NPCA WATER QUALITY MONITORING PROGRAM:

2017 REPORT

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Table of Acronyms

AOC	Area of Concern
BC MOE	British Columbia Ministry of Environment
BioMAP	Biological Monitoring and Assessment Program
BMPs	Best Management Practices
CCME	Canadian Council of Ministers of the Environment
CWQG	Canadian Water Quality Guidelines
EC	Environment Canada
EMRB	Environmental Monitoring and Reporting Branch
HIA	Hamilton International Airport
MOE	Ontario Ministry of the Environment
NPCA	Niagara Peninsula Conservation Authority
PGMN	Provincial Groundwater Monitoring Network
PWQMN	Provincial Water Quality Monitoring Network
PWQO	Provincial Water Quality Objective
ODWS	Ontario Drinking Water Standards
OPG	Ontario Power Generation
RMN	Regional Municipality of Niagara
VOC	Volatile Organic Compounds
WQI	Water Quality Index- for CCME

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 and Climate Change, Regional Municipality of Niagara, Haldimand County and the City of Hamilton. Through these partnerships the NPCA collects water quality samples at 74 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 (MOE) 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 (agricultural/livestock runoff, faulty septic systems) and point sources (combined sewer overflow, 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.

For groundwater, results indicate that water quality generally meets Ontario Drinking Water Standards. Reported groundwater quality exceedances were mainly related to naturally occurring bedrock conditions; however, two groundwater monitoring stations were found to have elevated nitrate concentrations. These nitrate exceedances have been investigated thoroughly by the NPCA, Niagara Public Health and the MOE are likely attributed to surrounding agricultural land use 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 begin to 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 the NPCA watershed. Therefore, this degradation needs to be quantified to properly assess the progress of watershed restoration. Consequently, it will likely take several years for water quality in 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 water quality information available for the NPCA watershed.

NPCA WATER QUALITY MONITORING PROGRAM: 2017 REPORT

1.0 INTRODUCTION

The NPCA Water Quality Monitoring Program was initiated in 2001. Before 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 water 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 MOE, Regional Municipality of Niagara (RMN), Haldimand County 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 2017 Annual Report is to summarize the water quality data collected from these monitoring stations and provide recommendations for future monitoring and stewardship initiatives.

2.0 SURFACE WATER QUALITY MONITORING PROGRAM

2.1 CHEMICAL MONITORING

In 2016, the NPCA monitored surface water quality at 74 stations covering 45 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 stewardship efforts (MOE and EC 1995). To fulfill this recommendation, the Niagara River Area of Concern (AOC) Tributary Monitoring Program was implemented in 2003 through a partnership between the NPCA, Environment Canada (EC) 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.

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 13 NPCA has PWQMN stations are located on the

Black Creek, Welland River, Twenty Mile Creek, Forty Mile Creek, Four Mile Creek, and 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 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 RMN whereby NPCA staff collect water samples at ten stations located within the NPCA watershed and the Region provides laboratory services.

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. 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

INDICATOR PARAMETER	OBJECTIVE	REFERENCE
Chloride	120 mg/L (Long Term)	CWQG (CCME 2011)
Nitrate	13 mg/L	CWQG (CCME 2003)
Total phosphorus	30 µg/L	PWQO (MOE 1994)
Suspended solids	25 mg/L	BC MOE (2001)
Copper	5 µg/L	PWQO (MOE 1994)
Lead	5 µg/L	PWQO (MOE 1994)
Zinc	20 µg/L	PWQO (MOE 1994)
Escherichia coli	100 counts/100 mL	PWQO (MOE 1994)
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 Aquatic Life recommend that long-term chloride concentrations should not exceed 120 mg/L in surface water (CCME 2011).

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 CWQG for the Protection of Aquatic Life recommend that nitrate concentrations should not exceed 13 mg/L in surface water (CCME 2003).

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 30 µg/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 (BC MOE 2001). This is a conservative guideline and will be under review for future NPCA reporting.

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. Natural sources are wind-blown dust, decaying vegetation and from forest fires. Anthropogenic sources of copper include industrial wastewater, sewage discharges and pesticides. The interim PWQO for copper is 5 µg/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. Lead occurs naturally in the environment. However, most lead concentrations that are found in the environment are a result of human activities. Anthropogenic sources of lead include industrial wastewater, sewage discharges, municipal waste incineration, fertilizers and pesticides. The interim PWQO for lead is 5 µg/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. Zinc occurs naturally in air, water and soil. Anthropogenic sources of zinc include industrial wastewater, sewage discharges and stormwater runoff. The interim PWQO for zinc is 20 µg/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 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 2012 and 2016. This is a significant departure from previous water quality reports where the entire dataset (2002 to present) was used to generate the CCME WQI. Although this approach reduces the overall sample size of some water quality monitoring stations it allows for the partitioning of the water quality dataset to determine if CCME WQI ratings are changing over time. This approach is consistent with Conservation Ontario's recommendation for comparing water quality data in watershed reporting (Conservation Ontario 2011). Using the five-year blocks of data minimizes seasonal variation and provides sufficient data for reliable statistics in surface water analysis.

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 5 years of data, depending on the station. The reliability of the WQI rating improves over time (> 2 years) as more data is collected and a wider range of water quality conditions are captured in the dataset.

4.1 TREND ANALYSIS

The NPCA operates with its partners the most extensive surface water quality monitoring network in the NPCA watershed. The dataset that has been collected through this network has reached a sufficient size so that trend analysis can be conducted on some NPCA water quality monitoring stations. Trend analyses are very useful for determining if water quality parameter concentrations are increasing, decreasing or remaining unchanged over time. If the concentration of a water quality parameter is found to be increasing or remaining in an impaired status then appropriate corrective action can be taken. Trend analysis is also useful for evaluating the performance of stewardship or remediation efforts.

The data on many water quality parameters for the NPCA are not normally distributed and it is not appropriate to use parametric statistical methods to test for trends. Non-parametric statistical methods can deal effectively with non-normally distributed data and are flexible enough to account for seasonal variability. The Seasonal Mann-Kendall Test is often used to determine trends in water quality data (Helsel and Hirsch 1992). The Seasonal Mann-Kendall Test modified from the Mann-Kendall Test (Helsel and Hirsch 1992), compares relative ranks of data values from the same season. This means the water quality parameter concentrations of May would be compared with concentrations of May in other years. Similarly, June concentrations would be compared with June concentrations and so forth. The null hypothesis (H_0) is that the concentration of a water quality parameter is independent of time or, in other words, the datasets show no distinct trend. The alternative hypothesis (H_A) means that a significant increasing or decreasing trend is found over time. The Seasonal Mann-Kendall uses alpha (α) to quantify the probability that a trend exists. For this report, the alpha level for statistical significance was set at α =0.05. This alpha level is commonly used in statistical methods to test for statistical significance. It should be noted that a value of $\alpha = 0.05$ means there is a 5 percent possibility of falsely rejecting the null hypothesis that no trend exists. Probability values of less than 0.05 mean there was statistically significant trend (increasing or decreasing). Trend analysis using the Seasonal Mann-Kendall Test was conducted on chloride, *E. coli*, nitrate total phosphorus and total suspended solids concentrations at all stations with 5 or more years of data using software provided by the U.S. Geological Survey (Helsel *et al.*, 2005). Trend analysis for copper, lead, and zinc parameters could only be conducted on a small number of stations because the metal concentrations found were below the laboratory detections limits. These were reported as "non-detect" or a "less than" the laboratory detection limit. Trend analysis with many non-detections or less than values was not favourable for analysis and therefore was excluded from most stations.

4.2 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**, 28 of the 74 surface water quality monitoring stations are in the Welland River watershed, and 12 of these 28 stations are located on the main Welland River channel.

4.2.1 Welland River: Water Quality Index

The calculated Water Quality Index (WQI) for the Welland River ranges from *poor* to *fair*. Based on the 2012-2016 data collected, five of twelve Welland River stations have *poor* water quality, four stations were rated as *marginal* and three stations (WR000, WR004, WR010) was rated as fair. WQI results are illustrated in **Appendix A**. Mapping showing the spatial distribution of the eight WQI parameters from 2012 to 2016 are found in **Appendix B** to **Appendix I**. Highlights of the water quality monitoring in the Welland River are summarized in **Table 3**:

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

Table 3: Summary of NPCA water quality data for the Welland River (2012-2016)

STATION	WQI RATING	BIOMAP RATING	FACTORS AFFECTING WATER QUALITY (%)= PERCENTAGE OF SAMPLES EXCEEDING GUIDELINES THIS IS ONLY REPORTED WHEN >50% OF SAMPLES EXCEED GUIDELINE	TREND GREEN- DECREASING BLACK- STABLE RED- INCREASING
WR00A Welland River	Marginal	Impaired	• Exceedances of copper, *E. coli*, total phosphorus (90%), and total suspended solids • Potential stressors include: agricultural and roadway run-off • Groundwater discharges sustains continuous baseflow at this site.	• Decreasing *E.coli,* total phosphorus and total suspended solid concentrations. • Stable chloride concentrations
WR000 Welland River	Fair	Impaired	• Exceedances of copper, *E. coli* (63%) and total phosphorus (95%), total suspended solids and zinc. • Potential stressors include: agricultural and roadway run-off • Groundwater discharge provides intermittent baseflow at this but the watercourse will dry up in the summer when groundwater levels drop	• Decreasing chloride, total phosphorus and total suspended solid concentrations. • Stable *E. coli* concentrations
WR001 Welland River	Poor	Impaired	• Exceedances of chloride, copper, *E. coli* (55%), lead, nitrate, total phosphorus (51%), total suspended solids and zinc (62%) • Potential stressors include: agricultural, airport and roadway run-off	• Decreasing zinc concentrations • Stable *E. coli,* total phosphorus, and total suspended solid concentrations. • Increasing chloride concentrations
WR002 Welland River	Poor	Impaired	• Exceedances of chloride (93%), copper, *E. coli*, nitrate, total phosphorus, total suspended solids and zinc (93%) • Potential stressors include: agricultural, airport and roadway run-off	• Stable *E. coli,* nitrate, total phosphorus, total suspended solid and zinc concentrations. • Increasing chloride concentrations .
WR003 Welland River	Marginal	Impaired	• Exceedances of chloride (62%), copper, *E. coli*, total phosphorus (93%), and total suspended solids • Potential stressors include: agricultural and roadway run-off	• Decreasing total suspended solid concentrations • Stable *E. coli*, and total phosphorus concentrations • Increasing chloride concentrations
WR004 Welland River	Fair	Grey Zone	• Exceedances of chloride, *E. coli*, total phosphorus (90%) and total suspended solids • Potential stressors include: agricultural and roadway run-off • Lake Niapenco is improving the water quality the Welland River at this site	• Decreasing *E. coli,* total Phosphorus, and Total Suspended Solids concentrations • Stable chloride concentrations
WR005 Welland River	Poor	Impaired	• Exceedances of chloride, copper, *E. coli* (77%), total phosphorus (97%) and suspended solids (73%) • Potential stressors include: agricultural and roadway run-off • Algae and duckweed observed during summer months	• Decreasing total phosphorus concentrations • Stable chloride, nitrate and total suspended solid concentrations • Increasing *E.coli* concentrations
WR006 Welland River	Poor	Impaired	• Exceedances of chloride, copper, *E. coli,* lead, nitrate, total phosphorus (100%), suspended solids (62%) and zinc • Potential stressors include: agricultural and roadway run-off • Algae and duckweed observed during summer months	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations

WR007 Welland River	Poor	Impaired	• Exceedances of copper, *E. coli,* lead, nitrate, total phosphorus (100%) total suspended solids (71%) and zinc • Potential stressors include: agricultural, roadway run-off • Algae and duckweed observed during summer months • Site is invaded by non-native Zebra Mussels	• Decreasing lead concentrations • Stable chloride, *E. coli*, lead, nitrate, and total phosphorus concentrations • Increasing copper, total suspended solid and zinc concentrations
WR009B Welland River	Marginal	n/a	• Exceedances of *E.coli*, total phosphorus (95%), total suspended solid and zinc • Potential stressors include: Sewage treatment plant effluent and agricultural and urban run-off • Site strongly influenced by Niagara River backwater which has the potential to improve water quality	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
WR010 Welland River	Fair	n/a	• Exceedances of copper, *E. coli*, lead, total phosphorus (79%), total suspended solids and zinc • Potential stressors include: Sewage treatment plant effluent and agricultural and urban run-off • Site strongly influenced by Niagara River backwater which has the potential to improve water quality	• Stable chloride, *E. coli*, lead, total phosphorus and total suspended solid concentrations • Increasing copper and zinc and zinc concentrations
WR011 Welland River	Marginal	n/a	• Exceedances of *E. coli,* nitrate, total phosphorus (65%) and total suspended solids • Potential stressors include: Sewage treatment plant effluent and agricultural and urban run-off • Site strongly influenced by Niagara River backwater which has the potential to improve water quality	• Decreasing *E.coli* and total phosphorus concentrations • Stable chloride and total suspended solid concentrations

4.2.2 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 2012 and 2016 are illustrated in **Appendix J**.

Benthic invertebrates at stations WR001 and WR002 are negatively impacted by discharges from Hamilton International Airport (HIA). The NPCA has completed annual BioMAP assessments for Hamilton International Airport since 1998 (NPCA 2012). Recent NPCA reports recommend that HIA review its stormwater and de-icing management practices to improve water quality in the upper Welland River. 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 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. Stations WR005 and WR006 were designated as *impaired* due to sediment loading, lack of in-stream habitat, and nutrient enrichment. A BioMAP assessment was not completed for WR009B, WR010 and WR011 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 would require boat access for sample collection.

4.2.3 Welland River: Keys Findings

- Based on the 2012-2016 data, elevated concentrations of total phosphorus are a widespread cause of water quality impairment in the Welland River. Greater than 95% of samples collected in the main Welland River exceeded the Provincial Water Quality Objective (PWQO) with some concentrations greater than 20 times the PWQO. High phosphorus in the Welland River has stimulated the overgrowth of algae and duckweed throughout the watershed. When these plants transpire, and decompose they deplete dissolved oxygen in the water and this in turn stresses aquatic organisms such as fish and benthic invertebrates. Manure from livestock operations, sewage discharges, soil erosion, fertilizers, and pesticides are sources of total phosphorus in the Welland River.
- Generally, the overall water quality of the Welland River downstream of the City of Welland is less stressed than the water upstream of the City of Welland. This is caused by the redirection of the Niagara River water down the Welland River in Chippawa for Ontario Power Generation (OPG). This results in a dilution effect that reduces the concentrations of water quality parameters. This effect is observed all the way to the east side of the City of Welland. However, upstream of the City of Welland, the river flow pattern caused by OPG operations and canal siphons are likely restricting the natural flushing of sediment, nutrients and other contaminates from the central Welland River watershed and exacerbating water quality conditions in this watershed.
- The Hamilton International Airport (HIA) water quality stations WR001 and WR002 continue to have water quality designated as *poor* due to elevated concentrations of chloride, total phosphorus, *E. coli*, copper and zinc. Total phosphorus concentrations have been found to be increasing over time at both sites. It is not entirely clear what is causing the total phosphorus increase at these stations. Chloride concentrations at both stations remain unchanged; however, it is expected that chloride concentrations will decrease with the recent removal of the road salt storage pad. Zinc concentrations found at these stations consistently exceed the PWQO and are the highest observed in the NPCA water quality network. The current information that the HIA has suggests that zinc is coming off the brake system of the airplanes. It should be noted that zinc concentrations have been decreasing at WR001 since 2002 but have remained unchanged at WR002. The NPCA also has not observed any propylene glycol discharge in WR001 or WR002 this year. In 2011, the HIA expanded its facilities and upgraded its water quality safeguards to WR001 and WR002. Continued monitoring by the NPCA will track water quality changes at these tributaries. The NPCA does not monitor the water quality of the Hamilton Airport tributary identified as the potential source of Perfluorooctane Sulfonate (PFOS) that has been found in turtle/fish tissue sampled at Binbrook Conservation Area. PFOS is a man-made compound belonging to a large family of compounds known as perfluorinated chemicals. These compounds do not readily breakdown and have the potential to bioaccumulate in animal tissue. The PFOS investigation is currently being led by the Ministry of the Environment and Hamilton Public Health, and new fish consumption guidelines were implemented for the 2011 Guide to Eating Ontario Sport Fish. The NPCA has been notifying Binbrook Conservation Area park users about the new fish consumption guidelines and information regarding PFOS has been posted on the NPCA website. The NPCA water quality department has added PFOS sampling in 2014 as part of special project monitoring program at Binbrook Reservoir.

- The water quality rating at station WR004 continues to be rated (*Fair*) as one of the highest in the upper Welland River watershed. Significant decreases in chloride, *E. coli*, total phosphorus, and total suspended solids concentrations have been observed from 2002. Binbrook Reservoir is likely improving the Welland River water quality by retaining wet weather events, settling out suspended sediment and providing an opportunity for biological activity to reduce water quality contaminants.

4.3 Welland River Tributaries

Twelve 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, Thompson Creek, Power Canal and Lyons Creek (**Figure 1**). Tributaries were selected based on drainage area, landuse, restoration projects, and watershed plans.

4.3.1 Welland River Tributaries: Water Quality Index

Based on the results of the Water Quality Index (WQI) eleven of fifteen Welland River tributary stations have water quality that is rated as *poor* (**Table 4**). Grassy Brook (GR001), Lyons Creek (LY003), Power Canal (PR001) and Mill Creek (MI001) were found to have water quality rated as *marginal*. WQI results are illustrated in **Appendix A.** Mapping showing the spatial distribution of the eight WQI parameters from 2012 to 2016 are found in **Appendix B** to **Appendix I**. Highlights of the water quality monitoring in the Welland River are summarized in **Table 4**:

Table 4: Summary of NPCA water quality data for Welland River tributaries (2012-2016)

Station Watershed	WQI Rating	BioMAP Rating	Factors Affecting Water Quality (%)= Percentage of samples exceeding guidelines This is only reported when >50% of samples exceed guideline	Trend Green- Decreasing Black- No Trend Red- Increasing
BF001 Big Forks Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli*, nitrate, total phosphorus (100%), and total suspended solids • Potential stressors include: agricultural and roadway run-off • Significant algae and overabundance of duckweed observed during summer months • Prone to zero baseflow conditions in the summer months	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
BU000 Buckhorn Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli* (59%), nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Prone to zero baseflow conditions in the summer months	• Stable *E. coli*, total phosphorus and total suspended solid concentrations • Increasing chloride concentrations

BU001 Buckhorn Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli* (68%), lead, nitrate, total phosphorus (98%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Prone to zero baseflow conditions in the summer months	• Stable *E. coli*, total phosphorus and total suspended solid concentrations • Increasing chloride concentrations
BV001 Beaver Creek	Poor	Impaired	• Exceedances in copper, *E. coli*, nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Significant algae observed during summer months • Prone to zero baseflow conditions in the summer months	• Decreasing total phosphorus concentrations • Stable chloride, *E. coli*, nitrate, and total suspended solid concentrations
CO001 Coyle Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli*, lead, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Site invaded by non-native Zebra Mussels	• Decreasing total suspended solids concentrations • Stable in chloride, *E. coli*, nitrate, and total phosphorus concentrations
DR001 Drapers Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli* (87%), total phosphorus (100%), total suspended solids and zinc • Potential stressors include: urban run-off • Algae observed during summer months	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
EL001 Elsie Creek	Poor	Impaired	• Exceedances in chloride, *E. coli*, nitrate, total phosphorus (98%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Algae observed during summer months • Prone to zero baseflow conditions in the summer months	• Stable *E. coli*, nitrate, total phosphorus and total suspended solid concentrations • Increasing chloride concentrations
GR001 Grassy Brook	Marginal	Impaired	• Exceedances in chloride, copper, *E. coli*, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Algae observed during summer months • Prone to zero baseflow conditions in the summer months	• Stable, *E. coli*, nitrate, total phosphorus and total suspended solid concentrations • Increasing chloride concentrations
TE001 Tee Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli*, nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Nutrient enrichment from upstream agricultural areas • Prone to zero baseflow conditions in the summer months	• Stable chloride, *E. coli*, nitrate, total phosphorus and total suspended solid concentrations

LY003 Lyons Creek	Marginal	Impaired	• Exceedances in copper, *E. coli*, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Site strongly influenced by Niagara River backwater which has the potential to improve water quality	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
MI001 Mill Creek	Marginal	Impaired	• Exceedances in chloride, *E. coli*, nitrate, total phosphorus (90%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Algae and overabundance of duckweed observed during summer months	• Decreasing total phosphorus concentrations • Stable *E. coli*, and total suspended solid concentrations • Increasing chloride concentrations
OS001 Oswego Creek	Poor	Impaired	• Exceedances in copper, *E. coli* (55%), nitrate, total phosphorus (100%), total suspended solids (91%) and zinc • Potential stressors include: agricultural and roadway run-off • Algae and overabundance of duckweed observed during summer months	• Stable chloride and *E. coli* concentrations • Increasing total phosphorus and total suspended solids
OS002 Oswego Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli* (64%), nitrate, total phosphorus (100%), total suspended solids (59%) and zinc • Potential stressors include: agricultural and roadway run-off • Algae and overabundance of duckweed observed during summer months	• Stable *E. coli*, total phosphorus and total suspended solid concentrations • Increasing chloride concentrations
TC001 Thompson Creek	Poor	Impaired	• Exceedances in copper, *E. coli* (85%), nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off	• Decreasing total phosphorus concentrations • Stable *E. coli*, and total suspended solid concentrations
PR001 Power Canal	Marginal	n/a	• Exceedances in *E. coli* (85%), total phosphorus, and total suspended solids • Potential stressors include: urban run-off and Niagara Falls waste water treatment plant • Water source at this site is Niagara River water which potentially improves water quality	• Stable chloride, *E. coli*, total phosphorus concentrations • Increasing total suspended concentrations

4.3.2 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 2012 and 2016 are illustrated in **Appendix J**. Generally, the BioMAP results match with water chemistry ratings. 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 2016 indicate that water quality is impaired; however, there is no additional impairment resulting from the landfill (NPCA, 2015).

4.3.3 Welland River Tributaries: Key Findings

- Based on the 2012-2016 data, elevated concentrations of total phosphorus are a widespread cause of water quality impairment in the Welland River tributaries. Approximately 95% of samples collected from the Welland River tributaries exceeded the Provincial Water Quality Objective (PWQO) with some concentrations greater than 30 times the PWQO. Concentrations of total phosphorus are very high in Beaver Creek, Big Forks Creek, Oswego Creek and Tee Creek. These subwatersheds have been prioritized for Best Management Practice works to reduce phosphorus loads. Sources of phosphorus include manure from livestock operations, sewage discharges, soil erosion, fertilizers, and pesticides.
- Lyons Creek has the highest water quality rating among the Welland River tributaries owing to the influence of Welland Canal water being pumped into the headwaters of Lyons Creek and from additional inflow of the Niagara River redirected up the Welland River.
- *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. Efforts should be implemented to reduce the sources of *E. coli* in these tributaries.
- Decreasing total phosphorus concentrations at several Welland River tributaries (Beaver Creek, Mill Creek and Thompson Creek) are now being observed with the NPCA's long-term data. Beaver Creek and Mill Creek watersheds have been targeted by the NPCA's stewardship program over the last twenty years to reduced non-point pollution such as nutrients and sediment. These data provide some evidence that this program is reducing nutrient runoff.

4.4 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. Nine of 74 NPCA surface water quality monitoring stations are located within the Twenty Mile Creek watershed. There are seven stations on the main channel. There are also monitoring stations for each of the subwatersheds which include Spring Creek, North Creek and Gavora Ditch (**Figure 4**).

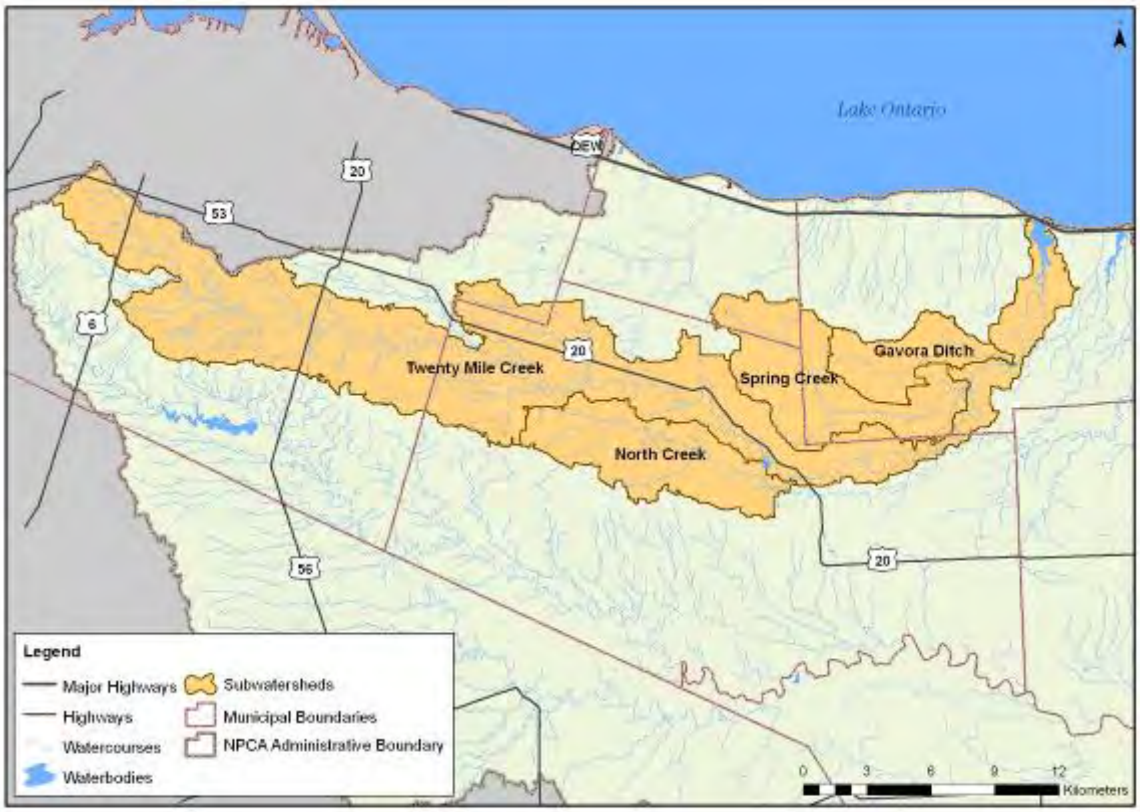

Figure 4: Map of the subwatersheds monitored for water quality within the Twenty Mile Creek watershed

4.4.1 TWENTY MILE CREEK WATERSHED: WATER QUALITY INDEX

Based on the results of the Water Quality Index (WQI) nine of nine Twenty Mile Creek watershed stations have water quality that is rated as *poor*. WQI results are illustrated in **Appendix A**. Mapping showing the spatial distribution of the eight WQI parameters from 2012 to 2016 are found in **Appendix B** to **Appendix I**. Highlights of the water quality monitoring in the Twenty Mile Creek are summarized in **Table 5**:

Table 5: Summary of NPCA water quality data for the Twenty Mile Creek watershed (2012-2016)

STATION WATERSHED	WQI RATING	BIOMAP RATING	FACTORS AFFECTING WATER QUALITY (%)= PERCENTAGE OF SAMPLES EXCEEDING GUIDELINES THIS IS ONLY REPORTED WHEN >50% OF SAMPLES EXCEED GUIDELINE	TREND GREEN- DECREASING BLACK- NO TREND RED- INCREASING
TN001 Twenty Mile Creek	Poor	Impaired	• Exceedances in chloride (53%), copper, *E. coli* (80%), lead, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and urban run-off • Site invaded by the non-native Chinese Mystery Snails • Excessive algae observed during the summer months	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
TN002 Twenty Mile Creek	Marginal	Impaired	• Exceedances in chloride, copper, *E. coli* (61%), total phosphorus (93%), total suspended solids and zinc • Potential stressors include: agricultural and urban run-off • Prone to zero baseflow conditions in the summer months	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
TN003 Twenty Mile Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli* (58%), nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and urban run-off • Excessive algae observed during the summer months	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
TN003A Twenty Mile Creek	Poor	Impaired	• Exceedances in chloride, *E. coli*, nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and urban run-off • Excessive algae observed during the summer months	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
TN004 Twenty Mile Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli* (58%), lead, nitrate, total phosphorus (100%), total suspended solids (53%) and zinc • Potential stressors include: agricultural and roadway run-off • Algae observed during the summer months	• Stable *E. coli*, total phosphorus and total suspended solid concentrations • Increasing chloride concentrations
TN006 Twenty Mile Creek	Poor	Grey Zone	• Exceedances in copper, *E. coli*, lead, nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Excessive algae observed during the summer months	• Stable chloride, *E. coli*, lead, nitrate, total phosphorus and total suspended solid concentrations • Increasing copper and zinc and zinc concentrations

NC001 North Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli* (69%), lead, nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Prone to zero baseflow conditions in the summer months • Excessive algae observed during the summer months	• Decreasing total suspended solids concentrations • Stable chloride, *E. coli*, total phosphorus concentrations
SP001 Spring Creek	Poor	Impaired	• Exceedances in copper, *E. coli* (78%), nitrate, total phosphorus (97%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Prone to zero baseflow conditions in the summer months • Excessive algae observed during the summer months	• Stable *E. coli*, total phosphorus and total suspended solids concentrations • Increasing chloride concentrations
GV001 Gavora Ditch	Poor	Impaired	• Exceedances in *E. coli (80%)*, nitrate, total phosphorus (100%), and total suspended solids • Potential stressors include: agricultural and roadway run-off • Prone to zero baseflow conditions in the summer months • Algae observed during summer months	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations

4.4.2 Twenty Mile Creek Watershed: BioMAP Results

BioMAP results indicate that water quality is *impaired* at most Twenty Mile Creek monitoring stations (**Table 5**). Results from BioMAP assessments completed between 2012 and 2016 are illustrated in **Appendix J.** 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.

4.4.3 Twenty Mile Creek Watershed: Key Findings

- Based on the 2012-2016 data, elevated concentrations of total phosphorus are a widespread cause of water quality impairment in the Twenty Mile watershed. Approximately 99% of samples collected from the Twenty Mile watershed exceeded the Provincial Water Quality Objective (PWQO) with some concentrations greater than 30 times the PWQO. Total phosphorus in the upper Twenty Mile Creek watershed (TN003) is of concern with concentrations found to be significantly increasing. The upper portions of this watershed need to be prioritized for Best Management Practice (BMPs) works to reduce phosphorus loads.

- *E. coli* and total suspended solid concentrations frequently exceed the provincial objective in Twenty Mile Creek watershed. Efforts through BMPs works should continue to be implemented to reduce the sources of *E. coli* in this watershed.
- Although chloride concentrations do not exceed Canadian Water Quality Guidelines, significant decreases in chloride concentrations were observed at TN003 over the period of 2002 to 2016. Changes to the snow clearing operations in the City of Hamilton over this time may be reducing chloride concentrations at these stations.

4.5 LAKE ONTARIO TRIBUTARIES

Twelve tributaries discharging into Lake Ontario are monitored through the NPCA Water Quality Monitoring Program. These tributaries include: Forty Mile Creek, Thirty Mile Creek, Eighteen Mile Creek, Sixteen Mile Creek, Fifteen Mile Creek, Twelve Mile Creek, Walker's Creek, Eight Mile Creek, Six Mile Creek, Four Mile Creek, Two Mile Creek, One Mile Creek, Shriners Creek and Beaver Dam Creek (**Figure 6**). Twenty Mile Creek is also a tributary of Lake Ontario but is presented separately due to the relatively large size of the watershed.

4.5.1 LAKE ONTARIO TRIBUTARIES: WATER QUALITY INDEX

Based on the results of the Water Quality Index (WQI), fifteen of twenty-three Lake Ontario tributary stations have water quality that is rated as *poor*. Three stations were rated as *marginal*, three stations were rated as *fair and* two were rated as *good*. WQI results are illustrated in **Appendix A**. Mapping showing the spatial distribution of the eight WQI parameters from 2012 to 2016 are found in **Appendix B** to **Appendix I**. Highlights of the water quality monitoring in the Lake Ontario tributaries are summarized in **Table 6**.

Skunk Cabbage (*Symplocarpus foetidus*) growing in Upper Twelve Mile Creek.

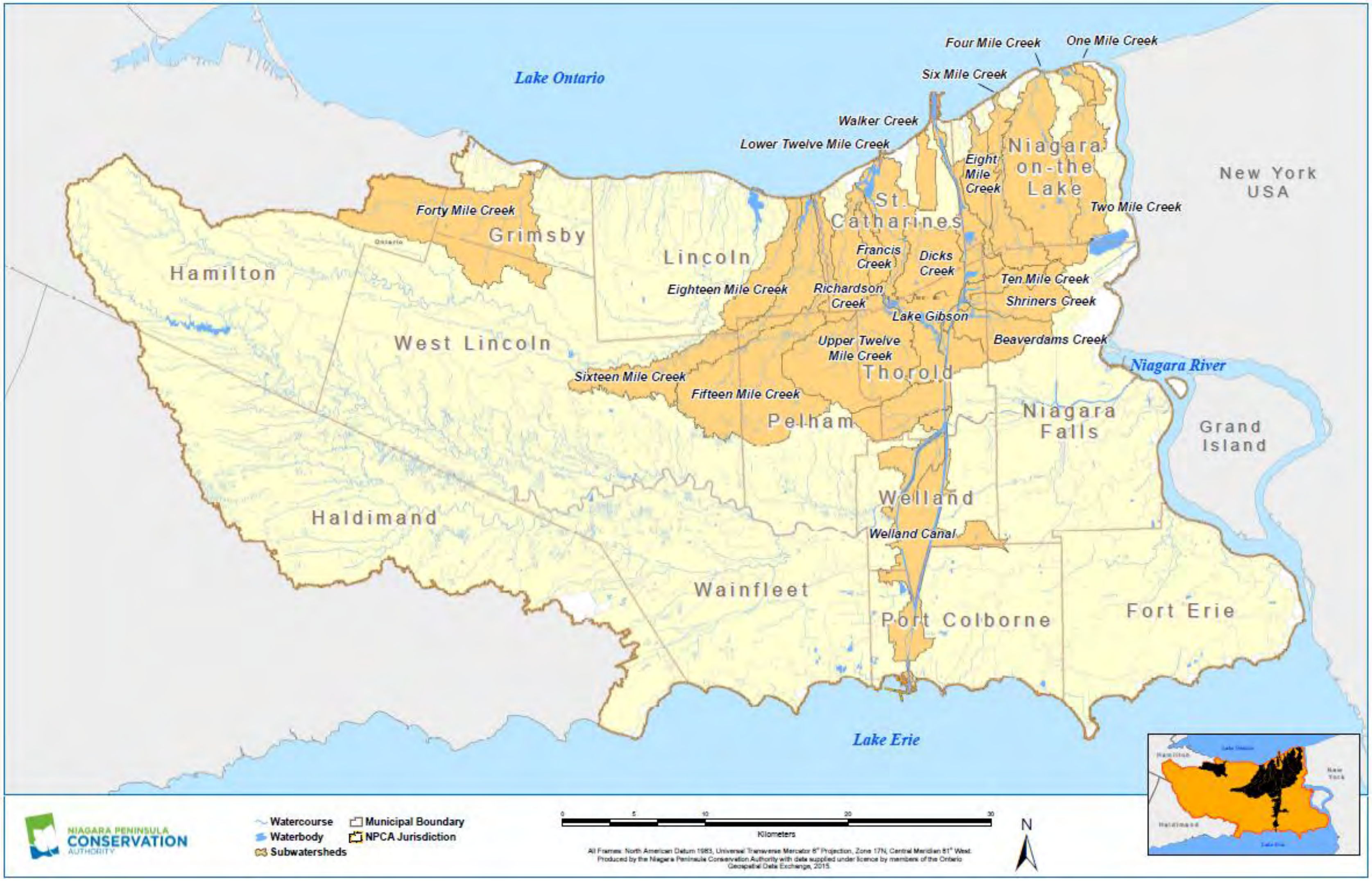

Figure 6: Map of the subwatersheds draining to Lake Ontario that are monitored for water quality

Table 6: Summary of NPCA water quality data for Lake Ontario tributaries (2012-2016)

Station Watershed	WQI Rating	BioMAP Rating	Factors Affecting Water Quality (%)= Percentage of samples exceeding guidelines This is only reported when >50% of samples exceed guideline	Trend Green- Decreasing Black- No Trend Red- Increasing
FM001 Forty Mile Creek	Poor	Grey Zone	• Exceedances in chloride (66%), copper, *E. coli* (68%), lead, nitrate, total phosphorus (94%), total suspended solids and zinc • Potential stressors include: road salt storage compound, quarry dewatering, urban and agricultural run-off. • Algae observed during summer months	• Stable chloride, *E. coli*, nitrate, total phosphorus and total suspended solid concentrations
ET001 Eighteen Mile Creek	Poor	Impaired	• Exceedances in chloride, copper (71%), *E. coli* (61%), lead, nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: greenhouse waste water, rural and agricultural run-off. • Watershed lacks adequate forest and riparian forest cover • Very frequent copper exceedances warrant further investigation	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations • Increasing copper concentrations
FF001 Fifteen Mile Creek	Poor	Impaired	• Exceedances in copper, *E. coli*, lead, nitrate, total phosphorus (100%), total suspended solids and zinc • Excessive algae observed during summer months • Potential stressors include: rural and agricultural run-off	• Stable chloride, *E. coli*, nitrate, total phosphorus and total suspended solid concentrations
SX001 Sixteen Mile Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli* (55%), lead, nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off	• Decreasing total suspended solid concentrations • Stable *E. coli*, nitrate and total phosphorus and concentrations • Increasing chloride concentrations
EI001 Eight Mile Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli* (90%), nitrate, total phosphorus (100%), and total suspended solids • Potential stressors include: agricultural and roadway run-off	• Stable chloride, E. coli, total phosphorus and total suspended solid concentrations
SI001 Six Mile Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli (87%)*, lead, nitrate, total phosphorus (79%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off	• Decreasing total suspended solid concentrations • Stable chloride, *E. coli*, nitrate, and total phosphorus concentrations
FU004 Four Mile Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli* (66%), nitrate, total phosphorus (94%), total suspended solids and zinc • Potential stressors include: agricultural and rural run-off	• Decreasing total suspended solid and total phosphorus concentrations • Stable chloride, *E. coli*, and nitrate concentrations
TM001 Two Mile Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli* (97%), nitrate, total phosphorus (97%), and total suspended solids • Excessive *E. coli* concentrations warrant further investigations	• Stable chloride, E. coli, total phosphorus and total suspended solid concentrations

			• Potential stressors include: rural and urban run-off	
OM001 One Mile Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli* (77%), total phosphorus (100%), total suspended solids and zinc • Potential stressors include: urban run-off • Prone to zero baseflow conditions in the summer months	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
TW001 Twelve Mile Creek	Poor	Impaired	• Exceedances in copper, *E. coli* (51%), lead, total phosphorus (69%), total suspended solids and zinc • Potential stressors include: rural and urban run-off • Groundwater discharges sustains continuous baseflow at this site.	• Decreasing total suspended solid concentrations • Stable *E.coli,* and total phosphorus concentrations • Increasing chloride concentrations
TW002 Twelve Mile Creek	Poor	Unimpaired	• Exceedances in copper, *E. coli* (56%), lead, total phosphorus, total suspended solids and zinc • Potential stressors include: agricultural and rural run-off • Groundwater discharges sustains continuous baseflow at this site.	• Decreasing total suspended solids • Stable chloride, *E. coli*, and total phosphorus concentrations
TW003 Twelve Mile Creek	Poor	Impaired	• Exceedances in copper, *E. coli* (73%), lead, total phosphorus (87%), total suspended solids and zinc • Potential stressors include: decommissioned landfill and rural run-off • Groundwater discharges sustains continuous baseflow at this site.	• Stable *E. coli*, total phosphorus and total suspended solid concentrations • Increasing chloride concentrations
TW004 Twelve Mile Creek	Marginal	Unimpaired	• Exceedances in copper, *E. coli*, nitrate (92%), total phosphorus, total suspended solids and zinc • Potential stressors include: golf course and rural run-off • Groundwater discharges sustains continuous baseflow at this site.	• Stable chloride, *E. coli*, total phosphorus, and total suspended solid concentrations • Increasing nitrate concentrations
TW005 Twelve Mile Creek	Marginal	Grey Zone	• Exceedances in copper, *E. coli* (67%), lead, total phosphorus (50%), total suspended solids and zinc • Potential stressors include: rural and urban run-off • Groundwater discharges sustains continuous baseflow at this site.	• Decreasing total phosphorus concentrations • Stable *E. coli*, lead, nitrate and total suspended solid concentrations • Increasing chloride, copper and zinc concentrations
TW006 Twelve Mile Creek	Fair	Unimpaired	• Exceedances in *E. coli* (59%), nitrate, total phosphorus and total suspended solids • Potential stressors include: rural run-off • Groundwater discharges sustains continuous baseflow at this site.	• Stable chloride, *E. coli*, lead, total phosphorus and total suspended solid concentrations • Increasing copper, nitrate and zinc concentrations

TW007 Twelve Mile Creek	Fair	Grey Zone	• Exceedances in copper, *E. coli* (60%), total phosphorus (50%), and total suspended solids • Potential stressors include: agricultural and rural run-off • Groundwater discharges sustains continuous baseflow at this site.	• Insufficient Data
TW008 Twelve Mile Creek	Poor	Impaired	• Exceedances in chloride (65%), *E. coli* (65%), total phosphorus (100%), and total suspended solids • Potential stressors include: agricultural and rural run-off • Prone to zero baseflow conditions in the summer months	• Decreasing total suspended solids concentrations • Stable in chloride, *E. coli*, nitrate, and total phosphorus concentrations
TW009 Twelve Mile Creek	Good	Insufficient Data	• Exceedances in *E. coli* and total phosphorus • Potential stressors include: urban run-off and industrial waste water • Water source at this site is predominately from the Welland Canal water which potentially improves water quality	• Insufficient Data
TH001 Thirty Mile Creek	Poor	Impaired	• Exceedances in chloride (54%), copper, *E. coli* (94%), lead, nitrate, total phosphorus (97%), total suspended solids and zinc • Potential stressors include: agricultural and rural run-off	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
WC001 Walkers Creek	Poor	Impaired	• Exceedances in chloride (61%), copper, *E. coli* (94%), total phosphorus (100%), total suspended solids and zinc • Potential stressors include: urban run-off	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
SH002 Shriners Creek	Marginal	Impaired	• Exceedances in chloride (74%), copper, *E. coli* (62%), total phosphorus (100%), and total suspended solids • Potential stressors include: urban run-off • Algae and duckweed observed during summer months	• Decreasing total suspended solids concentrations • Stable *E. coli* , nitrate, and total phosphorus concentrations
BE004 Beaver Dam Creek	Fair	Impaired	• Exceedances in *E. coli*, total phosphorus (85%), and total suspended solids • Potential stressors include: industrial and urban run-off • Algae and duckweed observed during summer months	• Decreasing total phosphorus concentrations • Stable chloride, *E. coli*, and total suspended solid concentrations

WE001 Welland Canal	Good	Insufficient Data	• Exceedance in *E.coli* and total phosphorus • Water source at this site is predominately from the Lake Erie water which improves water quality	• Insufficient Data

4.5.2 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 2012 and 2016 are illustrated in **Appendix J**. 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 can 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.

4.5.3 Lake Ontario Tributaries: Key Findings

- The Upper Twelve Mile Creek watershed represents some of the best water quality in the Niagara Peninsula. This portion of Twelve Mile Creek supports brook trout and a rich macroinvertebrate community that is unique in Niagara. The main stresses to the aquatic community include exceedances of total phosphorus and *E. coli*. Nitrate contamination has been identified as a stressor in on TW004 and its source is likely a golf course. Efforts to minimize these stressors through BMP initiatives will allow this watershed to remain in its current state. The TW003 has degraded from previous water quality ratings. Exceedances in copper and zinc concentrations and large exceedances in total phosphorus have allowed the WQI ratings to change from *marginal* to *poor*.
- Based on the 2012-2016 data, all the Lake Ontario tributaries have total phosphorus exceedances. The most impacted of these tributaries include Fifteen Mile Creek, Sixteen Mile Creek and Eighteen Mile Creek which had median concentrations nearly 10 times the PWQO. The upper portions of these watersheds need to be prioritized for BMPs to reduce phosphorus loads. Total phosphorus concentrations were found to be lower in the NOTL watersheds.
- The water quality rating at Twelve Mile Creek stations TW001 and TW002 changed from *marginal* to *poor*. The main reason for this decrease is due to exceedances in copper, lead and zinc concentrations detected during a significant wet-weather events. The water quality at Twelve Mile Creek station.
- The water quality rating at Twelve Mile Creek (TW009) and the Welland Canal (WE001) is rated as good owing to the input of water from Lake Erie.

- The Two Mile Creek (TM001) has the highest concentrations of *E. coli* in the NPCA watershed. This would suggest that there may be sewage entering the Two Mile Creek. The NPCA sampled the stormwater outfalls of Two Mile Creek Conservation Area identified found two sources of the bacteria and currently working with the Town of NOTL and MOECC to solve this issue.
- Copper and zinc concentrations in Eighteen Mile Creek consistently exceed PWQOs. Within the NPCA water quality monitoring network regular metal exceedances are uncommon but based on the landuse in this watershed there may be pesticides entering the watercourse. The MOE has been alerted to these exceedances and will be investigating further.

4.6 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**).

4.6.1 NIAGARA RIVER TRIBUTARIES: WATER QUALITY INDEX

Based on the results of the Water Quality Index (WQI) Usshers Creek station (US001) and Black Creek station (BL001) were rated as *poor* water quality. Bayer Creek (BA001), Beaver Creek (BR001), Black Creek (BL003), and Frenchman Creek (FR001 &FR003) stations were all rated as *marginal*. WQI results are illustrated in **Appendix A**. Mapping showing the spatial distribution of the eight WQI parameters from 2011 to 2015 are found in **Appendix B** to **Appendix I**. Highlights of the water quality monitoring in the Niagara River Tributaries are summarized in **Table 7:**

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

Table 7: Summary of NPCA water quality data for Niagara River tributaries (2012-2016)

Station Watershed	WQI Rating	BioMAP Rating	Factors Affecting Water Quality (%)= Percentage of samples exceeding guidelines This is only reported when >50% of samples exceed guideline	Trend Green- Decreasing Black- Stable Red- Increasing
BA001 Bayer Creek	Poor	Impaired	• Exceedances in chloride, copper, *E. coli,* total phosphorus (95%) and total suspended solids • Potential stressors include: agricultural and rural run-off	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
BL001 Black Creek	Poor	Impaired	• Exceedances of copper (64%), *E. coli*, nitrate, total phosphorus (100%), total suspended solids and zinc (44%) • Potential stressors include: agricultural and rural run-off	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
BL003 Black Creek	Marginal	n/a	• Exceedances in *E.coli*, nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and rural run-off	• Stable chloride, *E.coli,* nitrate, and total phosphorus concentrations • Increasing total suspended solid concentrations
BR001 Beaver Creek	Fair	n/a	• Exceedances in chloride, *E. coli, total* phosphorus (100%) and total suspended solids • Potential stressors include: agricultural and rural run-off	• Stable chloride, *E.coli,* and total phosphorus concentrations • Increasing total suspended solid concentrations
FR001 Frenchman Creek	Marginal	Impaired	• Exceedances in chloride, *E. coli* (66%), total phosphorus (87%), and total suspended solids • Potential stressors include: agricultural and rural run-off • Algae observed during summer months	• Decreasing total phosphorus concentrations • Stable *E. coli*, nitrate, and total suspended solid concentrations • Increasing chloride concentrations
FR003 Frenchman Creek	Marginal	Impaired	• Exceedances in chloride, *E. coli* (58%), total phosphorus (77%), total suspended solids and zinc • Potential stressors include: agricultural and rural run-off • Algae observed during summer months	• Decreasing chloride and total phosphorus concentrations • Stable *E. coli*, nitrate, and total suspended solid concentrations

US001 Usshers Creek	Poor	Impaired	• Exceedances in chloride, copper (60%), *E. coli*, lead (55%), nitrate, total phosphorus (100%), total suspended solids and zinc (50%) • Potential stressors include: agricultural and rural run-off • Prone to zero baseflow conditions in the summer months • Algae and duckweed observed during summer months	• Stable chloride, *E. coli*, nitrate, total phosphorus and total suspended solid concentrations

4.6.2 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 2012 and 2016 are illustrated in **Appendix J**. 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.

4.6.3 Niagara River Tributaries: Key Findings

- Generally, the water quality in these smaller Niagara River tributaries is better than the rest of the NPCA watershed. Significant decreases in phosphorus (FR001 and FR003), chloride (BA001 and FR003) and *E. coli* (BL001) were observed owing to these water quality results. The degree landuse impact from urban and rural pressures is significantly less.
- Based on the 2012-2016 data, all the Niagara River tributaries had total phosphorus exceedances. The most impacted of these tributaries include Usshers Creek, Black Creek and Bayer Creek which had median concentrations 6 times the Provincial Water Quality Objective. Total phosphorus concentrations were found to be much lower in Frenchman Creek with median concentrations only 2 times the PWQO. Nonetheless these watersheds would benefit by Best Management Practice works to reduce phosphorus loads.

4.7 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 Wignell Drain (**Figure 10**).

4.7.1 LAKE ERIE TRIBUTARIES: WATER QUALITY INDEX

Based on the results of the Water Quality Index (WQI) two of eight Lake Erie tributary stations are rated as having *poor* water quality and six stations are rated as *marginal* (**Table 8**). WQI results are illustrated in **Appendix A**. Mapping showing the spatial distribution of the eight WQI parameters from 2012 to 2016 are found in **Appendix B** to **Appendix I**. Highlights of the water quality monitoring in the Lake Erie Tributaries are summarized in **Table 7:**

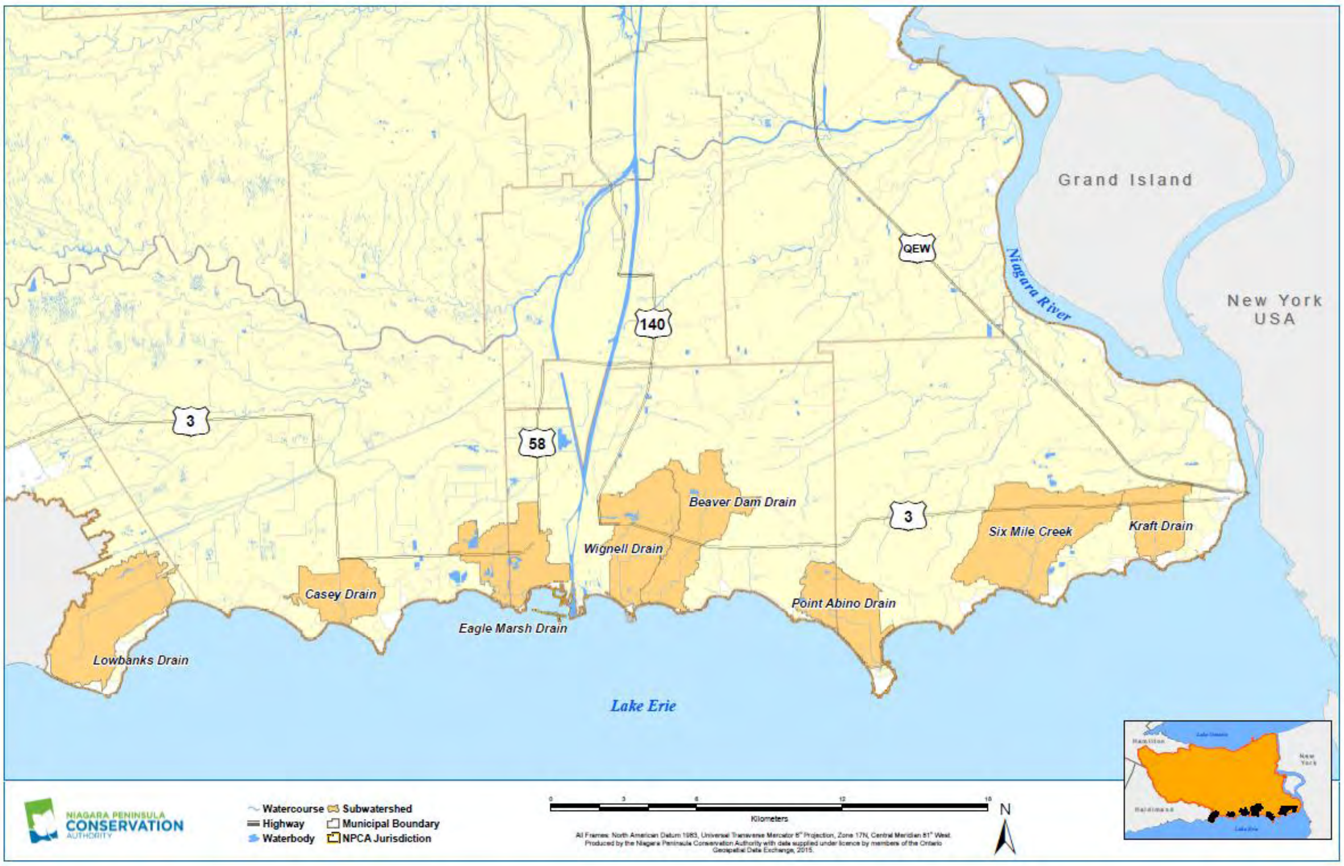

Figure 10: Map of the subwatersheds monitored for water quality along the north shore of Lake Erie

Table 8: Summary of NPCA water quality data for Lake Erie tributaries (2012-2016).

Station Watershed	WQI Rating	BioMAP Rating	Factors Affecting Water Quality (%)= Percentage of samples exceeding guidelines This is only reported when >50% of samples exceed guideline	Trend Green- Decreasing Black- No Trend Red- Increasing
BD001 Beaver Dam Drain	Poor	Impaired	• Exceedances in chloride, copper, *E. coli* (67%), nickel, nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: historic industrial pollution, agricultural and rural run-off	• Decreasing total suspended solids concentrations • Stable chloride, *E. coli*, and total phosphorus concentrations
CD001 Casey Drain	Poor	Impaired	• Exceedances in chloride, copper, *E. coli* (77%), nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and rural run-off	• Decreasing total suspend solids concentrations • Stable chloride, *E. coli*, and total phosphorus concentrations
EM001 Eagle Marsh Drain	Marginal	Impaired	• Exceedances in chloride (91%), copper, *E. coli* (76%), total phosphorus (94%), and total suspended solids • Potential stressors include: quarry dewatering, agricultural and rural run-off	• Decreasing total suspended solids concentrations • Stable chloride, *E. coli* and total phosphorus concentrations
KD001 Krafts Drain	Poor	Impaired	• Exceedances in chloride, *E. coli* (79%), nitrate, total phosphorus (90%), total suspended solids and zinc • Potential stressors include: rural and urban run-off • Algae observed during summer months	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
LB001 Low Banks Drain	Marginal	Impaired	• Exceedances in copper, *E. coli*, nitrate, total phosphorus (95%), total suspended solids and zinc • Potential stressors include: agricultural and rural run-off • Severe algae growth observed during summer months	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
PA001 Point Abino Drain	Fair	Impaired	• Exceedances in *E. coli*, nitrate, total phosphorus (92%), and total suspended solids • Potential stressors include: agricultural and rural run-off	• Decreasing total suspended solids concentrations • Stable *E. coli* and total phosphorus

			• Site is influenced by backflow from Lake Erie which is likely improving water quality	concentrations • Increasing chloride concentrations
SM001 Six Mile Creek	Marginal	n/a	• Exceedances in chloride, copper, *E. coli*, total phosphorus (100%), and total suspended solids • Potential stressors include: agricultural and rural run-off	• Decreasing total suspended solids concentrations • Stable chloride, *E. coli*, and total phosphorus concentrations
WD001 Wignell Drain	Marginal	Grey Zone	• Exceedances in copper, *E. coli*, nickel, nitrate, total phosphorus (100%), and total suspended solids • Potential stressors include: quarry dewatering historic industrial pollution, agricultural and rural run-off • Algae observed during summer months	• Stable chloride, *E. coli* and total suspended solids concentrations • Increasing total phosphorus concentrations

4.7.2 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 J**. 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 SM001 due to high water depth, channel morphology, and access restrictions.

4.7.3 LAKE ERIE TRIBUTARIES KEY FINDINGS

- Based on the 2012-2016 data, all the Lake Erie tributaries have total phosphorus exceedances. The most impacted of these tributaries include Casey Drain and Wignell Drain which had median concentrations 7 times the Provincial Water Quality Objective. In addition, the total phosphorus concentrations in Eagle Marsh Drain, Kraft Drain and Wignell Drain have been significantly increasing since 2007. These watersheds need to be prioritized for Best Management Practice (BMPs) works to reduce phosphorus loads.
- Chloride concentrations have been found to be significantly decreasing in the Lake Erie tributaries since 2007. These decreases have been observed in Casey Drain (CD001), Kraft Drain (KD001), and Wignell Drain (WD001). Possible reasons for this decrease may include reduced quarry discharges to Wignell Drains as well as reduced road salt entering these watercourses.
- Total suspended solid concentrations have been found to be significantly decreasing in the Lake Erie tributaries since 2007. These decreases have been observed in Beaver Dams (BD001), Casey Drain (CD001), Eagle Marsh Drain (EM001), Six Mile Creek (SM001), and Wignell Drain (WD001). The decreasing trend observed in these watersheds could be the result of several factors which include improved farming practices such as no-till minimize soil erosion, improved construction site sediment controls (silt fences/sedimentation basin), water retention ponds and drier watershed conditions.

- 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. These nickel exceedances are likely from previous industrial landuse.

5.0 GROUNDWATER QUALITY MONITORING PROGRAM

5.1 PROVINCIAL GROUNDWATER MONITORING NETWORK

The Provincial Groundwater Monitoring Network (PGMN) is a partnership between the MOE and the Conservation Authorities of Ontario. The 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. There are currently 470 ambient groundwater monitoring wells in the program. Groundwater is monitored through a network of 15 monitoring wells located throughout the NPCA watershed in locally significant hydrogeological areas. 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. The two other wells W356-2 and W356-3 were not sampled due to the request of the well owner. Refer to **Figure 11** for NPCA groundwater monitoring locations.

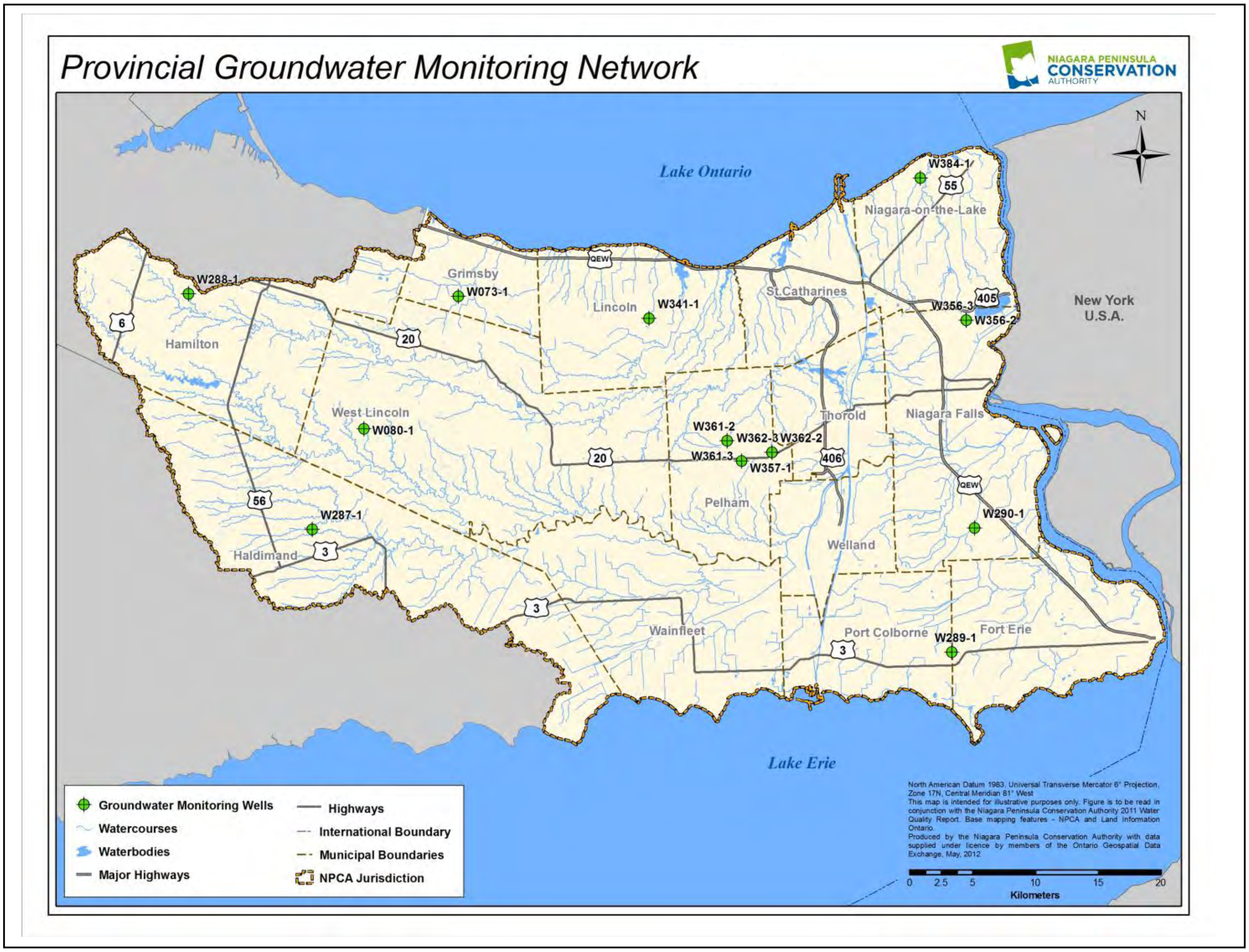

Figure 11: Location of PGMN monitoring wells in the NPCA watershed

5.1.1 Groundwater Levels

The NPCA has been monitoring water levels at all PGMN wells since 2003. Groundwater levels at this well are typically at their highest during the late-winter and spring but drop during the dry summer months. There is also yearly variation in water levels at PGMN wells which is dependent on precipitation. In dry years (such 2012) and water levels can drop substantially from seasonally high water levels; and conversely water level drops in wet years (2009) were not substantial. PGMN monitoring wells each have water levels that are seasonally and yearly variable due to several factors (formation that well is placed into, soils, precipitation, etc.).

The data from the PGMN will is also being used to help in the understanding of the impact of both local dry weather events and broader provincial scale drought events and therefore can assist in climate change adaptation planning.

5.1.2 Groundwater Chemistry

The first round of groundwater quality samples was collected by the NPCA and MOE between 2002 and 2005 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 by the NPCA during the spring and fall seasons of most field seaons. Groundwater quality samples are analyzed for bacteria, nutrients, metals, and general chemistry. 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. Based on the type and source of the exceedance these agencies formulate an action plan to protect human health. Confirmed exceedances of the ODWS (MOE 2003) at NPCA PGMN wells sampled between 2011 and 2016 are summarized in **Table 9**.

Table 9: NPCA PGMN stations with Health Related Exceedances of the ODWS (2012-2016). Blue text exceedances are caused by natural groundwater conditions and red text exceedances are caused by human influences

Well ID Location	Well Type	Formation	Year				
			2012	2013	2014	2015	2016
W073-1 Grimsby	Bedrock	Guelph-Lockport	Sodium	Sodium	Sodium	Sodium	Sodium
W080-1 West Lincoln	Bedrock	Guelph-Lockport	Sodium Fluoride	Sodium Fluoride	Sodium Fluoride	Sodium Fluoride	Sodium Fluoride
W287-1 Haldimand County	Bedrock	Salina	Sodium	Sodium	Sodium	Sodium	Sodium
W288-1 Hamilton	Bedrock	Guelph-Lockport					
W289-1 Port Colborne	Bedrock	Onondaga					
W290-1 Niagara Falls	Bedrock	Salina	Sodium Boron	Sodium Boron	Sodium Boron	Sodium Boron	Sodium Boron
W341-1 Lincoln	Bedrock	Clinton	Sodium	Sodium	Sodium	Sodium	Sodium
W356-2 Niagara Falls	Overburden	St.David's Buried Gorge					
W356-3 Niagara Falls	Overburden	St.David's Buried Gorge					
W357-1 Pelham	Overburden	Fonthill Kame					
W361-2 Pelham	Overburden	Fonthill Kame	Nitrate	Nitrate	Nitrate	Nitrate	Nitrate
W361-3 Pelham	Overburden	Fonthill Kame	Sodium	Sodium	Sodium	Sodium	Sodium
W362-2 Pelham	Overburden	Fonthill Kame	Sodium	Sodium	Sodium	Sodium	Sodium
W362-3 Pelham	Overburden	Fonthill Kame					
W384-1 NOTL	Overburden	Iroquois Sandplain	Nitrate	Nitrate	Nitrate	Nitrate	Nitrate

5.1.3 PGMN Key Findings

- The elevated concentrations of boron, and fluoride observed in monitoring wells W080-1, W290-1, and W341-1 have been attributed to natural groundwater conditions by the MOE Environmental Monitoring and Reporting Branch (EMRB) staff. These elements occur naturally in the groundwater and the MOE reports these exceedances are likely due to the dissolution of minerals from the bedrock formations. No anthropogenic activities or potential sites were identified. This appears to be an aquifer wide issue that will likely be present when this water is extracted for use. Water treatment is recommended when using these sources for drinking. NPCA Staff are participating in the provincial working group that was formed to improve the public notification process when naturally occurring chemical or biological contaminants are identified in the groundwater. The working group will address Recommendation 5b of the Auditor General's 2014 report on the provincial source protection program.

- Elevated sodium concentrations have been observed in W073-1, W080-1, W287-1, W290-1, W341-1, W361-3, and W362-2. MOE EMRB staff has attributed these exceedances to natural groundwater conditions and impacts from road salt. As per the MOE exceedances protocol the Niagara Medical Officer of Health was notified when the sodium concentration exceeded 20 mg/L for each PGMN well, so that this information could be communicated to local physicians for their use with patients on sodium restricted diets.

- Elevated nitrate concentrations observed at monitoring wells W384-1 and W361-2 are likely attributed to agricultural landuse and/or faulty septic systems. Nitrate concentrations at W384-1 have remained unchanged since 2003, but nitrate concentrations have been significantly increasing at W361-2. In response to these exceedances additional groundwater sampling was completed by the NPCA in partnership with the Region of Niagara Public Health Unit in October 2008 and November 2009. The purpose of the additional sampling was to determine the extent of nitrate contamination near PGMN wells (W384-1 and W361-2) and to notify affected residents of potential health concerns related to elevated nitrate concentrations in drinking water. Sampling results indicated that none of the private wells tested exceeded the Ontario Drinking Water Standard (ODWS) for nitrate (MOE 2003) near W384-1 and one well was found to exceed the ODWS near W361-2. The well exceeding the ODWS was determined to be a shallow dug well with poor construction, and is likely not related to the nitrate exceedance at PGMN well W361-2.

5.2 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 $2000 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).

To date, 76 water wells have been decommissioned with the NPCA water well decommissioning program **Table 10**. An example of a water well decommissioning project is shown in **Figure 12**. Recently the participation with this program has been very strong with a 100% of the funding allocated. Increased participation is attributed to improved exposure of the program in the watershed through various media sources and word of mouth from licensed well contractors.

Table 10: Number and location of abandoned water wells decommissioned through the NPCA Water Well Decommissioning Grant from 2007 to 2016.

Year	# of Projects	Location of Projects
2007	4	Hamilton (2), Lincoln (1), Niagara Falls (1)
2008	1	Niagara-on-the-Lake (1)
2009	3	Grimsby (1), Lincoln (1), Niagara Falls (1)
2010	7	Grimsby (1), Lincoln (1), Pelham (3), St. Catharines (2), West Lincoln (1)
2011	9	Niagara Falls (1), NOTL (1), Pelham (2), Port Colborne (3), Wainfleet (1), West Lincoln (1)
2012	10	St. Catharines (1), NOTL (1), Pelham (1), Port Colborne (1), Wainfleet (1), West Lincoln (1), Fort Erie (2), Lincoln (2)
2013	12	St. Catharines (2), Niagara Falls (1), NOTL (3), Pelham (1), Lincoln (2), Wainfleet (2), West Lincoln (1)
2014	12	Niagara Falls (1), Fort Erie (1), NOTL (2), Pelham (3), Lincoln (1), Welland (2), Port Colborne (1), Thorold (1)
2015	9	NOTL (1), Pelham (3) Colborne (1), St. Catharines (2), Wainfleet (2)
2016	9	Hamilton (1), Lincoln (2), Niagara Falls (1), NOTL (1), Pelham (1), Wainfleet (3),

Figure 12: An example of a NPCA Water Well Decommissioning Project. Left photo shows an abandoned dug well in need of decommissioning and the right photo shows same dug well after decommissioning had been completed by a licensed well contractor.

6.0 OTHER PROJECTS

6.1 HAMILTON INTERNATIONAL AIRPORT

Since 1998, the NPCA has been commissioned and funded by the Hamilton International Airport (HIA) to complete annual biological assessments of water quality near their property. 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 de-icing management practices at HIA. Despite the continuing water quality issues the HIA has made considerable efforts to improve water quality by: 1) Relocating the road salt storage area; 2) Sending glycol off-site for recovery where concentrations allow; 3) Use of both recovery from glycol recovery vehicles and containment through catchbasin practices; 4) Glycol waste water is discharged to the Hamilton sanitary sewer and 5) Using smaller salt trucks for de-icing. The NPCA applauses these operational changes and strongly recommends the HIA continue to investigate new and innovated methods to improve water quality on their property. The NPCA generates a separate report for the HIA.

6.2 GLANBROOK LANDFILL

Since 1998, the NPCA has been commissioned and funded by the City of Hamilton to complete biennial 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 biennial 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 2016. The NPCA generates a separate report for the City of Hamilton.

6.3 TWELVE MILE CREEK TEMPERATURE MONITORING

The upper Twelve Mile Creek watershed contains the only identified coldwater streams in the NPCA watershed and its biota are very sensitive to water temperature changes. In 2013, the NPCA reinitiated temperature monitoring in the upper Twelve Mile Creek watershed to (1) identify and classify the thermal regime for the Twelve Mile Creek surface water sampling stations; (2) identify possible areas of restoration within the Twelve Mile Creek watershed; and (3) identify any changes that may have occurred to the thermal stability of Twelve Mile Creek. The results of this monitoring are found in **Appendix K**.

6.4 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 2016 are summarized in **Table 11**.

Table 11: Summary of joint projects completed between the NPCA Water Quality Program and other NPCA programs

PROJECT DESCRIPTION	NPCA PROGRAMS INVOLVED
Mud Lake - Benthic Monitoring	Water Quality and Operations Departments
Binbrook- Perfluorinated Compound Monitoring	Water Quality and Operations Department
Binbrook- Winter Dissolved Oxygen Monitoring	Water Quality and Operations Department
Balls Falls Septic System- Certificate of Approval Surface Water and Groundwater Monitoring	Water Quality and Operations Department

6.5 CANADA ONTARIO AGREEMENT CLIMATE CHANGE MONITORING NETWORKS REVIEW PROJECT

A climate change sensitivity assessment completed by the MOE in 2009 identified the NPCA watershed as one of several southern Ontario watersheds that are highly vulnerable to the impacts of climate change. Indicators used in their analysis were related to water quality and quantity for both surface and groundwater resources. These indicators included frequency of low water levels, water use, water quality at active PWQMN stations, shallow well vulnerability, and baseflow. As a follow-up to this assessment, the NPCA conducted a detailed assessment in 2009-2010 of their existing monitoring networks and made specific recommendations for climate change detection and adaptation monitoring. Based on the NPCA and MOE assessments the existing monitoring station at Balls Falls Conservation Area was upgraded to an integrated monitoring site in 2015.

6.6 NPCA DATA REQUESTS

The NPCA Water Quality Monitoring Program generates a large wealth of scientific data that is a valuable resource to several clients. In 2016, the NPCA water quality monitoring program received 58 data requests from a variety of agencies and the public. These include:

- Ontario Ministry of the Environment
- Ontario Ministry of Agriculture, Food and Rural Affairs
- Ontario Ministry of Natural Resources
- Academia (McMaster University & University of Waterloo)
- Environment Canada

- Municipalities (Region of Niagara and City of Hamilton)
- Municipalities (Niagara-on-the-Lake, St. Catharines, Pelham)
- Health Units (Hamilton and Niagara)
- Consultants
- NGOs
- Public

7.0 CONCLUSIONS

The NPCA Water Quality Monitoring Program was implemented in 2001 and is operated in partnership with the MOE, the RMN, Haldimand County and the 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 74 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 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. The NPCA collects water quality data and water level data from 15 PGMN monitoring wells since 2003 in partnership with the MOE. This data is important to assess the ambient conditions of several bedrock and overburden aquifers found in Niagara. The NPCA also participates in many special and collaborative studies that have provided valuable information about the NPCA watershed.

In general, water quality monitoring data collected between 2001 and 2016 is summarized as follows:

- Based on the results of the 2012 to 2016 WQI, 64% of the NPCA surface water monitoring stations are rated as *poor*, 23% are rated as *marginal*, 10% are rated as *fair* and 3% are rated as *good*. None of the stations could achieve a WQI rating of *excellent*.
- Based on the results of the 2012 to 2016 BioMAP assessments, water quality was found to have: 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.
- Generally, the WQI ratings at water quality stations were relatively stable when compared to historic NPCA data. However, water quality improvements were observed in Beaver Dams Creek, Beaver Creek, Grassy Brook, Low Banks Drain, a tributary in the upper Twenty Mile Creek watershed, a tributary of the upper Welland River and the lower Welland River when comparing to previous water quality assessments. The Effingham tributary of upper Twelve Mile Creek, the lower section of Twelve Mile Creek in Port Dalhousie, the Welland Canal, Frenchman Creek (Fort Erie), Beaver Creek (Fort Erie) and the Welland River downstream of Binbrook Conservation Area continue to achieve the highest water quality ratings in the NPCA watershed. WQI ratings decreased in Bayer Creek, Coyle Creek, Drapers Creek, Elsie Creek, Lyons Creek, Shriners Creek, because of increased exceedances of water quality parameters.
- Assessment of the potential impact of an increase in nutrients on an aquatic system depends on the magnitude of the increase and the actual recorded concentrations present.

- The NPCA watershed has total phosphorous exceedances of the Provincial Water Quality Objective at virtually all monitoring stations owing to the higher population densities, and larger concentration of agriculture and industry. Based on the data collected to date, elevated concentrations of total phosphorus are the most frequent (over 95% observations) and widespread cause of water quality impairment in the NPCA watershed. The relative high frequency and magnitude of these exceedances is the driving factor in lowering the WQI at all stations. However, the NPCA is now observing statistically significant decreases of total phosphorus concentrations in approximately 20% of NPCA's long-term monitoring stations while only 2% of stations are showing a statistical increase. There are many potential reasons for these decreases such as a change in agricultural practices, improve nutrient management initiative, implementation of the watershed stewardship initiatives and climatic conditions. It should be noted that despite these decreases most of these stations are still 5 to 20 times the PWQO. Also, these trend results did not indicate whether such an change in ecologically significant.
- Exceedances of *E. coli* also contribute greatly to lower WQI ratings in the NPCA watershed. Approximately 60% of the NPCA stations have median *E. coli* concentrations greater than the PWQO. *E.coli* concentrations in the 5 watersheds (One Mile Creek, Two Mile Creek, Six Mile Creek, Walkers Creek and Kraft Drain) are high relative to other watersheds and the sources of these exceedances need to be examined further. The NPCA initiated a trackdown of *E.coli* sources in Two Mile Creek Conservation Area and discovered a storm sewer outfall as the likely source of the *E.coli* contamination. This information has been provided to the Town of the Niagara-on-the-Lake and the Town staff are investigating the neighbouring subdivision for a source. The NPCA will continue to work with municipalities to identify *E.coli* sources.
- WQI ratings and BioMAP results did not agree at every station (i.e. where the WQI rating is *marginal* the BioMAP rating is *impaired*) indicating that the benthic invertebrate data does not entirely support the chemical data. Instances where the WQI and BioMAP ratings did not match up may be attributed to the lack of intermediate ratings within the BioMAP scoring (BioMAP with 3 ratings, WQI with 5 ratings). There may be other 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 rating, and influence of parameters not monitored by the NPCA that may be affecting this agreement. Nonetheless biological and chemical monitoring remain important tools to evaluating water quality.
- Exceedances for chloride, metals (copper, lead, and zinc), nitrate, and total suspended solids were uncommon in the NPCA watershed. Elevated copper exceedances in Beaver Dam Creek (Port Colborne) and Eighteen Mile Creek warrant further investigation. Zinc exceedances in the Welland River are related to Hamilton Airport operations and the NPCA and Ministry of Environment are working with the HIA to reduce concentrations. Chloride exceedances are related to road salt impacts and groundwater discharge to surface water. NPCA is also observing statistically significant increases of chloride concentrations in approximately 25% of NPCA's long-term monitoring stations. The NPCA will work with its partners to identify chloride sources, assessing seasonal trends and reduce impacts. Nitrate exceedances in the upper Twelve Mile Creek may be related to golf course operations or faulty septic systems in the area. Total suspended solids are mainly related wet weather events and inadequate riparian buffers along watercourses and the NPCA will work with landowners in those watersheds to reduce their sediment inputs.

- The water quality at most PGMN monitoring wells meets the ODWS and therefore can be characterized as good water quality. Some of the PGMN monitors where found to have exceedances in boron, fluoride and sodium that were attributed to natural conditions of the groundwater. Nitrate exceedances found in two PGMN wells were attributed to agricultural landuse near the monitoring well. Follow-up monitoring in 2008-2009 by the NPCA and Niagara Public Health determined that these nitrate exceedances were site specific to the PGMN monitoring well only. It is recommended that residents using groundwater near these monitoring wells regularly test their water not only for bacteria but also for metals, general chemistry and nutrients.

- The NPCA's water temperature monitoring of the Upper Twelve Mile Creek headwaters classified seven stations as coolwater, two stations as coldwater and one station as as warmwater. Changes in the landscape in the upper Twelve Mile watershed since 2006 have not affected the thermal stability classifications of the NPCA monitoring stations in this watershed.

- The NPCA Water Quality Monitoring Program continues to generate a large wealth of scientific data that is a valuable resource to the public, environmental consultants, community groups, educational institutions, and other governmental agencies. In addition, this program continues to provide technical support to other NPCA programs, including Technical, Stewardship and Development Services.

8.0 ACTIONS

Actions from the NPCA Water Quality Monitoring Program 2016 Annual Report are summarized as follows:

1. It is recommended that the NPCA continue to collect up-to-date and reliable water quality data and continue to make this information freely accessible to the public.

2. It is recommended that the NPCA continue to analyze all collected water quality data with the intent to identify significant trends or abnormalities.

3. It is recommended that the NPCA continue to work with our partner municipalities and the MOECC to mitigate abnormally high sources of water pollution as they are identified through the Water Quality Monitoring field sampling program.

4. It is recommended that the NPCA continue to monitor summer water temperatures within streams that have been identified as being cool or cold water systems which are sensitive to temperature change.

5. It is recommended that the NPCA continue to undertake annual water quality assessments for the Hamilton International Airport and the City of Hamilton's Glanbrook Landfill (both presently commissioned and funded by the City of Hamilton).

6. It is recommended that the NPCA continue to implement the 'Water Quality & Habitat Improvement Program'. This landowner stewardship program can help to

reduce the levels of total phosphorus and *E. coli* which have been identified to be major contributors to the impairment of water quality within the NPCA watershed.

7. It is recommended that the NPCA continue to offer the 'Water Well Decommissioning Program' to the public in an effort to help reduce the risk of groundwater contamination by removing old and abandoned wells.

8. As it is no longer typical to have watercourses completely frozen from December to March, it is recommended that the NPCA pursue opportunities to expand the surface water quality monitoring program outside of the months of April to November in order to address water quality data gaps which presently exist for the winter months.

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10.0 ACKNOWLEDGEMENTS

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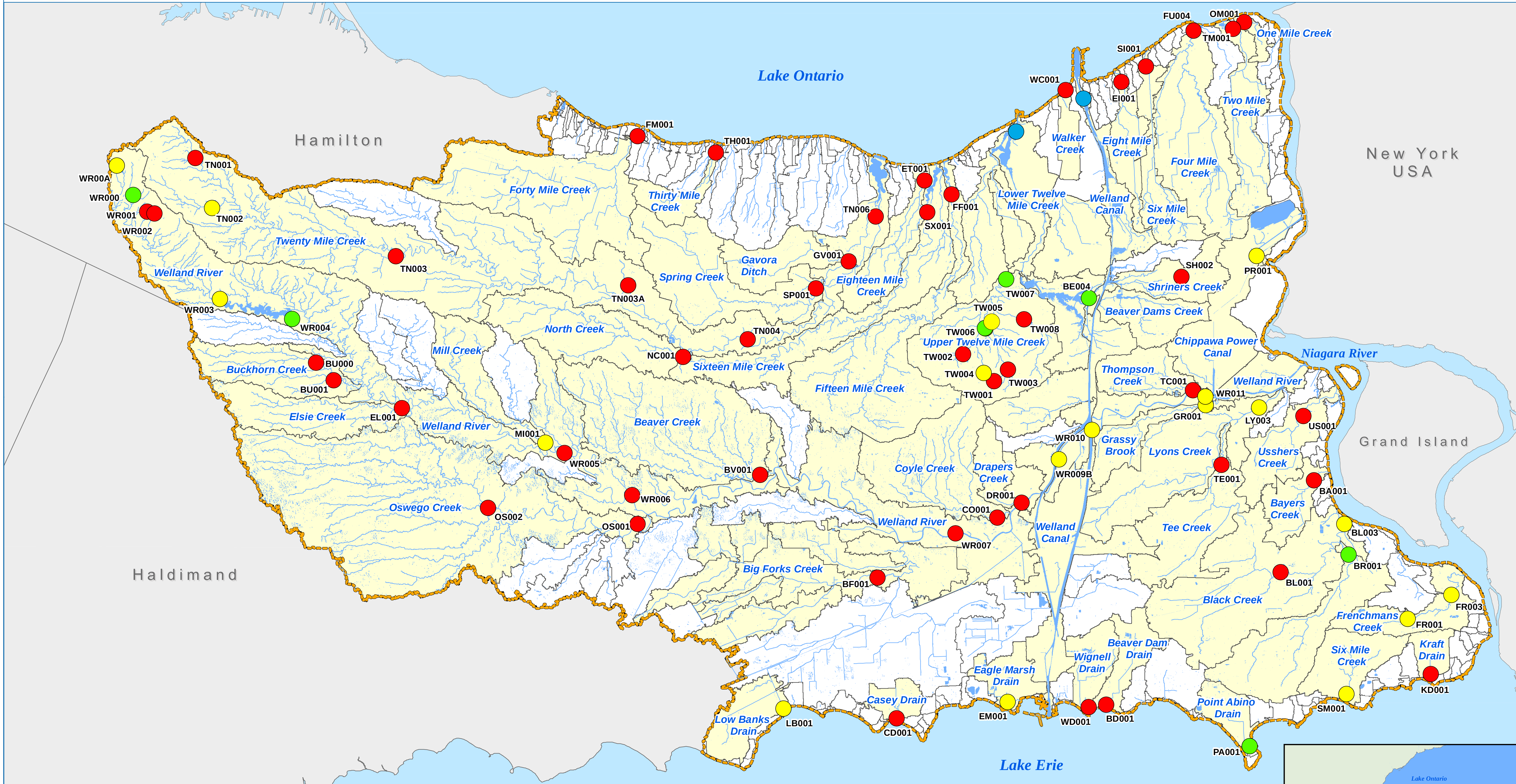
Appendix A

Niagara Peninsula Conservation Authority
2017 Water Quality Report

Water Quality Ratings



- Watercourses
- Waterbodies
- Sampled Subwatersheds
- NPCA Jurisdiction

Surface Water Quality Monitoring Station

Water Quality Rating

- Good
- Fair
- Marginal
- Poor

0 5 10 20 30

Kilometers

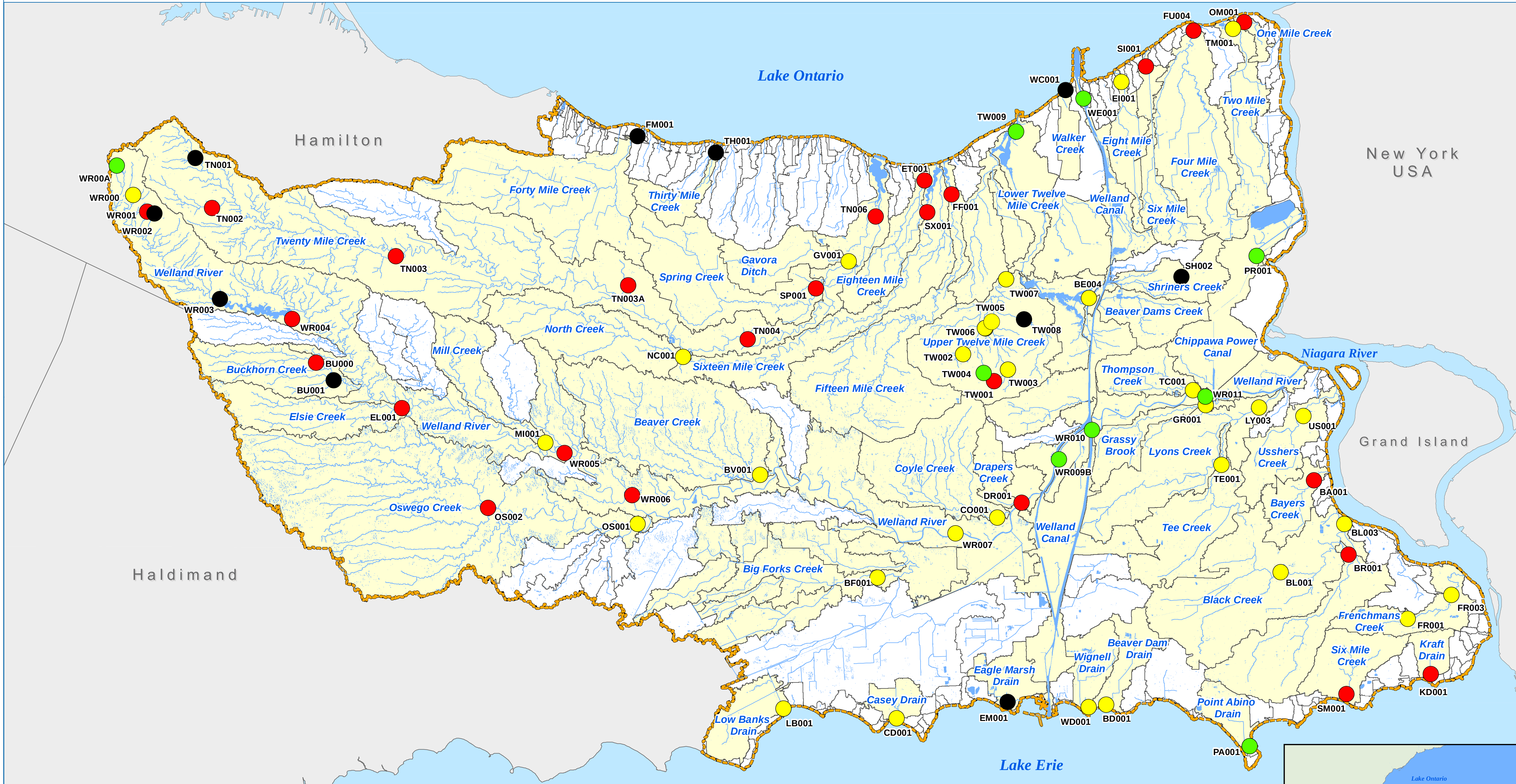
N

All Frames: North American Datum 1983, Universal Transverse Mercator 6° Projection, Zone 17N, Central Meridian 81° West.
Produced by the Niagara Peninsula Conservation Authority with data supplied under licence by members of the Ontario Geospatial Data Exchange, 2017.

Appendix B

Niagara Peninsula Conservation Authority
2017 Water Quality Report

Median Chloride Concentrations



- Watercourses
- Waterbodies
- Sampled Subwatersheds
- NPCA Jurisdiction

Surface Water Quality Monitoring Station
Chloride (mg/L)

- < 25
- 25 - 60
- 61 - 120
- > 120

0 5 10 20 30
Kilometers

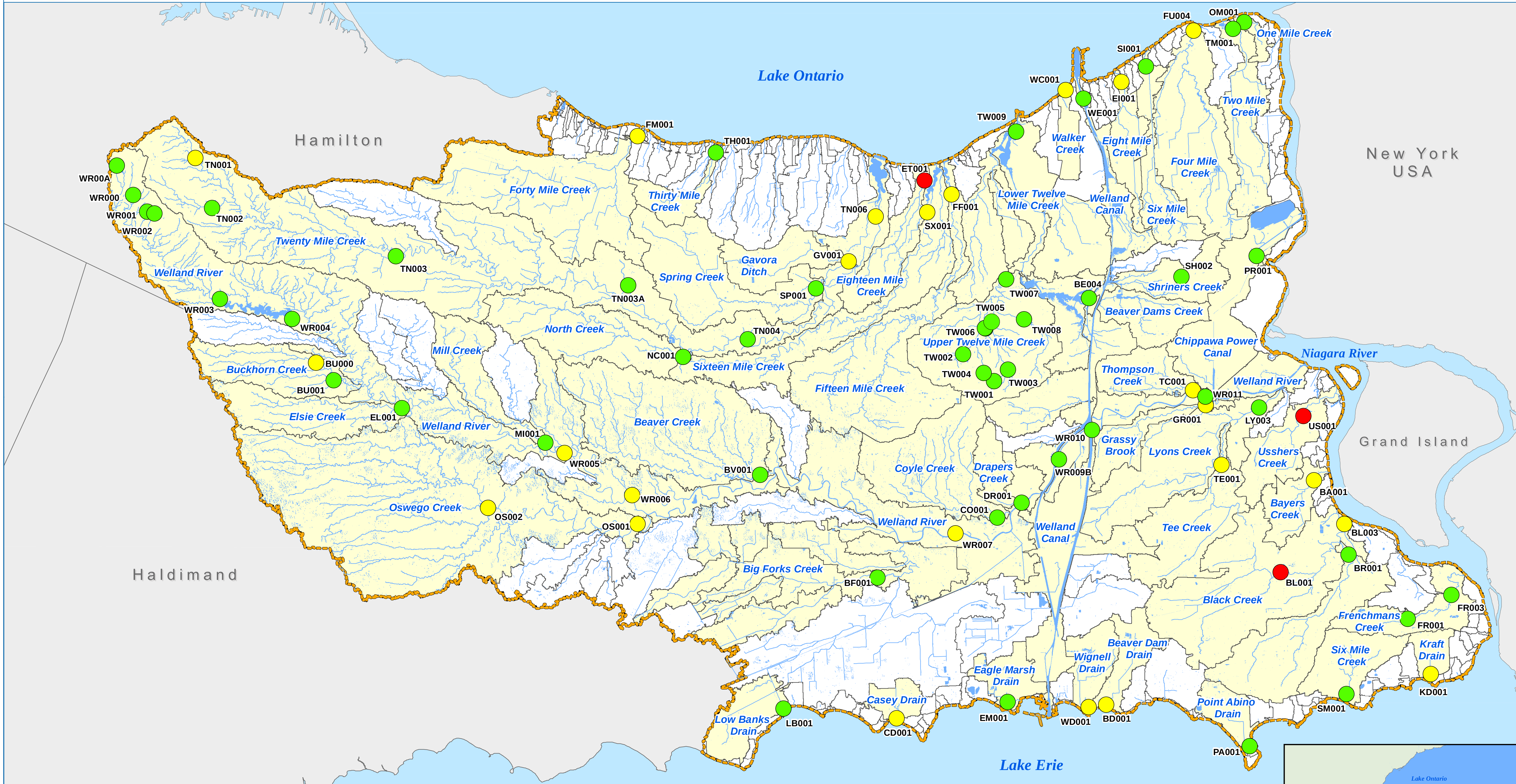
N

All Frames: North American Datum 1983, Universal Transverse Mercator 6° Projection, Zone 17N, Central Meridian 81° West.
Produced by the Niagara Peninsula Conservation Authority with data supplied under licence by members of the Ontario Geospatial Data Exchange, 2017.

Appendix C

Niagara Peninsula Conservation Authority
2017 Water Quality Report

Median Copper Concentrations



- Watercourses
- Waterbodies
- Sampled Subwatersheds
- NPCA Jurisdiction

Surface Water Quality Monitoring Station
Copper (µg/L)

- < 2.5
- 2.5 - 5.0
- 5.1 - 10
- > 10

0 5 10 20 30
Kilometers

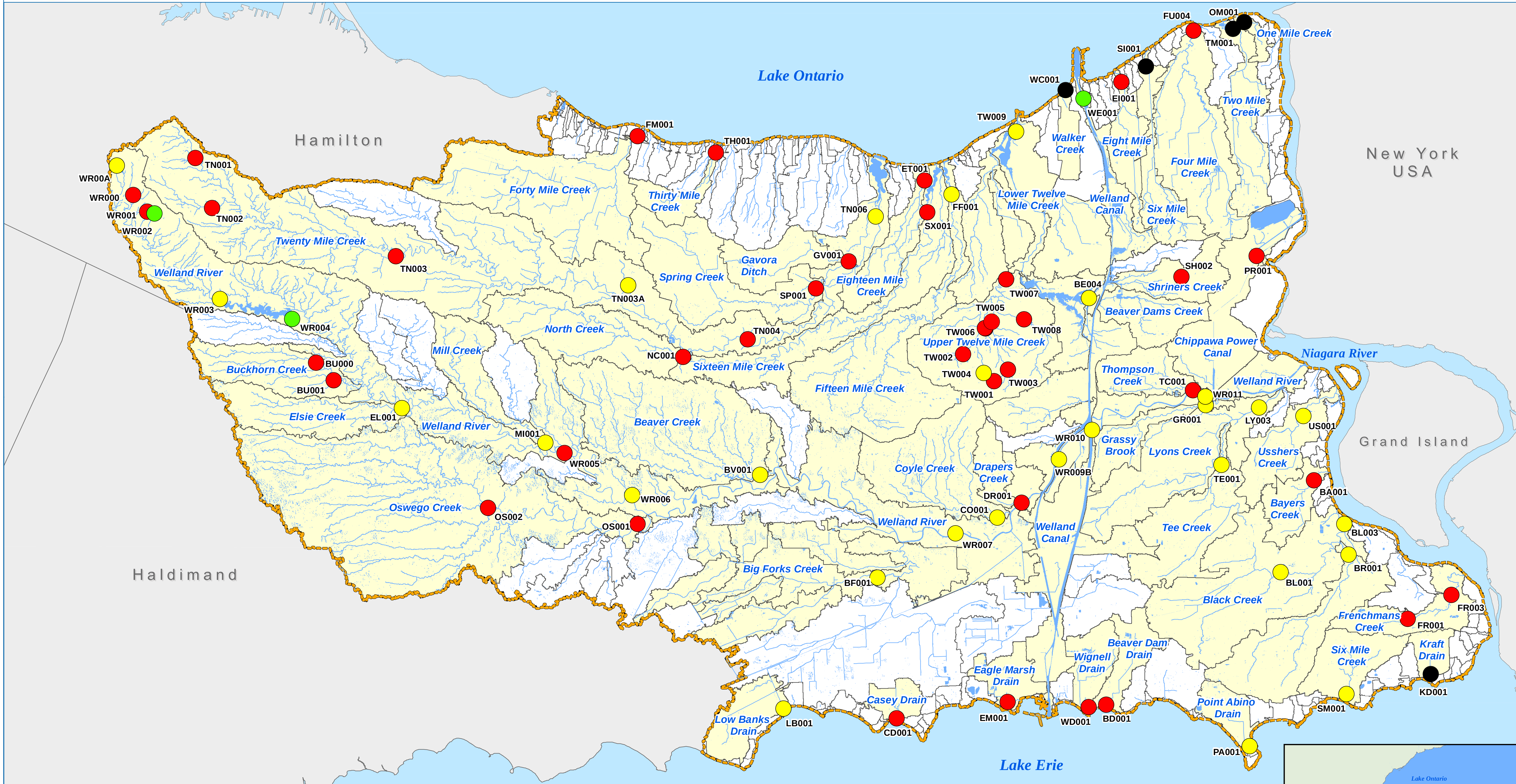
N

All Frames: North American Datum 1983, Universal Transverse Mercator 6° Projection, Zone 17N, Central Meridian 81° West.
Produced by the Niagara Peninsula Conservation Authority with data supplied under licence by members of the Ontario Geospatial Data Exchange, 2017.

Appendix D

Niagara Peninsula Conservation Authority 2017 Water Quality Report

Median E.coli Concentrations



Watercourses
Waterbodies
Sampled Subwatersheds
NPCA Jurisdiction

Surface Water Quality Monitoring Station
E.Coli (cfu\100ml)

- < 25
- 25 - 100
- 101 - 500
- > 500

0 5 10 20 30
Kilometers

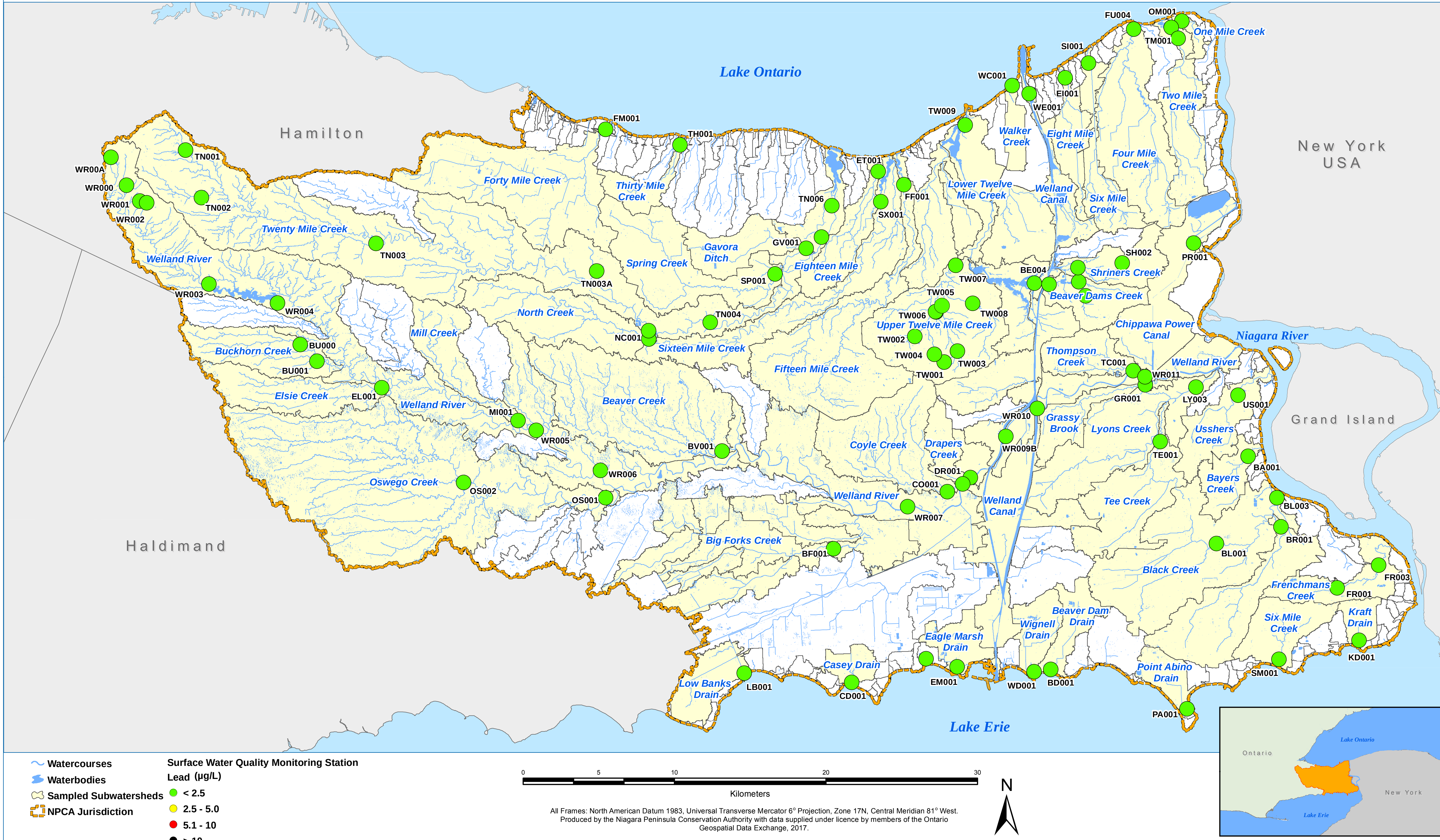
N

All Frames: North American Datum 1983, Universal Transverse Mercator 6° Projection, Zone 17N, Central Meridian 81° West.
Produced by the Niagara Peninsula Conservation Authority with data supplied under licence by members of the Ontario Geospatial Data Exchange, 2017.

Appendix E

Niagara Peninsula Conservation Authority
2017 Water Quality Report

Median Lead Concentrations



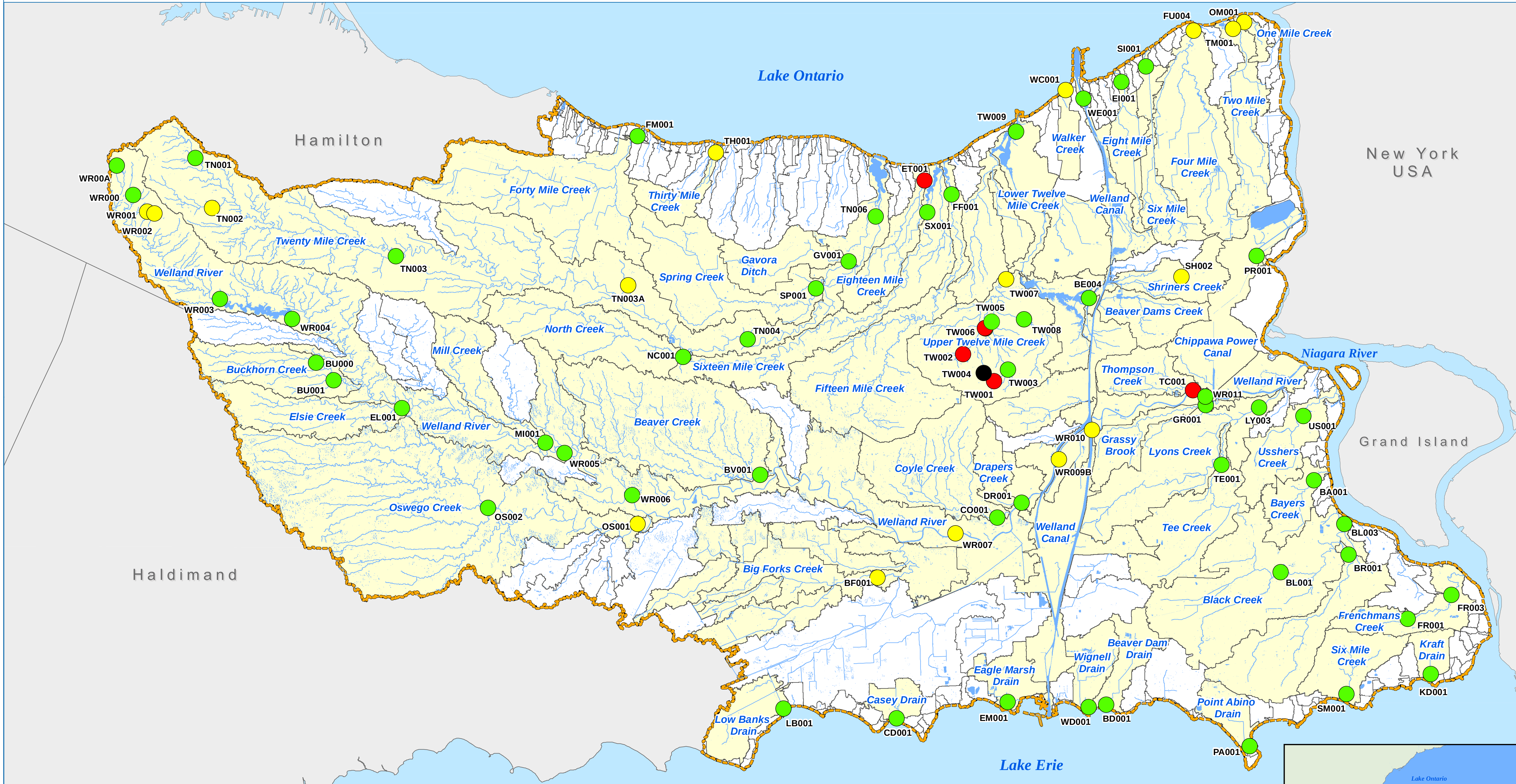
All Frames: North American Datum 1983, Universal Transverse Mercator 6° Projection, Zone 17N, Central Meridian 81° West.
Produced by the Niagara Peninsula Conservation Authority with data supplied under licence by members of the Ontario Geospatial Data Exchange, 2017.

Appendix F

Niagara Peninsula Conservation Authority 2017 Water Quality Report

NIAGARA PENINSULA CONSERVATION AUTHORITY

Median Nitrate Concentrations



- Watercourses
- Waterbodies
- Sampled Subwatersheds
- NPCA Jurisdiction

Surface Water Quality Monitoring Station

Nitrate (µg/L)

- < 500
- 500 - 1300
- 1301 - 2900
- > 2900

0 5 10 20 30

Kilometers

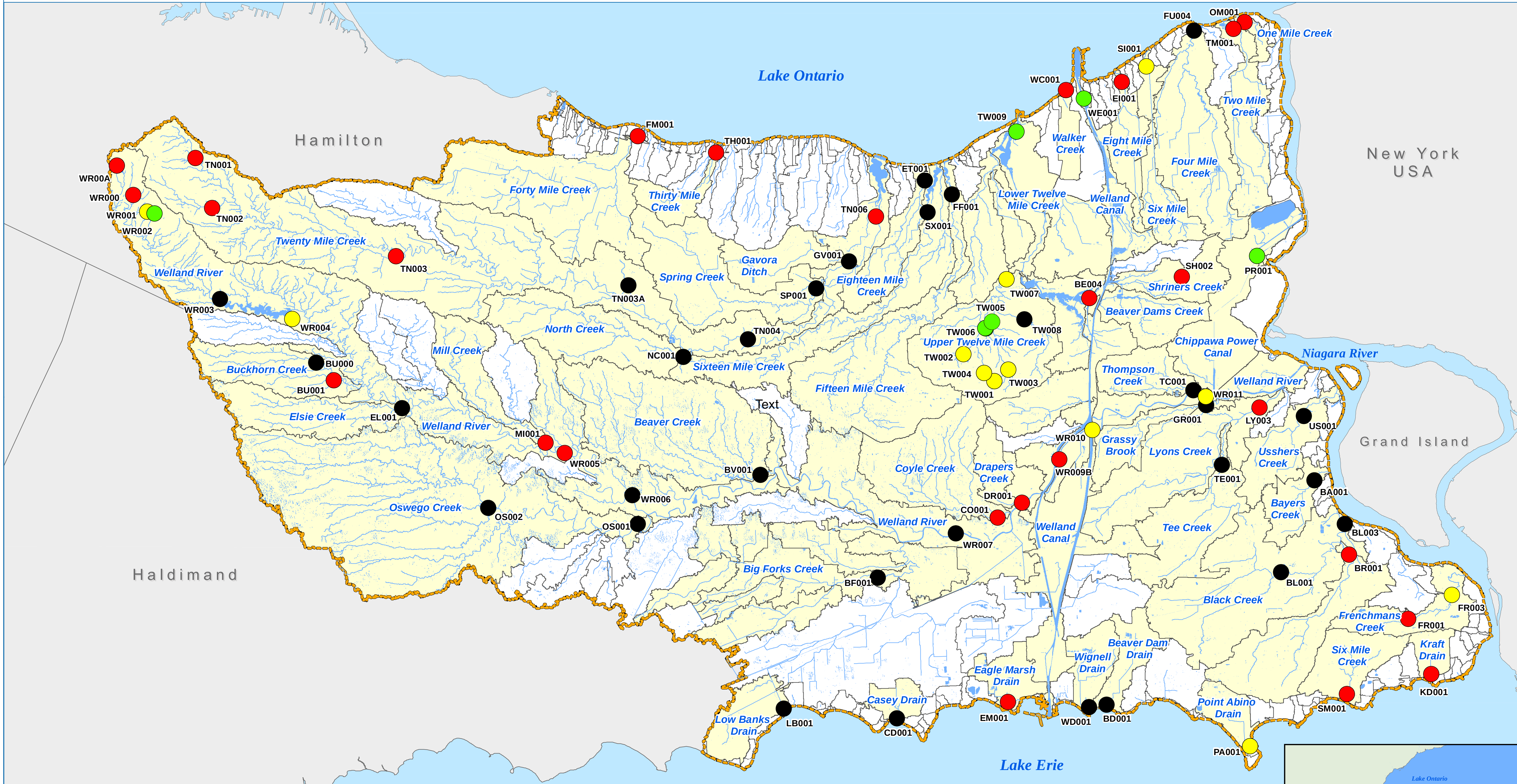
N

All Frames: North American Datum 1983, Universal Transverse Mercator 6° Projection, Zone 17N, Central Meridian 81° West. Produced by the Niagara Peninsula Conservation Authority with data supplied under licence by members of the Ontario Geospatial Data Exchange, 2017.

Appendix G

Niagara Peninsula Conservation Authority
2017 Water Quality Report

Median Total Phosphorus Concentrations



- Watercourses
- Waterbodies
- Sampled Subwatersheds
- NPCA Jurisdiction

Surface Water Quality Monitoring Station
Total Phosphorus (µg/L)
- < 30
- 30 - 60
- 61 - 120
- > 120

0 5 10 20 30
Kilometers

N

All Frames: North American Datum 1983, Universal Transverse Mercator 6° Projection, Zone 17N, Central Meridian 81° West.
Produced by the Niagara Peninsula Conservation Authority with data supplied under licence by members of the Ontario Geospatial Data Exchange, 2017.

Appendix H

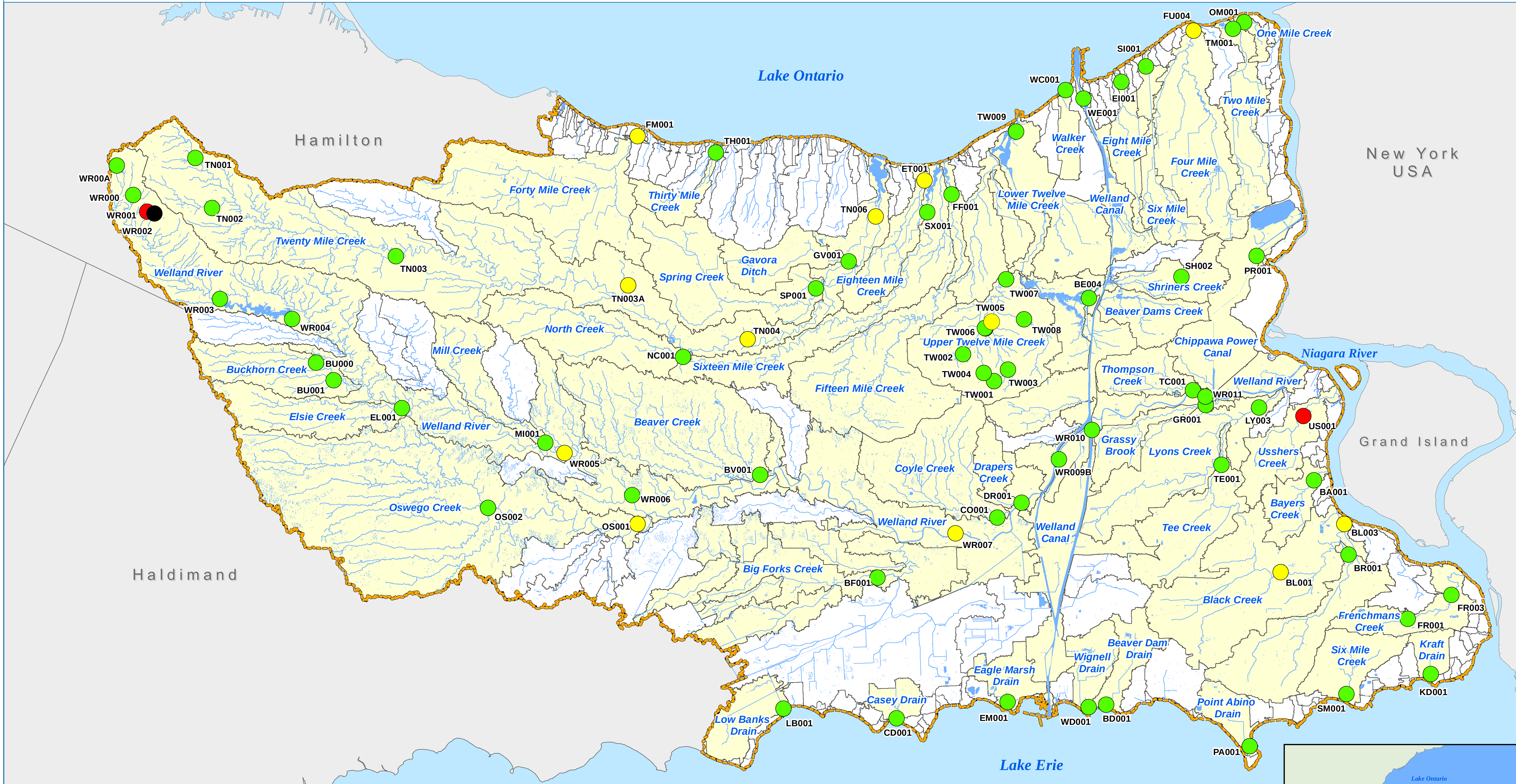
Niagara Peninsula Conservation Authority 2017 Water Quality Report

Median Total Suspended Solids Concentrations

Appendix I

Niagara Peninsula Conservation Authority
2017 Water Quality Report

Median Zinc Concentrations



- Watercourses
- Waterbodies
- Sampled Subwatersheds
- NPCA Jurisdiction

Surface Water Quality Monitoring Station

Zinc (µg/L)

- < 11
- 12 - 20
- 21 - 40
- > 40

0 5 10 20 30

Kilometers

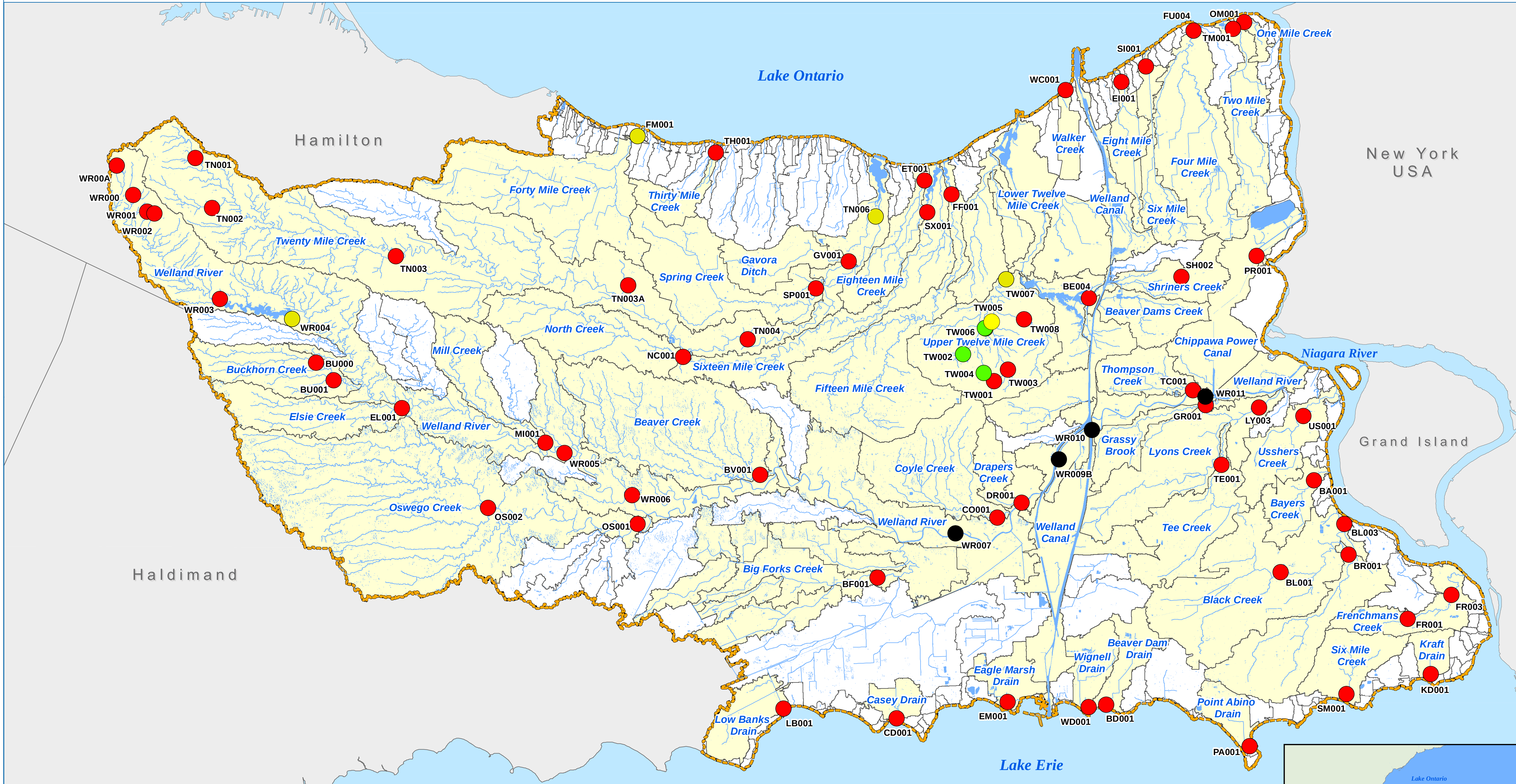
N

All Frames: North American Datum 1983, Universal Transverse Mercator 6° Projection, Zone 17N, Central Meridian 81° West.
Produced by the Niagara Peninsula Conservation Authority with data supplied under licence by members of the Ontario Geospatial Data Exchange, 2017.

Appendix J

Niagara Peninsula Conservation Authority
2017 Water Quality Report

BioMap Ratings



- Watercourses
- Waterbodies
- Sampled Subwatersheds
- NPCA Jurisdiction

Surface Water Quality Monitoring Station

BioMap Rating

- Unimpaired
- Grey Zone
- Impaired
- Insufficient Data

All Frames: North American Datum 1983, Universal Transverse Mercator 6° Projection, Zone 17N, Central Meridian 81° West.
Produced by the Niagara Peninsula Conservation Authority with data supplied under licence by members of the Ontario Geospatial Data Exchange, 2017.

Appendix K

Upper Twelve Mile Creek Temperature Monitoring: 2016 Summary Report

Niagara Peninsula Conservation Authority

Contents

Tables and Figures

1.0 Introduction

The Twelve Mile Creek watershed covers 178 km^2 of the Niagara Peninsula and is over 22 km in length. Twelve Mile Creek's headwaters can be found in Pelham, Ontario. The creek runs north from Pelham through the urbanized St. Catharines and empties into Lake Ontario at Port Dalhousie. The Upper Twelve Mile Creek tributaries are groundwater fed and they support the only naturally reproducing Brook Trout (*Salvelinus fontinalis*) population in Niagara. The map below (**Figure 1**) shows the Twelve Mile Creek watershed broken down into the upper and lower reaches. The upper reaches are more natural while lower reach has been highly altered by Ontario Power Generation and the Welland Canal and not considered brook trout habitat. The upper Twelve Mile Creek can be divided further into the Effingham and St.John's subwatersheds (**Figure 1**).

Stream temperature directly influences the physiology, metabolic rates and life history traits of aquatic species and influences processes such as nutrient cycling and productivity. Fluctuating and permanent natural and human induced changes to water temperature can render suitable habitat unusable to native species of fish, invertebrates and native aquatic communities (Coker *et al* 2001).

Brook Trout are indicators of high quality coldwater habitat. Once abundant throughout the Lake Ontario basin, Brook Trout populations have experienced severe declines since the mid-1900s because of habitat loss and stream temperature increases from forest clearing for agriculture and urban development activities. Brook Trout requirements include forested riparian cover, clean low nutrient water quality, base flow sufficient to maintain flow rates, cold water temperature, and up-welling groundwater or spring fed streams to aerate incubating eggs. The upper lethal temperature limit for Brook Trout is 24˚C with an optimum temperature range of 13 to 17˚C (Coker *et al*. 2001). The absence or impairment of any of these conditions can negatively affect the viability of individual populations.

To prevent the degradation and disruption of sensitive Brook Trout habitat and populations it is essential to establish monitoring programs to safeguard their quality and integrity. Water temperature, a key indicator and attribute of Brook Trout habitat health and viability, is easily monitored through the systematic use of temperature dataloggers.

Prior studies found that most tributaries fall within the healthy range for Brook Trout. There were no warm water classifications in 2015. These studies concluded that headwater streams remained classified as coolwater or coldwater, but downstream sites showed signs of possible warming. Additional sites were added for the 2016 study to expand the study area.

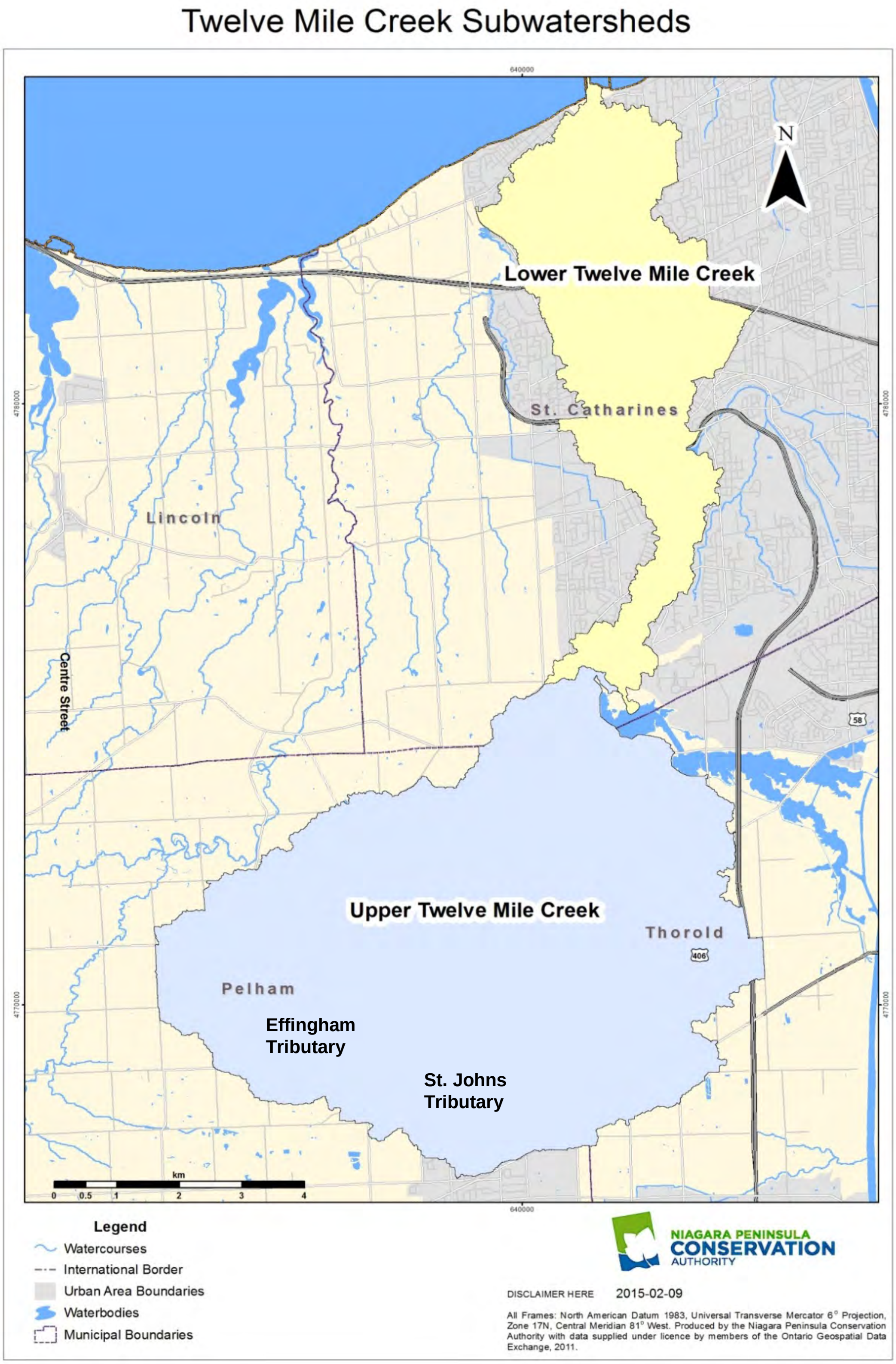


Figure 1: Twelve Mile Creek watershed divided into Upper and Lower reaches.

2.0 Objectives

The objectives of the 2016 temperature monitoring study are to:

- Identify and classify the thermal regime for the upper Twelve Mile Creek surface water sampling stations.
- Identify any changes that may have occurred to the thermal stability of Twelve Mile Creek.
- Identify sites that exceed the optimal range and/or lethal limit for Brook Trout.
- Follow up previous studies to determine areas in need of further monitoring and restoration.
- Expand the area of study to include more sites.

3.0 Methodology

Ten stream locations were chosen for the 2016 monitoring season. The stations were chosen due to the availability of background data, including water chemistry, benthic macroinvertebrate data, fisheries, stream morphology, hydrology data and stream temperature data. They are all locations that have been studied previously except for Sulphur Spring Dr. in the Effingham subwatershed which has never been apart of the temperature monitoring study.

Onset HOBO Water Temp Pro dataloggers **(Figure 2**) were used to record stream temperatures at ten locations identified in **Table 1**. Loggers were deployed in June 2016 and collected in October 2016.

Figure 2: Onset HOBO Temperature Logger

The dataloggers were installed in the stream bed at each location and anchored using metal spikes and aircraft cable. Stream bed locations were selected to provide shading from direct sunlight (where possible) and ensure adequate water depth to keep the datalogger fully submerged throughout the summer. The dataloggers were programmed to record stream temperature at one hour intervals and synchronized to commence logging at the same date and time. Refer to **Figure 3** for monitoring station locations within Twelve Mile Creek.

To analyze the data, it is first organized into excel worksheets with air temperature data from Environment Canada. The box and whisker plots were used to show how stream temperature data lies in relation to the Brook Trout's optimum temperature range. The box represents where 50% of the temperature values fall. The line within the box represents the median value, and the whiskers represent the minimum and maximum values that were recorded. The red line represents the lethal limit of 24ºC for Brook Trout and the blue line represents the maximum of the optimum temperature range If 13 ºC to 17 ºC.

Modified nomograms were created to observe the stream thermal stability and identify the thermal regime of each creek. The method used to create this figure was taken from Stoneman and Jones (1996), where a simple method to classify stream thermal stability with single observations of daily maximum air temperatures and water temperatures at 1600 hours from July 1 to September 10. Their method determines whether a watercourse is to be classified as coldwater, coolwater or warmwater. Air temperature data for this analysis was obtained from Environment Canada's web page which had data from a Welland-Pelham station (Enviroment Canada, 2016). This station was chosen due to the proximity to the study.

Table 1: Stream temperature monitoring stations for Twelve Mile Creek

STATION	WATERSHED	LOCATION DESCRIPTION	TEMPERATURE LOGGER APPROX. LOCATIONS (UTM'S)
Hamilton Sanctuary - "Center"	Effingham	Located within Hamilton Sanctuary property at Metler Road and Center Street in Pelham. "Center" flows from Center street in the east direction before meeting up with the Metler Road branch	4769365.76, 636334.29
TW000	St. John's	Located within Marlene Stewart Streit Park	4767556.525, 639439.166
TW001	St. John's	Located on Pelham Street at Overholt Road	4768719.62, 639606.196
TW002	Effingham	Located on Effingham Street upstream of Sulphur Springs Road	4770344.807, 637672.872
Sulphur Springs Road	Effingham	Located on Sulphur Springs Road. Effingham branch downstream of TW002	4771120.39, 638189.36
TW003	St. John's	Located off McSherry Lane	4769351.985, 640458.542
TW004	Effingham	Located on Metler Road at Haist Street	4769137.206, 638947.218
TW005	St. John's	Located at the confluence of St. John's and Effingham tributaries at Roland Road	4771944.266, 639053.941

TW006	Effingham	Located at the confluence of St. John’s and Effingham tributaries at Roland Road	4771967.481, 639028.628
TW007	Main Branch	Located at 1st Street Louth	4775028.65, 640332.03

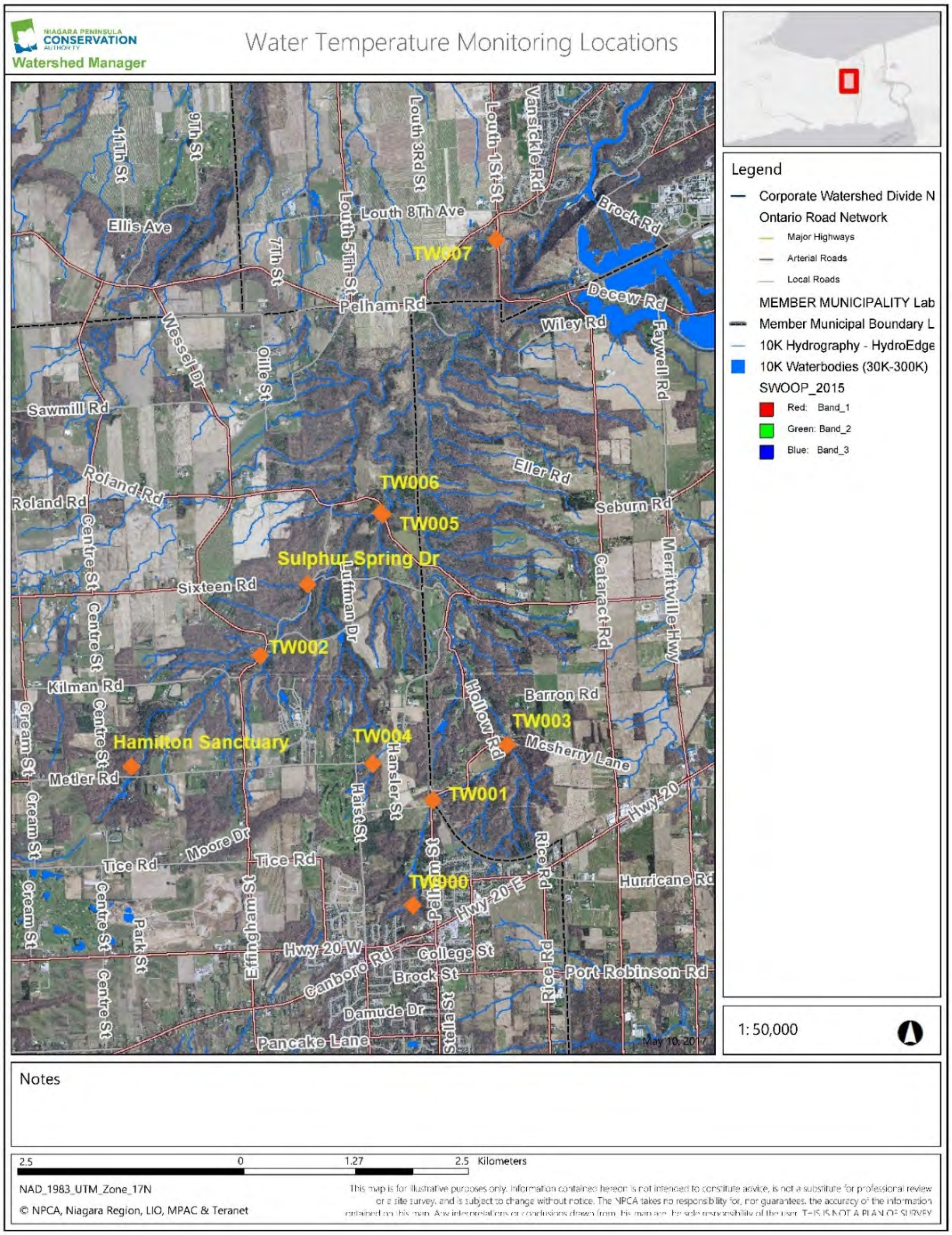


Figure 3. Map showing temperature logger locations in Twelve Mile Creek

4.0 Results

4.1 St. John's Tributaries

The St. John's Tributary of Twelve Mile Creek was monitored at four stations between July and September in 2016. **Figure 4** also includes TW007 which is part of the larger 12 Mile Creek main channel downstream of the Effingham/St. John's convergence. A summary of the temperature data is provided in **Table 2.**

TW001, TW005, and TW007 all sit above the optimum temperature range. TW000 and TW003 have 50% of all values falling within the optimum temperature range. Maximum temperatures stayed below the lethal limit of 24°C, with the exception of TW007 which had a max temperature was 26.02 °C.

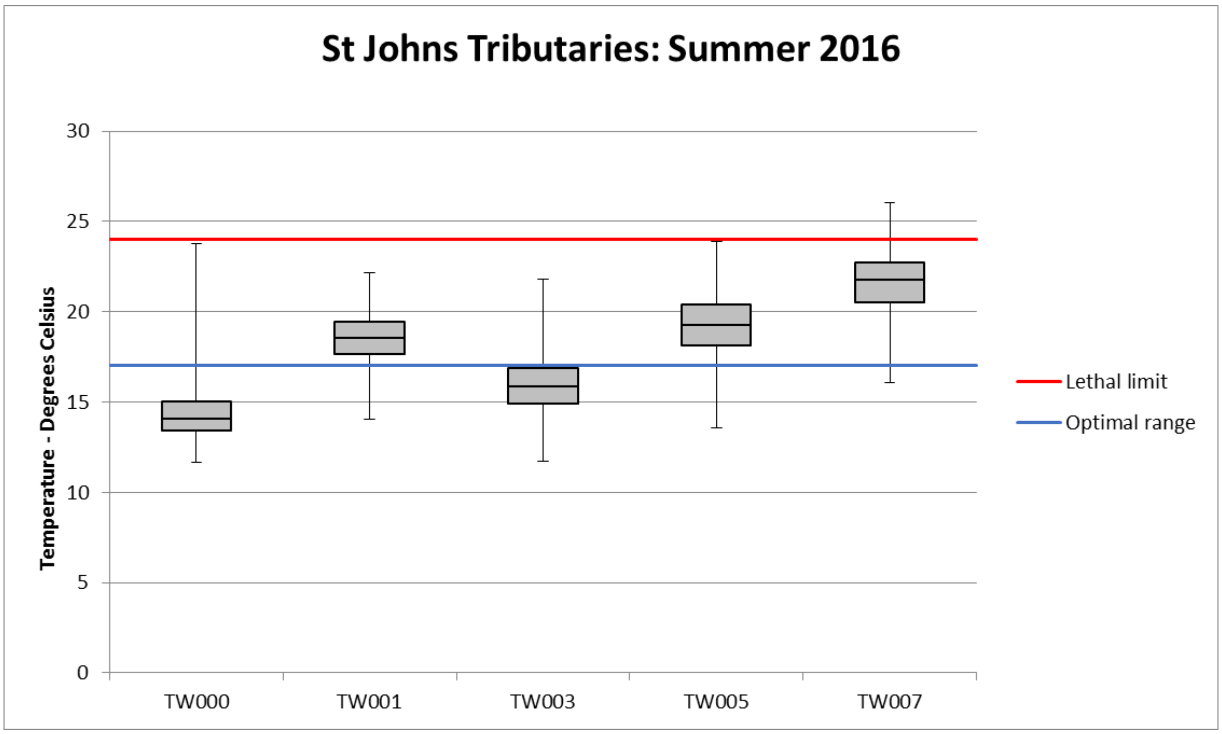


Figure 4: Box and whisker plot for St. John's tributary stations and the main channel location TW007. The box length of the box-and-whisker plots represents the inter-quartile range that contains the median value shown as a horizontal line. The whiskers represent the minimum and maximum values.

In the St. John's tributary, some warming occurs aritficially due to upstream land use. On-line ponds upstream hold water and cause warming at TW001. These ponds are leftover from a former cannery. Holding time in these ponds means temperature increases. This results in above normal temperatures relative to the locations near it.

Figure 5 is a scatter plot nomogram that represents the classification of stream thermal stability. Maximum daily air temperature was plotted against the corresponding water temperature at 1600 hrs from July 1 to September 10, 2016 according to procedures described by Stoneman and Jones (1996).

When plotted, the nomogram shows that TW007 falls largely in warmwater classification while TW005, TW003, and TW001 are coolwater. TW000 is classified as coldwater. The only change in thermal classification in the St. John's subwatershed was TW003 which changed from coldwater to coolwater.

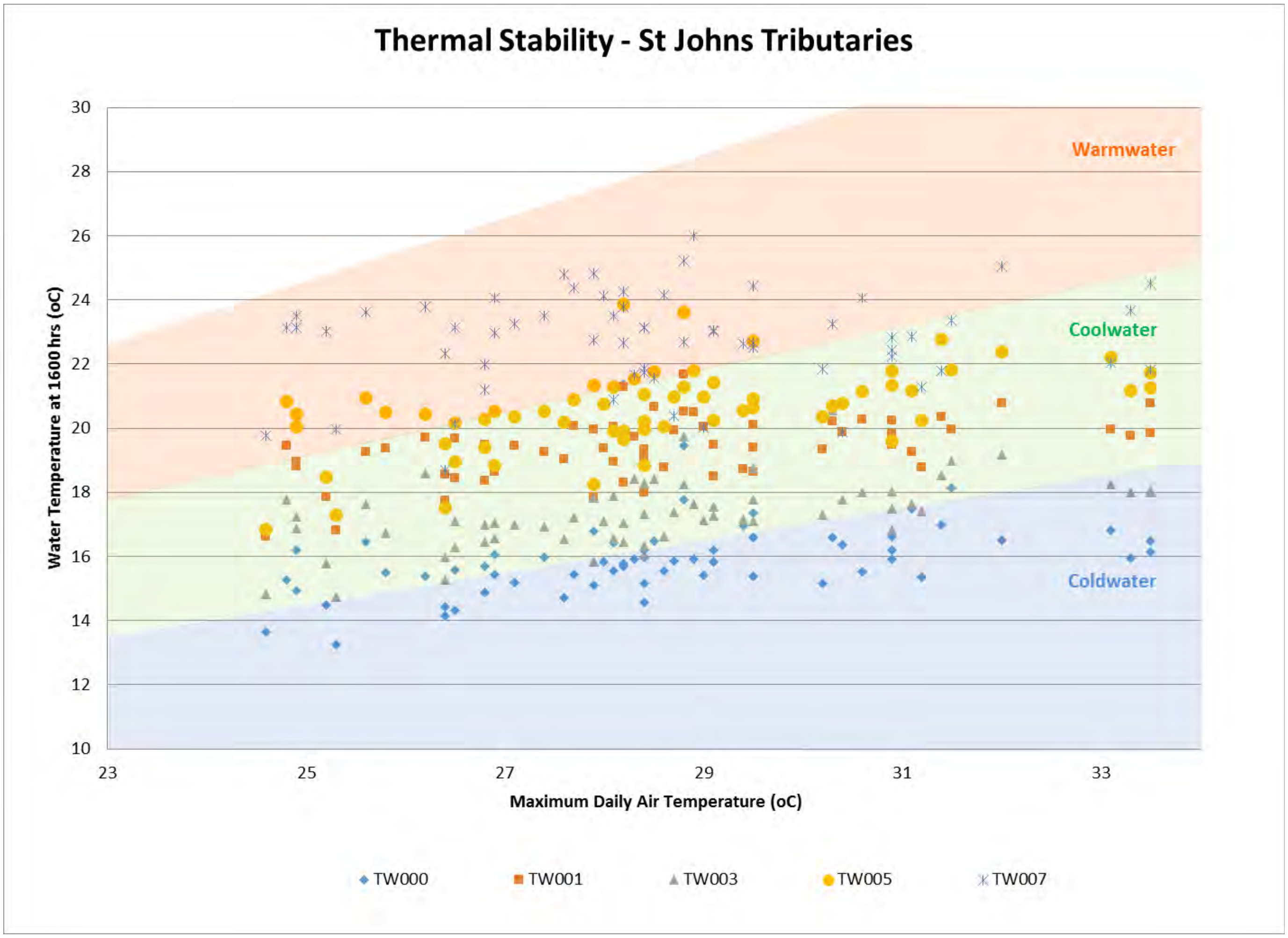


Figure 5: Thermal Stability - modified nomogram showing coldwater, coolwater, and warmwater classifications for St. John's tributaries and main branch location TW007.

4.2 Effingham Tributaries

Stream temperature was monitored in the Effingham Tributaries of Twelve Mile Creek at five stations between July and September 2016. A summary of the data collected is provided in **Table 2**.

Figure 6 shows that Sulphur Springs Drive, TW004 and TW006 have at least 50% of their values falling above the optimum temperature range. Hamilton Sanctuary and TW002 largely fell within or below optimal range. All maximum temperatures are below the lethal limit.

The Effingham Tributary found in the Hamilton Sanctuary was added back into the study and remained coldwater as was observed in 2014. Sulphur Springs Drive location is just downstream of TW002 yet slightly warmer water was observed. While it did not change classifications, it is important to note that a lot of construction and erosion is occurring in this stretch. Portions of this reach have widened greatly due to recent storm events. Wider, shallower creeks may see temperatures rise over time.

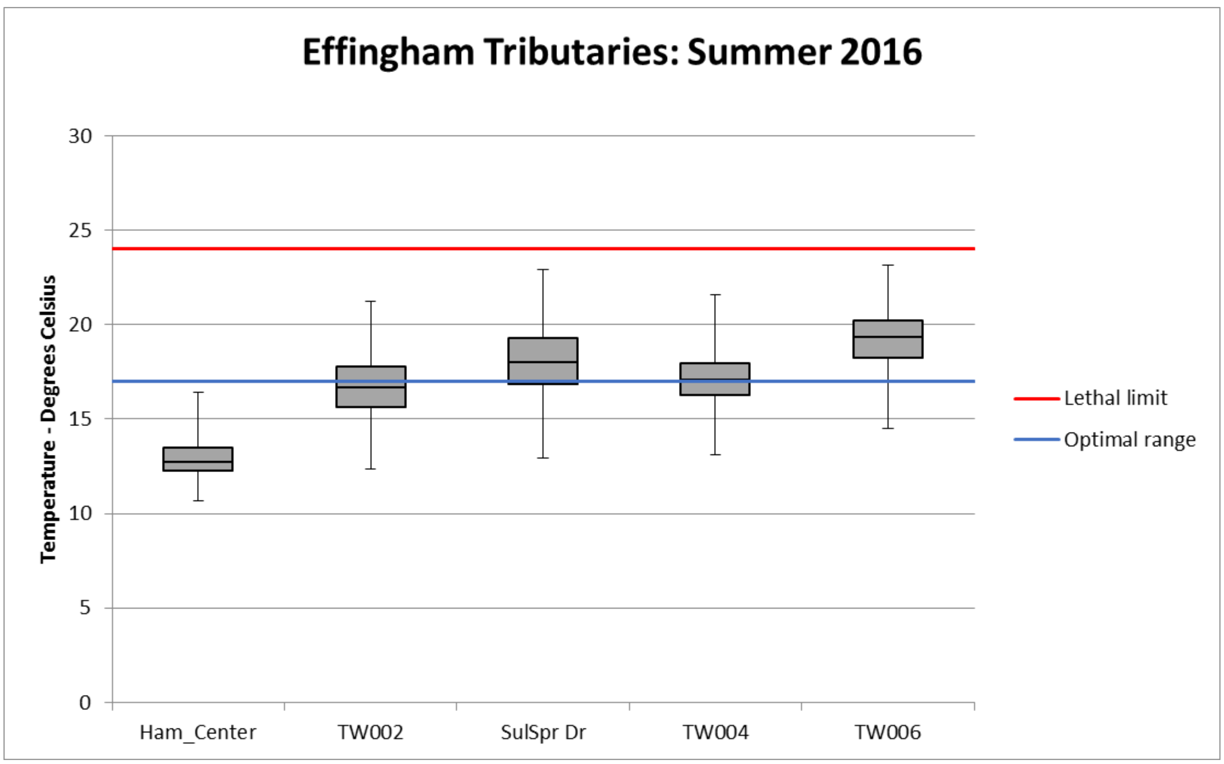


Figure 6: Box and whisker plot for Effingham tributary stations. The box length of the box-and-whisker plots represents the inter-quartile range that contains the median value shown as a horizontal line. The whiskers represent the minimum and maximum values.

Figure 7 shows the maximum daily temperatures were plotted against water temperatures at 1600 hrs from July 1 to September 10 2016. All stations are classified as coolwater, except for Hamilton Sanctuary, which is coldwater.

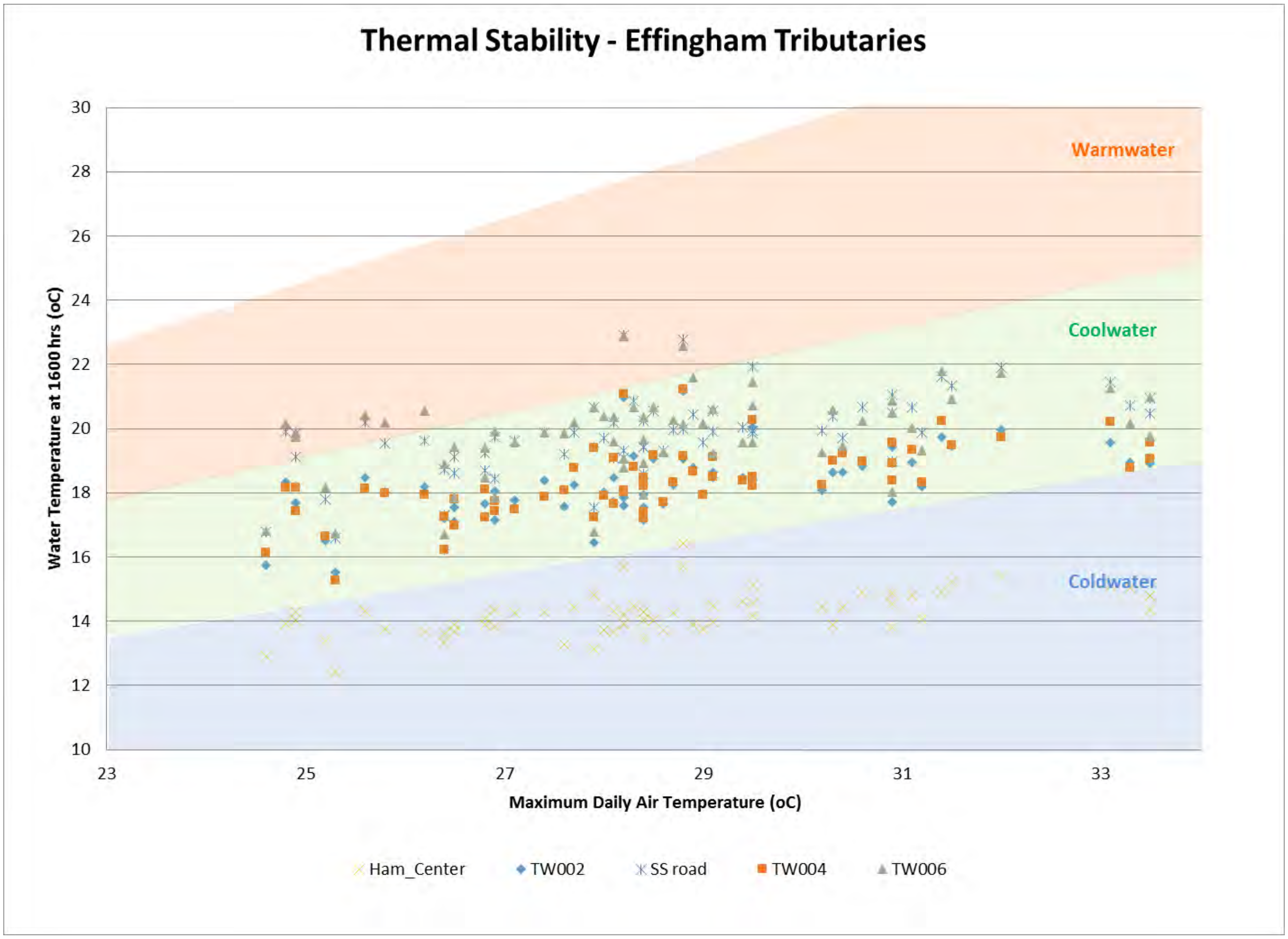


Figure 7: Thermal Stability - modified nomogram showing coldwater, coolwater and warmwater classifications for Effingham tributaries.

Table 2 summaries the mean temperature, maximum temperature and the change in classification over time for each station from 2011. Thermal stability classifications are stable for most stations with only the classification of TW003 changing from coldwater to coolwater.

Table 2: Summary of thermal stability classifications, mean temperature and maximum temperatures for each site from 2011-2016

Site	2011			2013			2014			2015			2016		
	Classification	Mean Temp (Celsius)	Max Temp (Celsius)	Classification	Mean Temp (Celsius)	Max Temp (Celsius)	Classification	Mean Temp (Celsius)	Max Temp (Celsius)	Classification	Mean Temp (Celsius)	Max Temp (Celsius)	Classification	Mean Temp (Celsius)	Max Temp (Celsius)
Ham Centre	N/A	N/A	N/A	N/A	N/A	N/A	Coldwater	11.55	15.18	N/A	N/A	N/A	Coldwater	12.88	16.42
TW000	Coldwater	13.74	20.56	Coldwater	14.11	17.63	Coldwater	13.27	20.53	Coldwater	13.47	20.6	Coldwater	14.33	23.76
TW001	Coolwater	17.98	24.61	Coolwater	17.38	24.61	Coolwater	16.78	21.94	Coolwater	17.02	22.03	Coolwater	18.45	22.15
TW002	Coolwater	15.96	21.01	Coolwater	15.53	21.29	Coldwater	14.51	19.41	Coolwater	15.37	18.72	Coolwater	16.65	21.22
Sulphur Springs	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Coolwater	17.98	22.9
TW003	Coolwater	14.99	23.09	Coldwater	14.65	21.49	Coldwater	14.37	21.32	Coldwater	14.52	20.39	Coolwater	15.88	21.8
TW004	Coolwater	16.16	21.68	Coolwater	15.69	21.72	Coldwater	15.23	18.01	Coolwater	15.46	18.91	Coolwater	17.09	21.58
TW005	Coolwater	18.16	24.05	Coolwater	17.41	24.22	Coolwater	16.77	22.01	Coolwater	17.37	21.25	Coolwater	19.15	23.91
TW006	Coolwater	18.25	24.36	Coolwater	17.35	24.15	Coolwater	17.1	22.42	Coolwater	17.56	21.72	Coolwater	19.15	23.14
TW007	Coolwater	17.05	26.13	Warmwater	17.98	26.7	N/A	N/A	N/A	N/A	19.7	23.75	Warmwater	21.52	26.02
Red Text: Maximum Temperature Over Lethal Limit for Brook Trout															

5.0 Conclusions

An overview of the 2016 findings:

- Upper Twelve Mile Creek tributaries can support Brook Trout based on the thermal stability classifications.
- Only TW007 main branch exceeds lethal limit for Brook Trout. It is also the only site that is classified as warmwater.
- Hamilton Sanctuary, TW000, TW002, and TW003 all had at least 50% of their values fall within the optimum range for Brook Trout.
- TW001, Sulphur Spring Dr., TW004, TW005, TW006, and TW007 had >50% of data fall above the optimal range.
- Groundwater influence protects upper tributaries from warming. As groundwater influence decreases, downstream locations may not be shaded enough to protect them from summer heating. The lower portions of the upper tributaries are exposed to air temperature fluctuations and natural protection wanes.
- There were two coldwater classifications – Hamilton Sanctuary, and TW000.
- TW003 changed from coldwater to coolwater.
- There was an increase to mean temperatures in 2016 which was cause by the extremely dry and hot summer. Despite this, most tributaries maintained their thermal classification.
- Some reach portions may exceed optimal levels during hotter years and may restrict moment or cause distress to the Brook Trout leading to lack of reproduction and potential disappearance of populations.

5.1 Future Considerations

- Temperature studies continue a yearly basis to build consistent trends.

- Fish studies should be completed to determine the actual population distribution of Brook Trout within these tributaries.

- Stewardship projects with landowners in the Twelve Mile Creek watershed to restore riparian zones and continue best practices are necessary. Areas prone to erosion and widening should be targeted.

- Other types of loggers such as conductivity loggers would also be beneficial in the Twelve Mile Creek watershed. Monitoring conductivity can help locate areas of high runoff which will affect fish and benthic communities.

6.0 References

Coker, G.A., C.B. Portt and C.K. Minns. 2001. *Morphological and Ecological Characteristics of Canadian Freshwater Fishes*. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2554: Department of Fisheries and Oceans, Canada.

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