeologically sensitive areas and follow-up actions

Study Recommendations	Follow-up Action(s) by NPCA
Develop specific Groundwater Management and Protection Strategies for the identified hydrogeologically sensitive areas, and areas of medium or high groundwater intrinsic susceptibility.	• The NPCA requires preparation of Hydrogeologic Assessments for development at (i) Vulnerable (quality) and Sensitive (recharge) areas or (ii) areas with private servicing as per the Provincial Policy Statement. • The NPCA has prepared a document titled "Guidelines for Hydrogeology Studies" to direct studies. Note: only high susceptibility areas are included at this time.
Complete a thorough contaminant sources inventory across all areas that are mapped as medium or high susceptibility.	• The NPCA Source Water Protection program may complete these inventories within highly vulnerable aquifers; however, it is not mandatory at this time.
Complete a review of permitted land uses such as industrial, commercial, and extractive industrial located in medium or high susceptibility areas.	• The NPCA requires preparation of Hydrogeologic Assessments for development at (i) Vulnerable (quality) and Sensitive (recharge) areas or (ii) areas with private servicing as per the Provincial Policy Statement. • The NPCA has prepared a document titled "Guidelines for Hydrogeology Studies" to direct studies. Note: only high susceptibility areas are included at this time.
Require a site-specific hydrogeological assessment as a condition of development in medium or high susceptibility areas.	• The NPCA requires preparation of Hydrogeologic Assessments for development at (i) Vulnerable (quality) and Sensitive (recharge) areas or (ii) areas with private servicing as per the Provincial Policy Statement. • The NPCA has prepared a document titled "Guidelines for Hydrogeology Studies" to direct studies. Note: only high susceptibility areas are included at this time.
Develop septic system planning initiatives, and education and awareness programs in medium or high susceptibility areas.	• The NPCA recommends the installation of on-site sewage systems that provide tertiary treatment in vulnerable groundwater areas. Inter-agency cooperation is required to ensure that this recommendation becomes a mandatory requirement.
Improve the understanding of local geology and hydrogeology in hydrogeologically sensitive areas.	• Long-term monitoring of groundwater quality and quantity in hydrogeologic areas of interest through the PGMN • Inventory and mapping of karst areas as part of NPCA hazard mapping (Slaine 2006)

- The NPCA Water Quality Monitoring Program continues to provide technical support to other NPCA programs, including Restoration, Regulation, and Source Water Protection.
- Most of the recommendations made in the NPCA Groundwater Study (WHI 2005) have been fulfilled through various NPCA initiatives.

8.0 RECOMMENDATIONS

Based on the surface water quality monitoring data collected to date, upper Twelve Mile Creek represents the best water quality conditions in the NPCA watershed. Nutrient inputs from surrounding urban, rural and agricultural landuse continue to be a source of water quality degradation in the NPCA watershed. As such, it is recommended that surface and groundwater monitoring be continued in order to track changes in water quality over time throughout the watershed, target restoration activities, provide information for other NPCA programs, and assist in the development of source water protection plans.

Recommendations from the NPCA Water Quality Monitoring Program 2009 Annual Report are summarized as follows:

- Key water quality sampling stations established during the preparation of Watershed Plans should be integrated into the permanent water quality monitoring network. Currently, monitoring at many of these stations is discontinued with the completion of a Watershed Plan resulting in significant discontinuities in the data.
- Additional monitoring stations should be implemented in the vicinity of urban areas to better assess the impacts of municipal runoff (i.e. stormwater outfalls, combined sewer overflows) on the ecology of the watershed.
- Develop and implement a pilot septic system inspection program in partnership with the Region of Niagara Public Health Department. It is evident that aging and faulty septic systems contribute to poor water quality by discharging partly or untreated effluent into subsurface and surface drainage pathways. The persistently elevated concentrations of nutrients and bacteria in the Welland River between the Binbrook Reservoir and the City of Welland makes a sub-basin in this reach an ideal location for a pilot program.
- Increase the base budget allocation for the Water Quality Monitoring Program to allow for the implementation of the previous three recommendations listed above.
- Continue to implement watershed restoration projects with an emphasis on nutrient management, riparian buffers and increased forest cover. Watersheds with a combination of persistent nutrient exceedances and high stream sediment loading should be targeted. For example, observations by both the NPCA and the agricultural community indicate that the upper reaches of Twenty Mile Creek, Fifteen Mile Creek, and tributaries of the Welland River (i.e. Beaver Creek) are candidates for restoration efforts.
- Continue to implement the recommendations outlined in the Groundwater Management Strategy of the NPCA Groundwater Study (WHI 2005). The Groundwater Management Strategy recommends several actions to assist in protecting groundwater quantity and quality, with a special emphasis on hydrogeologically sensitive areas where there is a high potential for groundwater contamination.

- Continue to promote the NPCA Water Well Decommissioning Program in order to reduce the risk of groundwater contamination and improve local water well awareness.
- Continue to work in partnership with Hamilton International Airport and the City of Hamilton Glanbrook Landfill to monitor water quality.
- Continue to foster and expand partnerships with other agencies to strengthen support for water quality monitoring initiatives in the NPCA watershed. This includes representation through community outreach and education projects such as the Niagara Children's Water Festival and broader initiatives such as the Niagara Water Strategy (Region of Niagara 2003).
- Continue to investigate PGMN water quality exceedances with respect to public health protection.

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