NIAGARA PENINSULA CONSERVATION AUTHORITY

NPCA WATER QUALITY MONITORING PROGRAM: SUMMARY REPORT OF THE YEAR 2020

MAY 2021

TABLE OF CONTENTS

Table of Acronyms

AOC	Area of Concern
BMPs	Best Management Practices
CCME	Canadian Council of Ministers of the Environment
CWQG	Canadian Water Quality Guidelines
ECCC	Environment and Climate Change Canada
EMRB	Environmental Monitoring and Reporting Branch
HIA	Hamilton International Airport
HBI	Hilsenhoff Biotic Index
MECP	Ministry of Environment Conservation and Parks
NPCA	Niagara Peninsula Conservation Authority
PFC	Perfluorinated Compound
PGMN	Provincial Groundwater Monitoring Network
PWQMN	Provincial Water Quality Monitoring Network
PWQO	Provincial Water Quality Objective
OBBN	Ontario Benthos Biomonitoring Network
ODWS	Ontario Drinking Water Standards
OGS	Ontario Geologic Survey
OPG	Ontario Power Generation
RMN	Regional Municipality of Niagara
WQI	Water Quality Index for CCME

Executive Summary

The Niagara Peninsula Conservation Authority's (NPCA) Water Quality Monitoring Program was implemented in 2001 and is operated in partnership with the Ontario Ministry of Environment, Conservation and Parks (MECP), Regional Municipality of Niagara, Haldimand County, and the City of Hamilton. Through these partnerships the NPCA collects water quality samples at 80 surface water stations and 46 groundwater wells 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 chloride, nutrients, *E. coli*, suspended solids, and metals. Surface water results are used to calculate the Canada Council of Ministers of Environment 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 Ontario Biological Benthos Monitoring (OBBN) protocol. The abundance and diversity of animals living in the watercourse provides a biological assessment of the water quality. Groundwater samples are evaluated by comparing monitoring results to the MECP's Drinking Water Standards (ODWS).

For surface water, the monitoring results indicate most of the NPCA's watersheds have poor 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. Watercourses under the direct influence from the Great Lakes and Niagara River such as the Lower Welland River have higher water quality ratings. Watershed tributaries that are strongly influenced by groundwater discharge like the Upper Twelve Mile Creek Effingham portion and Upper Welland River as well as the tributaries found with substantial natural landscapes like Point Abino Drain and Beaver Creek (Fort Erie) continue to have the best water quality ratings in the NPCA watershed.

The ambient groundwater geochemistry in NPCA jurisdiction was found to have some health and aesthetic ODWS exceedances. Health ODWS exceedances have been investigated by MECP and are attributed to natural conditions of the groundwater but in the case of sodium exceedances, the local Health Units are periodically notifying local physicians of elevated sodium levels in the groundwater for them to advise their patients with sodium-restricted diets. The NPCA recommends that residents using groundwater regularly test their well water and use the appropriate water treatment.

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 fact that the water quality is generally poor in the NPCA watershed has been caused by decades of environmental degradation. However, water quality improvement programs that refine how nutrients are managed, increase riparian buffers, and expand forest cover can begin to address these impacts. It will likely take many years of implementing these programs before the water quality in the NPCA watershed improves to the point where it is able to meet federal and provincial water quality guidelines and objectives. As such, it is recommended that the NPCA continue to monitor both our surface water and groundwater to ensure that there is up-to-date current water quality information available, be able to quantify trends, and continue to identify sources of contamination within the NPCA watershed.

NPCA WATER QUALITY MONITORING PROGRAM: SUMMARY REPORT FOR THE YEAR 2020

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 MECP, 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 this 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 2020, the NPCA monitored surface water quality at 80 stations covering 52 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. The chemical monitoring program is mainly funded through the municipal levy, however the NPCA does receive additional support for lab analysis from the following partners: RMN, MECP, ECCC and the City of Hamilton. These are described in detailed below.

2.1.1 NIAGARA RIVER AOC TRIBUTARY MONITORING PROGRAM

The Niagara River was listed as a Great Lakes' Area of Concern (AOC) in the late 1980s due to habitat loss and contaminants in water. A Remedial Action Plan (RAP) was first developed and implemented beginning in 1993. This monitoring program was established in 2003 out of a recommendation in the 1995 Niagara River Stage 2 RAP Report (MOE and EC 1995) which outlined 37 recommended remedial actions to restore the health of the watershed. Recommendation #29 was to develop and implement a Welland River and Niagara River tributaries monitoring program to monitor rural non-point sources of pollution, establish a baseline of water quality conditions at selected tributaries, and track the effectiveness of stewardship efforts in the watershed (MOE and EC 1995). Stations were selected to both overlap with historic stations and fill data gaps where required. The monitoring program was implemented as part of an agreement with the federal and provincial government until 2016. Given the scope of the AOC was recently focused on the Niagara River proper (as per guidance in the Great Lake Water Quality Agreement), the NPCA began funding the sample collection and lab analysis for these monitoring stations in 2017.

2.1.2 PROVINCIAL WATER QUALITY MONITORING NETWORK

In 2003 a partnership was established with the MECP through the Provincial Water Quality Monitoring Network (PWQMN) whereby NPCA staff collect monthly water samples at stations located within the NPCA watershed and the MECP 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 MECP and program-specific needs. The NPCA has 13 PWQMN stations which are located on the Black Creek (Fort Erie), Welland River (West Lincoln & Welland), Twenty Mile Creek (West Lincoln and Lincoln), Forty Mile Creek (Grimsby), Four Mile Creek (Niagara-on-the Lake), and Twelve Mile Creek (Pelham & St. Catharines).

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. This laboratory partnership was cancelled January 2018 by the City of Hamilton. However, after the cancellation of this program the NPCA continued to fund the lab analysis for these monitoring stations. The NPCA is also involved in monitoring at the Hamilton International Airport and the Glanbrook Landfill. For further details, please refer to section 6.0. In 2003 a similar monitoring arrangement was established with the RMN whereby NPCA staff collect water samples at ten stations located within the Niagara Regional Municipal boundary of the NPCA watershed and the RMN 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.

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 Ontario Benthos Biomonitoring Network (OBBN) protocol. The OBBN provides a standardized benthic invertebrate sampling protocol for the province of Ontario and provides 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. The NPCA uses the Hilsenhoff Biotic Index (HBI) to summarize biological monitoring data in this report.

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 NPCA watershed and are most useful in assessing relative stream health. 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 (Chronic)	CWQG (CCME 2011)
Nitrate	3.0 mg/L	CWQG (CCME 2003)
Total phosphorus	30 µg/L	PWQO (MOE 1994)
Suspended solids	35 mg/L	CWQG (CCME 2002)
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	HBI (Hilsenhoff 1987)

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 or chronic 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-nitrogen concentrations should not exceed 3.0 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 Total Suspended Solids

Total suspended solids (TSS) 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. The Canadian Water Quality Guidelines provides a narrative guideline for TSS: the maximum increase of TSS should be no more than 25 mg/L from background concentrations (with NPCA using a background TSS concentration of 10 mg/L determined using data from the NPCA jurisdiction; CCME 2002). 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 Biological Assessments: 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.

The NPCA collects benthic samples during the spring and fall seasons each year at approximately 30 monitoring sites. Once collected, counted, and preserved, the benthic invertebrates are identified to family level and various statistics were calculated. For this 2020 Report the Hilsenhoff Biotic Index (HBI) was calculated for each sample site. The HBI estimates the overall tolerance of the community in a sampled area, weighted by the relative abundance of each family taxonomic group. Organisms are assigned a tolerance values based on those provided Hilsenhoff (1987). Water quality is classified as gradient from *excellent* to *very poor* in to recognize the occurrence of organisms whose environmental requirements and tolerances match those which would be expected at the site without the input of environmental stresses to those with the organisms found are less sensitive. 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.

Threshold values to classify the water quality of watercourses based on Hilsenhoff Family Biotic Index (1987)	
Family Biotic Index	Water Quality Rating
0.00-3.75	Excellent
3.76-4.25	Very Good
4.26-5.00	Good
5.01-5.75	Fair
5.76-6.50	Fairly Poor
6.51-7.25	Poor
7.26-10.00	Very Poor

4.0 Surface Water Quality Monitoring Results

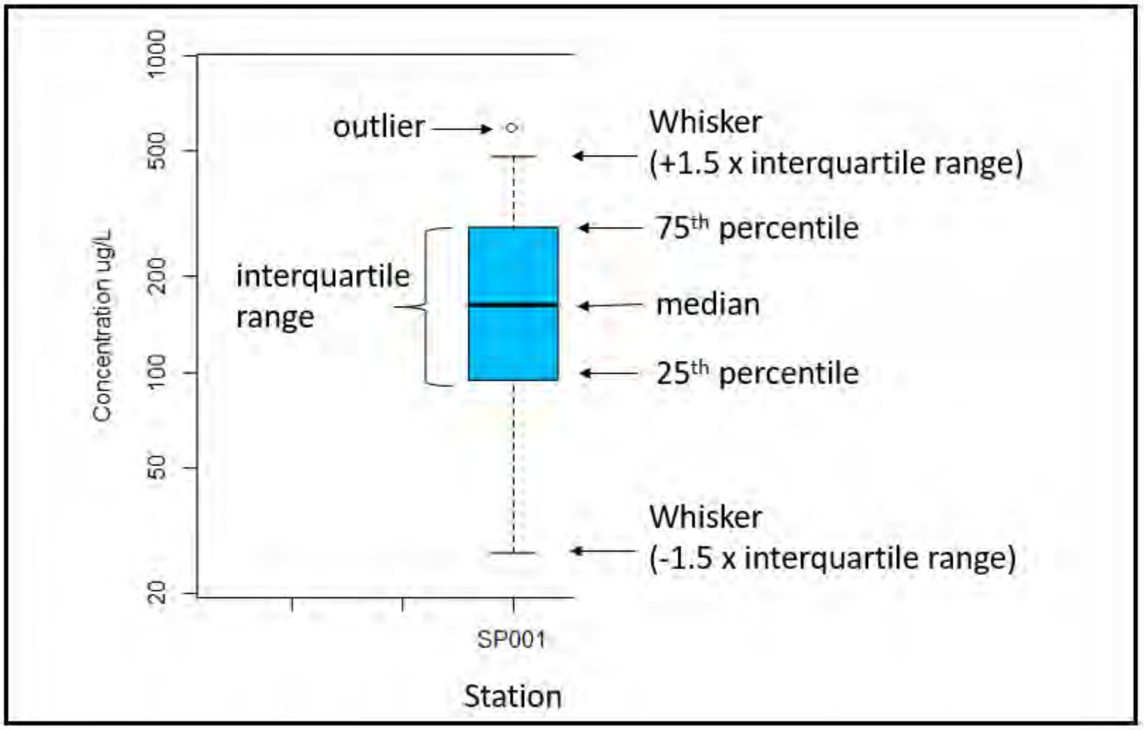
The Canadian Council of Ministers of the Environment (CCME) Water Quality Index (WQI) was used to summarize the indicator parameter data collected from NPCA surface water quality monitoring stations between 2016 and 2020. This approach reduces the overall sample size of water quality monitoring stations, but 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 (n=40 to 50) 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 (> 3 years) as more data is collected and a wider range of water quality conditions are captured in the dataset. In addition, water quality indicator parameters were summarized using boxplots which allow for comparison of the data distributions and basic statistical attributes such as median, percentiles, overall range, and outliers.



Example of a boxplot

4.1 TREND ANALYSIS

The NPCA surface water quality database has reached a sufficient size for trend analysis to be conducted. 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 α = 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*, 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, nitrate and zinc parameters could only be conducted on a small number of stations because many 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**, 30 of the 80 surface water quality monitoring stations are in the Welland River watershed, and 14 of these 30 stations are located on the main Welland River channel.

4.2.1 Welland River: Canadian Water Quality Index

The calculated WQI for the Welland River ranges from *poor* to *fair*. Based on the 2016-2020 data collected, seven of fourteen Welland River stations have *poor* water quality, five stations were rated as *marginal*, and two stations were rated as fair. WQI results are illustrated in **Appendix A**. Mapping showing the spatial distribution and boxplots of the eight indicator parameters from 2016 to 2020 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 (2016-2020)

Station	WQI Rating ↔ Stable ↓ Declining ↑ Improving	Hilsenhoff Family Biotic Index 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 ↔	Poor	• Exceedances of copper, *E. coli*, lead, total phosphorus, (95%), total suspended solids and zinc. • Potential stressors include: agricultural and roadway run-off • Groundwater discharges sustains continuous baseflow at this site.	• Decreasing total phosphorus concentrations • Stable chloride, and total suspended solid concentrations
WR000 Welland River	Fair ↔	Fairly Poor	• Exceedances of *E. coli* (58%) total phosphorus (79%), and total suspended solids. • 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 and total phosphorus and total suspended solid concentrations • Stable *E. coli* concentrations
WR001 Welland River	Poor ↔	Very Poor	• Exceedances of chloride, copper, *E. coli* (58%), nitrate, total phosphorus (69%), total suspended solids and zinc • Potential stressors include: agricultural, airport and roadway run-off	• Decreasing zinc concentrations • Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
WR002 Welland River	Poor ↔	Very Poor	• Exceedances of chloride (95%), copper, *E. coli*, lead, total phosphorus, total suspended solids and zinc (90%) • Potential stressors include: agricultural, airport and roadway run-off	• Stable chloride, *E. coli,* total phosphorus total suspended solid, and zinc concentrations
WR020 Welland River	Marginal	Insufficient Data	• Exceedances in chloride (71%), copper, *E. coli* (50%), total phosphorus (100%), and total suspended solids • Potential stressors include agricultural and roadway run-off	• Insufficient Data
WR003 Welland River	Poor ↔	Poor	• Exceedances of chloride (59%), copper, *E. coli*, nitrate total phosphorus (95%), total suspended solids (63%) and zinc • Potential stressors include: agricultural and roadway run-off	• Decreasing chloride concentrations • Stable *E. coli* and total phosphorus concentrations

WR004 Welland River	Marginal ↔	Very Poor	• Exceedances of chloride, copper, *E. coli*, total phosphorus (95%), total suspended solids and zinc. • Potential stressors include: agricultural and roadway run-off • Lake Niapenco is improving the water quality the Welland River at this site	• Decreasing Chloride, *E.coli*, total phosphorus and total suspended solid concentrations
WR005 Welland River	Poor ↔	Fairly Poor	• Exceedances of chloride, copper, *E. coli* (66%), nitrate, total phosphorus (98%), suspended solids (67%) and zinc. • Potential stressors include: agricultural and roadway run-off	• Stable chloride, *E.coli*, total phosphorus and suspended solid concentrations
WR006 Welland River	Poor ↔	Poor	• Exceedances of chloride, copper, *E. coli,* lead, nitrate, total phosphorus (100%), suspended solids (53%) 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 ↔	Very Poor	• Exceedances of copper, *E. coli,* nitrate, total phosphorus (100%) total suspended solids (63%) and zinc • Potential stressors include: agricultural, roadway run-off • Algae and duckweed observed during summer months • Site is invaded by non-native Zebra Mussels	• Stable chloride and total phosphorus concentrations • Increasing *E.coli* and total suspended solid concentrations
WR009B Welland River	Poor ↔	Insufficient Data	• Exceedances of copper, *E. coli*, nitrate, 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	• Decreasing chloride concentrations • Stable *E. coli*, total phosphorus and total suspended solid concentrations .
WR010 Welland River	Marginal ↔	Insufficient Data	• Exceedances of copper, *E. coli*, total phosphorus (79%), 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	• Stable chloride, *E. coli*, total phosphorus and total phosphorus concentrations
WR011 Welland River	Marginal ↔	Insufficient Data	• Exceedances of chloride, *E. coli,* total phosphorus (78%) 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	• Stable *E. coli*, total phosphorus and total suspended solid concentrations • Increasing chloride concentrations

WR012 Welland River	Fair ↓	Insufficient Data	• Exceedances of *E. coli,* total phosphorus and total suspended solids • Potential stressors include: Urban run-off • Site strongly influenced by Niagara River backwater which has the potential to improve water quality	• Insufficient Data

Cyanobacteria bloom on the Welland River at the Port Davidson Weir (Summer 2020)

4.2.2 *Welland River: Hilsenhoff Biotic Index Results*

Hilsenhoff Biotic Index (HBI) results indicate that water quality at most stations in the Welland River ranged from *Very Poor* to Poor (**Table 3**). Two sites managed to obtain a *Fairly Poor* rating (WR000 and WR005). Results from Hilsenhoff Biotic Index assessments completed between 2016 and 2020 are illustrated in **Appendix J**.

Low HBI scores observed in the Welland River mainly are due to road salts and metals in stormwater, sediment loading, lack of in-stream habitat, and nutrient enrichment. A biological assessment was not completed for WR009B, WR010, WR011 and WR012 due to high water depth and channel morphology. These stations are 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 2016-2020 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 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 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.
- Water quality stations in the vicinity of Hamilton Airport (HIA) continue to have water quality designated as *poor* due to elevated concentrations of chloride and zinc. Chloride concentrations are stable at WR001 but increasing at WR002 despite 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 both stations. 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 Perfluorinated compounds (PFCs) that has been found in turtle/fish tissue sampled at Binbrook

Conservation Area. PFCs are 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 PFCs investigation is currently being led by the MECP and Hamilton Public Health, and new fish consumption guidelines were implemented for the 2018 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 PFCs has been posted on the NPCA website. The NPCA water quality department has added PFCs sampling in 2014 as part of special project monitoring program at Binbrook Reservoir. The NPCA still undertakes this monitoring.

4.3 Welland River Tributaries

Fourteen 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, Feeder Canal, 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 WQI fourteen of sixteen Welland River tributary stations have water quality that is rated as *poor* (**Table 4**). Lyons Creek (LY003), and the Power Canal (PR001) were found to have water quality rated as *marginal*. WQI results are illustrated in **Appendix A.** Mapping showing the spatial distribution and boxplots of the eight indicator parameters from 2016 to 2020 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 (2016-2020)

Station Watershed	WQI Rating ↔ Stable ↓ Declining ↑ Improving	Hilsenhoff Family Biotic Index 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 ↔	Very Poor	• Exceedances in chloride, copper, *E. coli* (54%), nitrate, total phosphorus (100%), total suspended solids and zincs. • 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*, and total suspended solid concentrations • Increasing total phosphorus concentrations
BU001 Buckhorn Creek	Poor ↔	Fairly Poor	• Exceedances in chloride, copper, *E. coli* (69%), lead, nitrate, total phosphorus (95%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Prone to zero baseflow conditions in the summer months	• Decreasing chloride concentrations • Stable *E. coli*, total phosphorus and total suspended solid concentrations
BV001 Beaver Creek	Poor ↔	Poor	• Exceedances in copper, *E. coli*, lead, nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Significant algae observed during summer months	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
CO001 Coyle Creek	Poor ↔	Fairly Poor	• 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 chloride, *E. coli* and total phosphorus concentrations
DR001 Drapers Creek	Poor ↔	Poor	• Exceedances in chloride, copper, *E. coli* (85%), total phosphorus (95%), total suspended solids and zinc • Potential stressors include: urban run-off • Algae observed during summer months	• Stable *E. coli*, total phosphorus and total suspended solid concentrations • Increasing chloride concentrations

EL001 Elsie Creek	Poor ↔	Poor	• Exceedances in chloride, *E. coli*, lead, nitrate, total phosphorus (97%), 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 chloride, *E. coli*, total phosphorus and total suspended solid concentrations
GR001 Grassy Brook	Poor ↔	Poor	• Exceedances in chloride, copper, *E. coli*, nitrate, 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 chloride, E. coli, total phosphorus and total suspended solid concentrations
TE001 Tee Creek	Poor ↓	Very Poor	• 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, total phosphorus and total suspended solid concentrations
LY003 Lyons Creek	Marginal ↓	Poor	• Exceedances in chloride, copper, *E. coli*, nitrate, 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	• Decreasing chloride concentrations • Stable E. coli, total phosphorus and total suspended solid concentrations
MI001 Mill Creek	Poor ↓	Poor	• Exceedances in chloride, copper, *E. coli*, lead, nitrate, total phosphorus (97%), 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 chloride, *E. coli*, and total suspended solid concentrations
OS001 Oswego Creek	Poor ↔	Poor	• Exceedances in copper, *E. coli* (60%), nitrate, total phosphorus (100%), total suspended solids (83%) and zinc • Potential stressors include: agricultural and roadway run-off • Algae and overabundance of duckweed observed during summer months	• Stable chloride concentrations • Increasing E. coli, total phosphorus and total suspended solids

OS002 Oswego Creek	Poor ⟷	Poor	• Exceedances in chloride, copper, *E. coli* (65%), nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off • Algae and overabundance of duckweed observed during summer months	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
TC001 Thompson Creek	Poor ⟷	Poor	• Exceedances in chloride, copper, *E. coli* (72%), lead, nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
PR001 Power Canal	Marginal ⟷	Insufficient Data	• Exceedances in *E. coli* (62%), total phosphorus, total suspended solids and zinc. • 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 and total suspended solid concentrations
MR001 Mill Race Creek	Poor ⟷	Insufficient Data	• Exceedances in copper, *E. coli* (70%), total phosphorus (100%) and total suspended solids and zinc. • Potential stressors include: agricultural and roadway run-off	• Insufficient Data
FC001 Feeder Canal	Poor ⟷	Insufficient Data	• Exceedances in chloride, copper, *E. coli*, lead, total phosphorus (84%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off	• Insufficient Data

4.3.2 Welland River Tributaries: Hilsenhoff Biotic Index Results

HBI results indicate that water quality is ranged from *very poor* to *fairly poor* at all Welland River tributary stations currently monitored (**Table 4**). Results from biological assessments completed between 2016 and 2020 are illustrated in **Appendix J**. Generally, the HBI 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.

4.3.3 Welland River Tributaries: Key Findings

- Based on the 2016-2020 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 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.
- *E. coli* concentrations frequently exceed the PWQO in Buckhorn Creek, Big Forks Creek, Beaver Creek, Coyle Creek, Drapers Creek, Elsie Creek, Mill Creek, and Oswego Creek.
- Decreasing total phosphorus concentrations in Mill Creek are now being observed with the NPCA's long-term data. 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. This data provides some evidence that this program is reducing nutrient runoff.

NPCA staff conducting stream survey

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 80 NPCA surface water quality monitoring stations are located within the Twenty Mile Creek watershed. There are six 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**).

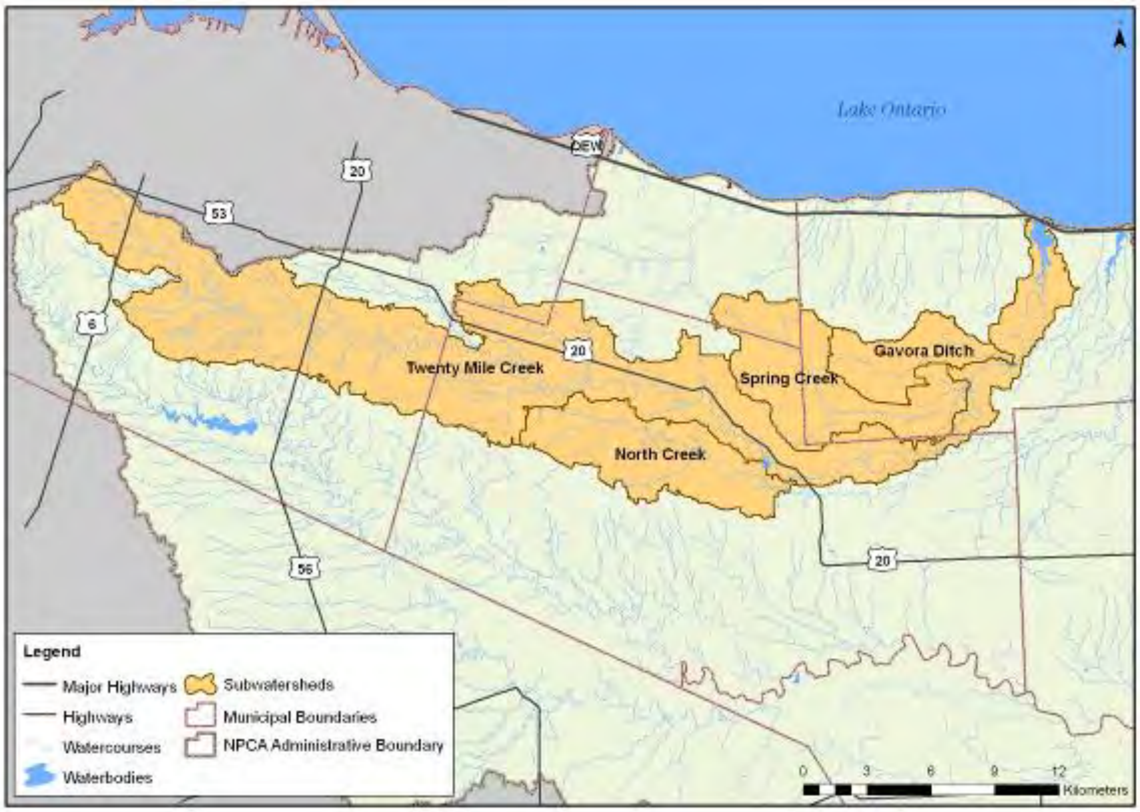


Figure 4: Map of the subwatersheds monitored for water quality within the Twenty Mile Creek watershed

4.4.1 TWENTY MILE CREEK WATERSHED: CANADIAN WATER QUALITY INDEX

Based on the results of the WQI seven of nine Twenty Mile Creek watershed stations have water quality that is rated as *poor*. Three stations (GV001 & TN002) were rated has marginal. WQI results are illustrated in **Appendix A**. Mapping showing the spatial distribution and boxplots of the eight indicator parameters from 2016 to 2020 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 (2016-2020)

Station Watershed	WQI Rating ↔ Stable ↓ Declining ↑ Improving	Hilsenhoff Family Biotic Index 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 ↔	Fairly Poor	• Exceedances in chloride (51%), copper, *E. coli* (74%), lead, total phosphorus (97%), 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 ↔	Poor	• Exceedances in chloride, copper, *E. coli* (52%), lead, 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 ↔	Fairly Poor	• Exceedances in chloride, copper, *E. coli* (56%), 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 ↔	Poor	• Exceedances in chloride, *E. coli* (60%), 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 ↔	Fairly Poor	• Exceedances in chloride, copper, *E. coli* (67%), lead, nitrate, total phosphorus (100%), total suspended solids (59%) and zinc • Potential stressors include: agricultural and roadway run-off • Algae observed during the summer months	• Stable chloride, E. coli, total phosphorus and total suspended solid concentrations

TN006 Twenty Mile Creek	Poor ↔	Fairly Poor	• Exceedances in copper, *E. coli* (50%), 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
NC001 North Creek	Poor ↔	Fairly Poor	• Exceedances in chloride, copper, *E. coli* (65%), 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	• Stable chloride, *E. coli*, total phosphorus and suspended solid concentrations
SP001 Spring Creek	Poor ↓	Poor	• Exceedances in copper, *E. coli* (79%),lead, 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	• Decreasing total suspended solids concentrations • Stable chloride *E. coli* and total phosphorus concentrations
GV001 Gavora Ditch	Marginal ↑	Fairly Poor	• Exceedances in *E. coli* (69%), 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: Hilsenhoff Biotic Index Results

HBI results indicate that water quality is ranged from *poor* to *fairly poor* at most Twenty Mile Creek monitoring stations (**Table 5**). Results from biological assessments completed between 2016 and 2020 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.

4.4.3 Twenty Mile Creek Watershed: Key Findings

- Based on the 2016-2020 data, elevated concentrations of total phosphorus are a widespread cause of water quality impairment in the Twenty Mile watershed. Approximately 95% of samples collected from the Twenty Mile watershed exceeded the PWQO with some concentrations greater than 30 times the PWQO.
- *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.

NPCA staff using a water quality sensor to measure stream temperature.

4.5 Lake Ontario Tributaries

Nineteen 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, Francis Creek, Richardson Creek, Walker's Creek, Eight Mile Creek, Six Mile Creek, Four Mile Creek, Two Mile Creek, One Mile Creek, Bartlett Creek, Purdhommes Drain, Welland Canal, 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: Canadian Water Quality Index

Based on the results of the WQI, sixteen of twenty-seven Lake Ontario tributary stations have water quality that is rated as *poor*. Nine stations were rated as *marginal*, and two stations were rated as *fair*. WQI results are illustrated in **Appendix A**. Mapping showing the spatial distribution and boxplots of the eight indicator parameters from 2016 to 2020 are found in **Appendix B** to **Appendix I**. Highlights of the water quality monitoring in the Lake Ontario tributaries are summarized in **Table 6**.

18 Mile Creek station in Lincoln

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 (2016-2020)

Station Watershed	WQI Rating ↔ Stable ↓ Declining ↑ Improving	Hilsenhoff Family Biotic Index 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 ⟷	Fairly Poor	• Exceedances in chloride, copper, *E. coli* (81%), lead, nitrate, total phosphorus (91%), total suspended solids and zinc (54%) • Potential stressors include: road salt storage compound, quarry dewatering, urban and agricultural run-off. • Algae observed during summer months	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
ET001 Eighteen Mile Creek	Poor ⟷	Fairly Poor	• Exceedances in chloride, copper (63%), *E. coli* (63%), nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: greenhouse waste water, rural and agricultural run-off. • Very frequent copper exceedances warrant further investigation	• Decreasing chloride concentrations. • Stable *E. coli*, total phosphorus and total suspended solid concentrations
FF001 Fifteen Mile Creek	Poor ⟷	Poor	• Exceedances in copper, *E. coli* (60%), lead, nitrate, total phosphorus (100%), total suspended solids and zinc • Excessive algae observed during summer months • Potential stressors include: rural and agricultural run-off	• Decreasing total suspended solid concentrations • Stable chloride, *E. coli*, and total phosphorus concentrations.
SX001 Sixteen Mile Creek	Poor ⟷	Poor	• Exceedances in chloride, copper, *E. coli* (68%), lead, nitrate, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off	• Decreasing total suspended solid concentrations • Stable chloride, *E. coli*, and total phosphorus concentrations
EI001 Eight Mile Creek	Poor ⟷	Poor	• Exceedances in chloride, copper, *E. coli* (62%), nitrate, total phosphorus (97%), and total suspended solids and zinc. • Potential stressors include: agricultural and roadway run-off	• Stable *E. coli*, and total suspended solid concentrations • Increasing chloride and total phosphorus concentrations

FA001 Francis Creek	Marginal ↔	Very Poor	• Exceedances in chloride (100%), copper, *E. coli (81%)*, nitrate, and total phosphorus (86%), total suspended solids and zinc. • Potential stressors include: agricultural and roadway run-off	Insufficient Data
RC001 Richardson Creek	Poor ↔	Very Poor	• Exceedances in chloride (50%), copper (61%), *E. coli (67%)*, nitrate (100%), and total phosphorus (100%), total suspended solids and zinc. • Potential stressors include: agricultural and roadway run-off	Insufficient Data
SI001 Six Mile Creek	Poor ↔	Poor	• Exceedances in chloride (55%), copper, *E. coli (81%)*, total phosphorus (77%), total suspended solids and zinc • Potential stressors include: agricultural and roadway run-off	• Decreasing total suspended solid concentrations • Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
FU004 Four Mile Creek	Poor ↔	Very Poor	• Exceedances in chloride, copper, *E. coli* (55%), nitrate, total phosphorus (98%), total suspended solids and zinc • Potential stressors include: agricultural and rural run-off	• Decreasing total suspended solid concentrations • Stable chloride, *E. coli* and total phosphorus concentrations
TM001 Two Mile Creek	Poor ↔	Poor	• Exceedances in chloride, copper, *E. coli* (92%), nitrate, total phosphorus (100%), and total suspended solids • Excessive *E. coli* concentrations warrant further investigations • Potential stressors include: rural and urban run-off	• Decreasing chloride concentrations • Stable *E. coli*, total phosphorus and total suspended solid concentrations
OM001 One Mile Creek	Poor ↔	Poor	• Exceedances in chloride, copper, *E. coli* (81%), nitrate, 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*, and total suspended solid concentrations • Increasing total phosphorus concentrations
TW001 Twelve Mile Creek	Poor ↓	Poor	• Exceedances in copper, *E. coli (38%)*, 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*, total phosphorus concentrations • Increasing chloride concentrations

TW002 Twelve Mile Creek	Marginal ↑	Fair	• Exceedances in copper, *E. coli*, 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 *E. coli*, total phosphorus and total suspended solids • Stable chloride concentrations
TW003 Twelve Mile Creek	Poor ↔	Fairly Poor	• Exceedances in chloride, copper, *E. coli* (74%), lead, total phosphorus (90%), 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 ↔	Fair	• Exceedances in copper, *E. coli (52%)*, nitrate (97%), total phosphorus, total suspended solids and zinc • Potential stressors include: golf course and rural run-off • Groundwater discharges sustains continuous baseflow at this site.	• Decreasing total phosphorus concentrations • Stable *E. coli*, and total suspended solid concentrations • Increasing chloride and nitrate concentrations
TW005 Twelve Mile Creek	Marginal ↔	Fairly Poor	• Exceedances in chloride, copper, *E. coli* (67%), total phosphorus (68%), total suspended solids and zinc • Potential stressors include: rural and urban run-off • Groundwater discharges sustains continuous baseflow at this site.	• Decreasing total phosphorus and total suspended solids concentrations • Stable *E. coli* concentrations • Increasing chloride concentrations
TW006 Twelve Mile Creek	Fair ↔	Fair	• Exceedances in *E. coli* (54%), total phosphorus (56%) and total suspended solids • Potential stressors include: rural run-off • Groundwater discharges sustains continuous baseflow at this site.	• Decreasing chloride concentrations • Stable *E. coli*, total phosphorus and total suspended solid concentrations

TW007 Twelve Mile Creek	Marginal ↔	Fairly Poor	• Exceedances in chloride, copper, *E. coli* (65%), nitrate, total phosphorus (70%), 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	Marginal ↑	Fairly Poor	• Exceedances in chloride (84%), copper, *E. coli* (50%), total phosphorus (100%), total suspended solids and zinc. • Potential stressors include: agricultural and rural run-off • Prone to zero baseflow conditions in the summer months	• Decreasing E. coli and total suspended solids concentrations • Stable chloride and total phosphorus concentrations
TW009 Twelve Mile Creek	Marginal ↔	Insufficient Data	• Exceedances in chloride, *E. coli,* nitrate, total phosphorus, total suspended solids and zinc. • 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 ↔	Poor	• Exceedances in chloride (51%), copper, *E. coli* (67%), 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 ↔	Very Poor	• Exceedances in chloride (77%), copper, *E. coli* (92%), lead, nitrate, total phosphorus (90%), 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	Poor ↔	Poor	• Exceedances in chloride (647%), copper, *E. coli* (54%), total phosphorus (100%), total suspended solids and zinc. • Potential stressors include: urban run-off • Algae and duckweed observed during summer months	• Decreasing total suspended solids concentrations • Stable chloride and *E. coli* concentrations • Increasing total phosphorus concentrations

BE004 Beaver Dam Creek	Fair ↔	Poor	• Exceedances in *E. coli*, total phosphorus (77%), total suspended solids and zinc. • Potential stressors include: industrial and urban run-off • Algae and duckweed observed during summer months	• Decreasing *E. coli* and total phosphorus concentrations • Stable total suspended solid concentrations • Increasing chloride concentrations
WE001 Welland Canal	Marginal ↓	Insufficient Data	• Exceedance in chloride, *E coli* and total phosphorus, totals suspended solids and zinc. • Water source at this site is predominately from the Lake Erie	• Insufficient Data
PD001 Prudhommes Drain	Poor ↔	Very Poor	• Exceedances in chloride (64%), copper, *E. coli* (88%), lead, nitrate, total phosphorus (96%), total suspended solids and zinc • Potential stressors include: urban run-off • Algae and duckweed observed during summer months	• Insufficient Data
BT001 Bartlett Creek	Marginal	Poor	• Exceedances in chloride, *E. coli* (88%), total phosphorus (100%), total suspended solids and zinc • Potential stressors include: highway and agricultural run-off	• Insufficient Data

4.5.2 Lake Ontario Tributaries: Hilsenhoff Biotic Index Results

HBI results indicate that water quality is ranged from *fair* to *very poor* at Lake Ontario tributary stations (**Table 6**). Results from biological assessments completed between 2016 and 2020 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. Upper Twelve Mile Creek stations TW002, TW004, and TW006 located on the Effingham tributary are rated as *fair*. 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 at TW004 and it may be sourced to local golf course. Efforts to minimize these stressors through BMP initiatives will allow this watershed to remain in its current state.
- Based on the 2016-2020 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 Lake Ontario tributary WQIs were stable when compared to previous assessments. There was an increase in WQI ratings (*poor* to *fair*) for Twelve Mile Creek at two sites (TW001 and TW008) due to no exceedances in metal parameters. The WQI rating decreased from *fair* to *marginal* at the Welland Canal site (WE001) due to continued exceedances in total suspended solids and zinc concentrations detected during wet-weather events.
- Two Mile Creek (TM001) has the highest concentrations of *E. coli* in the NPCA watershed and continues to suggest that there may be sewage entering the Two Mile Creek. The NPCA sampled the stormwater outfalls of Two Mile Creek Conservation Area and found two sources of the bacteria and are currently working with the Town of NOTL and MECP to solve this issue. Elevated *E.coli* concentrations for Walkers Creek (St. Catharines) and Purdhommes Drain (Lincoln) were also observed and additional DNA analysis will be initiated to source of the E.coli (animals vs human).
- 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 NPCA will investigate these exceedances further.

- Richardson Creek consistently exceeds CCME for nitrate and a significant upstream source exists that requires further investigation.

A mayfly collected from 12 Mile Creek

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: CANADIAN WATER QUALITY INDEX

Based on the results of the WQI, Usshers Creek (US001), Bayer Creek (BA001), and Frenchman Creek (FR003) stations were rated as *poor* water quality, Black Creek (BL003) station was rated as *marginal* and Beaver Creek (BR001) was rated as *fair*. WQI results are illustrated in **Appendix A**. Mapping showing the spatial distribution and boxplots of the eight indicator parameters from 2016 to 2020 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 (2016-2020)

Station Watershed	**WQI Rating** ↔ Stable ↓ Declining ↑ Improving	**Hilsenhoff Family Biotic Index 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 ↓	Poor	• Exceedances in chloride, copper, *E. coli* (59%), total phosphorus (100%), total suspended solids and zinc. • Potential stressors include: agricultural and rural run-off	• Decreasing total suspended solids concentrations • Stable chloride, *E. coli*, total phosphorus and concentrations
BL003 Black Creek	Marginal ↔	Insufficient Data	• Exceedances in copper, *E. coli*, total phosphorus (100%), total suspended solids and zinc • Potential stressors include: agricultural and rural run-off	• Stable chloride, total phosphorus and total suspended solid concentrations • Increasing *E.coli* and total suspended solid concentrations
BR001 Beaver Creek	Fair ↑	Insufficient Data	• Exceedances in chloride, *E. coli,* total phosphorus (100%) and total suspended solids • Potential stressors include: agricultural and rural run-off	• Stable chloride, *E. coli*, total phosphorus and total suspended solid concentrations
FR003 Frenchman Creek	Poor ↓	Poor	• Exceedances in chloride, *E. coli* (68%), total phosphorus (86%), 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* and total suspended solid concentrations
US001 Usshers Creek	Poor ↔	Very Poor	• Exceedances in chloride, copper, *E. coli* (50%),total phosphorus (100%), total suspended solids and zinc • 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*, total phosphorus and total suspended solid concentrations

4.6.2 Niagara River Tributaries: Hilsenhoff Biotic Index Results

HBI ratings ranged from *very poor* to *poor* at three Niagara River tributary stations (**Table 7**). Results from biological assessments completed between 2016 and 2020 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. Samples have not been collected from stations BR001 and BL003 due to high water depth, channel morphology, and access restrictions.

4.6.3 Niagara River Tributaries: Key Findings

- Generally, the water quality ratings in these smaller Niagara River tributaries where found to be higher than other NPCA watersheds. The degree of landuse impacts from urban and rural pressures are significantly less in these watersheds.
- Based on the 2016-2020 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 PWQO. 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**). In addition, the Welland Canal monitoring point in Port Colborne is also included with the Lake Erie tributaries. Water at this site enters the Welland Canal and outlets in Lake Ontario.

4.7.1 Lake Erie Tributaries: Canadian Water Quality Index

Based on the results of the WQI four of nine Lake Erie tributary stations are rated as having *poor* water quality three stations are rated as *marginal*, one station (PA001) rated as fair and one station (WE000) rated as *good* (**Table 8**). WQI results are illustrated in **Appendix A**. Mapping showing the spatial distribution and boxplots of the eight indicator parameters from 2016 to 2020 are found in **Appendix B** to **Appendix I**. Highlights of the water quality monitoring in the Lake Erie Tributaries are summarized in **Table 8.**

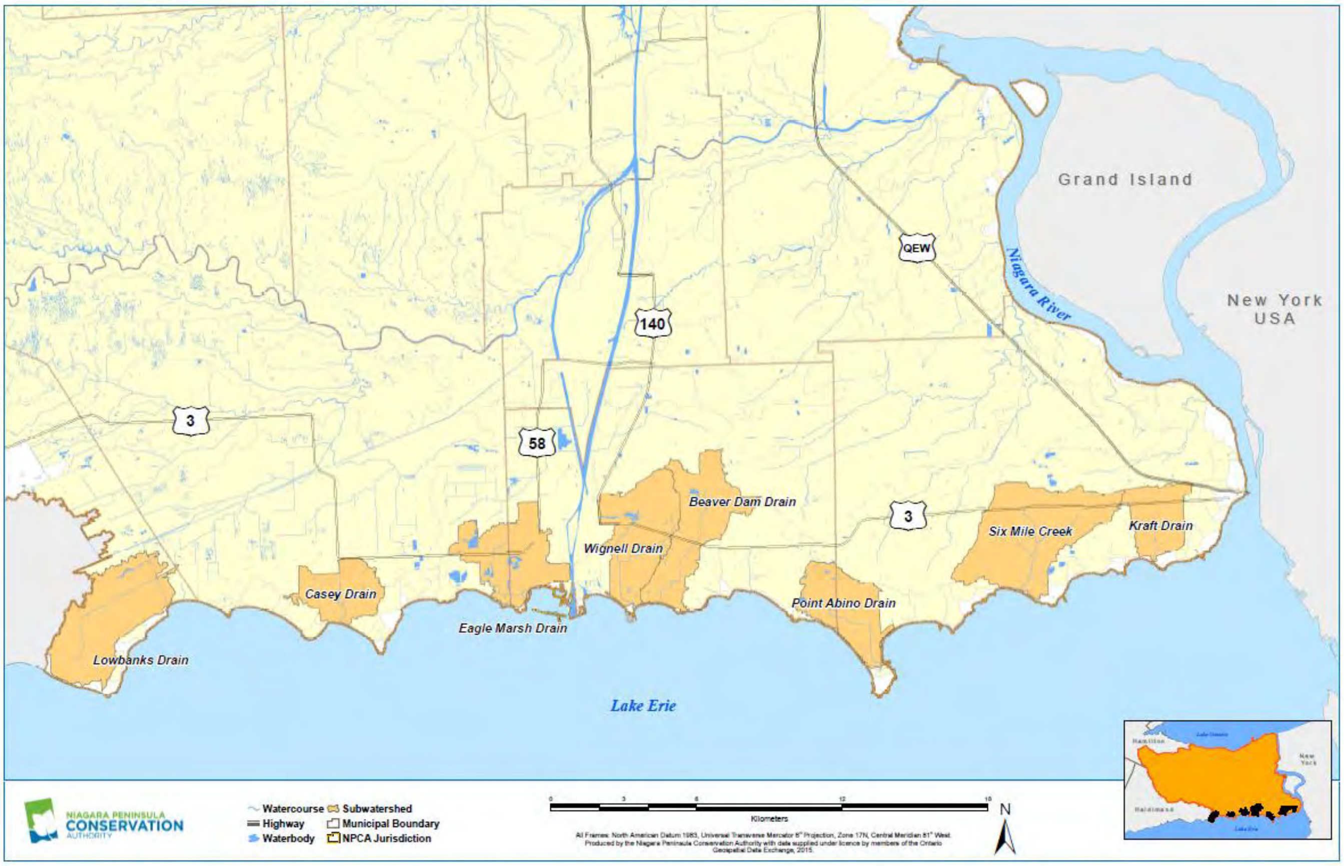


Figure 10: Map of the subwatersheds monitored for water quality along the north shore of Lake Erie

Table 8: Summary of NPCA water quality data for Lake Erie tributaries (2016-2020).

Station Watershed	WQI Rating ↔ Stable ↓ Declining ↑ Improving	Hilsenhoff Family Biotic Index 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 ↔	Very Poor	• Exceedances in chloride, copper (51%), *E. coli* (59%), nickel, nitrate, total phosphorus (97%), 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 ↔	Very Poor	• Exceedances in chloride, copper, *E. coli* (59%), nitrate, total phosphorus (97%), total suspended solids and zinc • Potential stressors include: agricultural and rural run-off	• Stable chloride, *E. coli* and total suspended solid concentrations • Increasing total phosphorus concentrations
EM001 Eagle Marsh Drain	Marginal ↔	Very Poor	• Exceedances in chloride (59%), *E. coli* (65%), total phosphorus (82%), total suspended solids and zinc. • Potential stressors include: quarry dewatering, agricultural and rural run-off	• Decreasing total suspended solids concentrations • Stable chloride, *E. coli*, and total phosphorus concentrations • Increasing total phosphorus concentrations
KD001 Krafts Drain	Poor ↔	Very Poor	• Exceedances in chloride, *E. coli* (76%), nitrate, total phosphorus (89%), total suspended solids and zinc • Potential stressors include: rural and urban run-off • Algae observed during summer months	• Decreasing chloride and total suspended solids concentrations • Stable *E. coli*, concentrations • Increasing total phosphorus concentrations
LB001 Low Banks Drain	Marginal ↔	Poor	• 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 ⟷	Poor	• Exceedances in copper, *E. coli*, and total phosphorus (74%). • Potential stressors include: agricultural and rural run-off • Site is influenced by backflow from Lake Erie which is likely improving water quality	• Decreasing total suspended solids concentrations • Stable chloride, *E. coli,* and total suspended solid concentrations
SM001 Six Mile Creek	Marginal ⟷	Insufficient Data	• Exceedances in chloride, copper, *E. coli*, total phosphorus (100%), and total suspended solids • Potential stressors include: agricultural and rural run-off	• Decreasing chloride and total suspended solids concentrations • Stable *E. coli* and total phosphorus concentrations
WD001 Wignell Drain	Poor ⟷	Very Poor	• Exceedances in chloride, copper, *E. coli*, nickel, nitrate, total phosphorus (100%), and total suspended solids and zinc • Potential stressors include: quarry dewatering historic industrial pollution, agricultural and rural run-off • Algae observed during summer months	• Decreasing chloride and total suspended solids concentrations • Stable *E. coli* concentrations • Increasing total phosphorus concentrations
WE000 Welland Canal	Good ⟷	Insufficient Data	• Exceedance total phosphorus • Water source at this site is predominately from the Lake Erie	Insufficient Data

4.7.2 Lake Erie Tributaries: Hilsenhoff Biotic Index Results

HBI results ranged from *very poor* to *poor* at most Lake Erie tributary stations (**Table 8**). Results from biological 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. 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 2016-2020 data, all the Lake Erie tributaries have total phosphorus exceedances. The most impacted of these tributaries is Wignell Drain which had median concentrations 10 times the Provincial Water Quality Objective. Wignell Drain watershed needs to be prioritized for Best Management Practice (BMPs) works to reduce phosphorus loads to Lake Erie.
- Nickel is not included in the WQI calculation; however, nickel concentrations were found to frequently exceed the PWQO 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 NPCA Groundwater Monitoring Network

The NPCA Groundwater Monitoring Network (**Figure 11**) comprises of two components. The first component is the Provincial Groundwater Monitoring Network (PGMN) which is a partnership between the MECP and the Conservation Authorities of Ontario. The PGMN was initiated in 2001 and is a province-wide groundwater monitoring program 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. Most PGMN monitoring wells are sampled yearly for water geochemistry and all wells are instrumented with datalogging equipment which records hourly groundwater levels.

The second component of the NPCA Groundwater Monitoring Network is a network of 31 monitoring wells installed at 23 different locations across the NPCA watershed through a project between the NPCA and the Ontario Geological Survey (OGS). This project was partially funded through the Niagara Water Smart Grant program for the installation of monitoring wells in 2014 and 2015. Each of the 23 locations has a groundwater monitoring well installed at the top of bedrock in an aquifer zone commonly known as the Contact-Zone Aquifer. Three (3) of 23 locations have a set of nested monitoring wells installed at various depths within the overburden sediments. These wells were initially installed to investigate regional groundwater flow of five distinct features within the NPCA jurisdiction, which include:

- Three (3) buried bedrock valleys (Erigan Channel, Chippawa-Niagara Falls Channel and Crystal Beach Channel) and their groundwater relationships to Lake Erie, Lake Ontario and the Niagara River;
- The Fonthill-Kame Delta Complex/Twelve Mile Creek watershed area; and

- The Upper Welland River watershed.

After the completion of the OGS project in 2018, the NPCA has continued to sample water geochemistry yearly in 23 Contact-Zone Aquifer wells and all these wells are instrumented with datalogging equipment which records hourly groundwater levels to provide a better understanding of ambient groundwater conditions across the NPCA watershed.

Provincial Groundwater Monitoring Well W0000362-2 in Pelham

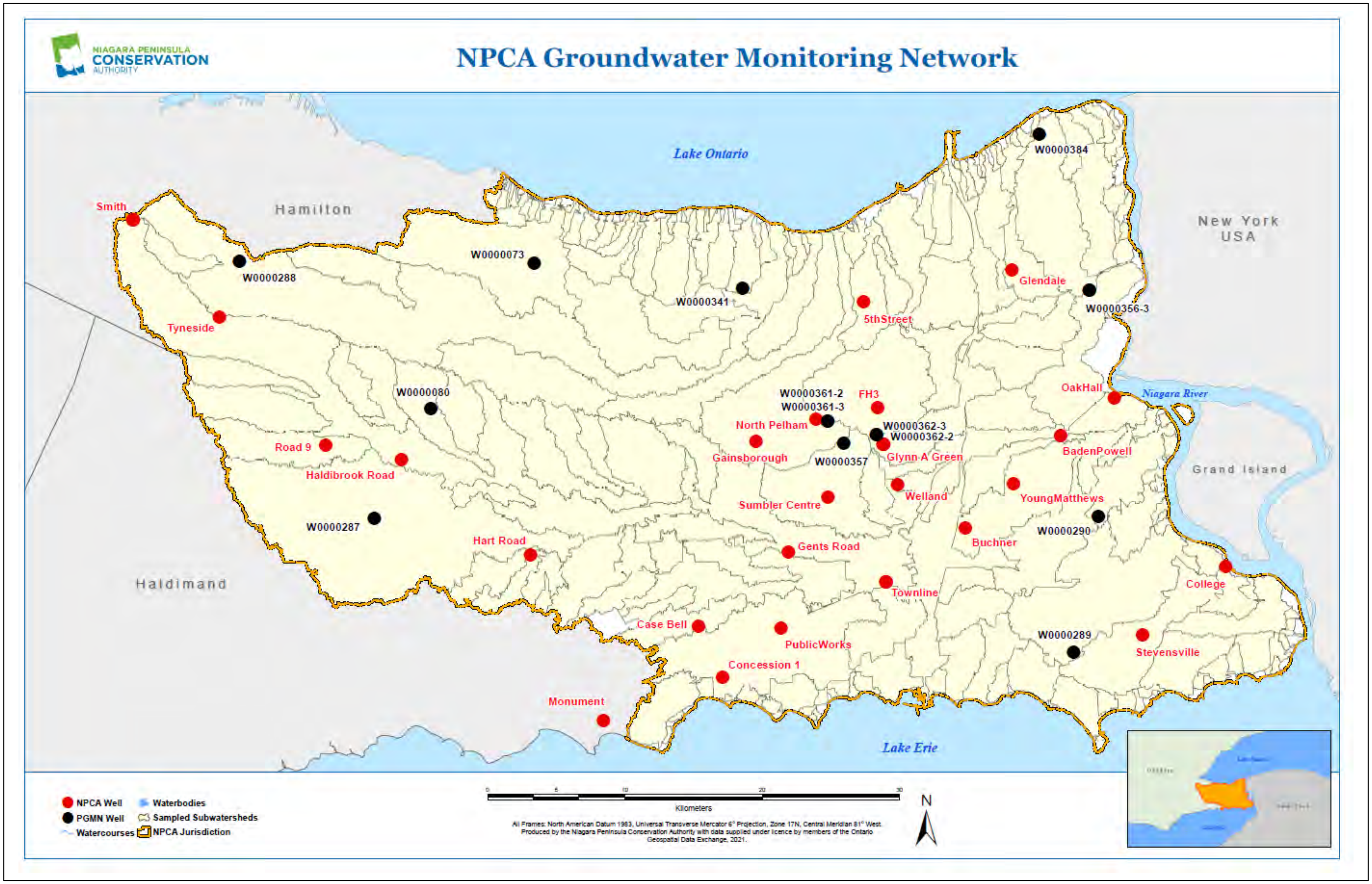


Figure 11: Location of monitoring wells in the NPCA watershed

5.1.1 Groundwater Levels

The NPCA has been monitoring water levels at all PGMN wells since 2003 and other NPCA wells since 2014. Groundwater levels are typically at their highest during the late-winter and spring but begin to drop during the dry summer months and are lowest in the fall. There is also yearly variation in the groundwater levels which is dependent on precipitation. In dry years (such as 2016), water levels can drop substantially from their seasonal highs; and conversely the water level drops in wet years (2009) are not as substantial. PGMN monitoring wells each have water levels that are seasonally and yearly variable due to several factors (geologic formation the well is installed in, soils, precipitation, etc.). The results of this monitoring are found in **Appendix K.** The groundwater level data from the NPCA groundwater monitoring network will be used to help better understand the impacts of local/provincial scale drought events and its connection to climate change.

5.1.2 Groundwater Geochemistry

The NPCA Groundwater Monitoring Network is sampled yearly in the fall by the NPCA. Water chemistry sampling for the PGMN component of the NPCA Groundwater Monitoring Network began in 2006 where groundwater quality samples are collected by NPCA staff and laboratory analysis is provided by the MECP. The remaining NPCA wells have been sampled since 2014. From 2014 to 2018 these monitoring wells were sampled in partnership with the OGS to assist with a Southern Ontario ambient geochemistry program; the results of which are presented in the OGS Groundwater Resources Study 17 (Colgrove, L.M. and Hamilton, S. M., 2018). Starting in 2019, the 23 Contact-Zone Aquifer monitoring wells have been sampled for the same parameters as the PGMN monitoring wells and analyzed through private lab.

Groundwater quality samples are analyzed for general chemistry, nutrients, metals, and project specific parameters. Groundwater chemistry results are compared to the Ontario Drinking Water Standards (ODWS, MOE 2003) to provide an indication of overall groundwater quality across the NPCA. **Table 9** summarizes the health-related exceedances of the ODWS from 2016-2020 for the NPCA Groundwater Monitoring Network. All health related ODWS exceedances in PGMN wells are flagged by the MECP 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 MECP to confirm the initial exceedance. Based on the type and source of the exceedance these agencies formulate an action plan to protect human health. In the case of the non-PGMN wells, exceedances were reviewed through the OGS Ambient Geochemistry program (Colgrove, L.M. and Hamilton, S. M., 2018).

Table 9: NPCA Groundwater Monitoring Network stations (PGMN Wells and NPCA Wells) with Health-Related Exceedances of the ODWS (2016-2020). 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				
			2016	2017	2018	2019	2020
W0000073 (Grimsby)	Bedrock	Guelph-Lockport	Sodium	Sodium	Sodium	Sodium	Sodium
W0000080 (West Lincoln)	Bedrock	Guelph-Lockport	Sodium Fluoride	Sodium Fluoride Uranium	Sodium Fluoride Uranium	Sodium Fluoride Uranium	Sodium Fluoride Uranium
W0000288 (Hamilton)	Bedrock	Guelph-Lockport	No Exceedance	No Exceedance	No Exceedance	No Exceedance	No Exceedance
Gainsborough (West Lincoln)	Bedrock	Guelph	No Exceedance	No Exceedance	No Exceedance	Fluoride	Fluoride
Welland (Welland)	Bedrock	Guelph	No Exceedance	No Exceedance	No Exceedance	No Exceedance	No Exceedance
Smith Road (Hamilton)	Bedrock	Guelph	No Exceedance	No Exceedance	No Exceedance	No Exceedance	No Exceedance
Tyneside (Hamilton)	Bedrock	Guelph	No Exceedance	No Exceedance	No Exceedance	No Exceedance	No Exceedance
Oak Hall (Niagara Falls)	Bedrock	Guelph	Sodium	Sodium	Sodium	Sodium	Sodium
Glynn A Green (Pelham)	Bedrock	Lockport	Fluoride	Fluoride	Fluoride	Fluoride	Fluoride Arsenic
W0000289 (Port Colborne)	Bedrock	Onondaga	No Exceedance	No Exceedance	No Exceedance	No Exceedance	No Exceedance

Well ID Location	Well Type	Formation	Year				
			2016	2017	2018	2019	2020
W0000341 (Lincoln)	Bedrock	Clinton	Sodium	Sodium	Sodium	Sodium	Sodium
W0000357 (Pelham)	Overburden	Fonthill Kame	No Exceedance	No Exceedance	Unable to sample	Unable to sample	Unable to sample
W0000361-2 (Pelham)	Overburden	Fonthill Kame	Nitrate	Nitrate	No Exceedance	No Exceedance	No Exceedance
W0000361-3 (Pelham)	Overburden	Fonthill Kame	Sodium	Sodium	Sodium	Sodium	Sodium
W0000362-2 (Pelham)	Overburden	Fonthill Kame	Sodium	Sodium	Sodium	Sodium	Sodium
W0000362-3 (Pelham)	Overburden	Fonthill Kame	No Exceedance	No Exceedance	No Exceedance	No Exceedance	No Exceedance
W0000384 (NOTL)	Overburden	Iroquois Sandplain	Sodium Nitrate	Sodium Nitrate	Sodium	Sodium	Sodium
Concession 1 (Wainfleet)	Bedrock	Bertie	Sodium	Sodium	Sodium	Sodium	Sodium
Stevensville (Fort Erie)	Bedrock	Bertie	No Exceedance	No Exceedance	No Exceedance	No Exceedance	No Exceedance
Monument (Haldimand County)	Bedrock	Bois Blanc	No Exceedance	No Exceedance	No Exceedance	No Exceedance	No Exceedance
North Pelham (Pelham)	Bedrock	Eramosa	N/A	No Exceedance	No Exceedance	No Exceedance	No Exceedance
	Bedrock	Queenston	Sodium	No Exceedance	Sodium	Sodium	Sodium

Well ID Location	Well Type	Formation	Year				
			2016	2017	2018	2019	2020
5th Street (St.Catharines)							
Baden Powell (Niagara Falls)	Bedrock	Salina	Sodium	Sodium	Sodium	Sodium	Sodium
Townline (Port Colborne)	Bedrock	Salina	Sodium	Sodium	Sodium	Sodium	Sodium
Young Matthews (Niagara Falls)	Bedrock	Salina	No Exceedance	No Exceedance	No Exceedance	No Exceedance	No Exceedance
Buchner (Welland)	Bedrock	Salina	Sodium	Sodium	Sodium	Sodium	Sodium
College (Fort Erie)	Bedrock	Salina	Sodium Boron	Sodium Boron	Sodium Boron	Sodium Boron	Sodium Boron
Gents Road (Wainfleet)	Bedrock	Salina	No Exceedance	No Exceedance	No Exceedance	No Exceedance	No Exceedance
Sumbler Centre (Pelham)	Bedrock	Salina	No Exceedance	No Exceedance	No Exceedance	No Exceedance	No Exceedance
Public Works (Wainfleet)	Bedrock	Salina	Sodium	Sodium	Sodium	Sodium	Sodium
Road 9 (Haldimand County)	Bedrock	Salina	No Exceedance	No Exceedance	No Exceedance	No Exceedance	No Exceedance
Haldibrook Road (Haldimand County)	Bedrock	Salina	Sodium	Sodium	Sodium	Sodium	Sodium
Hart Road	Bedrock	Salina	Sodium	Sodium	Sodium	Sodium	Sodium

Well ID Location	Well Type	Formation	Year				
			2016	2017	2018	2019	2020
(Haldimand County)							
Case Bell (Wainfleet)	Bedrock	Salina	Sodium	Sodium	Sodium	Sodium	Sodium
W0000287 (Haldimand County)	Bedrock	Salina	Sodium	Sodium	Sodium	Sodium	Sodium
W0000290 (Niagara Falls)	Bedrock	Salina	Sodium Boron	Sodium Boron	Sodium Boron	Sodium Boron	Sodium Boron

5.1.3 Key Groundwater Findings

- Exceedances of ODWS of arsenic (Glynn A Green), boron (W290-1 & College), fluoride (W080-1 & Glynn A Green) and uranium (W080-1) were observed in the NPCA sampling program, and these exceedances have been attributed to natural groundwater conditions by the MECP Environmental Monitoring and Reporting Branch (EMRB) staff and by OGS Ambient Geochemistry program (Colgrove, L.M. and Hamilton, S. M., 2018). These elements occur naturally in the groundwater 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. Regular water testing and treatment is recommended when using these aquifer sources for drinking.

- Most NPCA Groundwater Monitoring Network wells have sodium concentrations which exceed the 20 mg/L concentration. This is a health related ODWS exceedance where MECP has informed the Medical Officer of Health for the Health units so that this information could be communicated to local physicians for their use with patients on sodium restricted diets. MECP, EMRB and OGS Ambient Geochemistry program (Colgrove, L.M. and Hamilton, S. M., 2018) have attributed these exceedances to natural groundwater conditions and possibility from road salt in the shallow overburden wells. Regular water testing and treatment is recommended when using these aquifer sources for drinking.
- Elevated nitrate concentrations observed at monitoring wells W384-1 and W361-2 from 2003-2017 were attributed to agricultural landuse and/or faulty septic systems. In response to these exceedances, additional groundwater sampling of local private wells 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 private 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. From 2018 to 2020 nitrate ODWS exceedances were not detected, and these reductions may be attributed to changes of local land uses and allowed for attenuation of nitrate.
- In general, ambient groundwater geochemistry across the NPCA was found to have elevated levels of sulfate, iron, manganese, and chloride that exceed the Aesthetic Objectives within the ODWS (MOE 2003). The parameters which have Aesthetic Objectives may not be the source of any health-related issues, but these exceedances typically make the groundwater unpalatable or otherwise unpleasant for normal use (i.e., build-up/staining). Regular water testing and treatment is recommended when using these aquifer sources for drinking and other uses.

5.2 WATER WELL DECOMMISSIONING PROGRAM

In 2020, the NPCA continued to provide grants to watershed residents interested in properly decommissioning abandoned water wells on their property through the NPCA Water Well Decommissioning Program. The grant program offers an 80% subsidy for water well decommissioning to a maximum of $1000 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, 99 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**.

Table 10: Number and location of abandoned water wells decommissioned through the NPCA Water Well Decommissioning Grant from 2007 to 2020.

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)
2017	8	Hamilton (2), Pelham (1), NOTL (1), Wainfleet (2), West Lincoln (2)
2018	10	Lincoln (4), NOTL (2), Pelham (1), St. Catharines (2), West Lincoln (1)
2019	5	Grimsby (1), Hamilton (1), Lincoln (1), Niagara Falls (1), Pelham (1)
2020	8	Fort Erie (1), Grimsby (1), Lincoln (1), NOTL (2), Pelham (1), Port Colborne (1), Thorold (1)

Figure 12: An example of a NPCA Water Well Decommissioning Project. Left photo shows an abandoned drilled well in need of decommissioning and the right photo shows same 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 NPCA generates this separate report for the HIA for their exclusive information and use.

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. The NPCA generates this separate report for the City of Hamilton for their exclusive information and use.

6.3 Upper 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**.

Brook Trout from Twelve Mile Creek in Pelham

6.4 Lake Niapenco Perfluorinated compound Monitoring

Since 2012, the NPCA has been monitoring for perfluorinated compounds (PFCs) in Lake Niapenco and groundwater supply well at Binbrook Conservation Area. PFCs were found in the plasma of snapping turtles at Lake Niapenco in 2009 and 2010 by an Environment Canada (EC) scientist as part of an organic toxins accumulation study (de Solla et al. 2012). PFC trackdown studies by MECP confirmed the presence of PFCs in Lake Niapenco and identified John C. Munro International Airport as the source of the contamination (Fowler 2011).

NPCA collected a water sample at Lake Niapenco on August 31 2020. **Figure 13** shows the sample location in the Conservation Area. Water samples were collected following the same protocol used by the NPCA's Operation Department. This protocol was as follows: 1) Lake Niapenco samples were collected in waist-deep water at the beach (**Figure 14**); and 2) Samples were collected and placed in a cooler with ice and shipped the next day for PFC analysis.

Figure 13: Sample Location at Lake Niapenco

Figure 14: Sample location at the beach Lake Niapenco

The water chemistry results from Lake Niapenco indicate the presence of PFOS (a PFC of concern) at concentrations below Health Canada Provisional Drinking Water Guidelines (**Figure 15**). The concentration of PFOS generally matched the PFOS concentrations observed in previous NPCA sampling events but higher than the range of mean concentrations detected by de Solla *et al.* (2012) shown in **Figure 15**. Another PFC of concern, Perfluorooctanoic acid (PFOA) was not detected but several other PFCs were detected in the Lake Niapenco. These included Perfluorohexane Sulfonate (PFHxS), Perfluorohexanoic Acid (PFHxA) and Perfluoropentanoic Acid (PFPeA) (**Figure 16**). These concentrations generally matched previous sampling event concentrations and PFPeA concentrations were higher than those detected in the study by de Solla *et al.* (2012). These PFCs (PFHxS, PFHxA and PFPeA) have no drinking water guidelines.

Lake Niapenco was contaminated by historic PFC usage from Hamilton International Airport (de Solla 2012 and Fowler 2011). The NPCA's monitoring at Binbrook Conservation Area continues to support the evidence that PFCs and specifically PFOS are present in Lake Niapenco but not at concentrations above Health Canada drinking water guidelines. It is expected that PFCs will continue to be present in Lake Niapenco due the persistence of PFCs in the environment and due to the delay to contain upstream sources. It should be noted that Hamilton Public Health has evaluated previous PFC water quality data at Binbrook Conservation Authority and determined that the PFC concentrations detected would not adversely affect the park users.

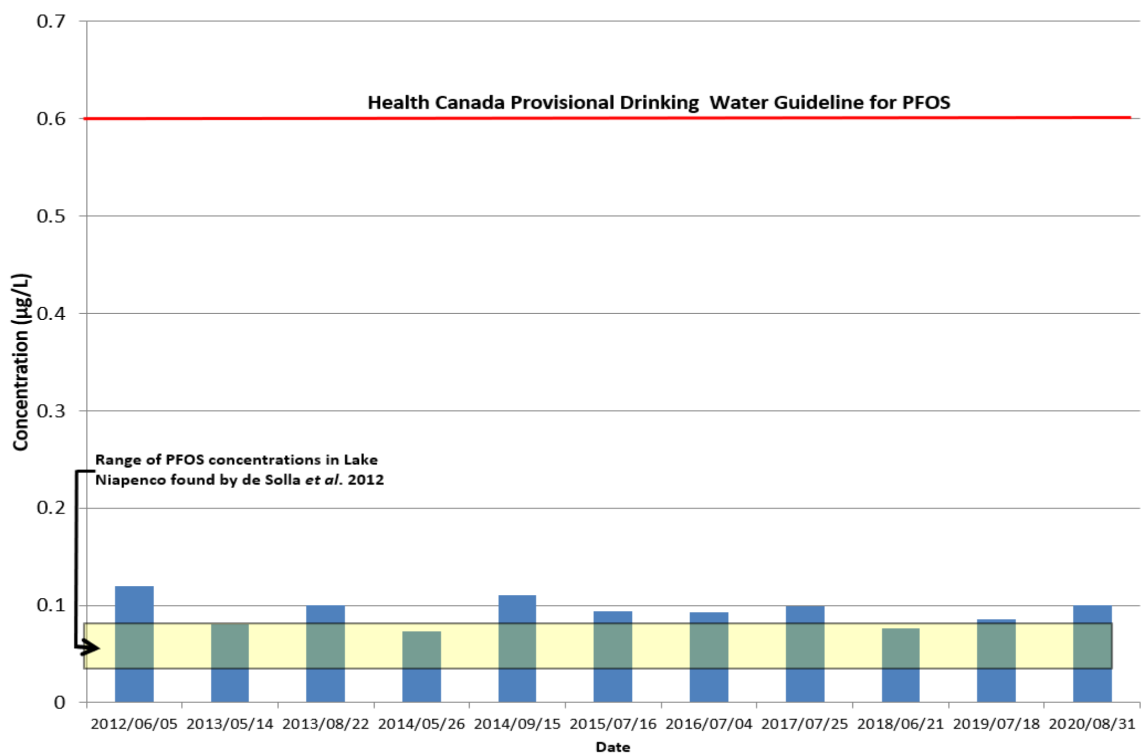


Figure 15. PFOS concentrations found in Lake Niapenco by NPCA monitoring 2012-2020

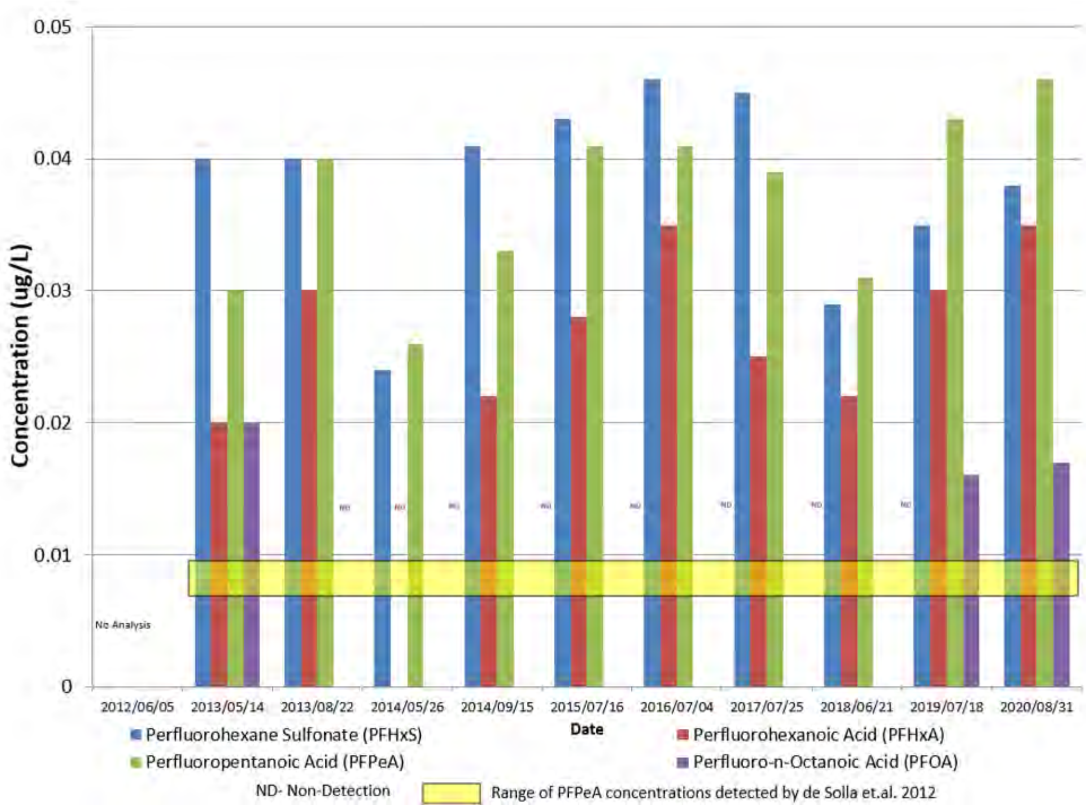


Figure 16: PFHxS, PFHxA and PFPeA concentrations found in Lake Niapenco by NPCA monitoring 2012-2020.

6.5 Canada Ontario Agreement Climate Change Monitoring Networks Review Project

A climate change sensitivity assessment completed by the MECP 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 MECP assessments the existing monitoring station at Balls Falls Conservation Area was upgraded to an integrated monitoring site in 2015 which includes a rain gauge, soil moisture sensors and extended laboratory analysis for event sampling.

6.6 Conservation Area Water Quality Monitoring

The NPCA Water Quality Monitoring Program was expanded in 2017 to include the waterbodies of the Conservation Areas: Dils Lake, Jordan Harbour, Lake Niapenco, Mud Lake, St. John's Pond, Virgil Reservoir, Wainfleet Wetlands and Wainfleet Bog. Water samples are collected quarterly or seasonally during the year and analyzed for general chemistry, nutrients, metals, and bacteria.

The water quality results for the NPCA Conservation Area locations are shown in **Figures 17-19**. Generally, the water quality observed in the Conservation Areas met environmental threshold values, but some exceedances were found. Total phosphorus exceeded the PWQO at most Conservation Areas, but Virgil Reservoir, Mud Lake and Wainfleet Bog had notably higher observed concentrations. The lentic Conservation Area environments (St. Johns, Binbrook, Mud Lake and Dils Lake) which have higher water temperatures, greater sunlight exposure, and reduced water flow are particularly vulnerable to excessive phosphorus concentrations which can stimulate the overgrowth and decomposition of plants and algae causing water quality concerns. There were chloride, copper, total suspended solids, and nitrate exceedances observed in Virgil Reservoir and these are likely due to adjacent rural land uses, proximity to Four Mile Creek Road and an abundance of carp in the reservoir. The pH of Wainfleet Bog also exceeded the lower threshold of the PWQO however this type of wetland is naturally acidic. This acidity is a by-product of microbial decay processes, cation exchange of the Sphagnum moss vegetation and input of additional acids from the atmosphere. Copper and zinc exceedances were observed at Wainfleet Bog main drainage ditch. This may be due past levels of atmospheric metal depositions that have accumulated in the peat soils and now being released in the surface water of the drainage ditch. The NPCA will investigate the source of these metal exceedances.

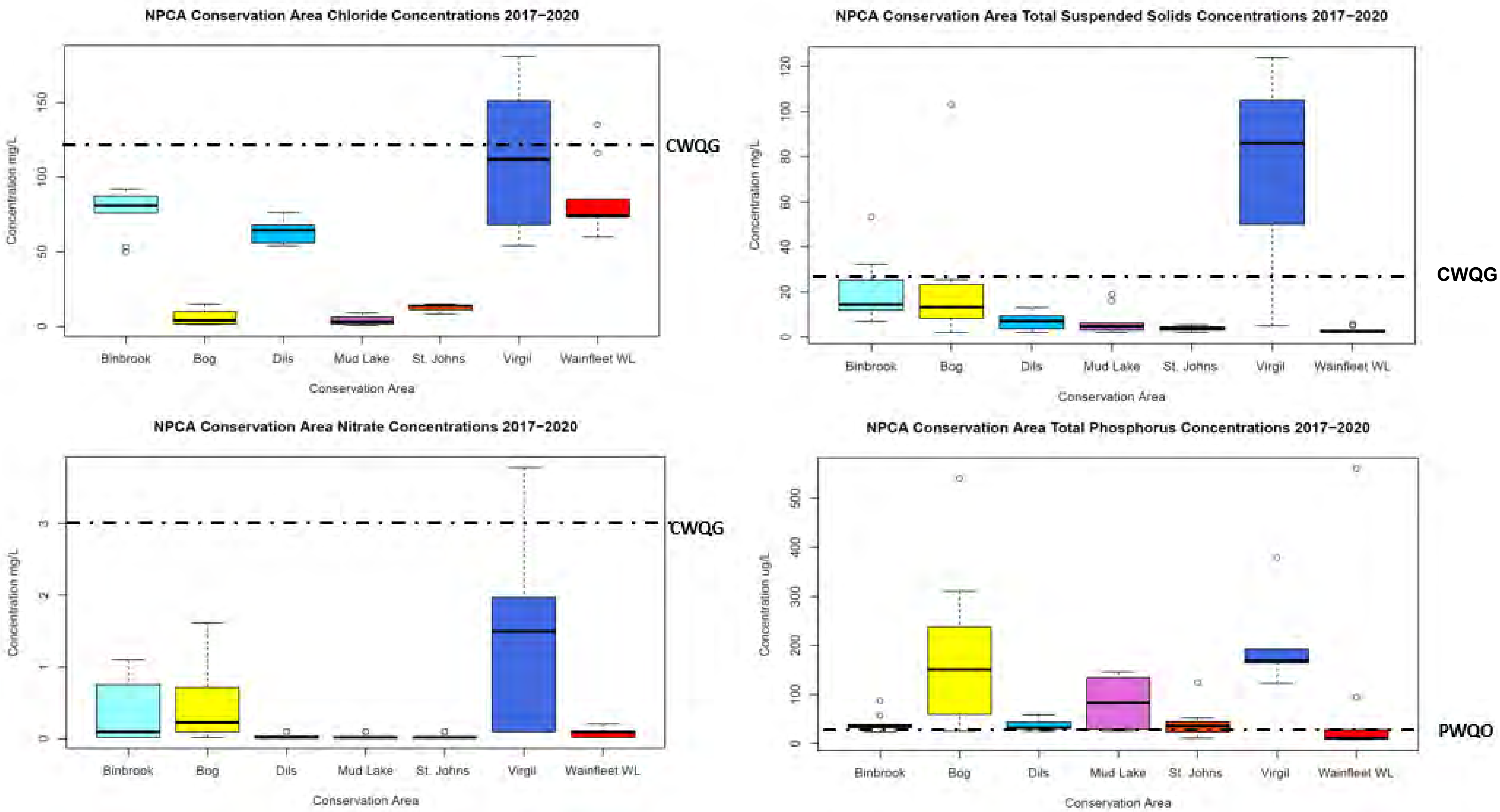


Figure 17: Box and Whisker Plot of chloride, total suspended solids, total phosphorus, and nitrate concentrations of the NPCA Conservation Area monitoring stations for 2017-2020 (n=10 for each station). The box length of the box-and-whisker plots represents the inter-quartile range that contains the median value shown as a horizontal line. The whiskers represent the minimum and maximum values. Outlier values represented by circles. Dashed lines represent Provincial Water Quality Objectives (PWQO), and Canadian Water Quality Guidelines (CWQG).

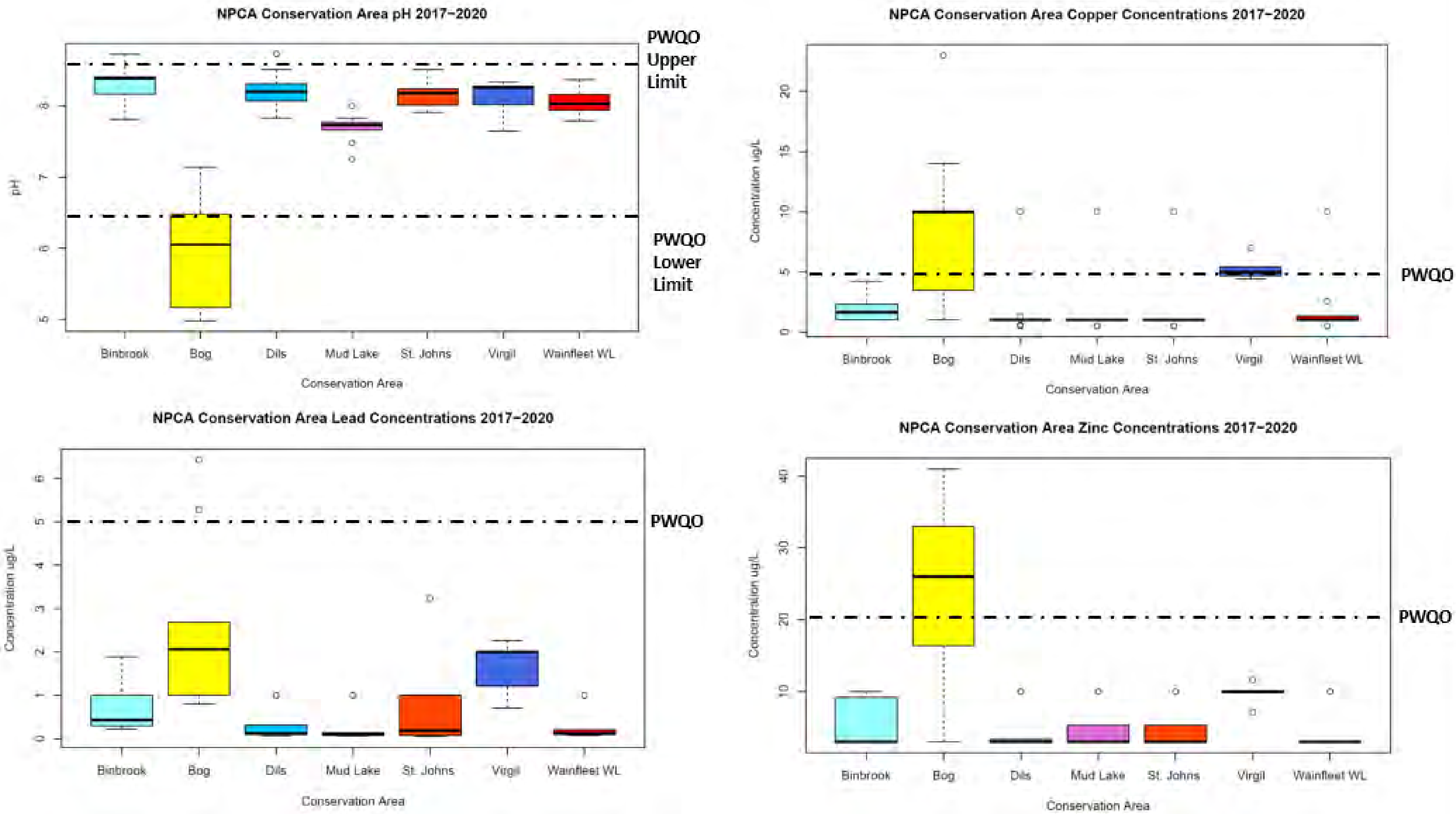


Figure 18: Box and Whisker Plot of pH, copper, lead, and zinc concentrations of the NPCA Conservation Area monitoring stations for 2017-2020 (n=10 for each station). The box length of the box-and-whisker plots represents the inter-quartile range that contains the median value shown as a horizontal line. The whiskers represent the minimum and maximum values. Outlier values represented by circles. Dashed lines represent Provincial Water Quality Objectives (PWQO).

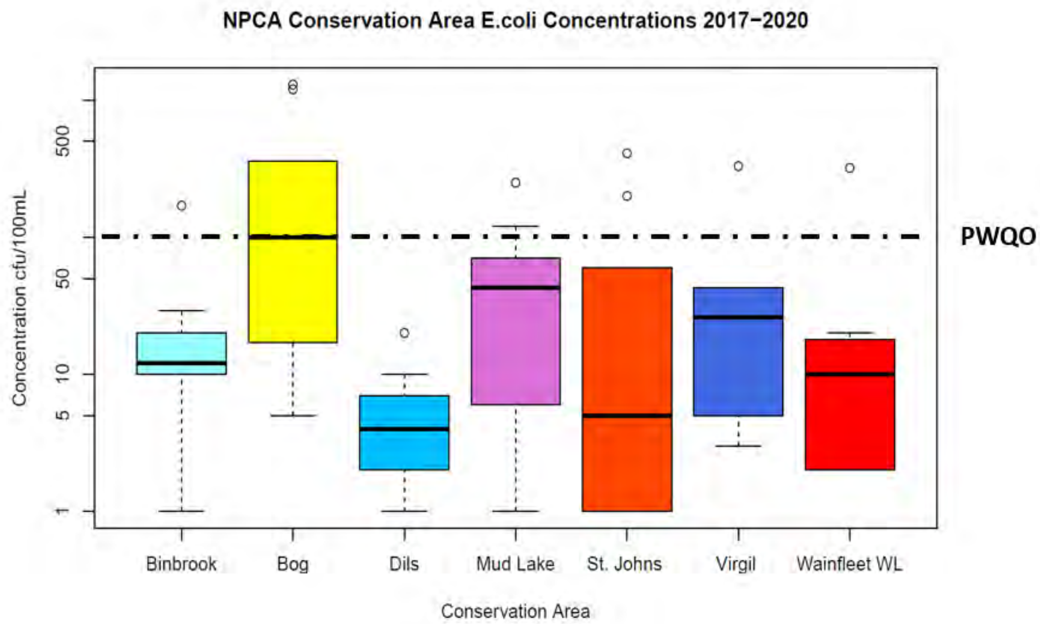


Figure 19: Box and Whisker Plot of *E.coli* concentrations of the NPCA Conservation Area monitoring stations for 2017-2020 (n=10 for each station). The box length of the box-and-whisker plots represents the inter-quartile range that contains the median value shown as a horizontal line. The whiskers represent the minimum and maximum values. Outlier values represented by circles. Dashed lines represent Provincial Water Quality Objectives (PWQO).

6.7 Lower Twelve Mile Creek Total PCBs Monitoring

In 2020, MECP and City of St. Catharines had been investigating potential offsite impacts on surface water of Twelve Mile Creek from the former GM industrial area. To support agency partners, the NPCA has provided monthly samples (beginning September 2020) upstream and downstream of the former GM plant on 12 Mile Creek. This project included enhanced monitoring at the PWQMN station at Lakeport Road (TW009) and the reactivating a former monitoring site (TW011) at Welland Vale Road (See **Figure 20**). Samples collected are being analyzed for general chemistry, metals, nutrients, bacteria, and total PCBs.

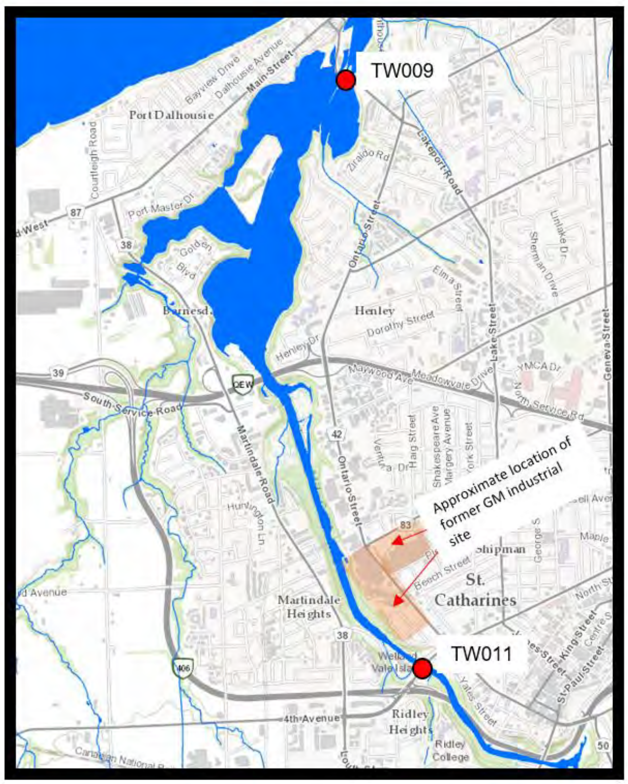


Figure 20: Location of monitoring stations in upstream (TW011) and downstream (TW009) of former GM industrial area

Table 10: Twelve Mile Creek Surface water quality laboratory results (monthly Sep to Dec 2020) from upstream (TW011) and downstream (TW009) of the former GM industrial Area

Site Code	PWQO/CWQG/ BC MOE	Upstream GM TW011	Downstream GM TW009	Upstream GM TW011	Downstream GM TW009	Upstream GM TW011	Downstream GM TW009	Upstream GM TW011	Downstream GM TW009
Date		2020-09-28	2020-09-28	2020-10-26	2020-10-26	2020-11-23	2020-11-23	2020-12-14	2020-12-14
Alkalinity (mg/L)		95	95	105	98.9	100	101	101	99.8
pH	6.5-8.5	8.31	8.32	8.01	8.3	8.14	8.28	8.22	8.27
Suspended Solids (mg/L)	25	9.2	9.6	14.4	8.9	27.4	24.7	11.5	9.1
Chloride (mg/L)	120	17.5	17.6	17.8	16.6	18.2	16.2	17.7	17.4
Conductivity (us/cm)		300	299	289	293	295	300	293	301
E. coli (cfu/100mL)	100	540	110	180	158	148	294	130	n/a
Hardness (mg/L)		124	123	127	118	140	121	141	120
Nitrate (mg/L)	3	0.102	0.092	0.161	0.199	0.218	0.266	0.257	0.328
Nitrogen; nitrite (mg/L)	0.06	<0.010	<0.010	<0.010	0.006	<0.010	0.007	<0.010	0.005
Total Phosphorus (ug/L)	30	16.2	14	20.9	21.4	33.5	44	25.2	21.9
Total PCBs (µg/L)	0.001	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040
Aluminum (µg/L)	75	208	191	273	83.9	628	179	260	71
Barium (µg/L)		21.7	22.2	23	21.2	28.6	25.9	24.7	22.8
Beryllium (µg/L)	1100	<0.1	<0.1	<0.1	0.0282	<0.1	0.053	<0.1	0.0435
Bismuth (µg/L)		<0.000050	<0.000050	<0.000050	-4.59	<0.000050	-4.73	0	-4.57
Cadmium (µg/L)	0.2	0.006	0.008	0.009	-0.0179	0.015	0.515	0.011	0.416
Calcium (mg/L)		34.4	33.8	34.7	32.5	39.3	33.4	39.9	33.3
Chromium (µg/L)	1	0.53	0.5	0.51	0.232	0.97	0.302	0.6	0.146
Cobalt (µg/L)	0.9	0.14	0.13	0.18	-0.302	0.4	0.37	0.18	0.562
Copper (µg/L)	5	1.06	1.17	1.4	2.4	1.67	2.43	2.31	2.09
Iron (µg/L)	300	271	250	354	166	807	210	379	91.8
Lead (µg/L)	25	0.184	0.197	0.298	-3.87	0.574	-3.33	2.12	-5.03
Lithium (µg/L)		2	1.9	2.3	1.88	2.2	1.78	2.2	-1.65
Magnesium (µg/L)		9.17	9.44	9.82	8.84	10.1	9.01	10.1	8.9
Manganese (µg/L)		9.64	9.97	13.3	8.47	24.9	17.2	13.8	6.15
Molybdenum (µg/L)	40	1.11	1.18	1.12	0.469	1.16	0.251	1.16	-0.0783
Nickel (µg/L)	25	0.84	0.78	0.99	1.84	1.57	1.2	1.13	1
Potassium (µg/L)		1.53	1.57	1.69	1.53	1.7	1.48	1.58	1.45
Silver (µg/L)	0.1	0.05	0.05	0.05	-0.0038	0.05	-0.251	0.05	0.459
Sodium (mg/L)		11.1	11.3	11.1	11.4	11.2	12.1	11.5	11.4
Strontium (µg/L)		172	177	177	164	188	181	192	171
Tin (µg/L)		0.1	0.1	0.1	-9.6	0.1	-2.48	0.1	-5.51
Titanium (µg/L)		4.18	3.92	5.82	1.97	14	4.14	5.78	2.45
Uranium (µg/L)	5	0.396	0.395	0.39	1.12	0.422	2.84	0.434	5.76
Vanadium (µg/L)	6	0.63	0.58	0.75	0.233	1.41	0.492	0.77	0.487
Zinc (µg/L)	30	3	3	4.4	1.95	4.7	3.55	45.6	6.17
Zirconium (µg/L)	4	0.2	0.2	0.2	-0.111	0.2	0.0711	0.2	-0.0476

The water quality results for monitoring Twelve Mile Creek upstream and downstream of the former GM industrial area are found in **Table 10**. Generally, the water quality observed met environmental threshold values, but some exceedances were found. *E. coli* concentrations were found to routinely exceed the PWQO at both stations and sources possibly could include wildlife or human sources. Minor total phosphorus PWQO exceedances were observed once at each station and appear related to elevated suspended stream sediment. There were some exceedances of metals observed which are from a combination of natural and anthropogenic sources. Aluminium routinely exceeded PWQO and this likely due to the contribution of naturally elevated levels aluminium found in soils of the watershed. There were two PWQO exceedances of cadmium observed in at TW009, but these exceedances were not higher than concentrations historically observed in the upper and less-impacted portions of the Twelve Mile Creek watershed. There was persistent PWQO exceedances of iron observed at TW011 which was not observed downstream at TW009. The samples collected in December 2020 exceeded the PWQO for Silver (TW009), Uranium (TW009) and Zinc (TW011). These concentrations all have been observed in the less-impacted portions of Twelve Mile Creek. Total PCBs results for both sites were less then laboratory detection limits. The NPCA acknowledges the high detection limit of Total PCB analysis and will be attempting to secure future analyses with lower detection limits to improve monitoring.

Based on these data (**Table 10**) there is not sufficient information to conclude that runoff from the former GM industrial area is impacting Twelve Mile Creek at Lakeport Road. The NPCA will continue to conduct water quality sampling at these stations and provide data to support the investigation of potential offsite impacts of surface water of Twelve Mile Creek from the former GM industrial area.

6.8. LAKE NIAPENCO WINTER DISSOLVED OXYGEN MONITORING

The Glanbrook Conservation Committee requested that the NPCA monitor wintertime dissolved oxygen (DO) concentrations in Lake Niapenco. The Glanbrook Conservation Committee was concerned that recent declines in crappie fish populations were the result of low wintertime DO concentrations in Lake Niapenco. Cold winters can cause significant ice cover on Lake Niapenco from January to April. It was hypothesized that ice cover was reducing DO levels within Lake Niapenco and negatively impacting the crappie populations. To address this concern the NPCA monitored DO concentration during the 2020-2021 winter by installing YSI EXO Water Quality Sondes (**Figure 21)** in Lake Niapenco (**Figure 22)**. Before deployment, the logger was lab calibrated for use. The logger was deployed to a depth of 3 m from surface of Lake Niapenco. The logger was suspended with buoys on a steel aircraft cable that was secured with an anchor. The logger was programed to take DO readings every 15 minutes. The YSI loggers was taken to the NPCA main office and the data downloaded to a computer. All data was analyzed with Excel.

Figure 21. YSI EXO Sensor used at Lake Niapenco

Figure 22. Logger Location at Lake Niapenco

During the winter 2020-2021 Lake Niapenco was covered with ice from the third week in January until the first week of March 2021 DO concentrations are shown in **Figure 23**. At the 2m depth DO concentrations during this study period did not dip below the Ontario Ministry of Environment's Provincial Water Quality Objective of 4.0 mg/L (Ontario Ministry of the Environment. 1994). The data provided by the logger demonstrate there was sufficient dissolved oxygen in Lake Niapenco to sustain warm water fish populations during the 2020-2021 winter. It is recommended that the NPCA monitor DO concentrations for the 2021-2022 winter by redeploying the YSI logger to assist the Glanbrook Conservation Committee.

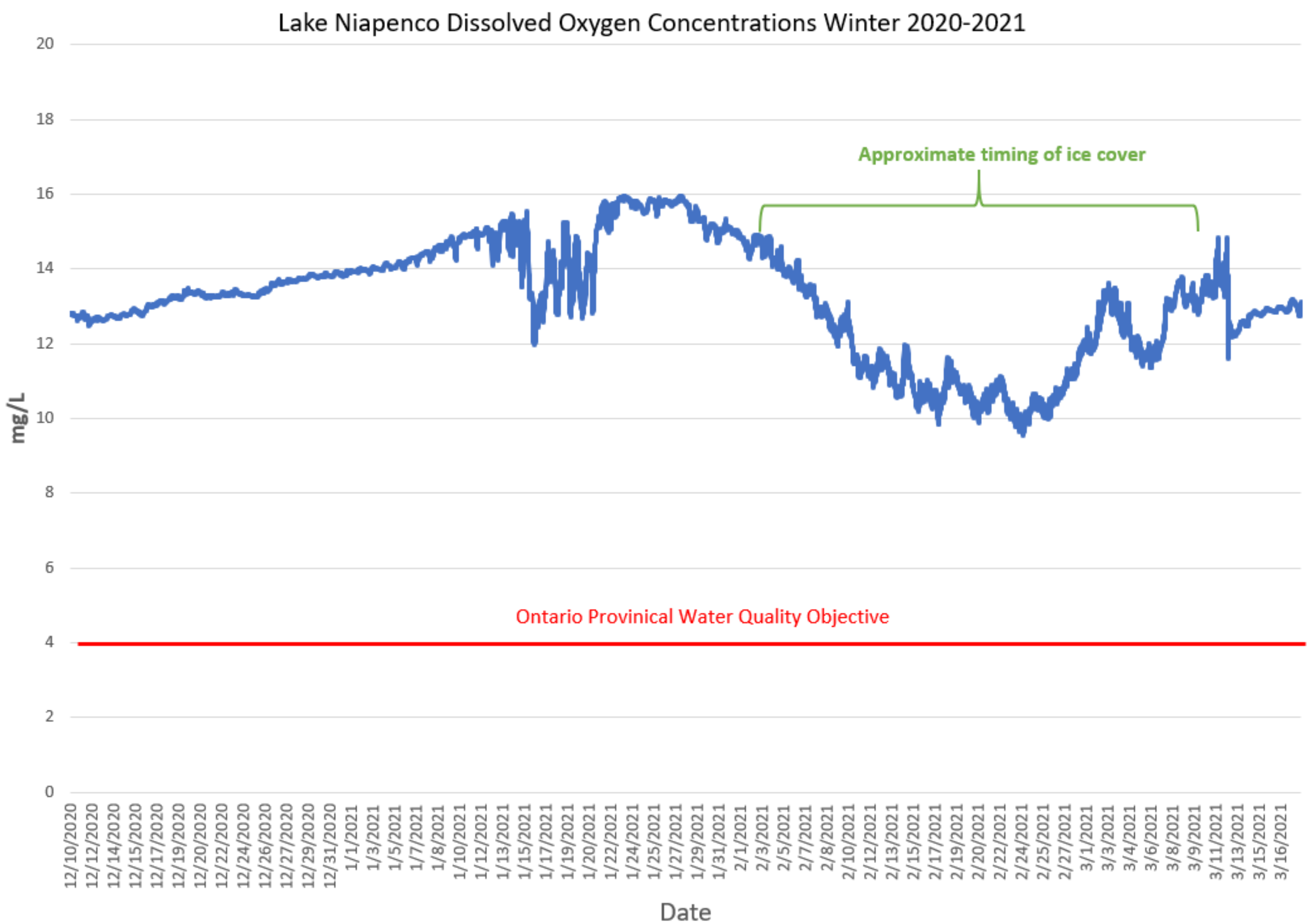


Figure 23. Lake Niapenco Dissolved Oxygen Concentrations (Jan to April 2019)

6.9 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 2020, the NPCA water quality monitoring program received 61 data requests from a variety of agencies and the public. These include:

- Ontario Ministry of the Environment Conservation and Parks
- Ontario Ministry of Agriculture, Food and Rural Affairs
- Ontario Ministry of Natural Resources
- Academia (McMaster University & University of Waterloo)
- Environment Canada
- Municipalities (Upper and Lower Tier)
- Health Units (Hamilton and Niagara)
- Consultants
- Non-Governmental Agencies
- Public

NPCA staff collecting a grab sample for laboratory analysis.

7.0 Conclusions

Based on the foregoing, the NPCA offers the following conclusions:

- Based on the results of the 2016 to 2020 WQI, 65% of the NPCA surface water monitoring stations are rated as *poor*, 27% are rated as *marginal*, 7% are rated as *fair,* 1% is rated as *good* and 1% is rated as *excellent*.
- Based on the results of the 2016 to 2020 biological assessments using the Hilsenhoff Biotic Index (HBI): 18% of the NPCA monitoring stations had water quality rated as very poor, 38% rated as poor, 24% rated as fairly poor, 4% rated as fair and 16% have not been assessed.

- Generally, the WQI ratings at water quality stations were relatively stable when compared to historic NPCA data. The Welland Canal (Port Colborne) has the highest water quality rating in the NPCA watershed. This is not unexpected as the water found in the Welland Canal is from Lake Erie. The other monitoring sites with high WQI ratings include the Point Abino Drain (Fort Erie), the Effingham tributary of Twelve Mile Creek (Pelham), the upper Welland River (Hamilton), and Beaver Creek (Fort Erie).

- 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 8% of NPCA's long-term monitoring stations. 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 a change is ecologically significant.

- Exceedances of *E. coli* also contribute greatly to lower WQI ratings in the NPCA watershed. Approximately 63% 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, Walkers Creek and Prudhommes 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 Hilsenhoff Biotic Index results did not agree at every station (i.e. where the WQI rating is *marginal* the Hilsenhoff Biotic Index rating is *very poor*) indicating that the benthic invertebrate data does not entirely support the chemical data. 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 Richardsons Creek (St.Catharines) and Eighteen Mile Creek (Lincoln) warrant further investigation. Zinc exceedances in the Welland River are related to Hamilton Airport operations and the NPCA and MECP are working with the HIA to reduce concentrations. Chloride exceedances are related to road salt impacts and groundwater discharge to surface water. Nitrate exceedances in the Richardson Creek and the upper Twelve Mile Creek may be related nearby commercial operations in the area. Total suspended solids are mainly related wet weather events and inadequate riparian buffers along watercourses.

- Most NPCA groundwater monitoring wells exceeded 20 mg/L ODWS for sodium which is a health-related concern for individuals with sodium restricted diet intakes. A small number of wells were found to have ODWS exceedances in arsenic, boron, fluoride, and uranium. In addition, ambient groundwater geochemistry across the NPCA was found to have elevated levels of sulfate, iron, manganese, and chloride that exceed the Aesthetic ODWS. ODWS exceedances have been investigated by MECP and are attributed to natural conditions of the groundwater but it is recommended that watershed residents using groundwater test their water regularly and treat water appropriately.

- The NPCA's 2020 water temperature monitoring of the Upper Twelve Mile Creek headwaters classified four stations as coldwater, four stations as coolwater and one station as warm water. The Upper Twelve Mile Creek watershed is capable of supporting Brook Trout based on temperatures monitoring data however there is signficant warming of the main channel of Twelve Mile as it travels through Short Hills Provincial Park where stream temperature at Decew Road are consistently above the optimal range for Brook Trout.

- 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 RECOMMENDATIONS

Recommendations from this NPCA Water Quality Monitoring Program Report are summarized as follows:

1. It is recommended that the NPCA continue the Water Quality Monitoring Program 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 MECP to identify and 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 coldwater 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 offer the 'Water Well Decommissioning Program' to the public to help reduce the risk of groundwater contamination by removing old and abandoned wells.

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

8. It is recommended that the NPCA continue to monitor Perfluorinated Compounds in Lake Niapenco to provide the public with up-to-date information on PFC concentrations within the lake. Yearly surveillance is an appropriate time interval for monitoring based on lab analysis costs and contaminant variability and concentrations.

9. It is recommended that the NPCA continue to support and MECP Climate Change project for Twenty Mile Creek at Balls Falls Conservation Area by continuing to operate and maintain this enhanced monitoring station.

9.0 References Cited

Canadian Council of Ministers of the Environment. 2001. Canadian Water Quality Index.

Canadian Council of Ministers of the Environment (CCME). 2002. Canadian water quality guidelines for the protection of aquatic life: Total particulate matter. In: Canadian Environmental Quality Guidelines, Canadian Council of Ministers of the Environment, Winnipeg

Canadian Council of Minister of the Environment. 2003. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Canadian Environmental Quality Guidelines.

Canadian Council of Ministers of the Environment. 2011. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Canadian Environmental Quality Guidelines.

Colgrove, L.M. and Hamilton, S.M. 2018. Geospatial distribution of selected chemical, bacteriological and gas parameters related to groundwater in southern Ontario; Ontario Geological Survey, Groundwater Resources Study 17.

Conservation Ontario. 2011. Guide to Developing Conservation Authority Watershed Report Cards. Newmarket.

de Solla, S., A. De Silva and R Letcher. 2012. Highly elevated levels of perflurooctane sulfonate and other perfluorinated acids found in biota and surface water downstream of an international airport, Hamilton, Ontario, Canada. *Environment International* 39:19-26.

Fowler, C. 2011. PFOS in the Welland River and Lake Niapenco. Ontario Ministry of the Environment. Technical Support Section, West Central Region Hamilton.

Griffiths, R.W. 1999. Hilsenhoff Biotic Index: Bioassessment of Water Quality. The Centre for Environmental Training, Niagara College: Niagara-on-the-Lake, Ontario.

Health Canada. 2016. Perfluorooctanoic Acid (PFOA) in Drinking Water. https://www.canada.ca/content/dam/hc-sc/healthy-canadians/migration/health-system-systeme-sante/consultations/acide-perfluorooctanoic-acid/alt/perfluorooctanoic-eng.pdf

Health Canada. 2016. Perfluorooctane Sulfonate (PFOS) in Drinking Water. https://www.canada.ca/content/dam/hc-sc/healthy-canadians/migration/health-system-systeme-sante/consultations/perfluorooctane-sulfonate/alt/perfluorooctane-sulfonate-eng.pdf

Helsel, D., and R. Hirsch. 1992. Statistical Methods in Water Resources, Elsevier, 522 p.

Helsel, D., D. Muller, and J. Slack. 2005. Computer Program for the Kendall Family of Trend Tests, Scientific Investigation Report, USGS, 1-4.

Hilsenhoff, William L. 1987. An Improved Biotic Index of Organic Stream Pollution. The Great LakesEntomologist. 20: 31-36.

Jones, C., K. Somers, B. Craig, and T. B. Reynoldson. 2005. Ontario Benthos Biomonitoring Network Protocol Manual: Version 1.0. Ontario Ministry of Environment: Dorset, Ontario.

Jones, C. 2006. Personal communication. Benthic Biomonitoring Scientist, Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment.

MacRitchie, S. 2009. Fluoride and Uranium Occurrence in PGMN Well 80-1. Ministry of the Environment: Environmental Monitoring and Reporting Branch.

Ontario Ministry of the Environment and Environment Canada. 1995. Niagara River Remedial Action Plan Stage 2 Report.

Ontario Ministry of the Environment. 1994. Water Management, Policies, Guidelines and Provincial Water Quality Objectives. Government of Ontario, Toronto.

Ontario Ministry of the Environment. 2003. Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines. Government of Ontario, Toronto.

Regional Municipality of Niagara. 2003. Niagara Water Quality Protection Strategy. Prepared for the Regional Municipality of Niagara by MacViro, Philips Engineering and CH2MHill.

Tchobanoglous, G, and E. Schroeder. 1987. Water Quality. Addison-Wesley Publishing Company: Reading, Massachusetts.

Waterloo Hydrogeologic Inc., 2005. NPCA Groundwater Study. Waterloo, Ontario.

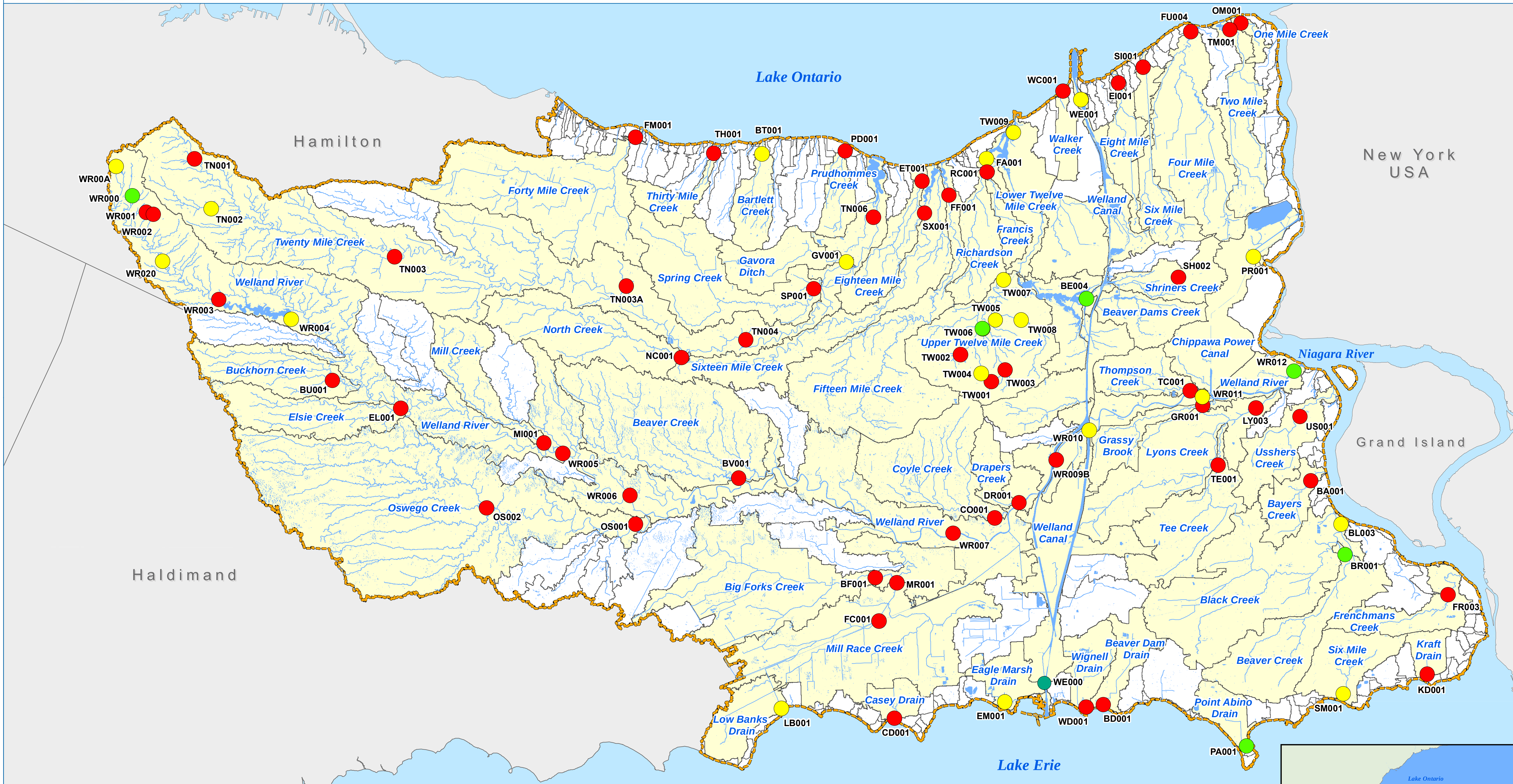
10.0 ACKNOWLEDGEMENTS

The NPCA would like to thank the City of Hamilton, Ontario Ministry of Environment, Conservation and Parks, Regional Municipality of Niagara, and Haldimand County for their support of the NPCA Water Quality Monitoring Program.

Appendix A

NIAGARA PENINSULA CONSERVATION AUTHORITY

Water Quality Index Rating 2016 - 2020



Surface Water Quality Monitoring Station

Water Quality Index Rating
- Excellent
- Good
- Fair
- Marginal
- Poor

- Watercourses
- Waterbodies
- Sampled Subwatersheds
- NPCA Jurisdiction

0 5 10 20 30

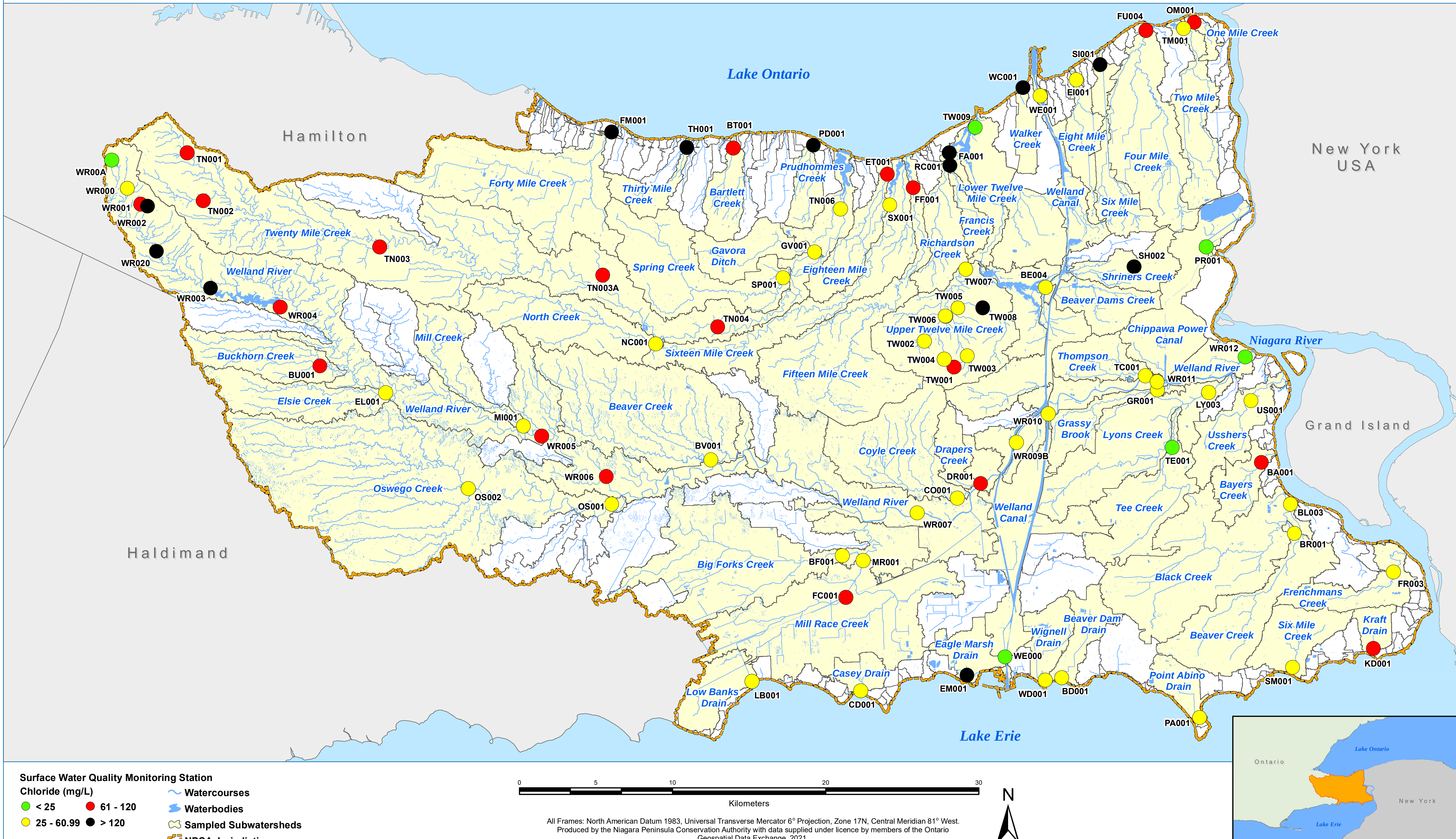
Kilometers

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, 2021.

Appendix B

Median Chloride Concentrations 2016 - 2020



Surface Water Quality Monitoring Station
Chloride (mg/L)

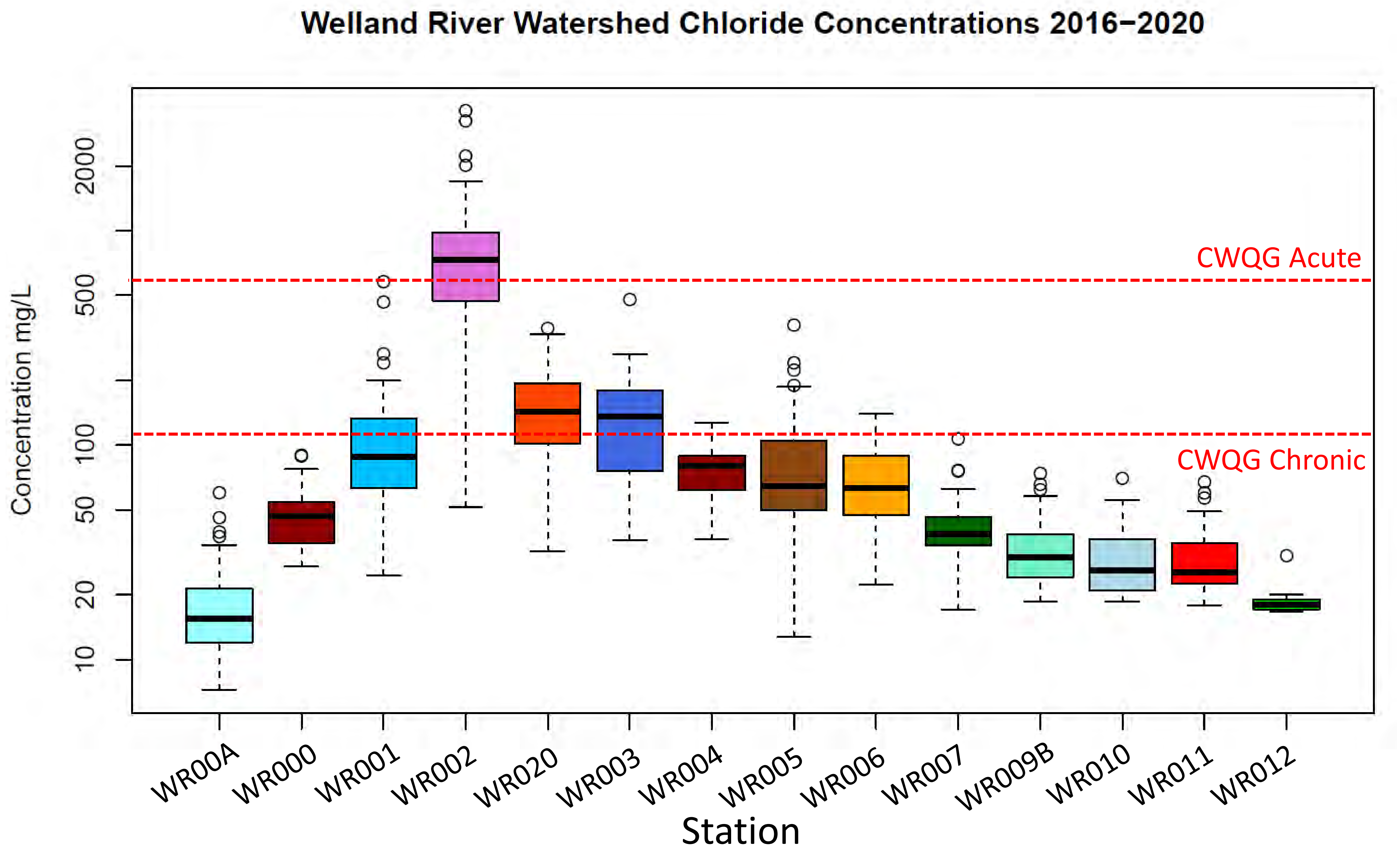
- < 25
- 25 - 60.99
- 61 - 120
- > 120

- Watercourses
- Waterbodies
- Sampled Subwatersheds
- NPCA Jurisdiction

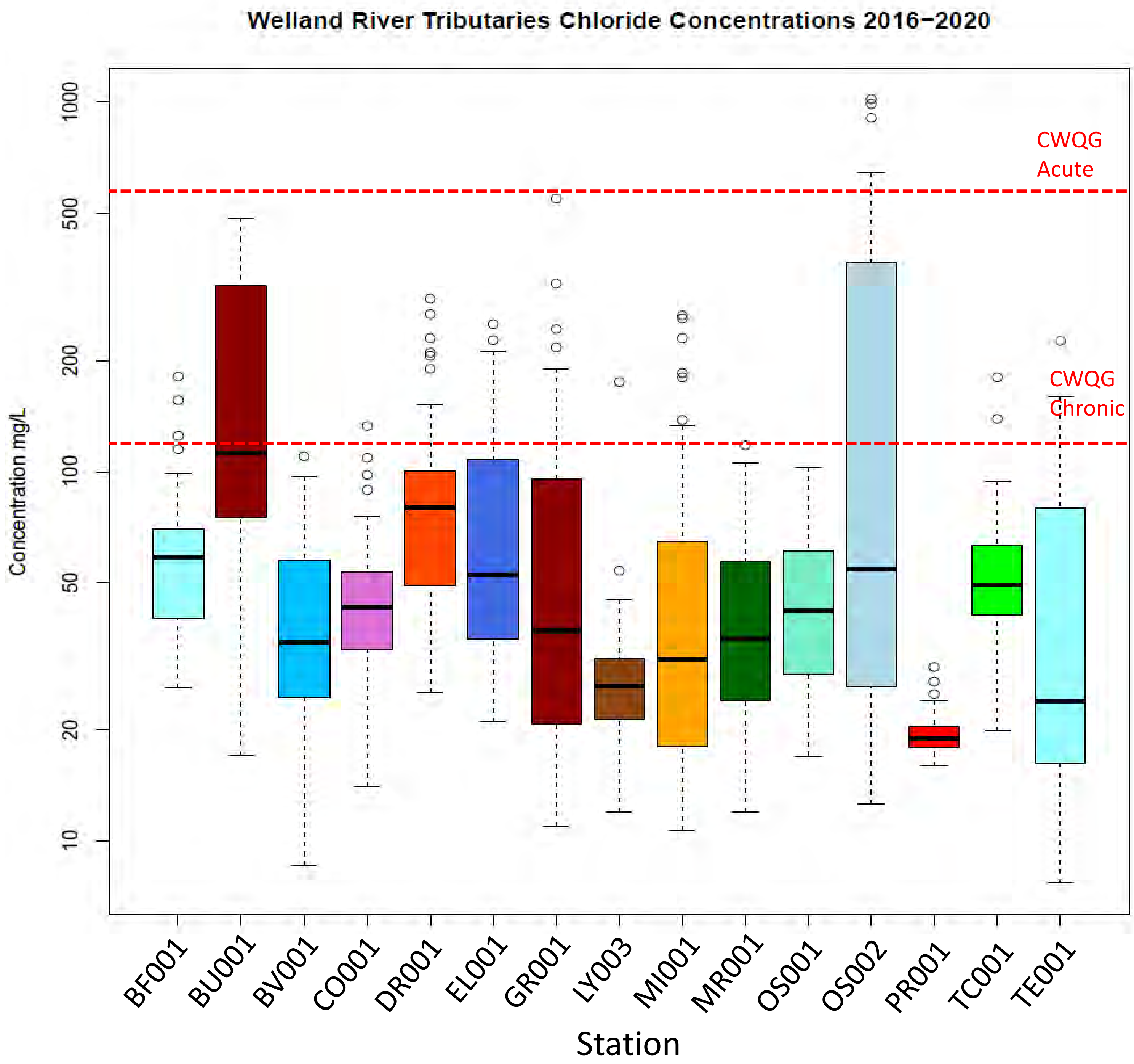
0 5 10 20 30
Kilometers

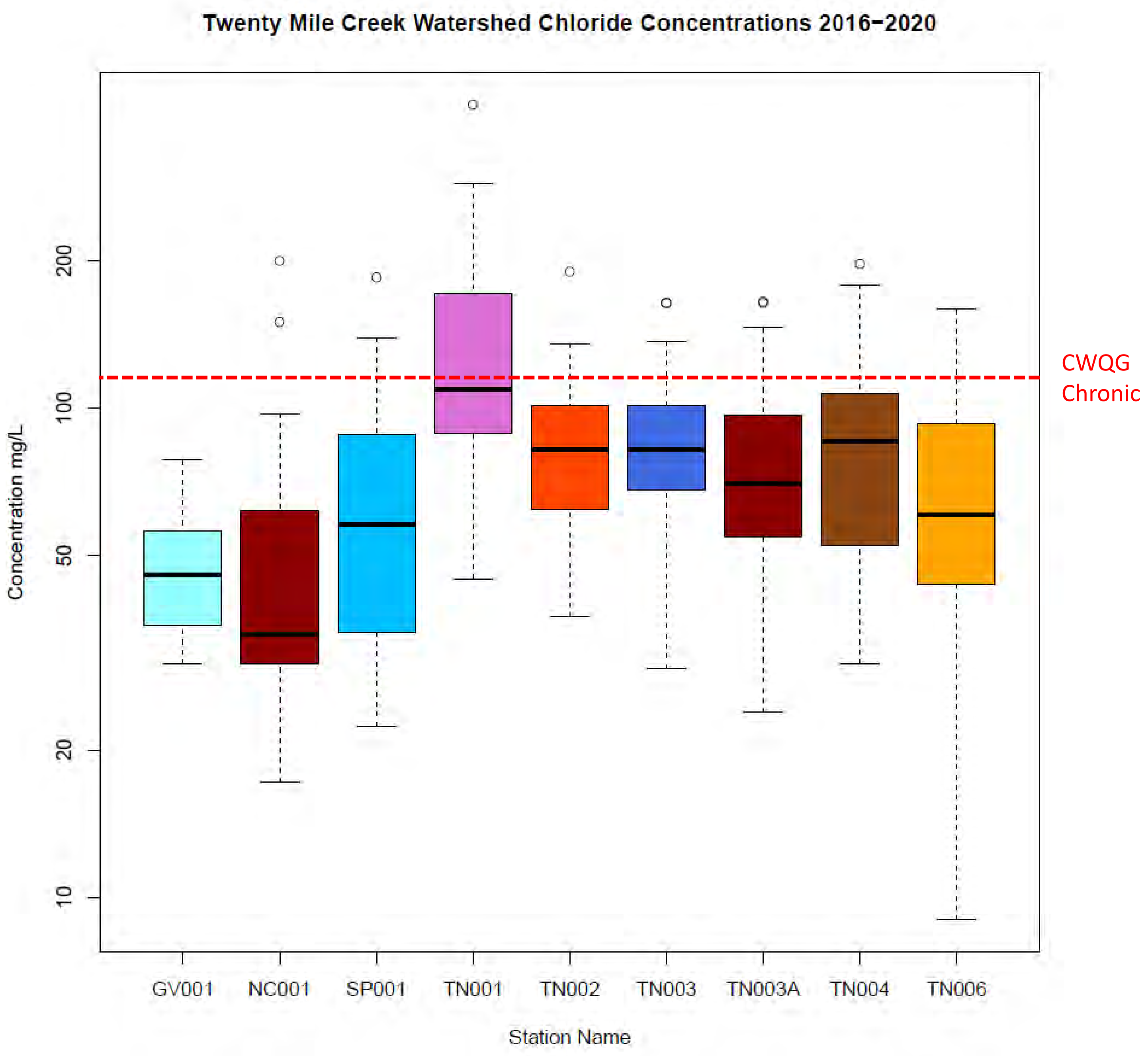
N

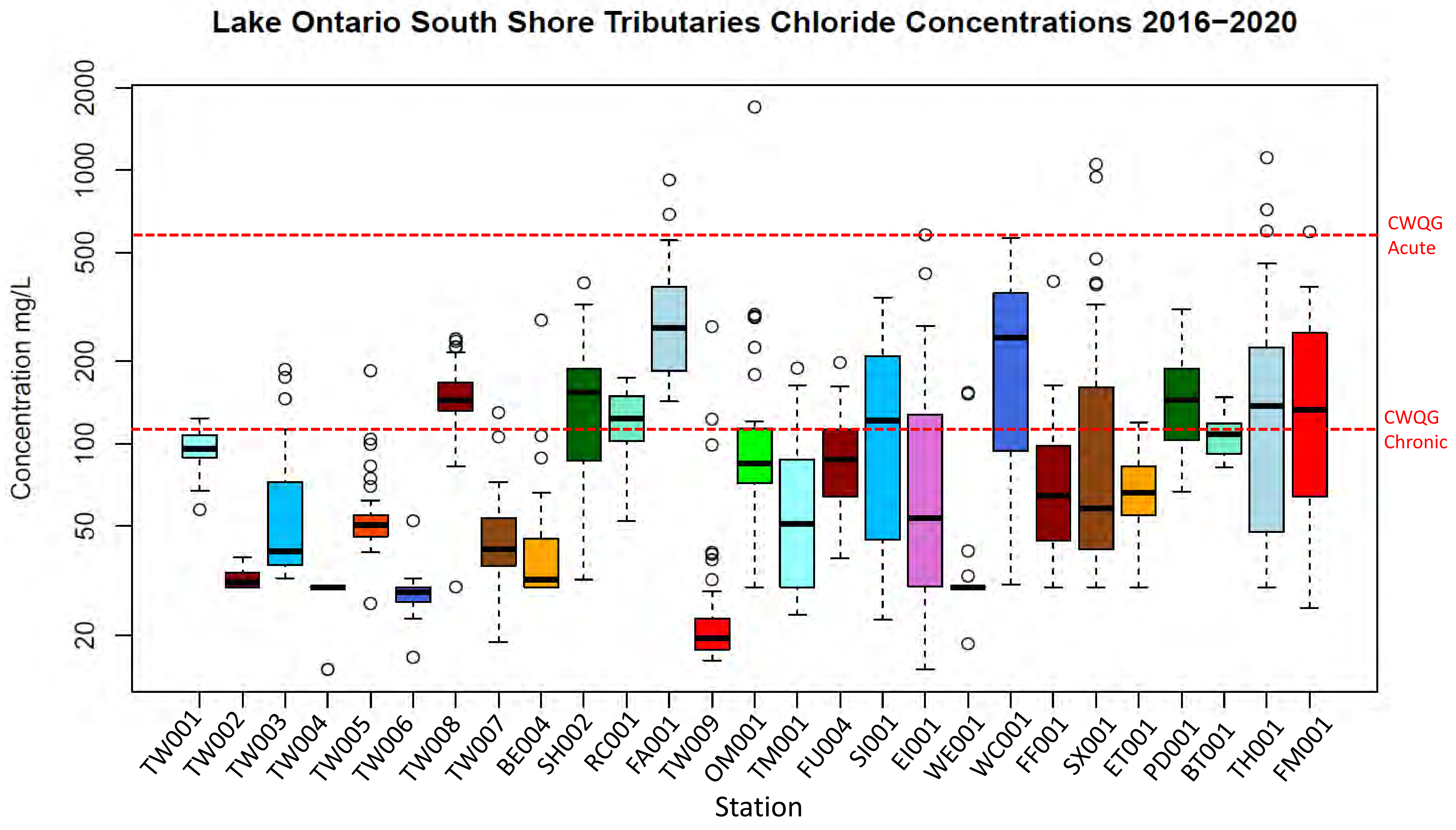
All Frames: North American Datum 1983, Universal Transverse Mercator 6° Projection, Zone 17N, Central Meridian 81° West.
Produced by the Niagara Peninsula Conservation Authority with data supplied under licence by members of the Ontario Geospatial Data Exchange, 2021.

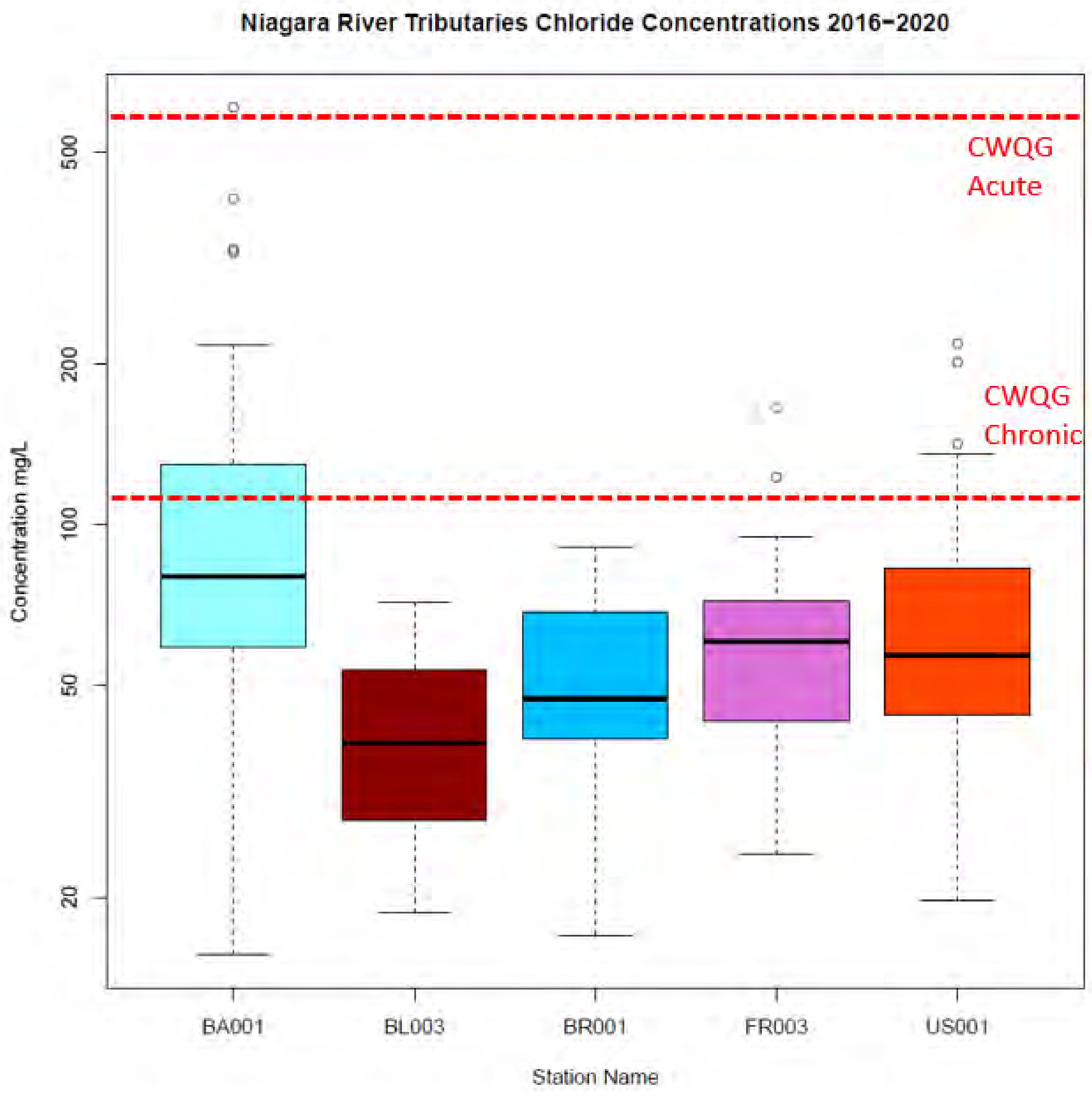


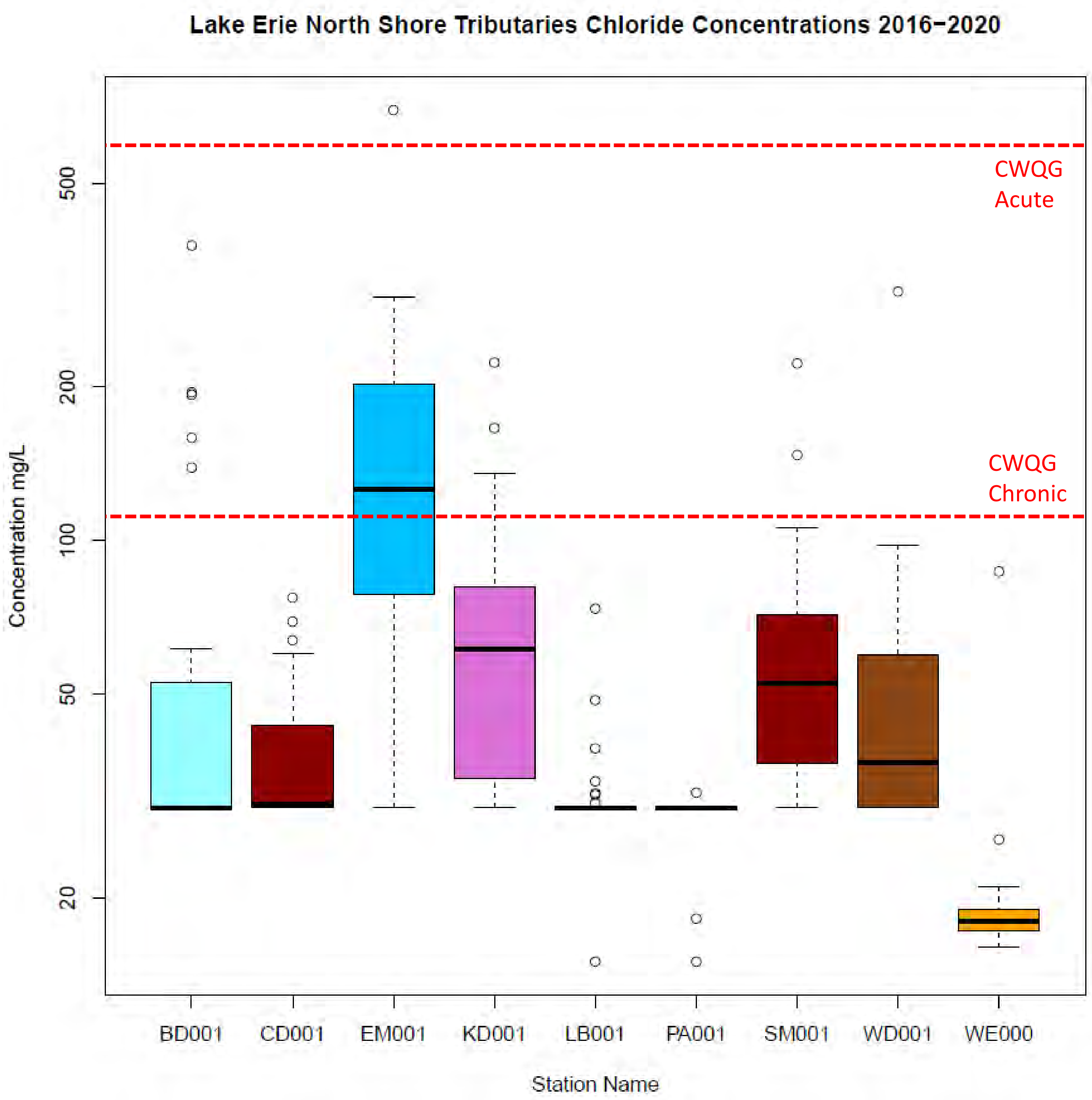
Welland River Watershed Chloride Concentrations 2016−2020
Concentration mg/L
2000
500
100
50
20
10
CWQG Acute
CWQG Chronic
WR00A
WR000
WR001
WR002
WR020
WR003
WR004
WR005
WR006
WR007
WR009B
WR010
WR011
WR012
Station


Welland River Tributaries Chloride Concentrations 2016−2020
CWQG
Acute
CWQG
Chronic
Concentration mg/L
1000
500
200
100
50
20
10
BF001
BU001
BV001
CO001
DR001
EL001
GR001
LY003
MI001
MR001
OS001
OS002
PR001
TC001
TE001
Station


Twenty Mile Creek Watershed Chloride Concentrations 2016−2020
Concentration mg/L
10
20
50
100
200
CWQG
Chronic
GV001
NC001
SP001
TN001
TN002
TN003
TN003A
TN004
TN006
Station Name


Lake Ontario South Shore Tributaries Chloride Concentrations 2016−2020
Concentration mg/L
2000
1000
500
200
100
50
20
CWQG Acute
CWQG Chronic
TW001
TW002
TW003
TW004
TW005
TW006
TW008
TW007
BE004
SH002
RC001
FA001
TW009
OM001
TM001
FU004
SI001
EI001
WE001
WC001
FF001
SX001
ET001
PD001
BT001
TH001
FM001
Station

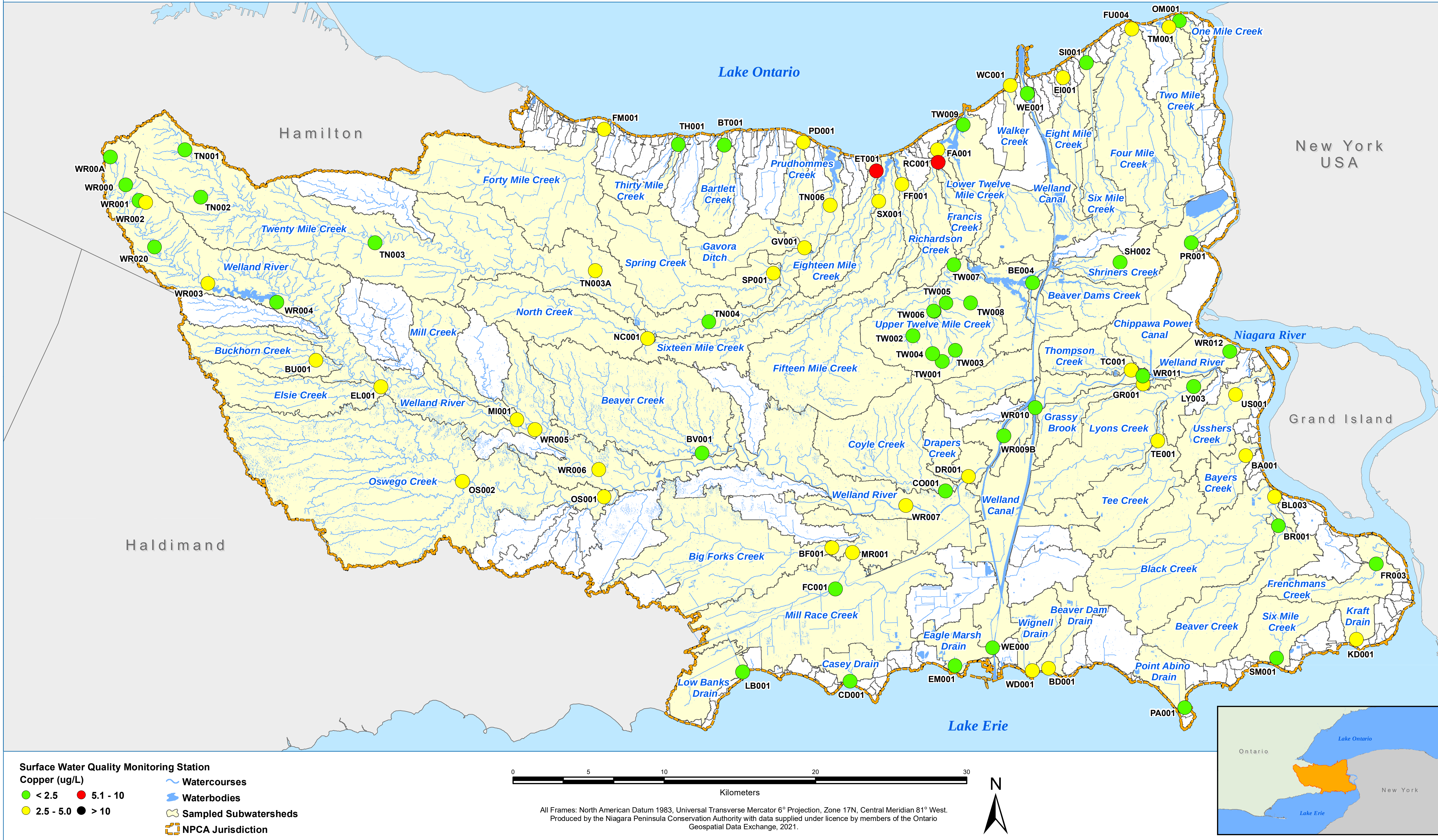

Niagara River Tributaries Chloride Concentrations 2016-2020
CWQG
Acute
CWQG
Chronic
Concentration mg/L
500
200
100
50
20
BA001
BL003
BR001
FR003
US001
Station Name


Lake Erie North Shore Tributaries Chloride Concentrations 2016−2020
CWQG
Acute
CWQG
Chronic
Concentration mg/L
500
200
100
50
20
BD001
CD001
EM001
KD001
LB001
PA001
SM001
WD001
WE000
Station Name

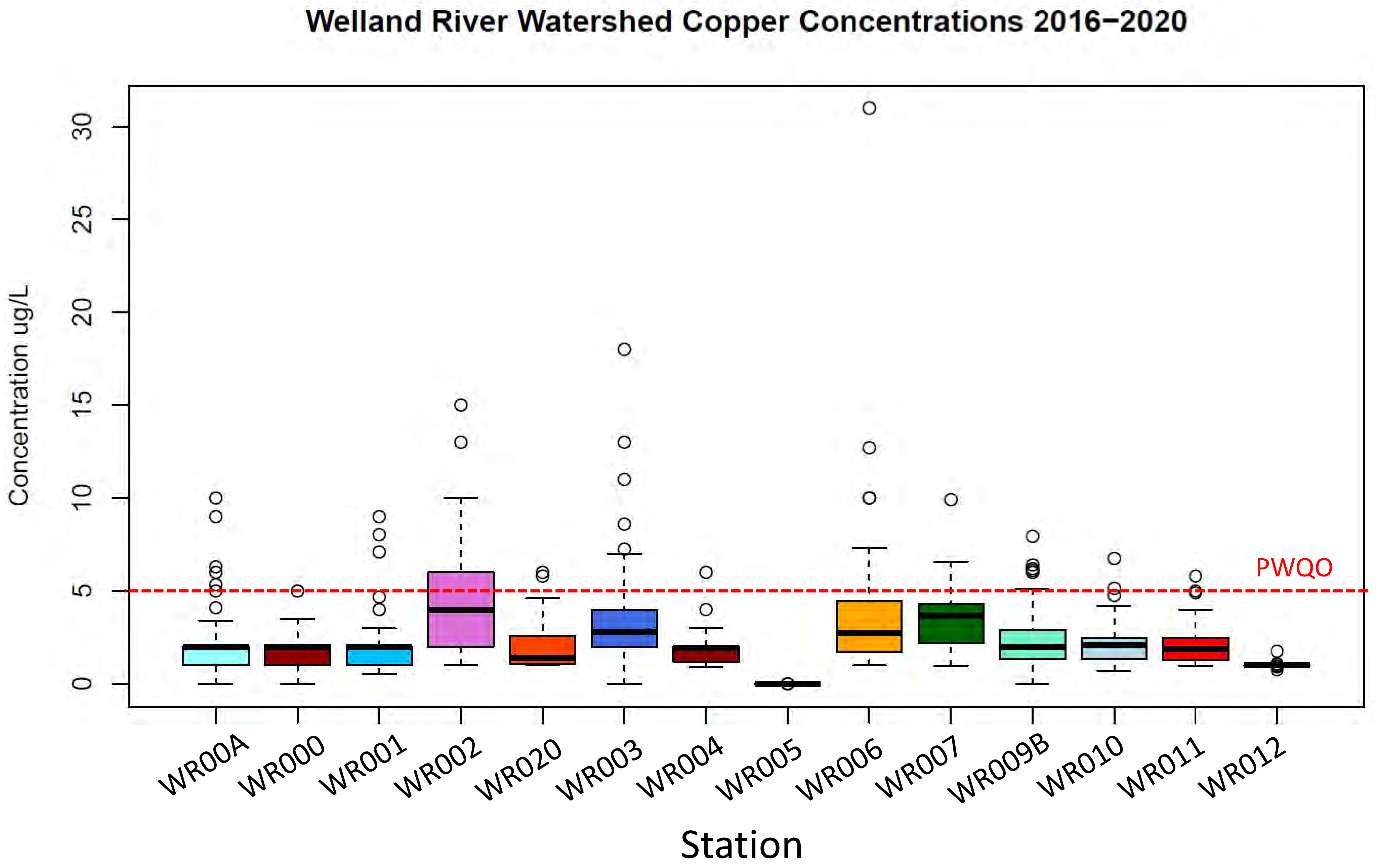
Appendix C

NIAGARA PENINSULA CONSERVATION AUTHORITY

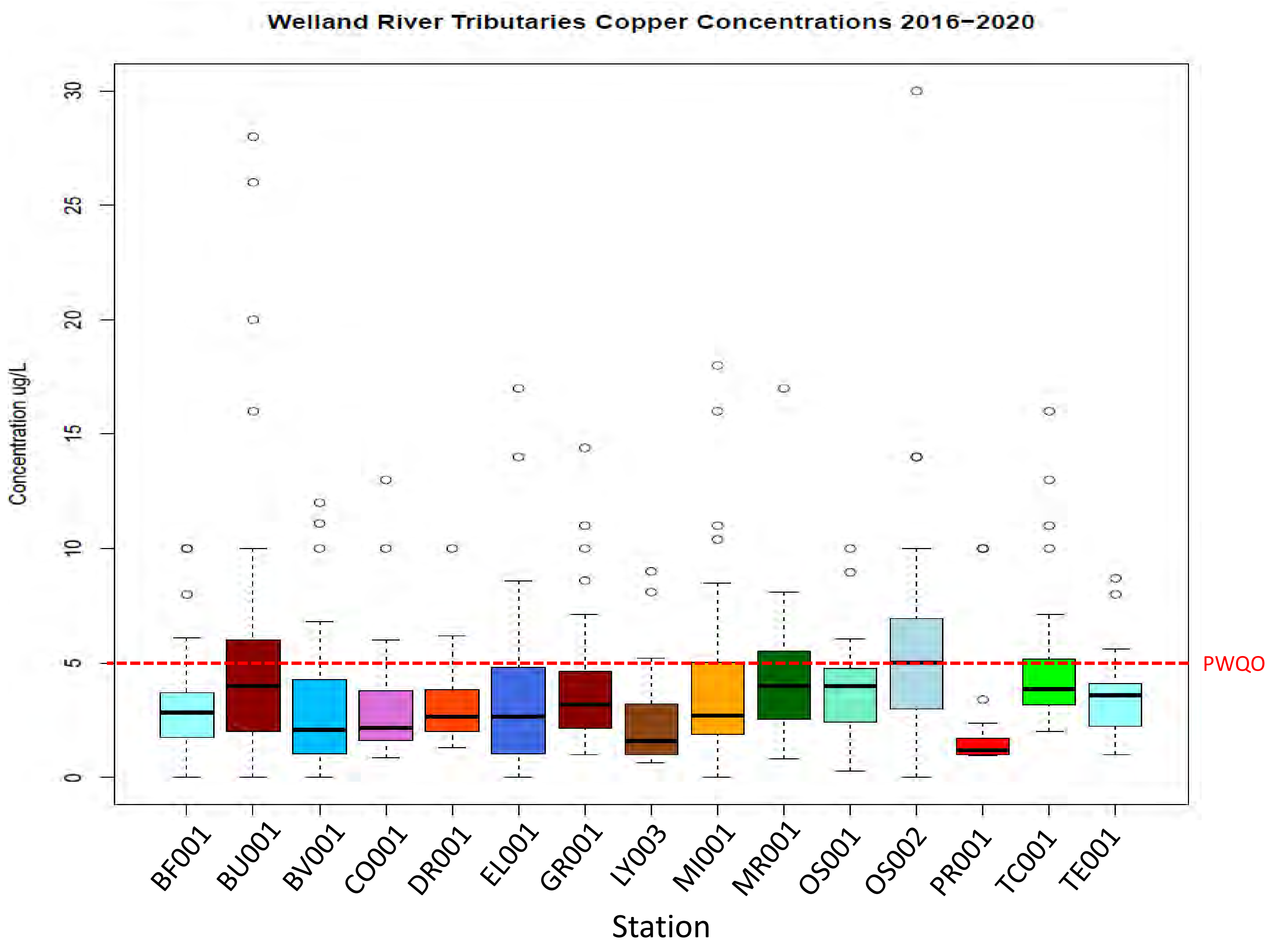
Median Copper Concentrations 2016 - 2020

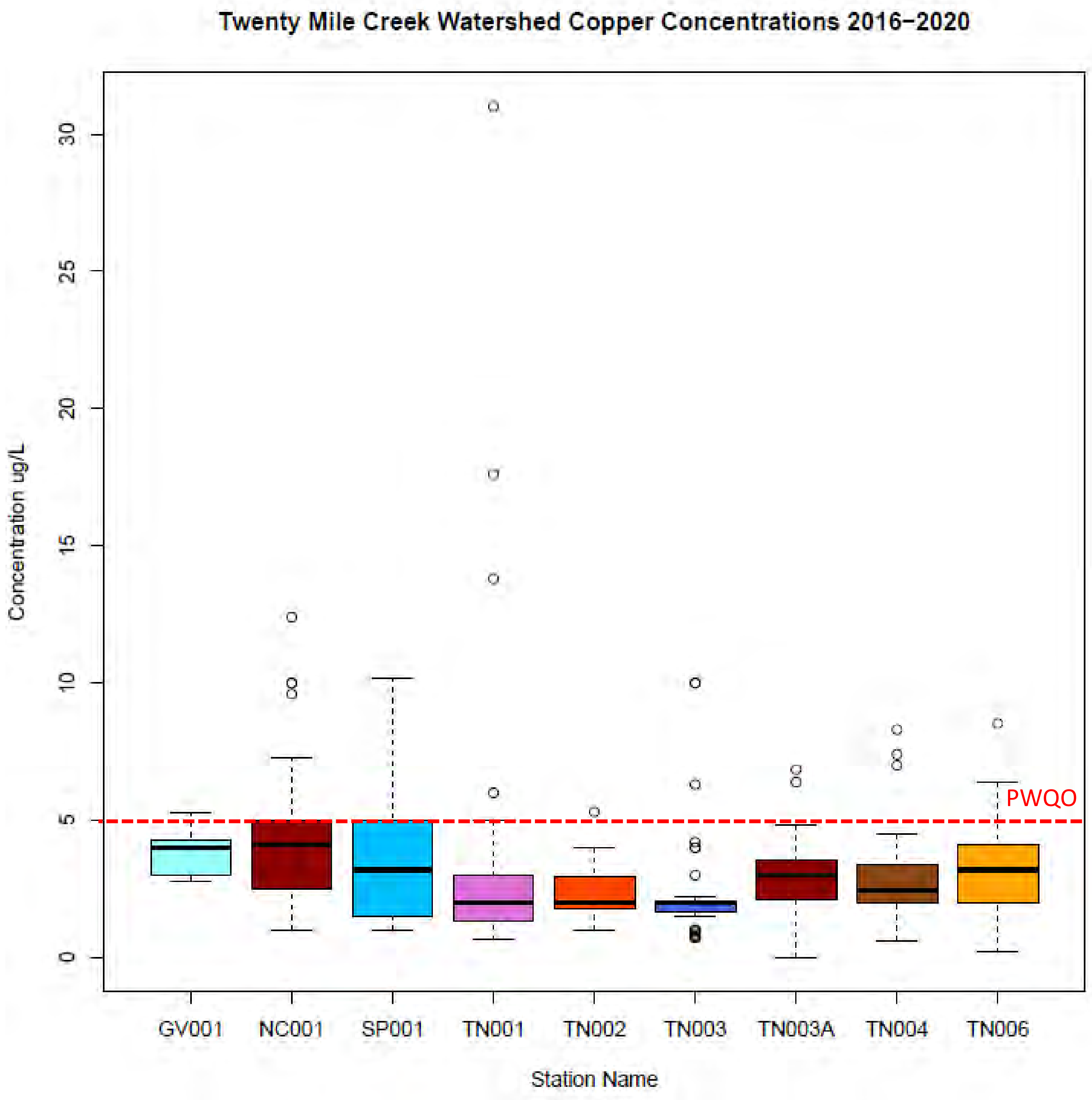


All Frames: North American Datum 1983, Universal Transverse Mercator 6° Projection, Zone 17N, Central Meridian 81° West.
Produced by the Niagara Peninsula Conservation Authority with data supplied under licence by members of the Ontario Geospatial Data Exchange, 2021.

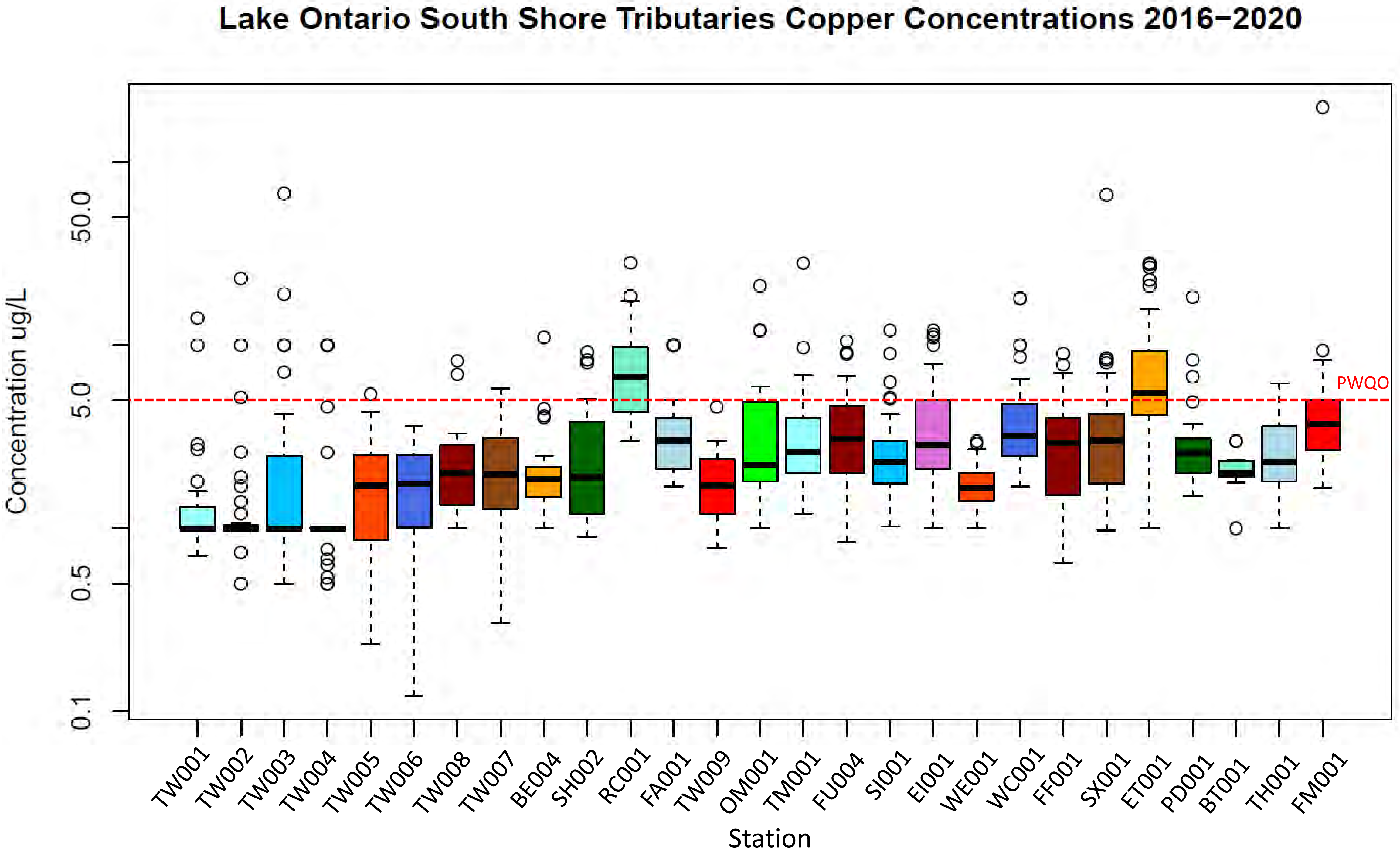


Welland River Watershed Copper Concentrations 2016−2020
Concentration ug/L
0
5
10
15
20
25
30
PWQO
WR00A
WR000
WR001
WR002
WR020
WR003
WR004
WR005
WR006
WR007
WR009B
WR010
WR011
WR012
Station

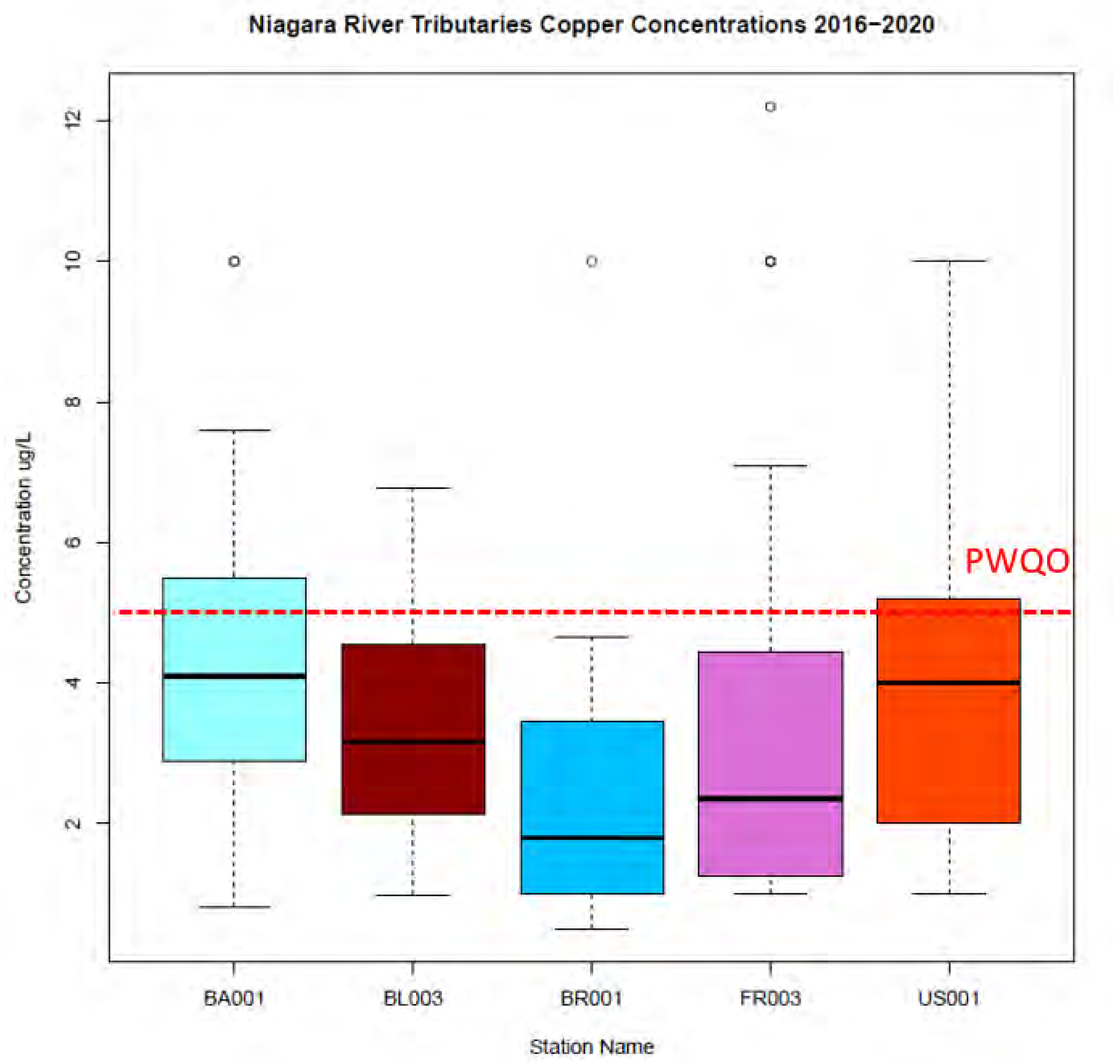

Welland River Tributaries Copper Concentrations 2016−2020
Concentration ug/L
0
5
10
15
20
25
30
PWQO
BF001
BU001
BV001
CO001
DR001
EL001
GR001
LY003
MI001
MR001
OS001
OS002
PR001
TC001
TE001
Station

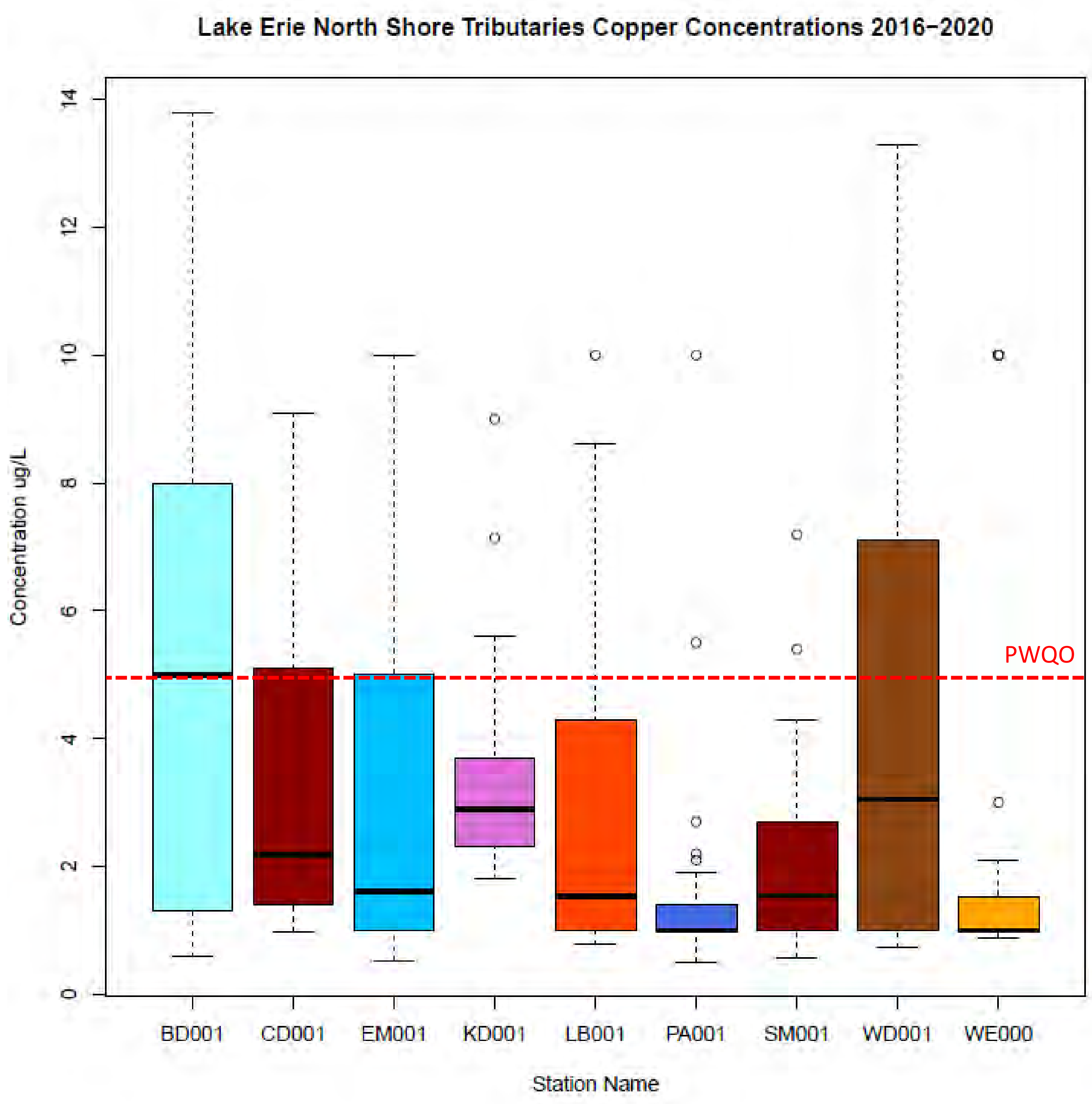


Twenty Mile Creek Watershed Copper Concentrations 2016–2020
Concentration ug/L
0
5
10
15
20
25
30
PWQO
GV001
NC001
SP001
TN001
TN002
TN003
TN003A
TN004
TN006
Station Name



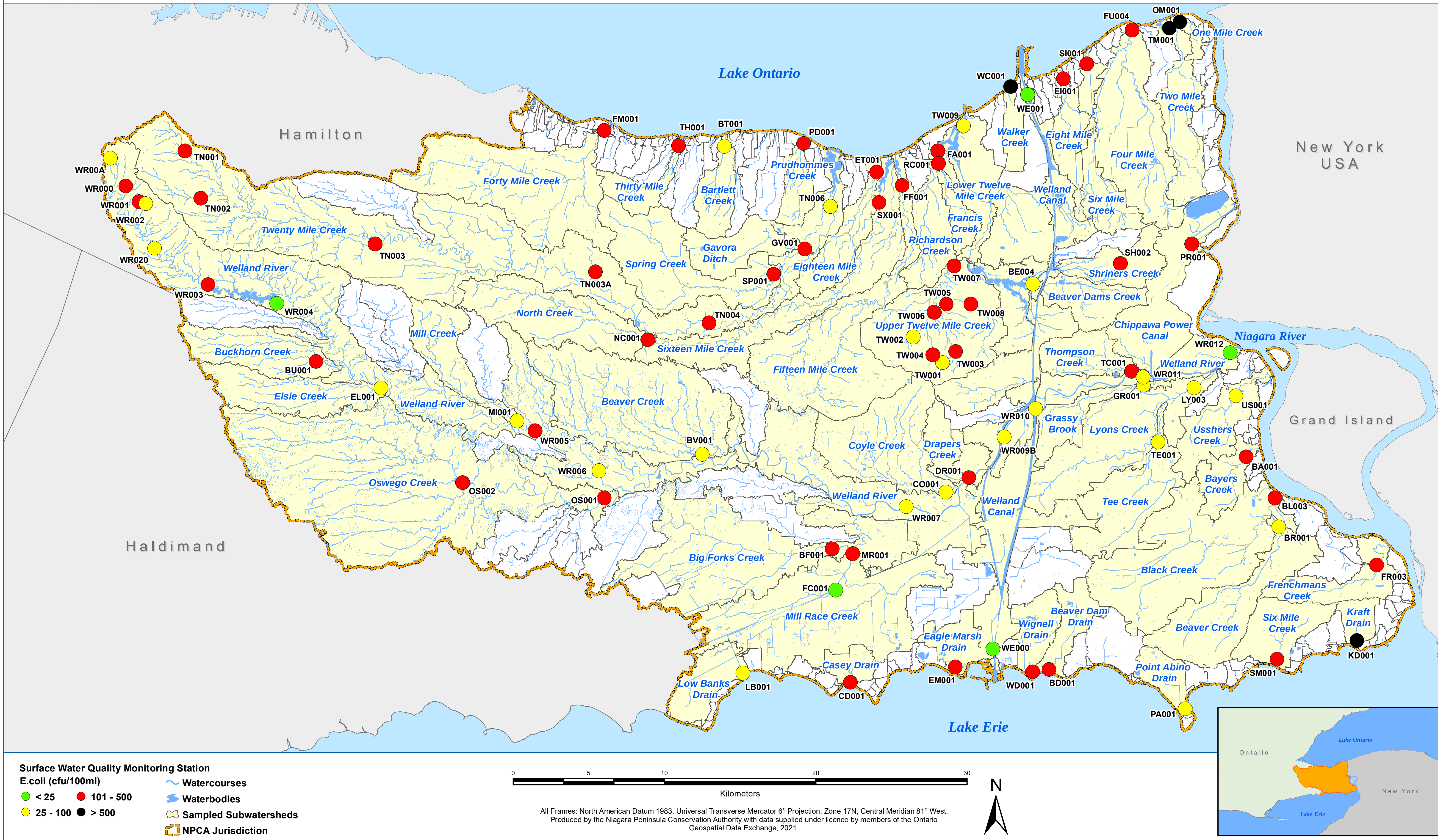
Lake Ontario South Shore Tributaries Copper Concentrations 2016−2020
Concentration ug/L
50.0
5.0
0.5
0.1
PWQO
TW001
TW002
TW003
TW004
TW005
TW006
TW008
TW007
BE004
SH002
RC001
FA001
TW009
OM001
TM001
FU004
SI001
EI001
WE001
WC001
FF001
SX001
ET001
PD001
BT001
TH001
FM001
Station

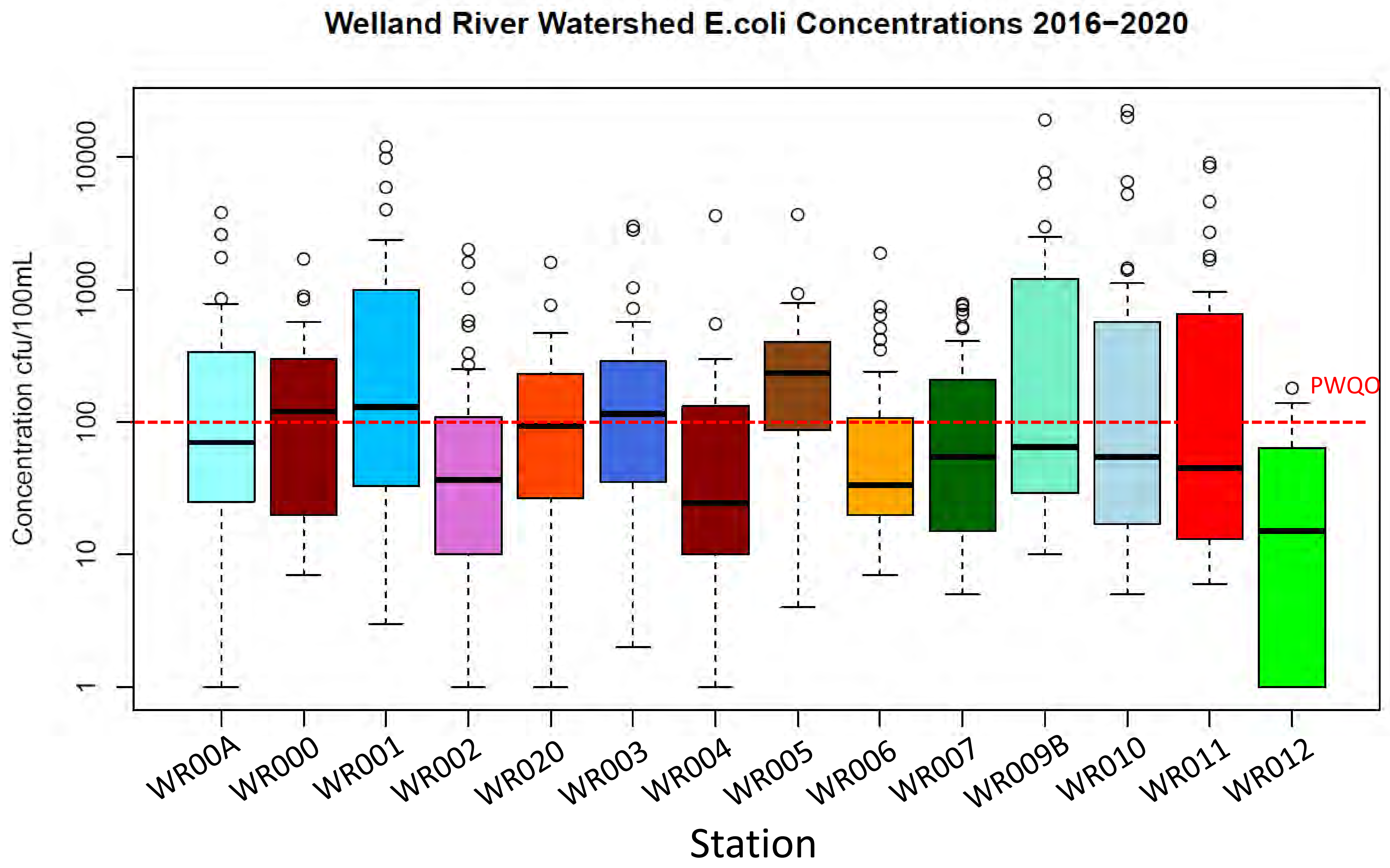

Niagara River Tributaries Copper Concentrations 2016−2020
Concentration ug/L
2
4
6
8
10
12
PWQO
BA001
BL003
BR001
FR003
US001
Station Name


Lake Erie North Shore Tributaries Copper Concentrations 2016−2020
Concentration ug/L
0
2
4
6
8
10
12
14
PWQO
BD001
CD001
EM001
KD001
LB001
PA001
SM001
WD001
WE000
Station Name

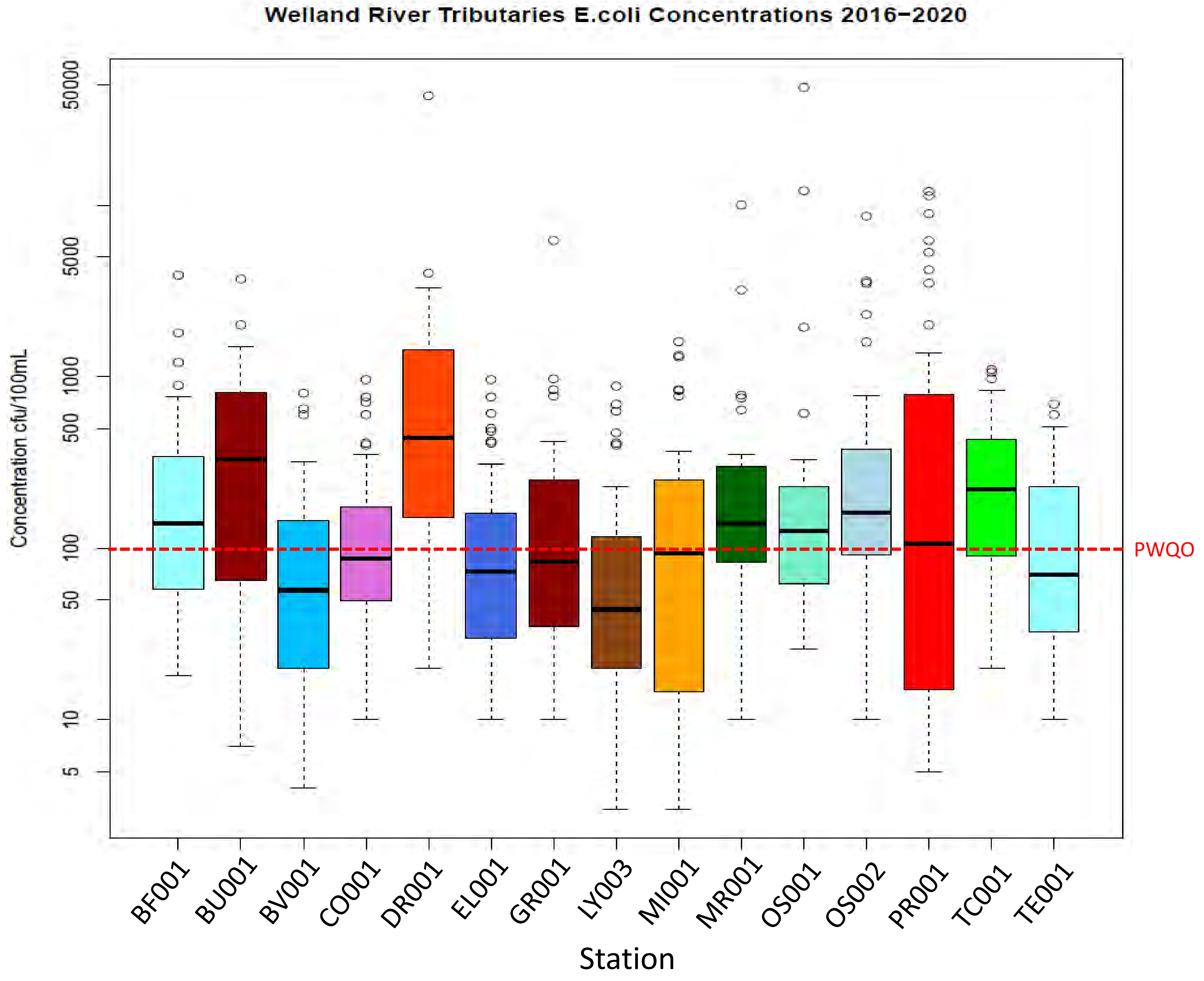
Appendix D

Median E.coli Concentrations 2016 - 2020

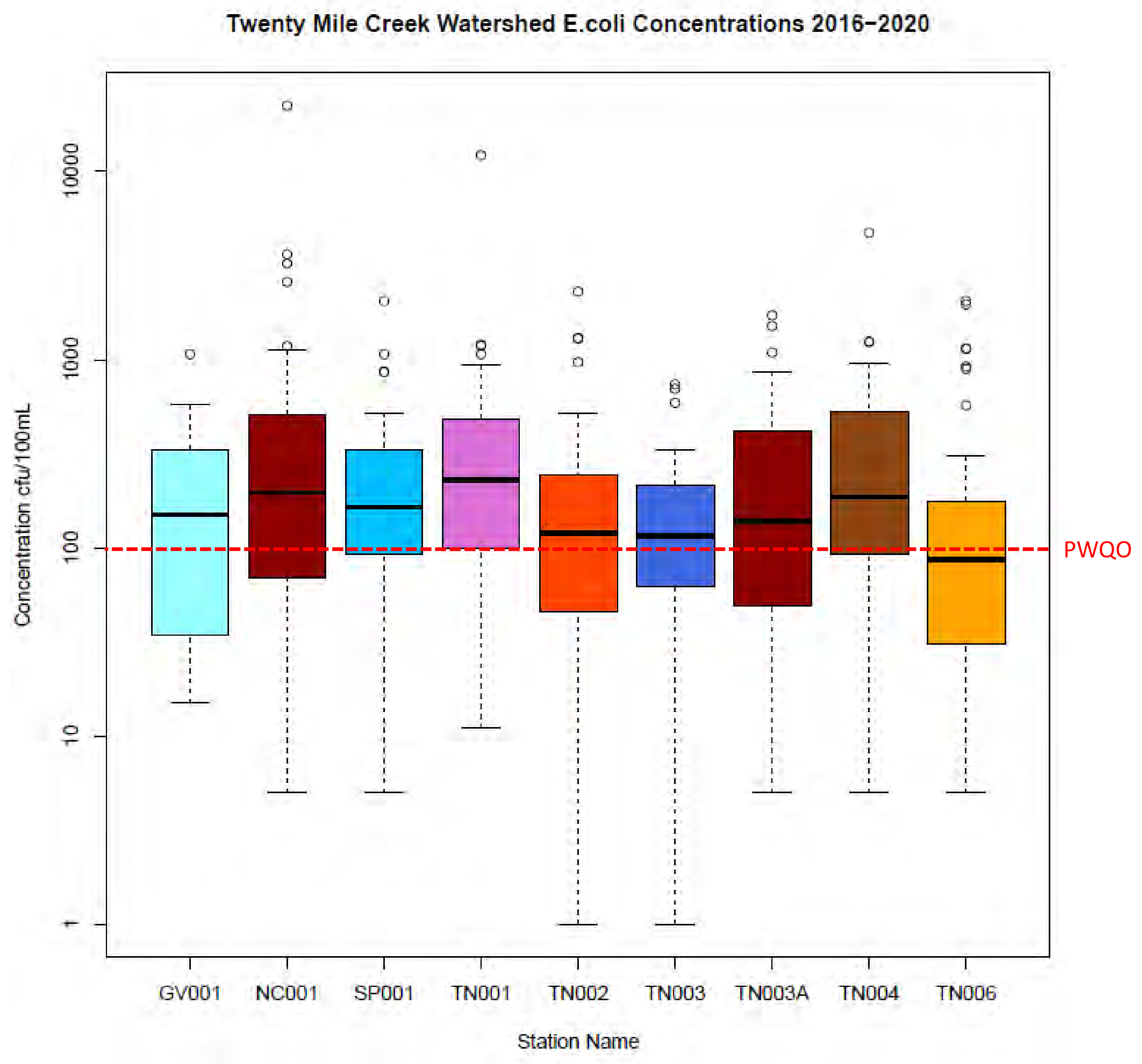




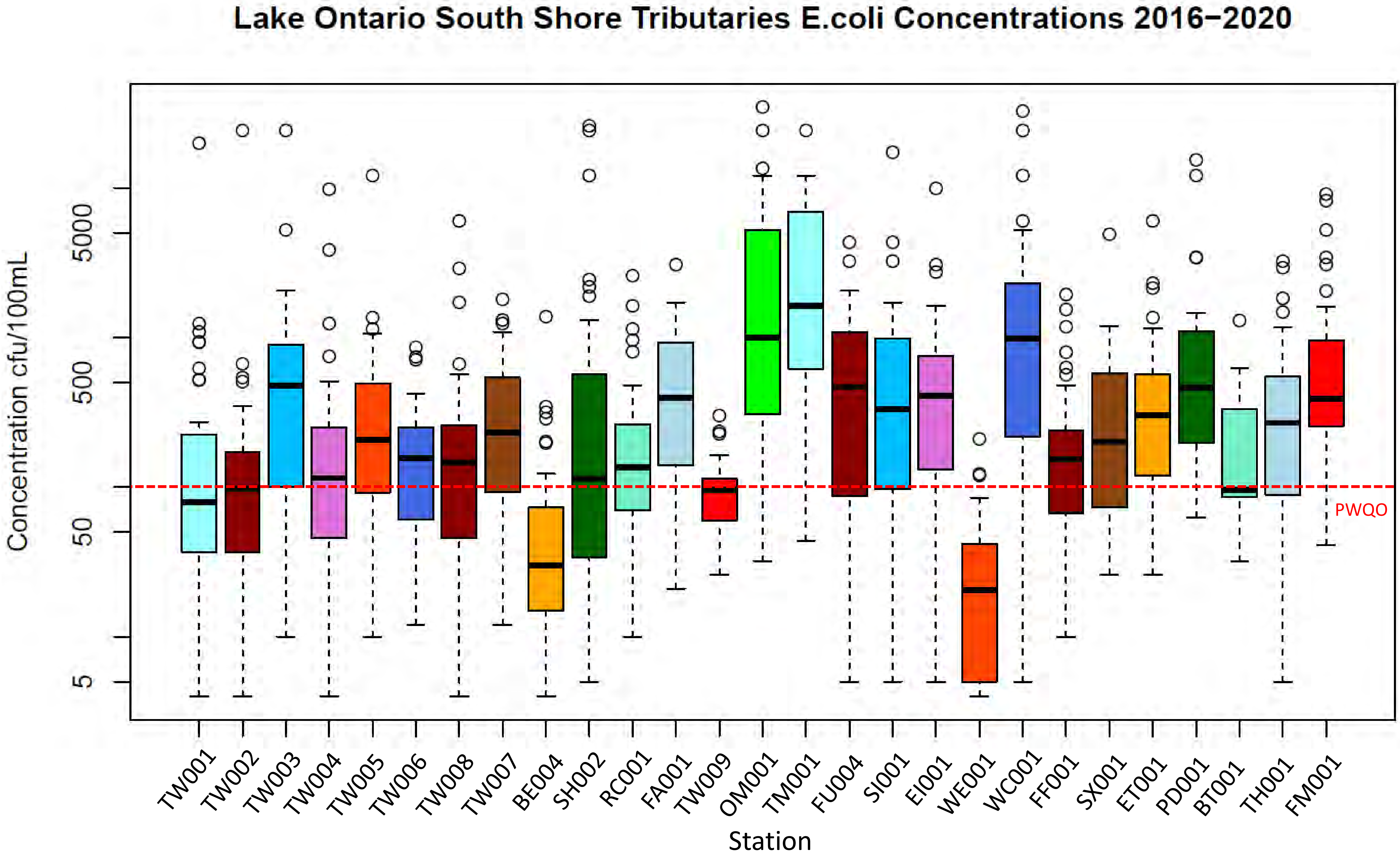
Welland River Watershed E.coli Concentrations 2016−2020
Concentration cfu/100mL
10000
1000
100
10
1
PWQO
WR00A
WR000
WR001
WR002
WR020
WR003
WR004
WR005
WR006
WR007
WR009B
WR010
WR011
WR012
Station



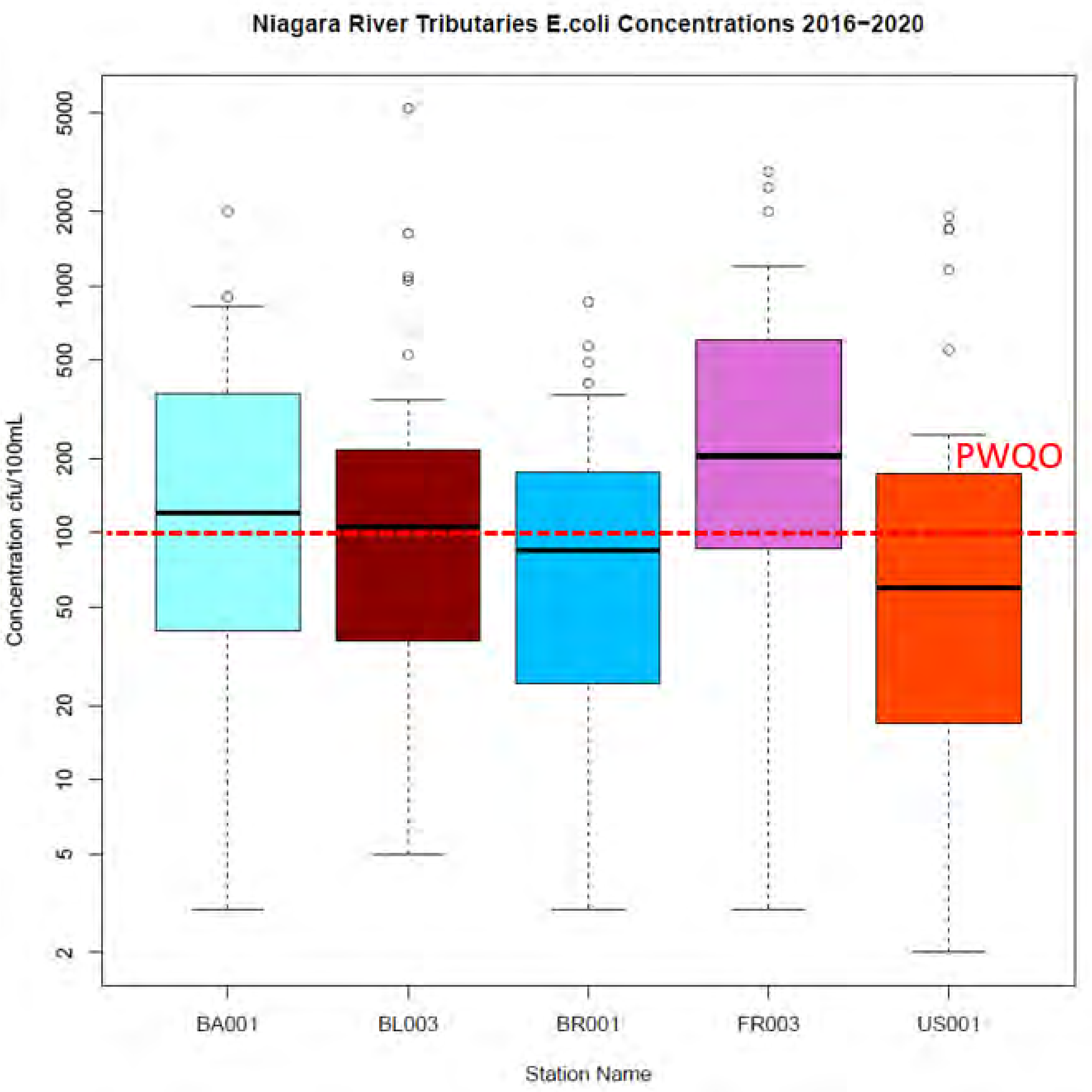
Welland River Tributaries E.coli Concentrations 2016−2020
Concentration cfu/100mL
50000
5000
1000
500
100
50
10
5
PWQO
BF001
BU001
BV001
CO001
DR001
EL001
GR001
LY003
MI001
MR001
OS001
OS002
PR001
TC001
TE001
Station

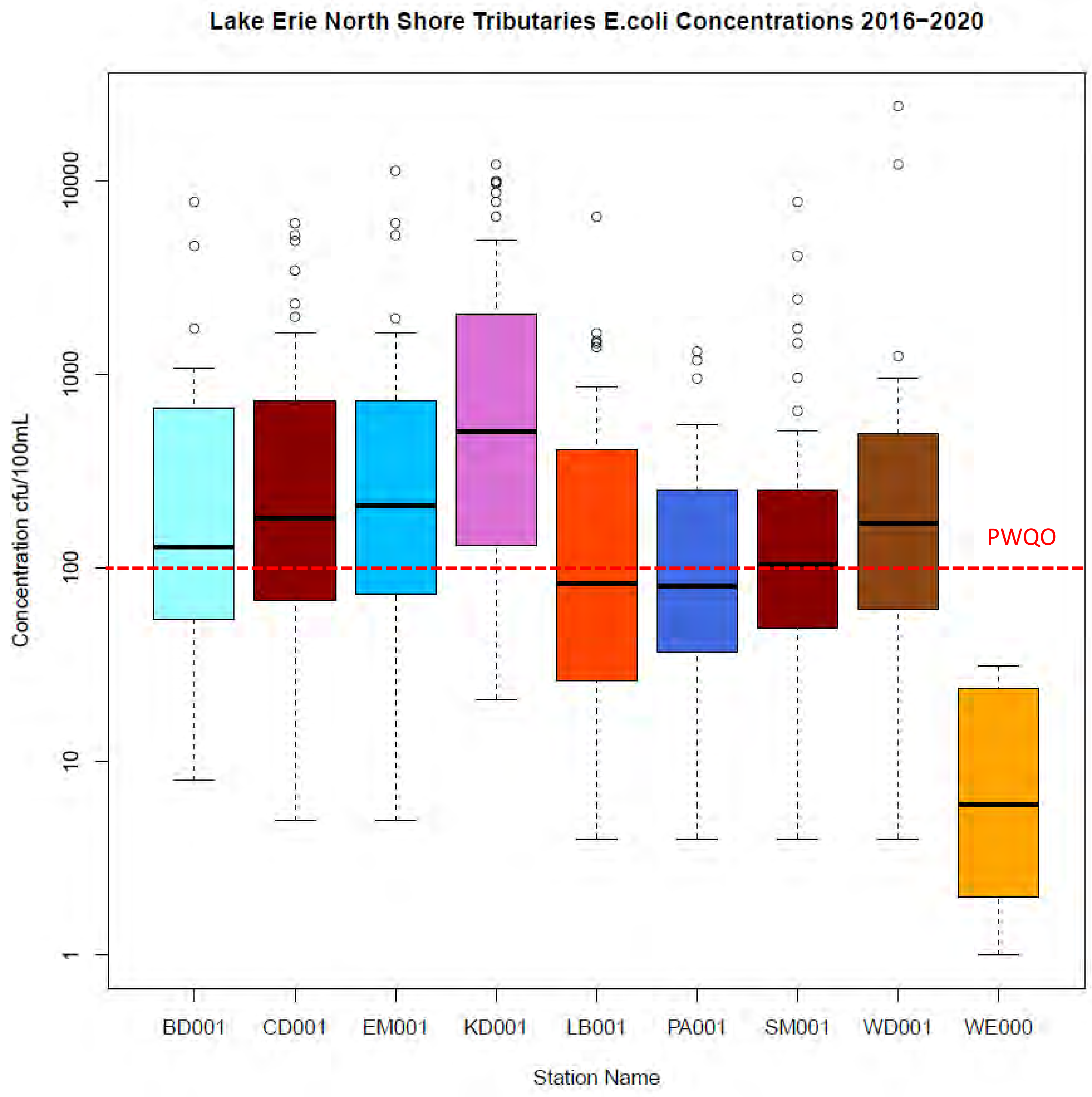


Twenty Mile Creek Watershed E.coli Concentrations 2016-2020
Concentration cfu/100mL
10000
1000
100
10
1
PWQO
GV001
NC001
SP001
TN001
TN002
TN003
TN003A
TN004
TN006
Station Name



Lake Ontario South Shore Tributaries E.coli Concentrations 2016−2020
Concentration cfu/100mL
5
50
500
5000
PWQO
TW001
TW002
TW003
TW004
TW005
TW006
TW008
TW007
BE004
SH002
RC001
FA001
TW009
OM001
TM001
FU004
SI001
EI001
WE001
WC001
FF001
SX001
ET001
PD001
BT001
TH001
FM001
Station

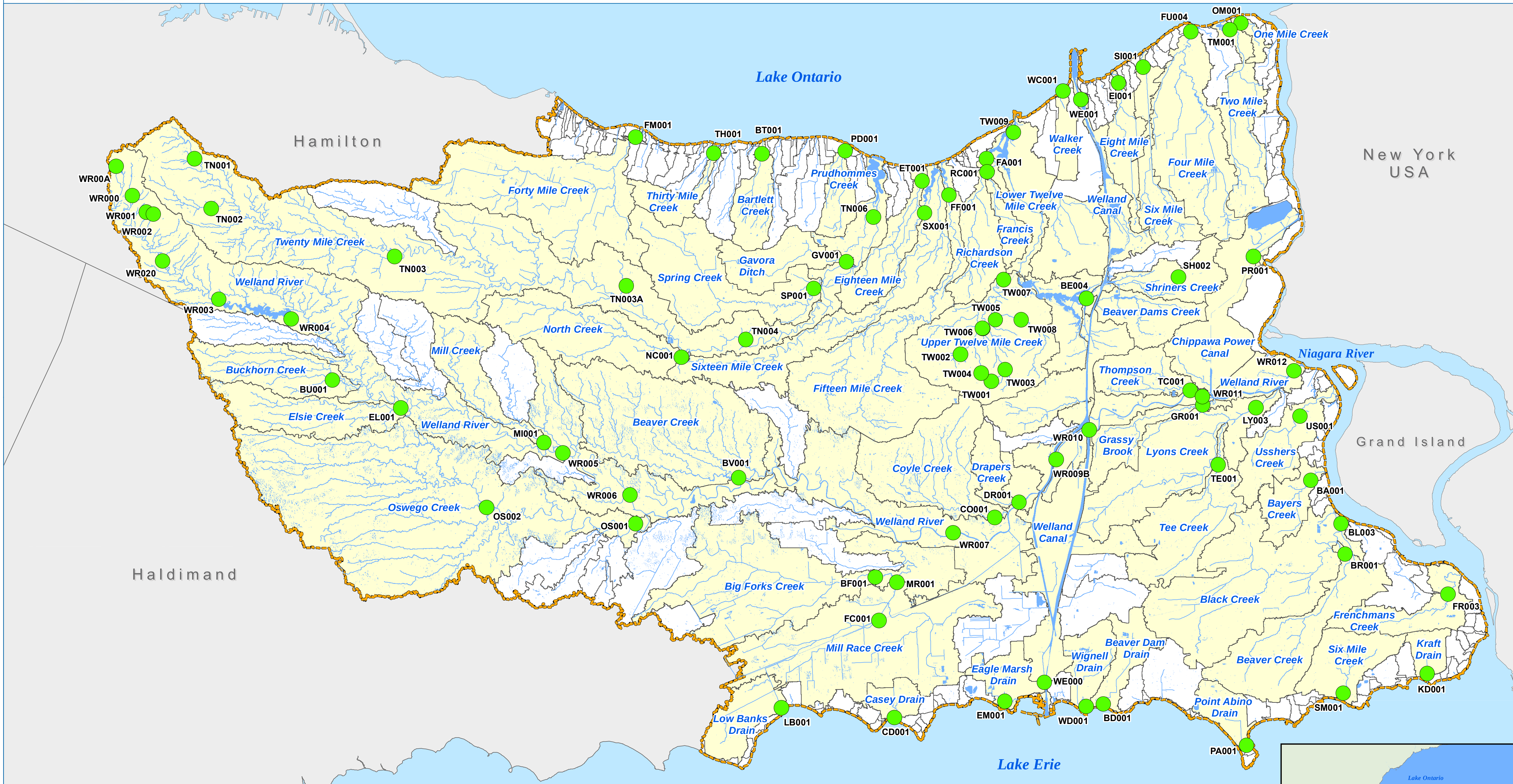

Niagara River Tributaries E.coli Concentrations 2016−2020
Concentration cfu/100mL
5000
2000
1000
500
200
100
50
20
10
5
2
PWQO
BA001
BL003
BR001
FR003
US001
Station Name


Lake Erie North Shore Tributaries E.coli Concentrations 2016−2020
Concentration cfu/100mL
10000
1000
100
10
1
PWQO
BD001
CD001
EM001
KD001
LB001
PA001
SM001
WD001
WE000
Station Name

Appendix E

NIAGARA PENINSULA CONSERVATION AUTHORITY

Median Lead Concentrations 2016 - 2020



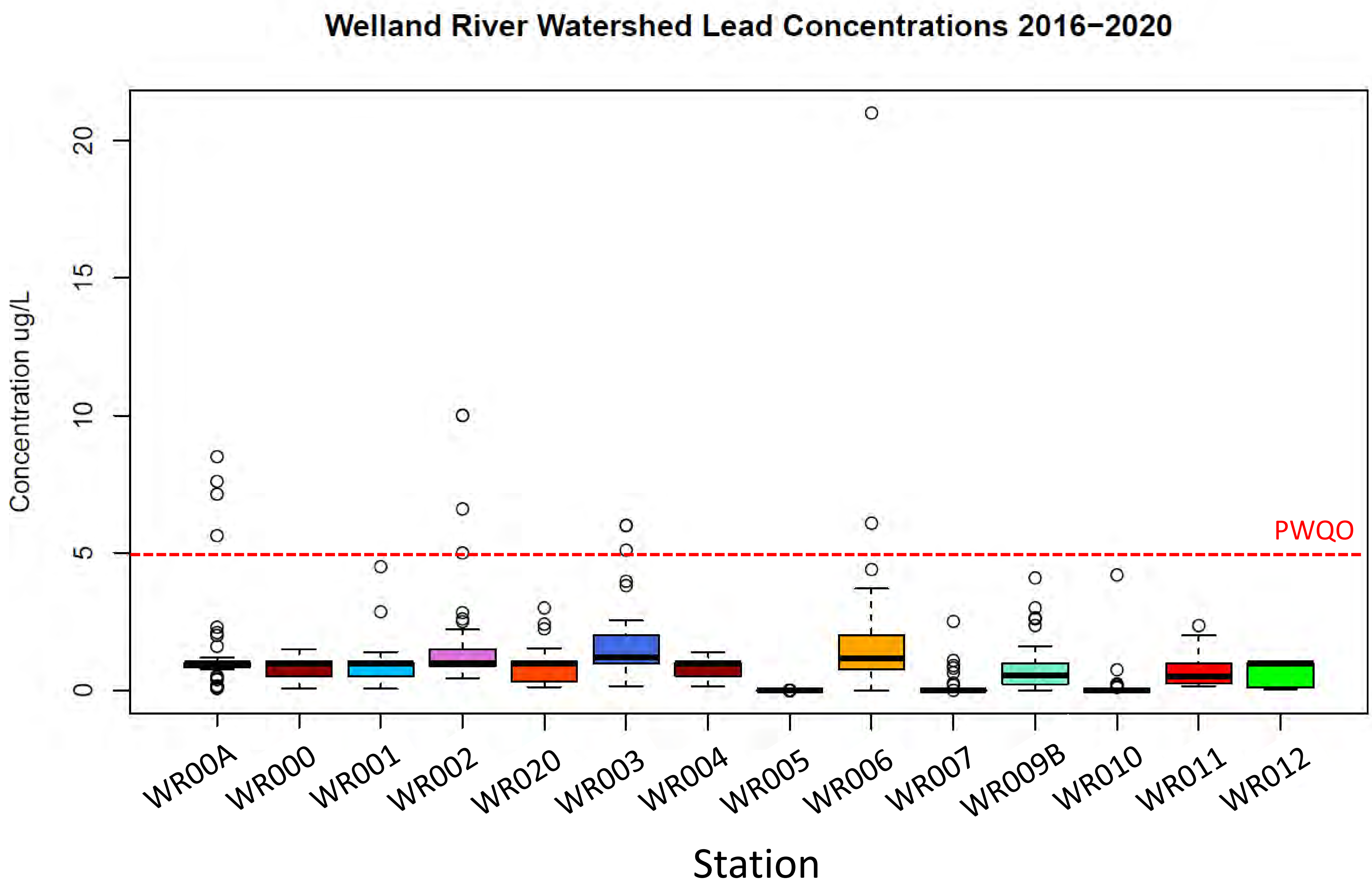
Surface Water Quality Monitoring Station

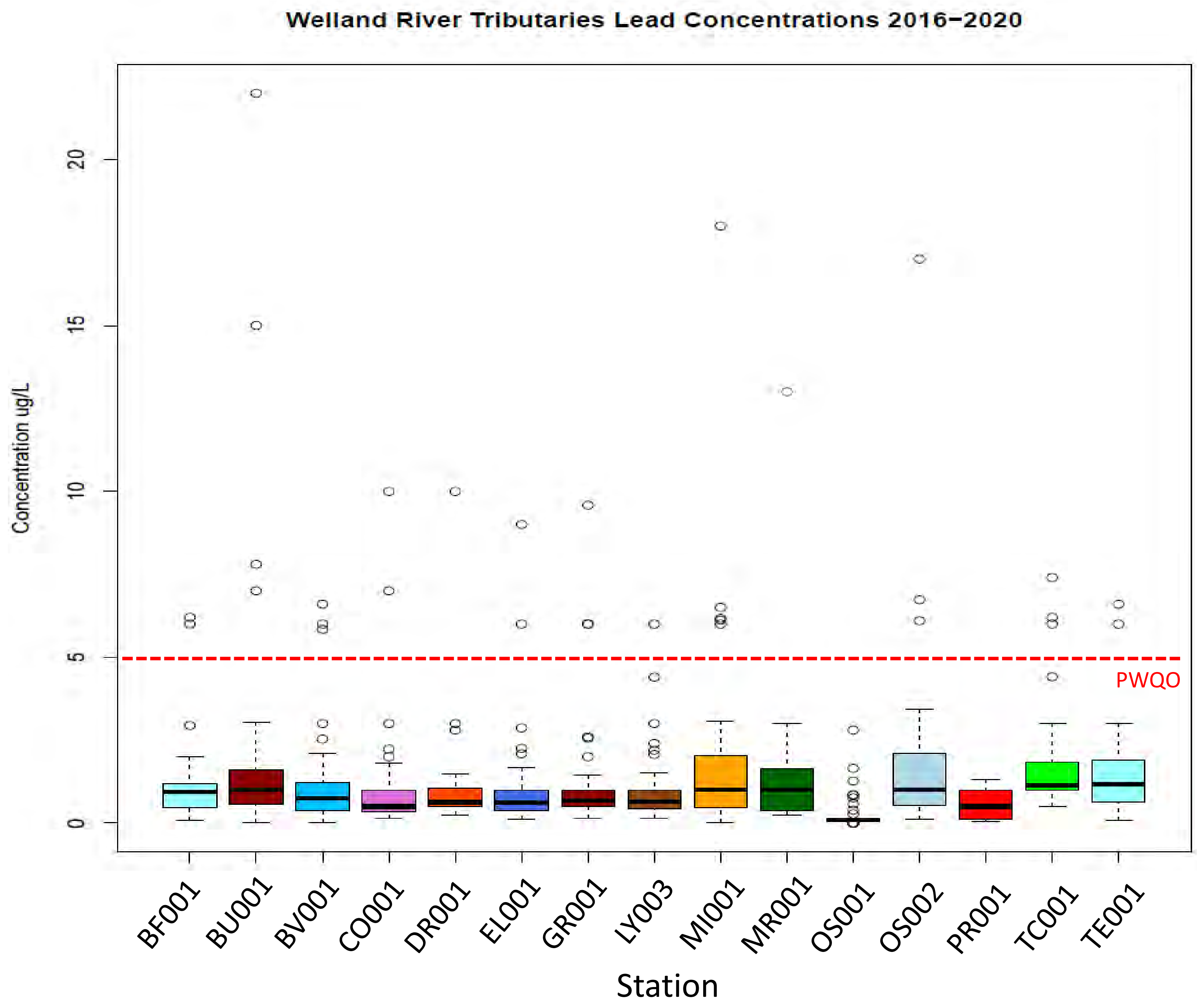
Lead (ug/L)

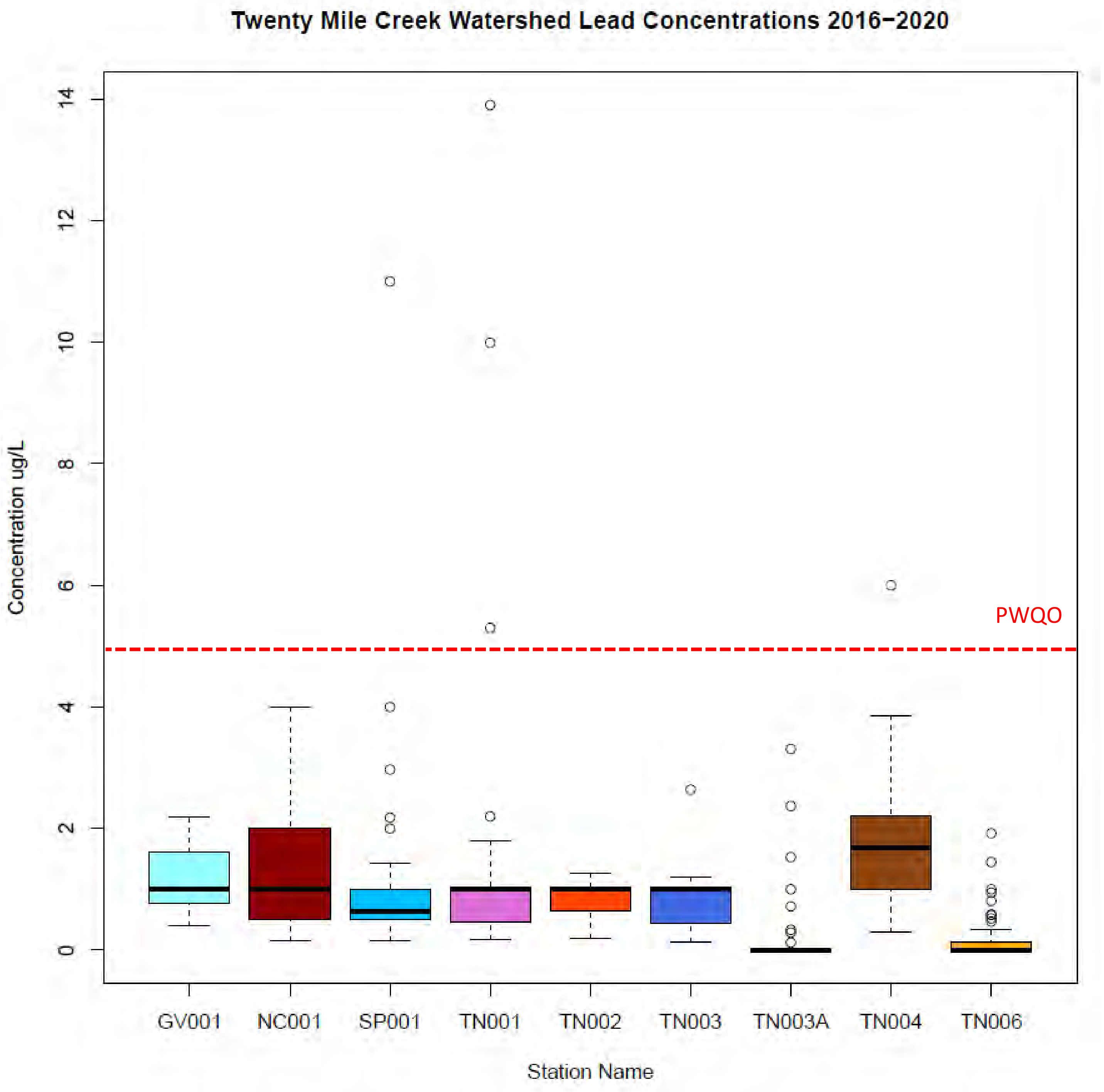
- < 2.5
- 2.5 - 5.0
- 5.1 - 10
- > 10

- Watercourses
- Waterbodies
- Sampled Subwatersheds
- NPCA Jurisdiction

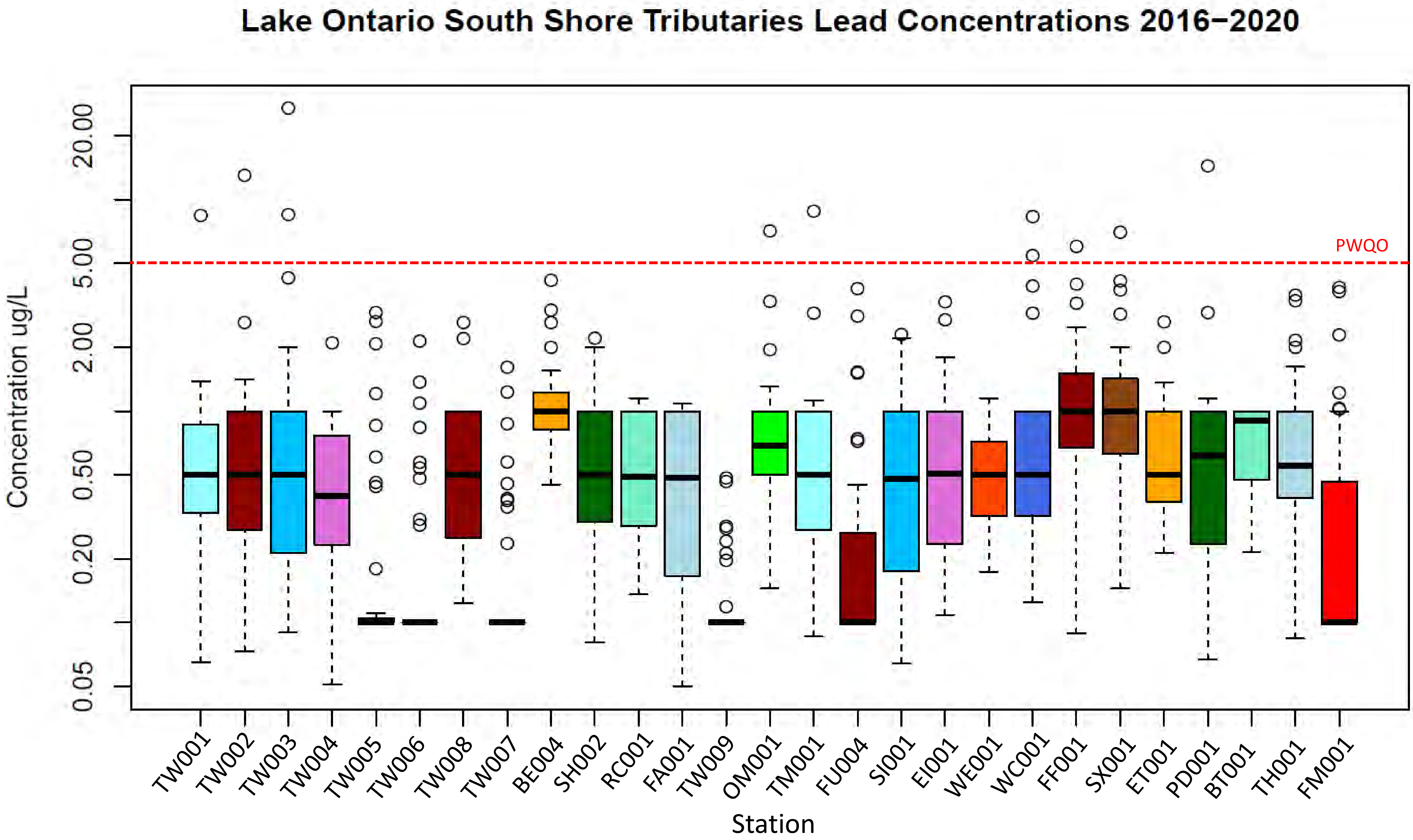
All Frames: North American Datum 1983, Universal Transverse Mercator 6° Projection, Zone 17N, Central Meridian 81° West.
Produced by the Niagara Peninsula Conservation Authority with data supplied under licence by members of the Ontario Geospatial Data Exchange, 2021.


Welland River Watershed Lead Concentrations 2016−2020
Concentration ug/L
0
5
10
15
20
PWQO
WR00A
WR000
WR001
WR002
WR020
WR003
WR004
WR005
WR006
WR007
WR009B
WR010
WR011
WR012
Station

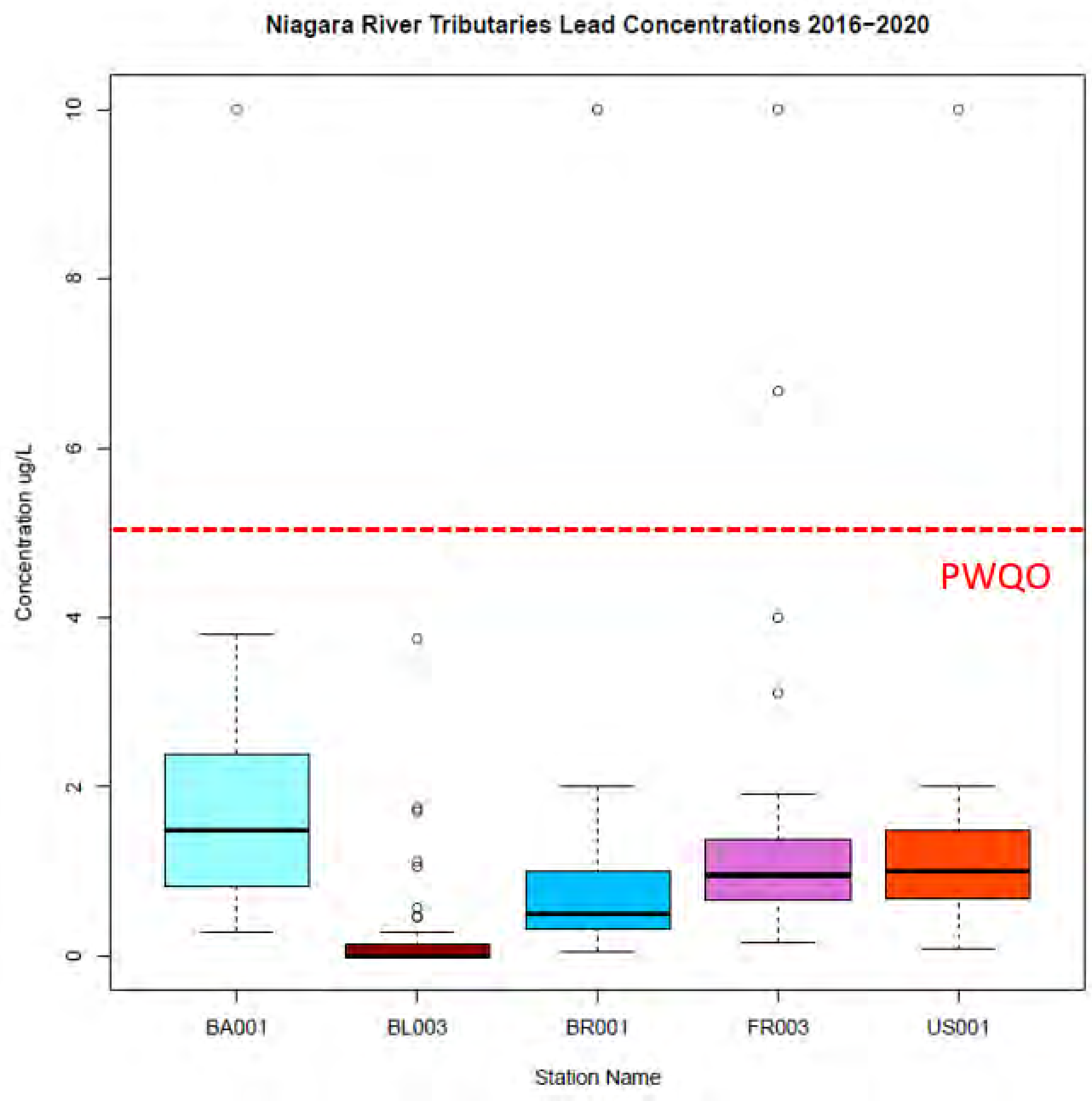

Welland River Tributaries Lead Concentrations 2016−2020
Concentration ug/L
0
5
10
15
20
PWQO
BF001
BU001
BV001
CO001
DR001
EL001
GR001
LY003
MI001
MR001
OS001
OS002
PR001
TC001
TE001
Station

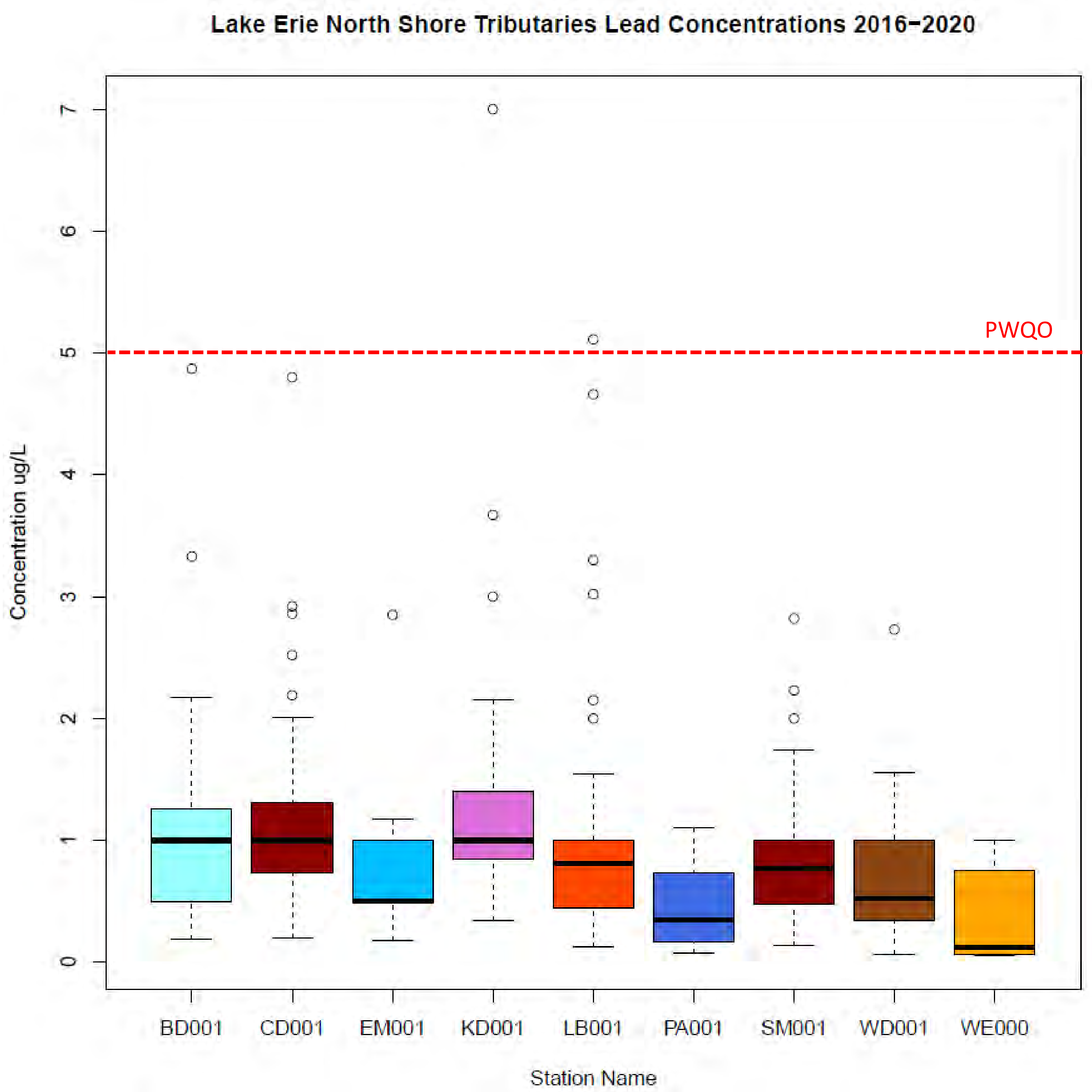


Twenty Mile Creek Watershed Lead Concentrations 2016−2020
Concentration ug/L
14
12
10
8
6
4
2
0
PWQO
GV001
NC001
SP001
TN001
TN002
TN003
TN003A
TN004
TN006
Station Name



Lake Ontario South Shore Tributaries Lead Concentrations 2016−2020
Concentration ug/L
20.00
5.00
2.00
0.50
0.20
0.05
PWQO
TW001
TW002
TW003
TW004
TW005
TW006
TW008
TW007
BE004
SH002
RC001
FA001
TW009
OM001
TM001
FU004
SI001
EI001
WE001
WC001
FF001
SX001
ET001
PD001
BT001
TH001
FM001
Station

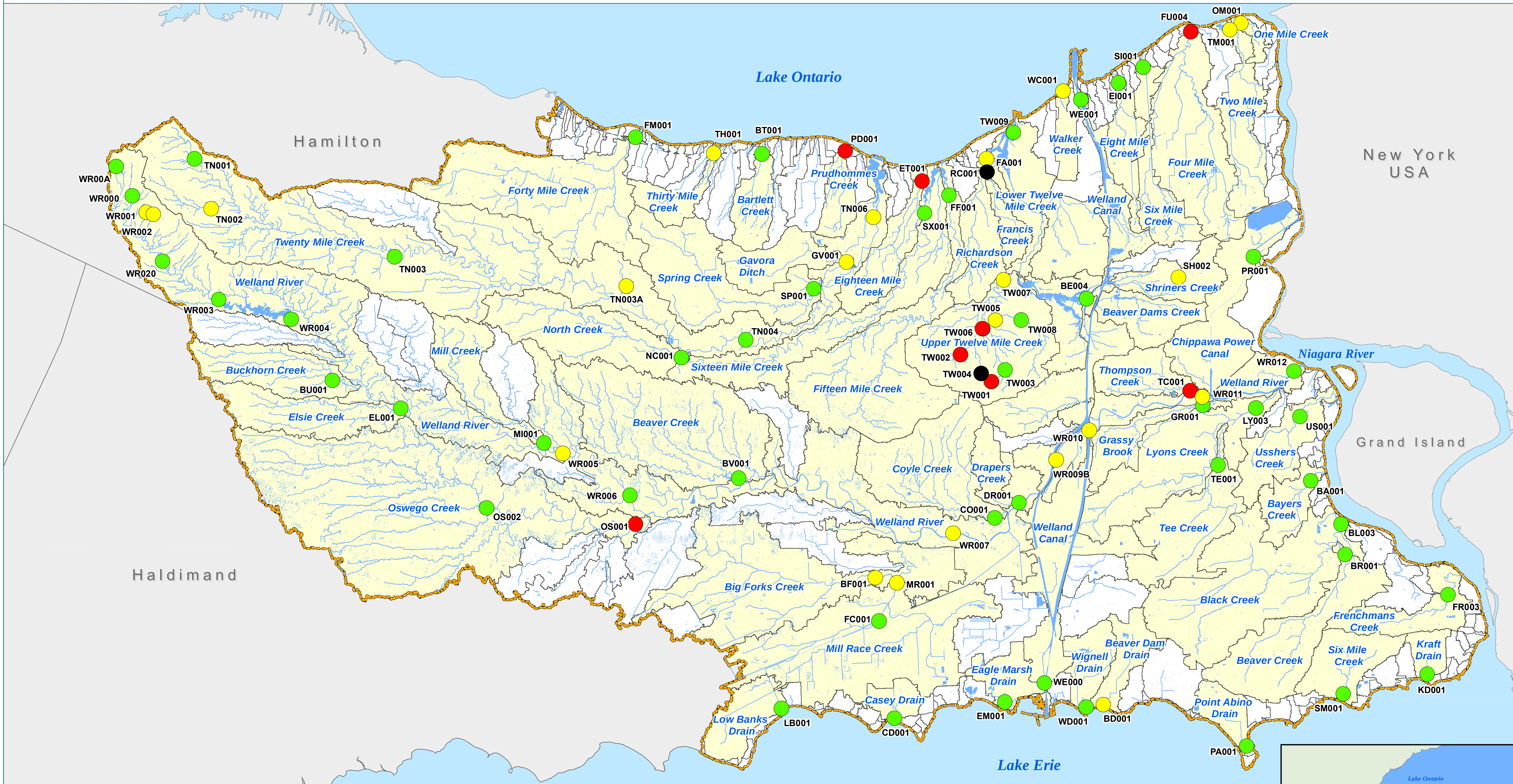

Niagara River Tributaries Lead Concentrations 2016−2020
Concentration ug/L
0
2
4
6
8
10
PWQO
BA001
BL003
BR001
FR003
US001
Station Name


Lake Erie North Shore Tributaries Lead Concentrations 2016-2020
Concentration ug/L
0
1
2
3
4
5
6
7
PWQO
BD001
CD001
EM001
KD001
LB001
PA001
SM001
WD001
WE000
Station Name

Appendix F

NIAGARA PENINSULA CONSERVATION AUTHORITY

Median Nitrate Concentrations 2016 - 2020



Surface Water Quality Monitoring Station

NO3-N (ug/L)

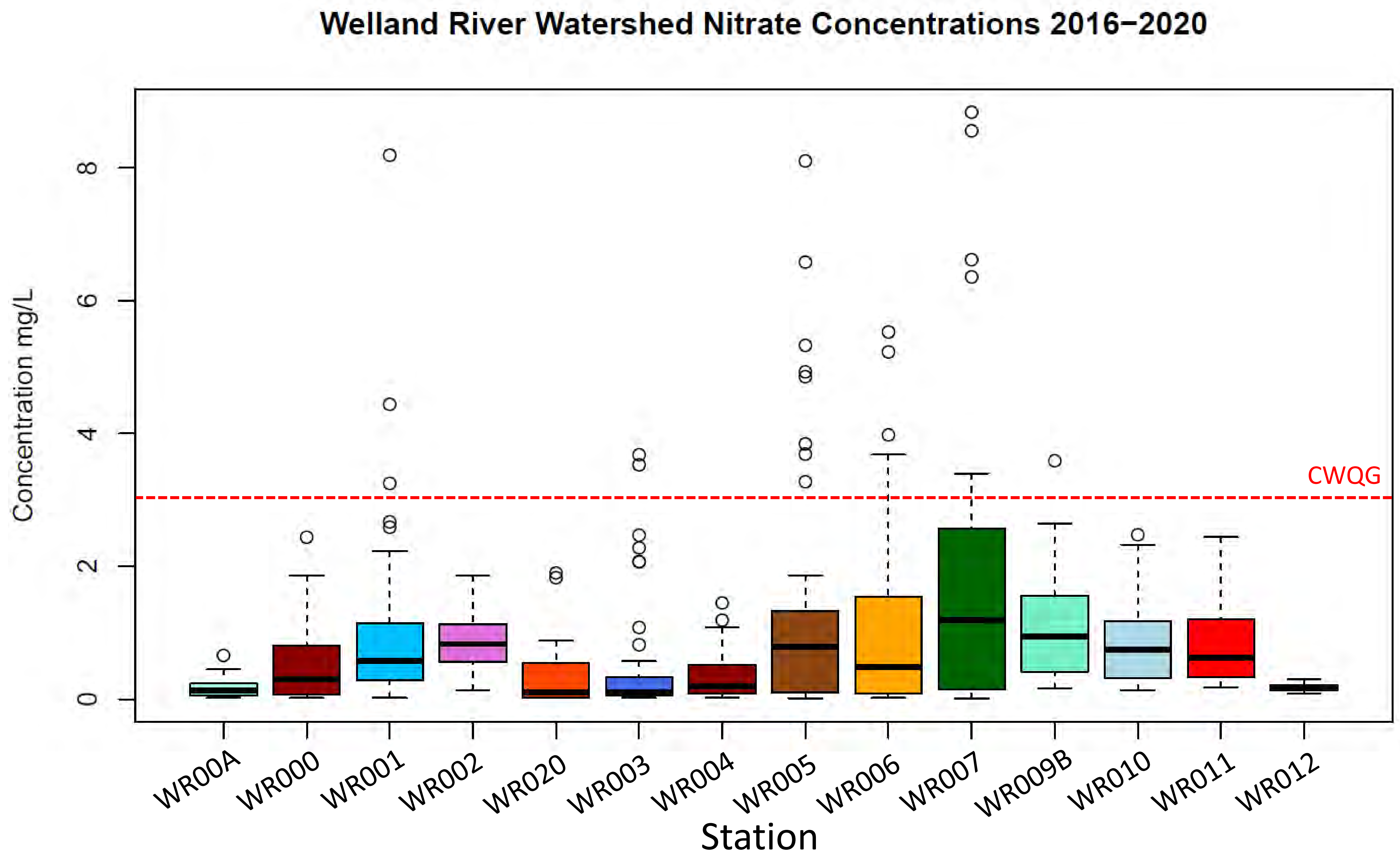
- < 500
- 500 - 1300
- 1301 - 2900
- > 2900
- Watercourses
- Waterbodies
- Sampled Subwatersheds
- NPCA Jurisdiction

0 5 10 20 30

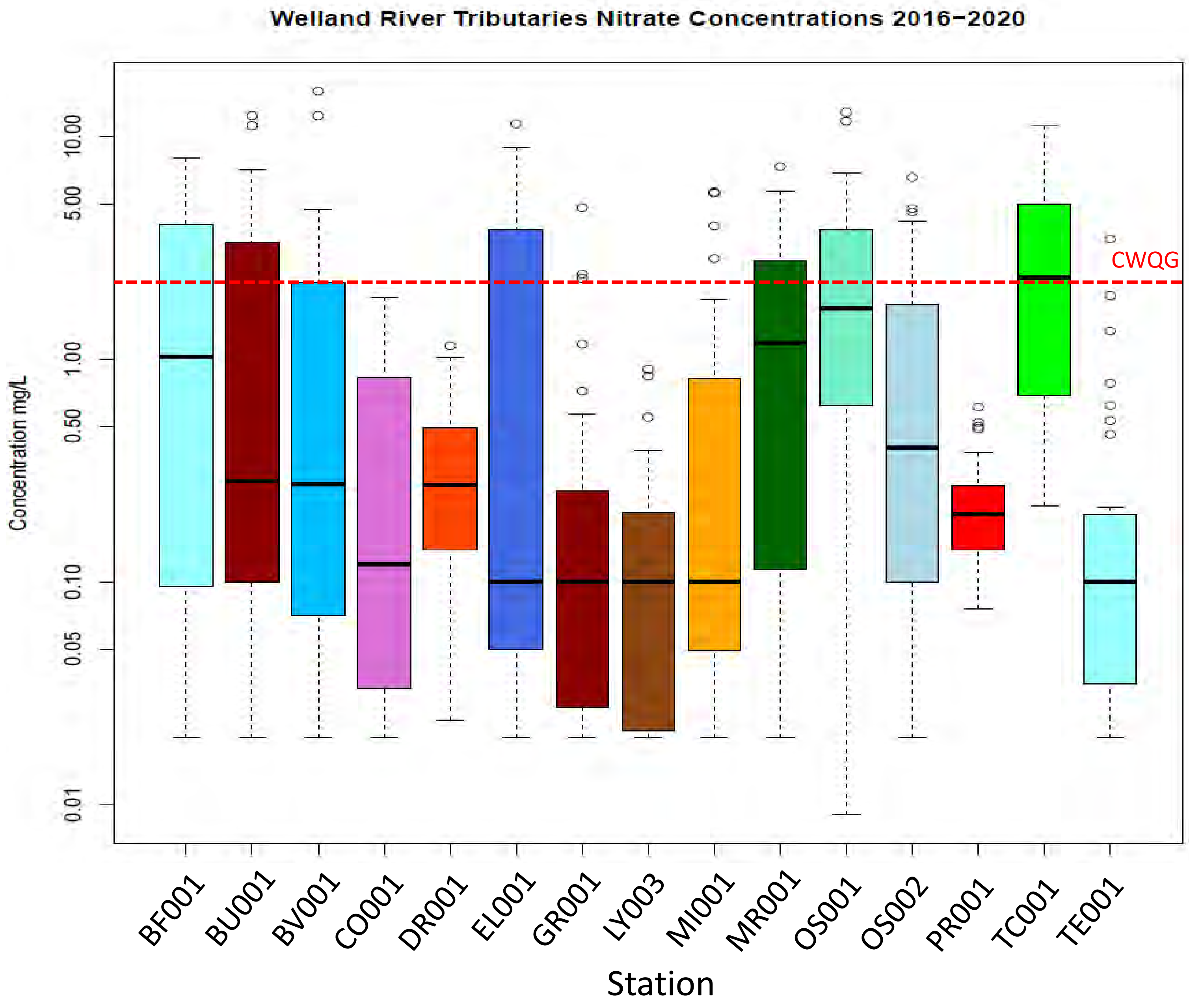
Kilometers

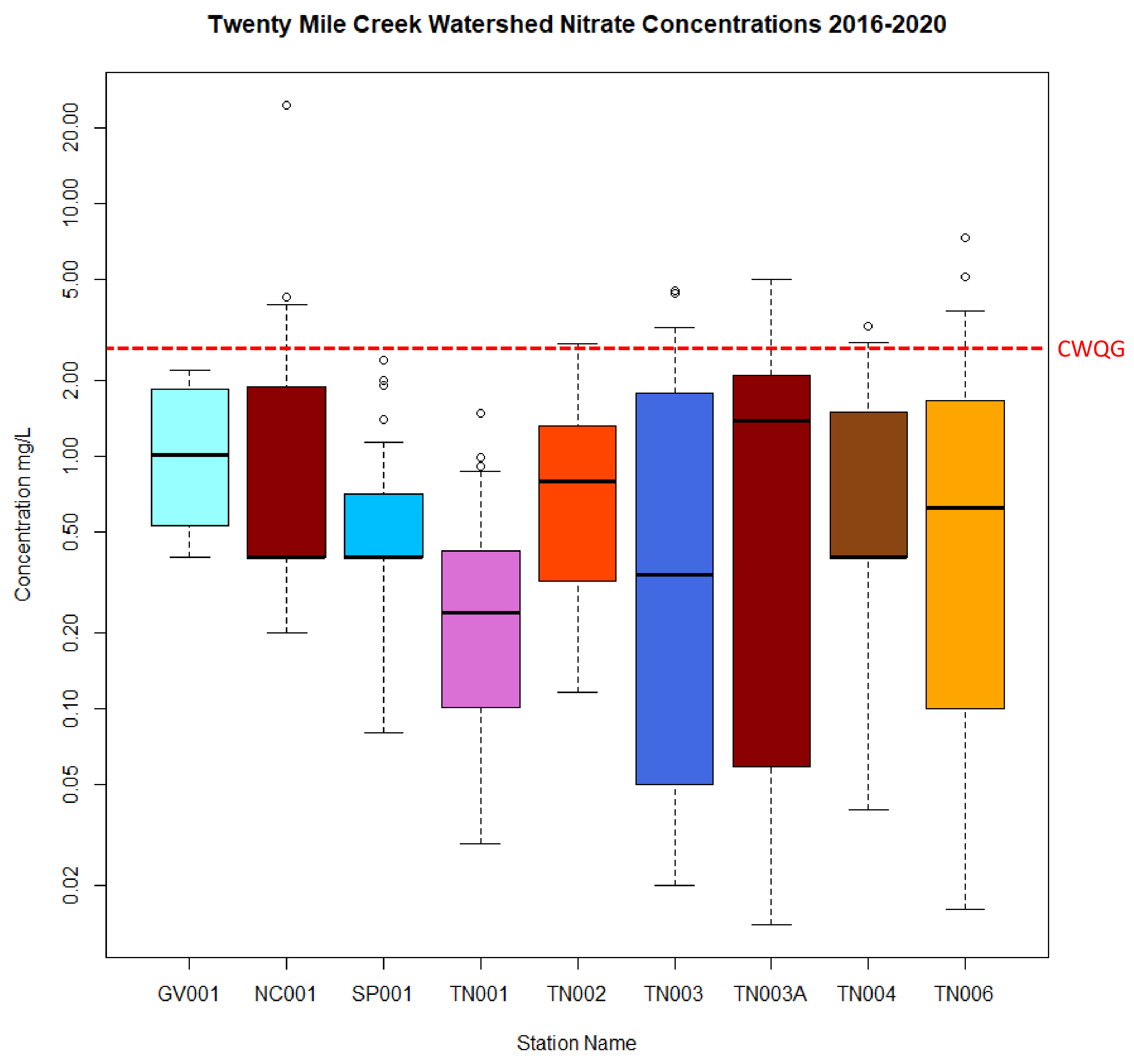
N

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, 2021.

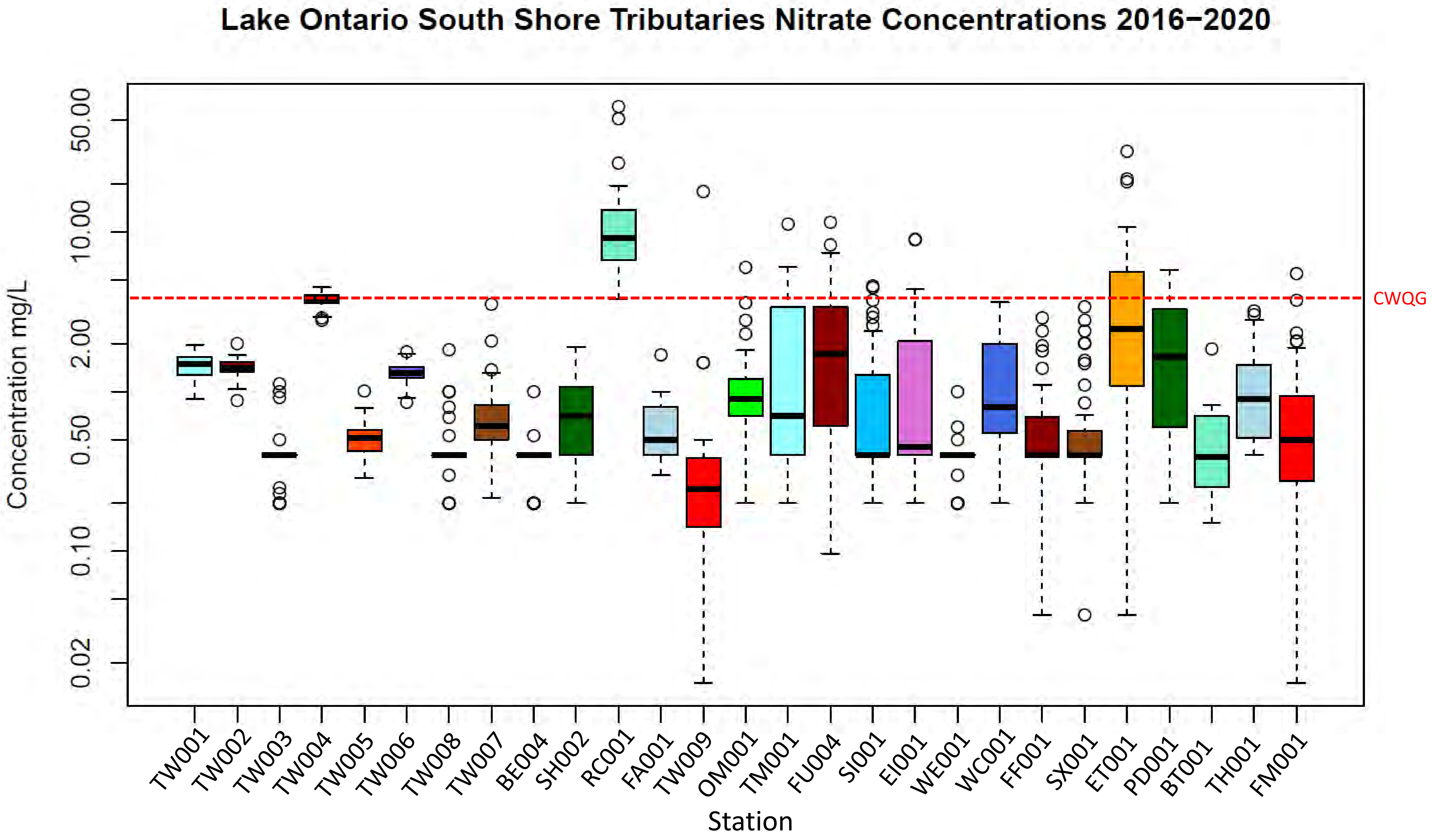


Welland River Watershed Nitrate Concentrations 2016–2020
Concentration mg/L
0
2
4
6
8
CWQG
WR00A
WR000
WR001
WR002
WR020
WR003
WR004
WR005
WR006
WR007
WR009B
WR010
WR011
WR012
Station

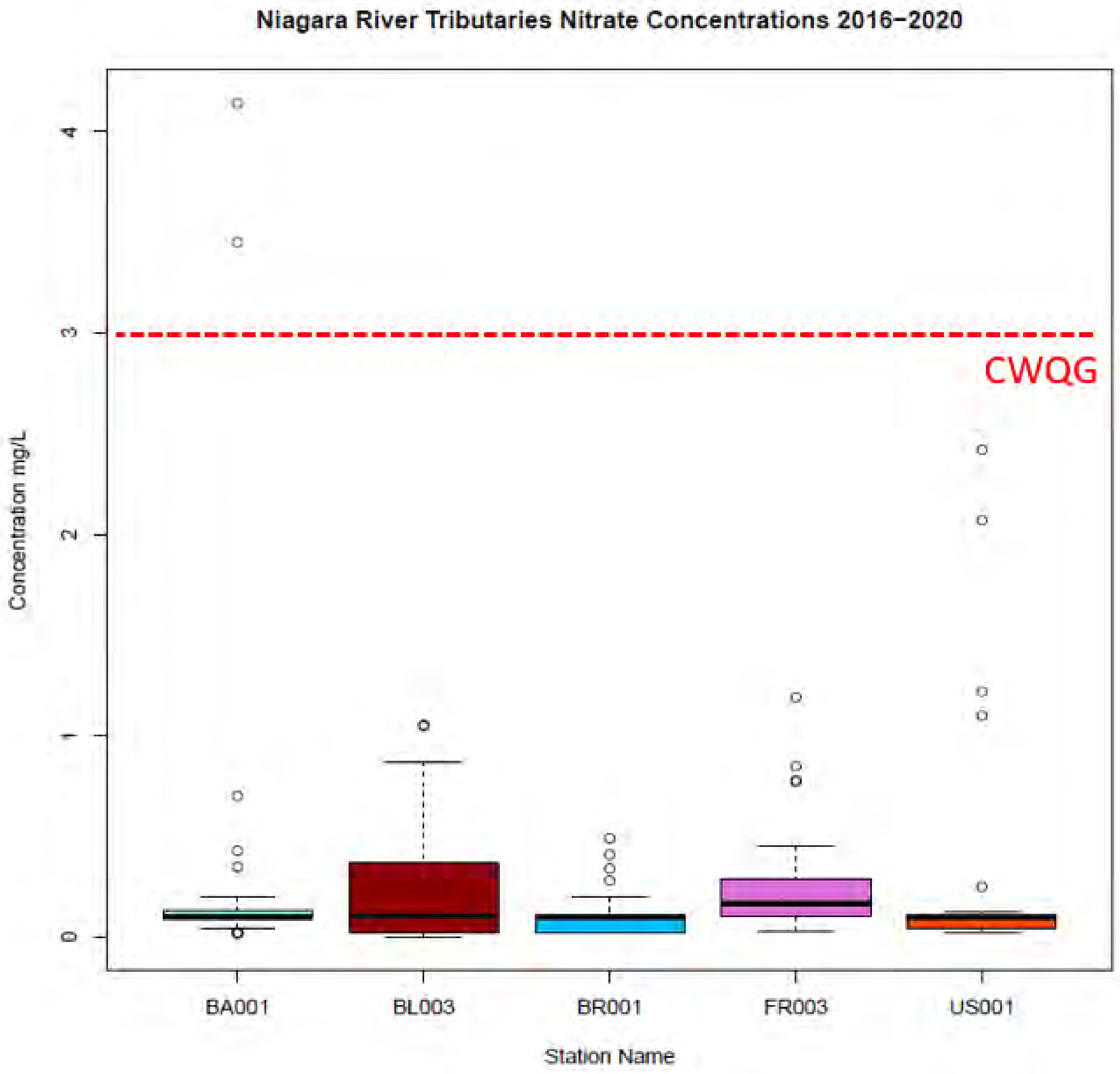

Welland River Tributaries Nitrate Concentrations 2016−2020
Concentration mg/L
10.00
5.00
1.00
0.50
0.10
0.05
0.01
CWQG
BF001
BU001
BV001
CO001
DR001
EL001
GR001
LY003
MI001
MR001
OS001
OS002
PR001
TC001
TE001
Station

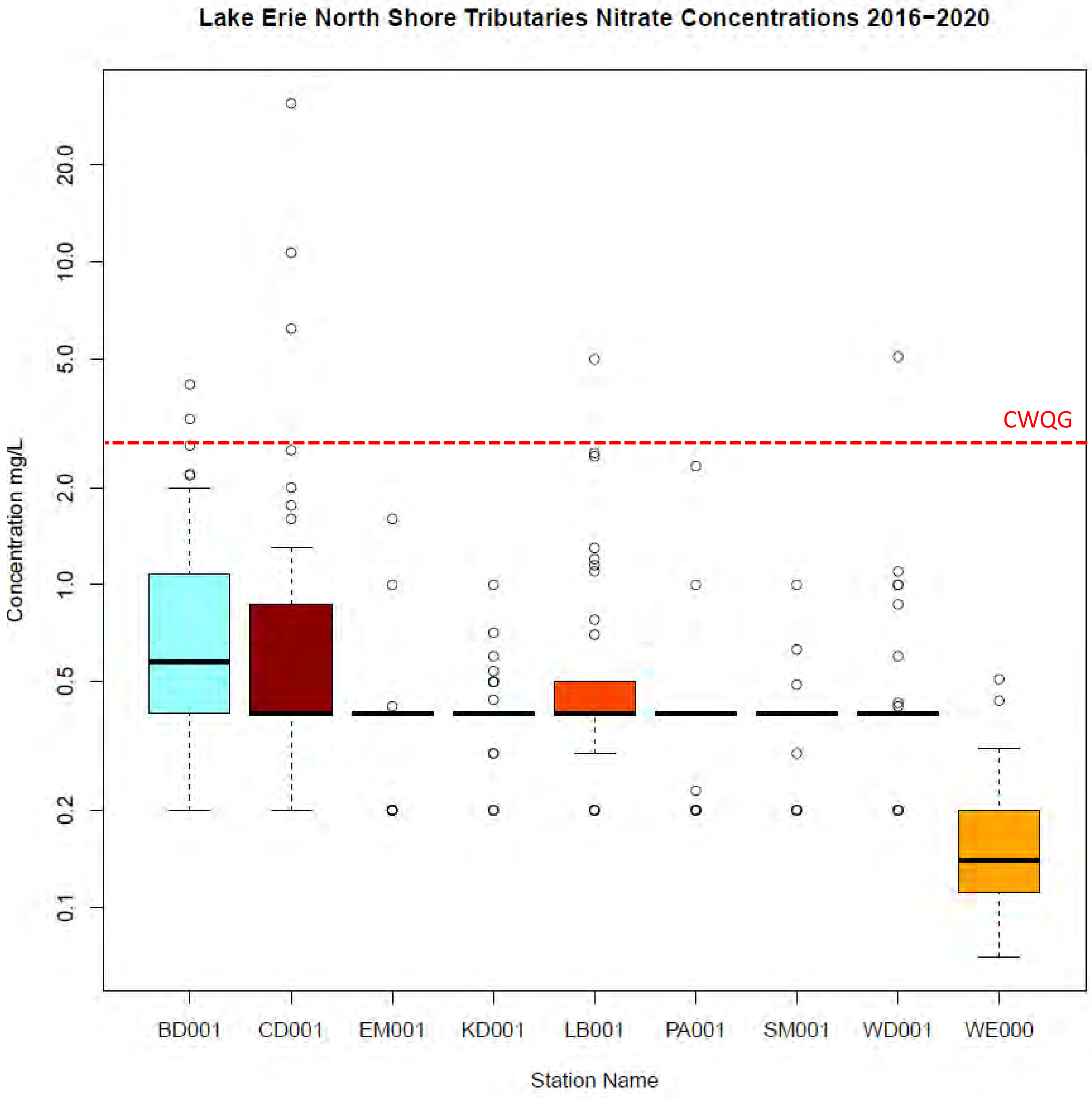


Twenty Mile Creek Watershed Nitrate Concentrations 2016-2020
Concentration mg/L
20.00
10.00
5.00
2.00
1.00
0.50
0.20
0.10
0.05
0.02
CWQG
GV001
NC001
SP001
TN001
TN002
TN003
TN003A
TN004
TN006
Station Name



Lake Ontario South Shore Tributaries Nitrate Concentrations 2016−2020
Concentration mg/L
50.00
10.00
2.00
0.50
0.10
0.02
CWQG
TW001
TW002
TW003
TW004
TW005
TW006
TW008
TW007
BE004
SH002
RC001
FA001
TW009
OM001
TM001
FU004
SI001
EI001
WE001
WC001
FF001
SX001
ET001
PD001
BT001
TH001
FM001
Station

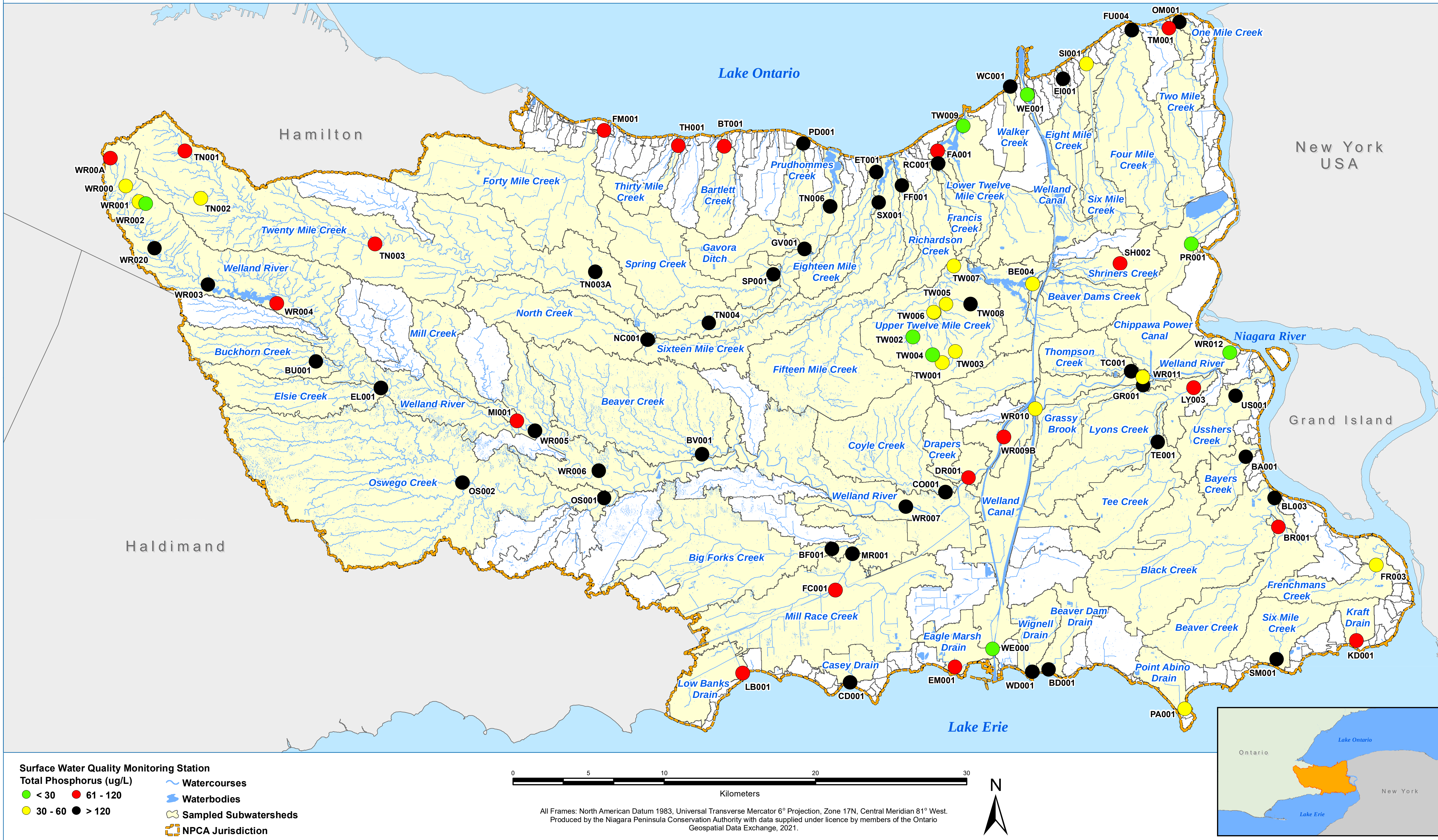

Niagara River Tributaries Nitrate Concentrations 2016−2020
Concentration mg/L
0
1
2
3
4
CWQG
BA001
BL003
BR001
FR003
US001
Station Name

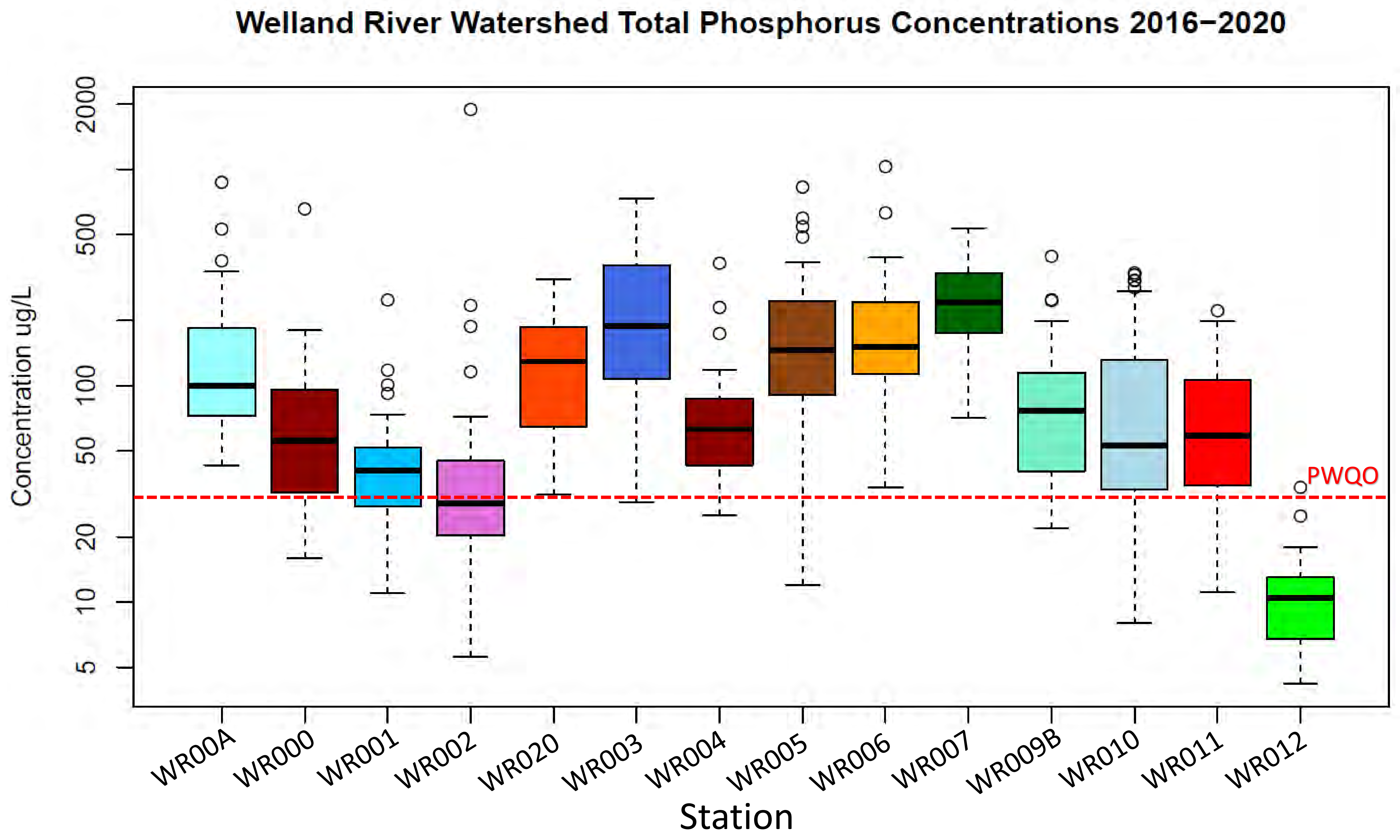


Lake Erie North Shore Tributaries Nitrate Concentrations 2016−2020
Concentration mg/L
20.0
10.0
5.0
2.0
1.0
0.5
0.2
0.1
CWQG
BD001
CD001
EM001
KD001
LB001
PA001
SM001
WD001
WE000
Station Name

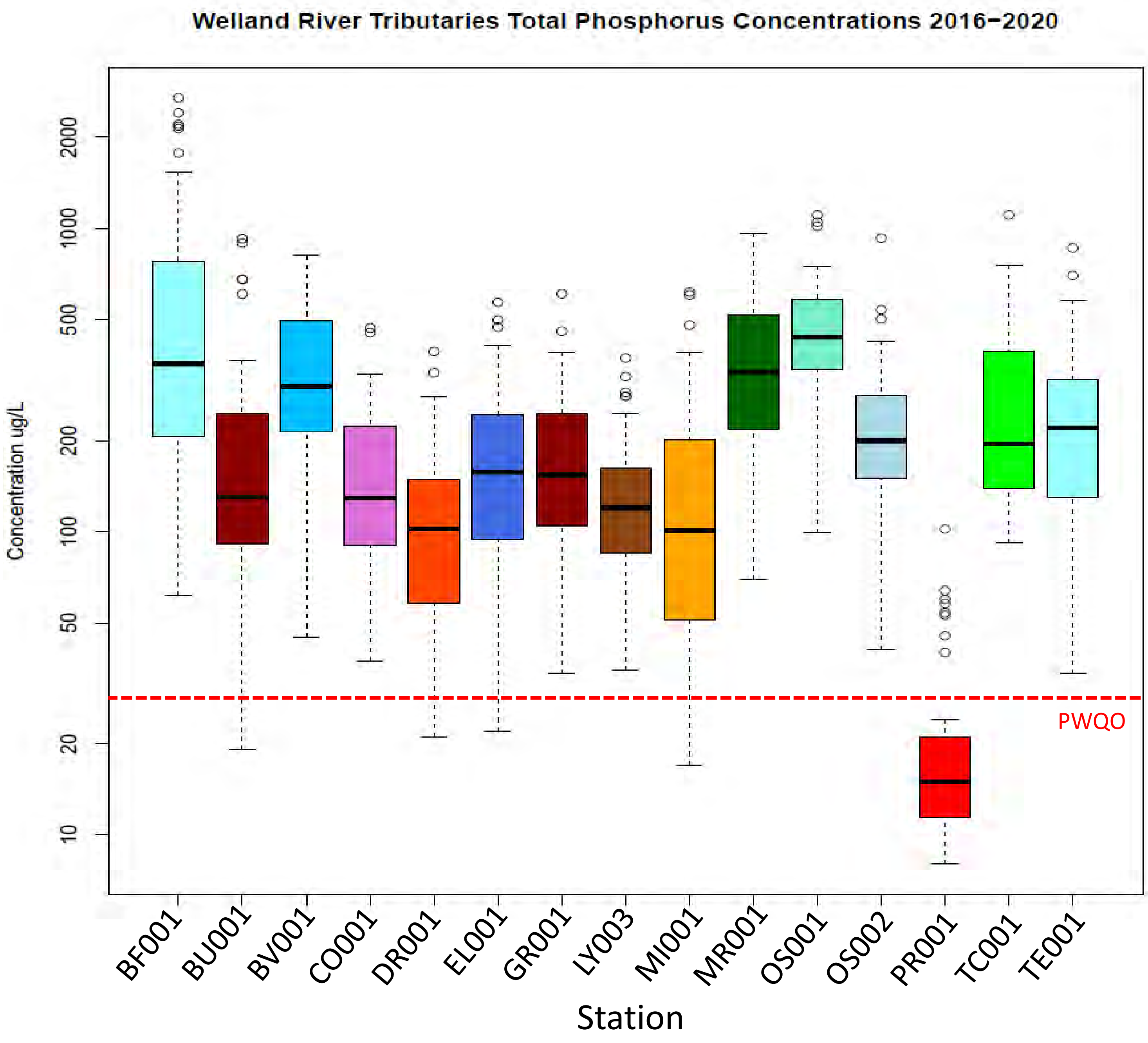
Appendix G

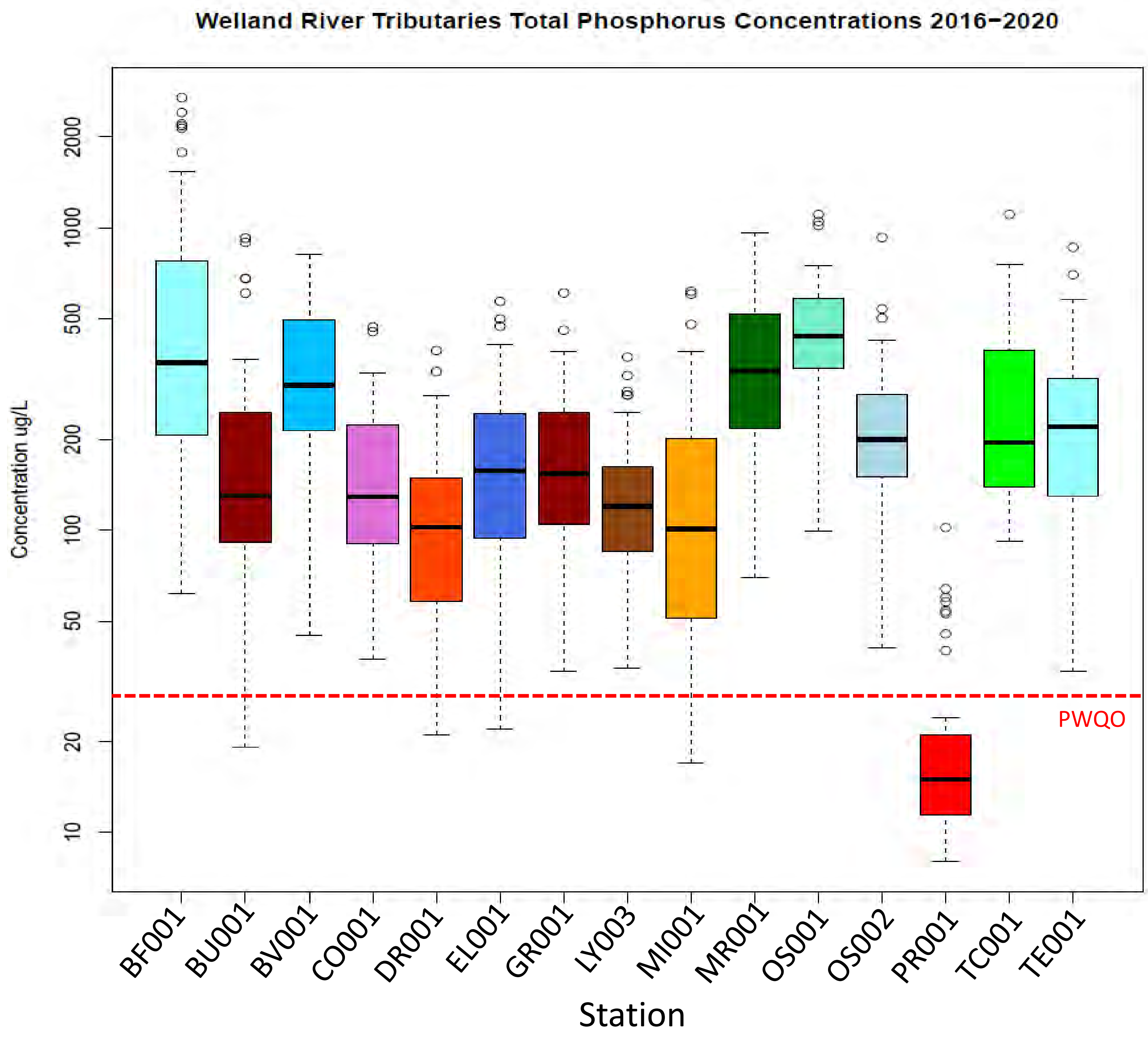
Median Total Phosphorus Concentrations 2016 - 2020



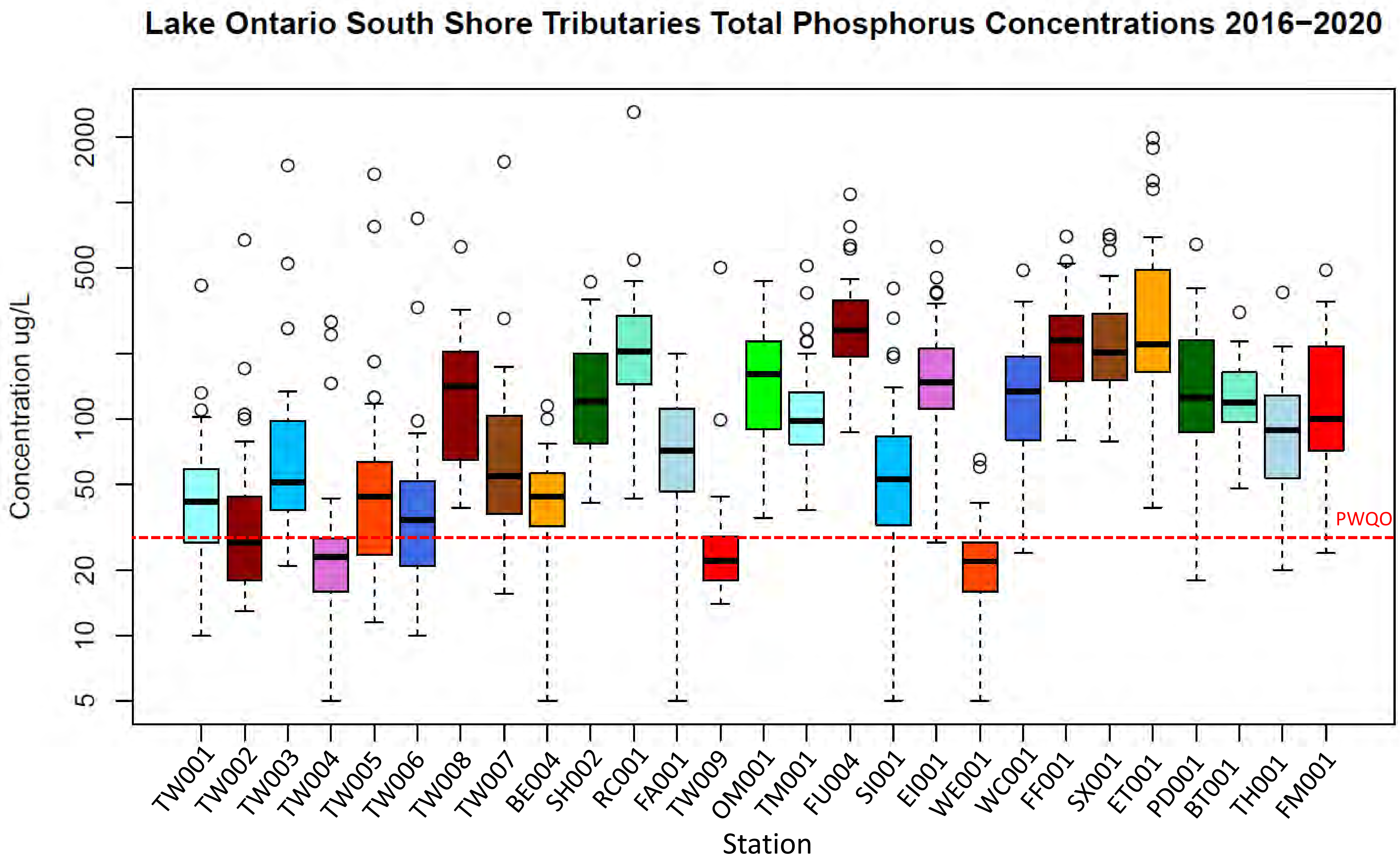


Welland River Watershed Total Phosphorus Concentrations 2016−2020
Concentration ug/L
2000
500
100
50
20
10
5
PWQO
WR00A
WR000
WR001
WR002
WR020
WR003
WR004
WR005
WR006
WR007
WR009B
WR010
WR011
WR012
Station

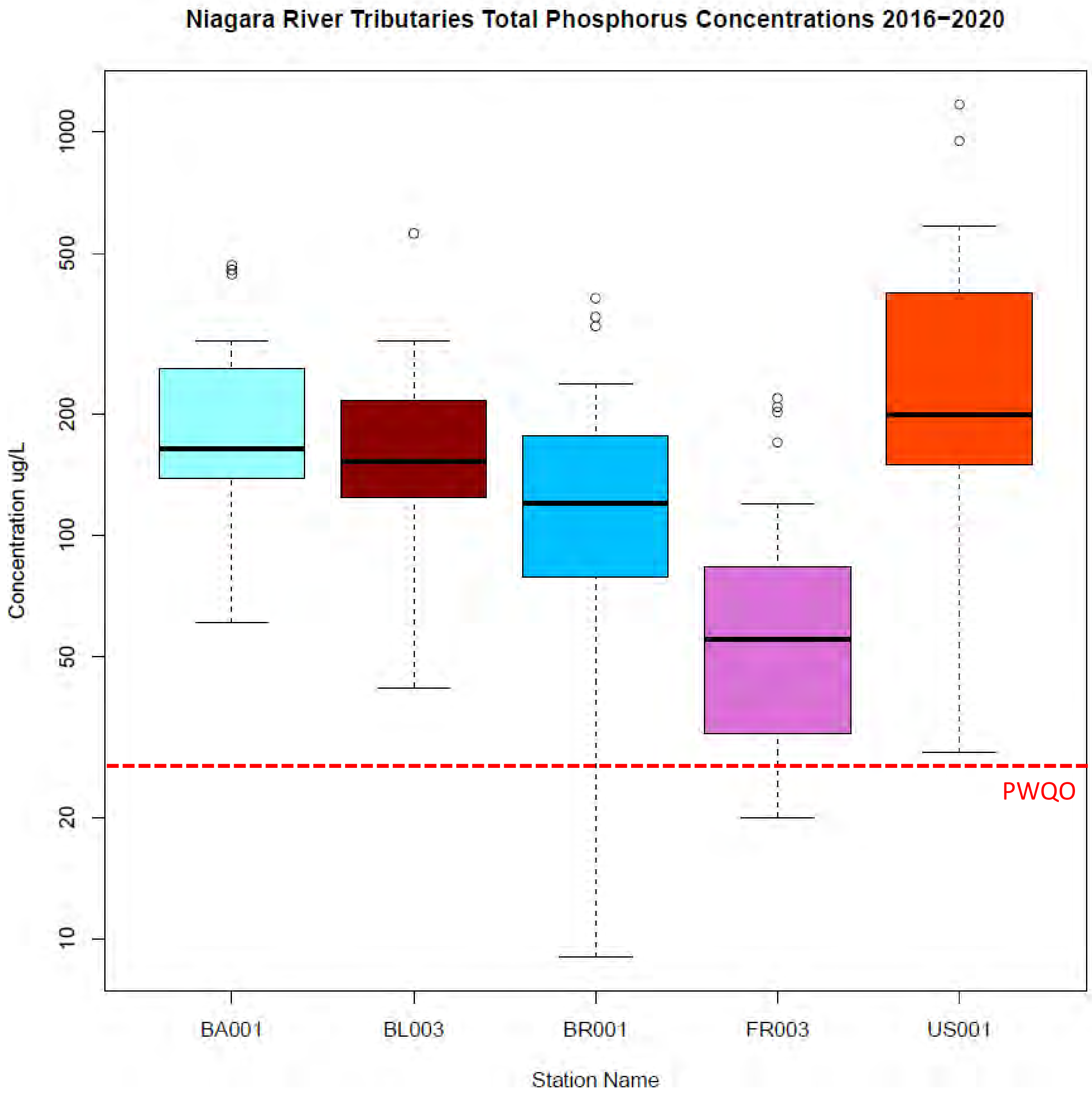

Welland River Tributaries Total Phosphorus Concentrations 2016−2020
Concentration ug/L
2000
1000
500
200
100
50
20
10
PWQO
BF001
BU001
BV001
CO001
DR001
EL001
GR001
LY003
MI001
MR001
OS001
OS002
PR001
TC001
TE001
Station

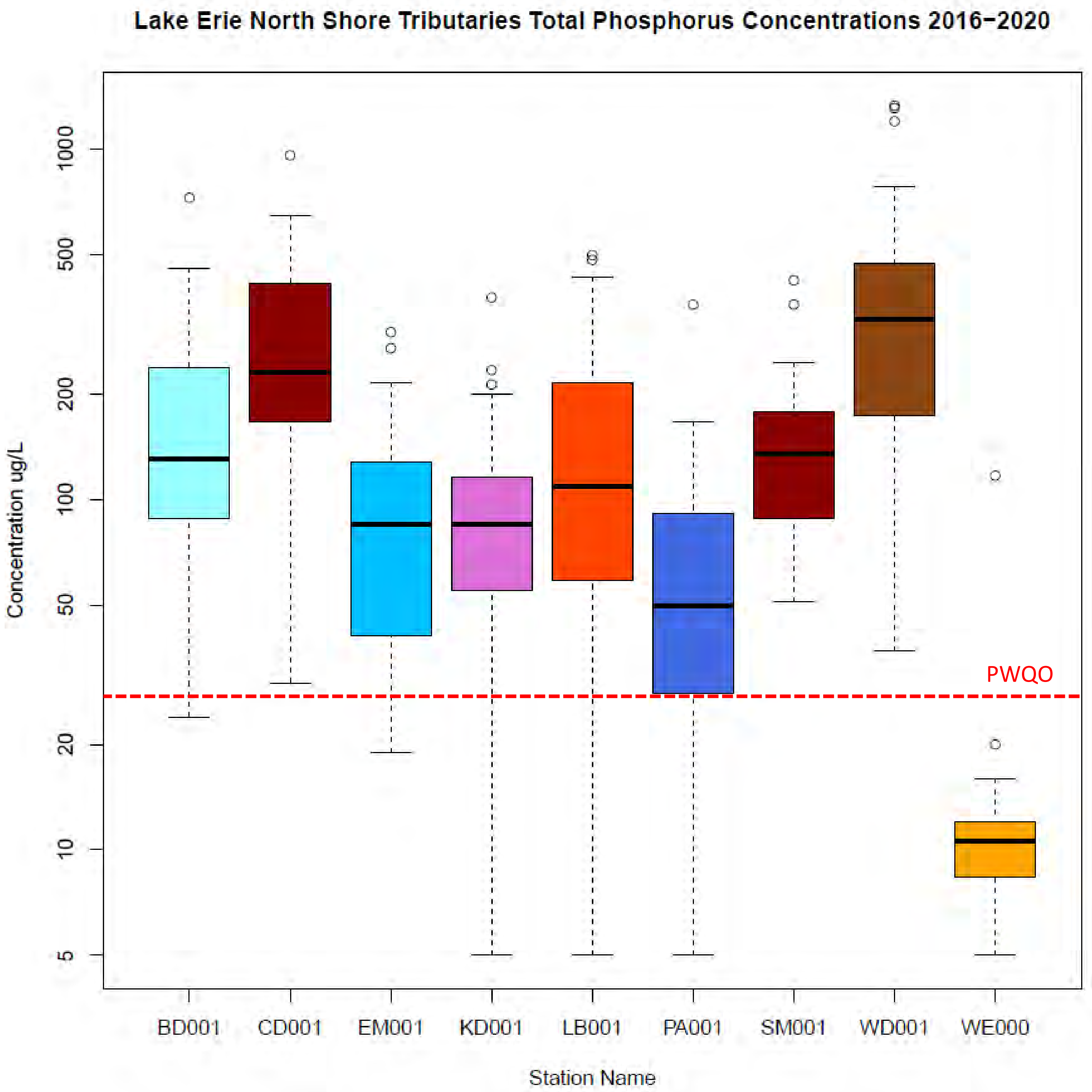


Welland River Tributaries Total Phosphorus Concentrations 2016−2020
Concentration ug/L
2000
1000
500
200
100
50
20
10
PWQO
BF001
BU001
BV001
CO001
DR001
EL001
GR001
LY003
MI001
MR001
OS001
OS002
PR001
TC001
TE001
Station



Lake Ontario South Shore Tributaries Total Phosphorus Concentrations 2016−2020
Concentration ug/L
2000
500
100
50
20
10
5
PWQO
TW001
TW002
TW003
TW004
TW005
TW006
TW008
TW007
BE004
SH002
RC001
FA001
TW009
OM001
TM001
FU004
SI001
EI001
WE001
WC001
FF001
SX001
ET001
PD001
BT001
TH001
FM001
Station

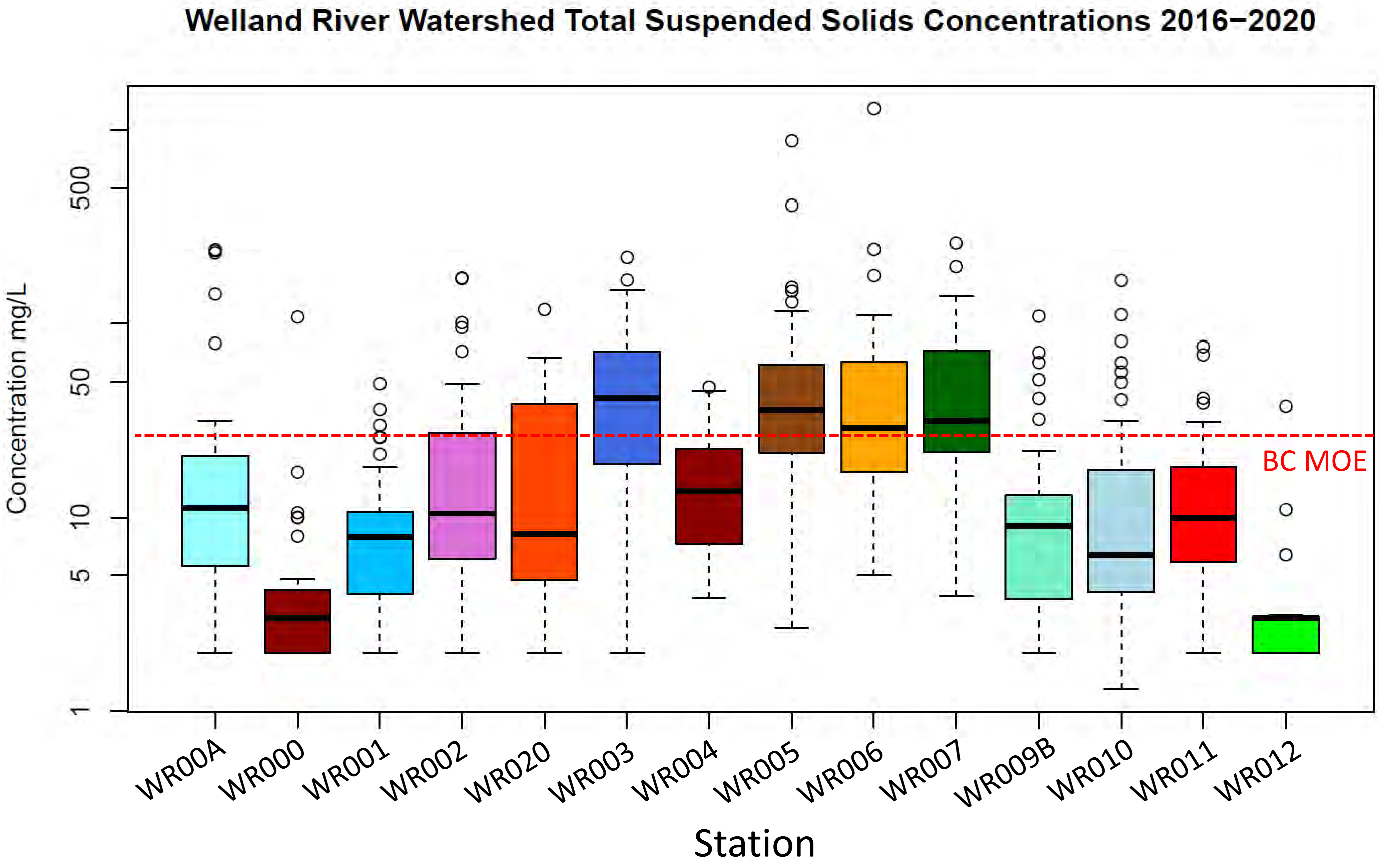

Niagara River Tributaries Total Phosphorus Concentrations 2016−2020
Concentration ug/L
1000
500
200
100
50
20
10
PWQO
BA001
BL003
BR001
FR003
US001
Station Name


Lake Erie North Shore Tributaries Total Phosphorus Concentrations 2016−2020
Concentration ug/L
1000
500
200
100
50
20
10
5
PWQO
BD001
CD001
EM001
KD001
LB001
PA001
SM001
WD001
WE000
Station Name

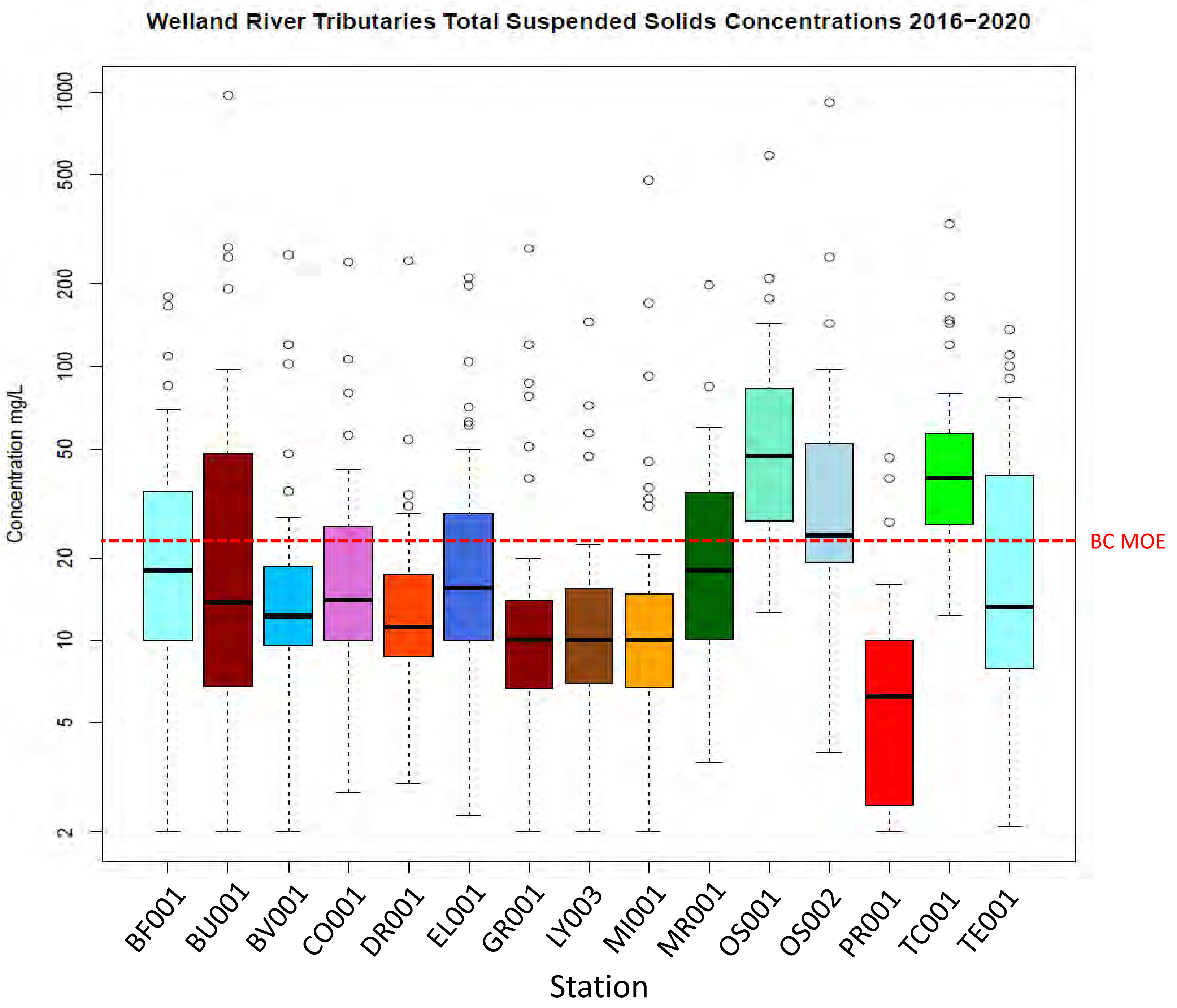
Appendix H

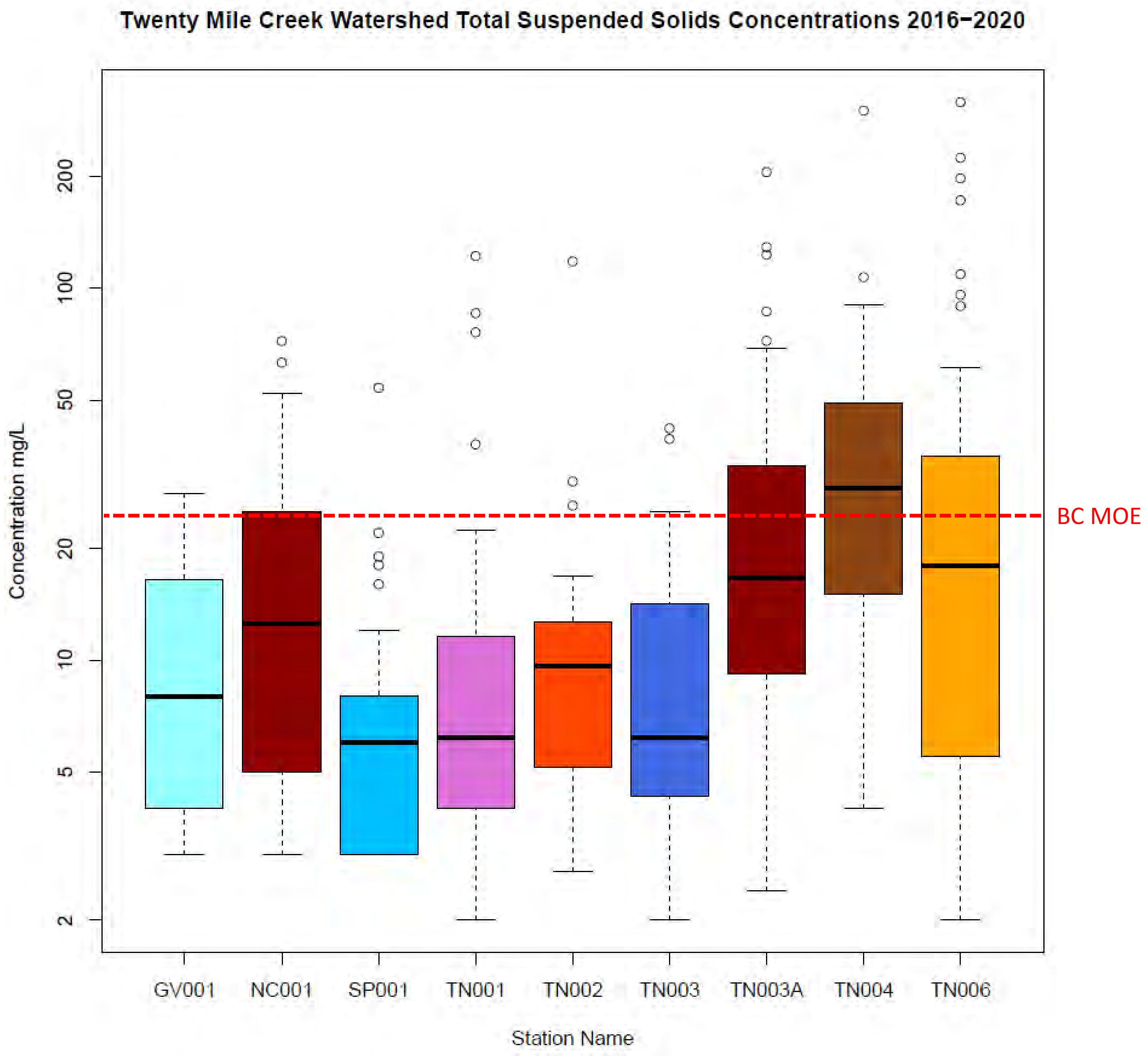
Median Total Suspended Solids Concentrations 2016 - 2020

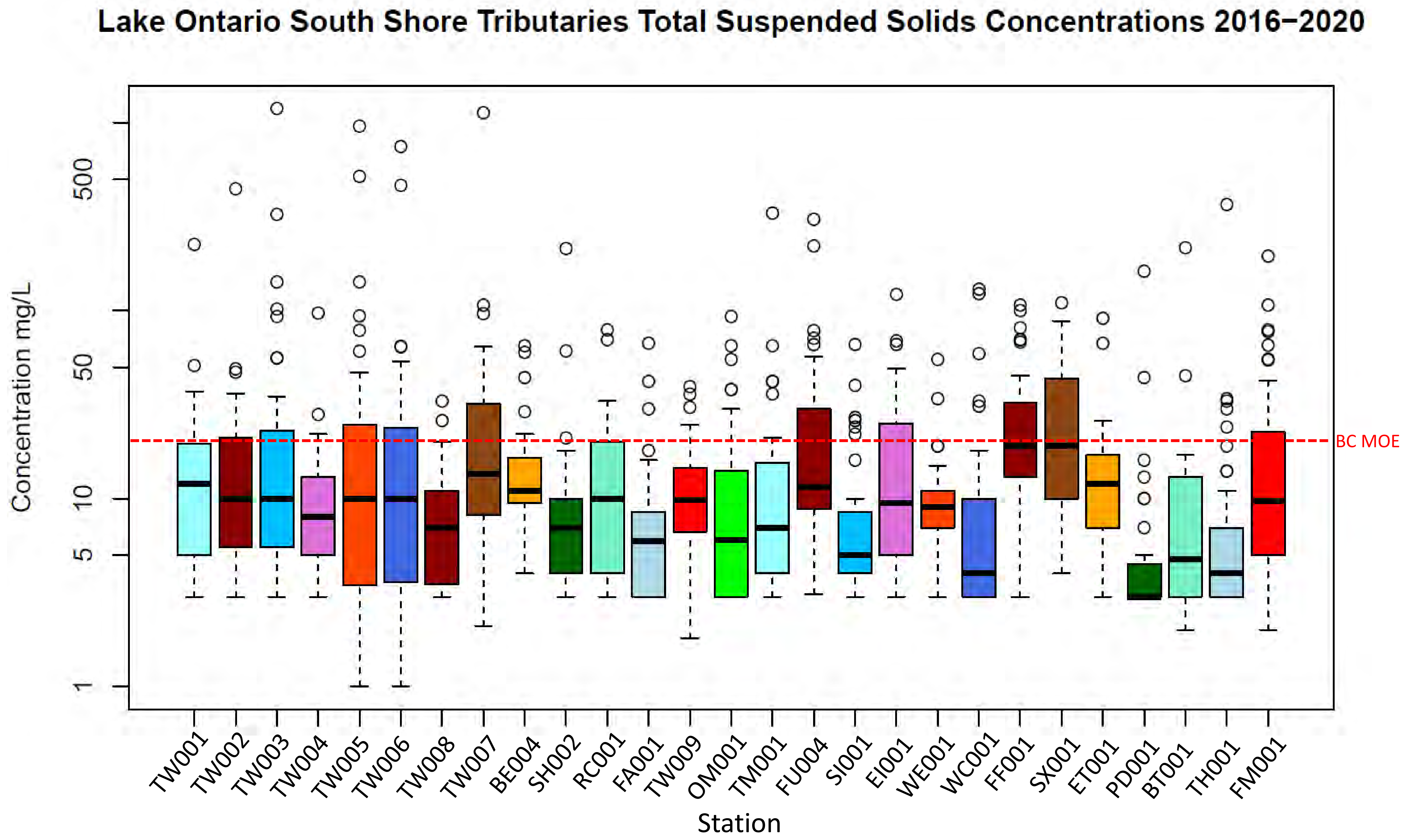
All Frames: North American Datum 1983, Universal Transverse Mercator 6° Projection, Zone 17N, Central Meridian 81° West.
Produced by the Niagara Peninsula Conservation Authority with data supplied under licence by members of the Ontario Geospatial Data Exchange, 2021.



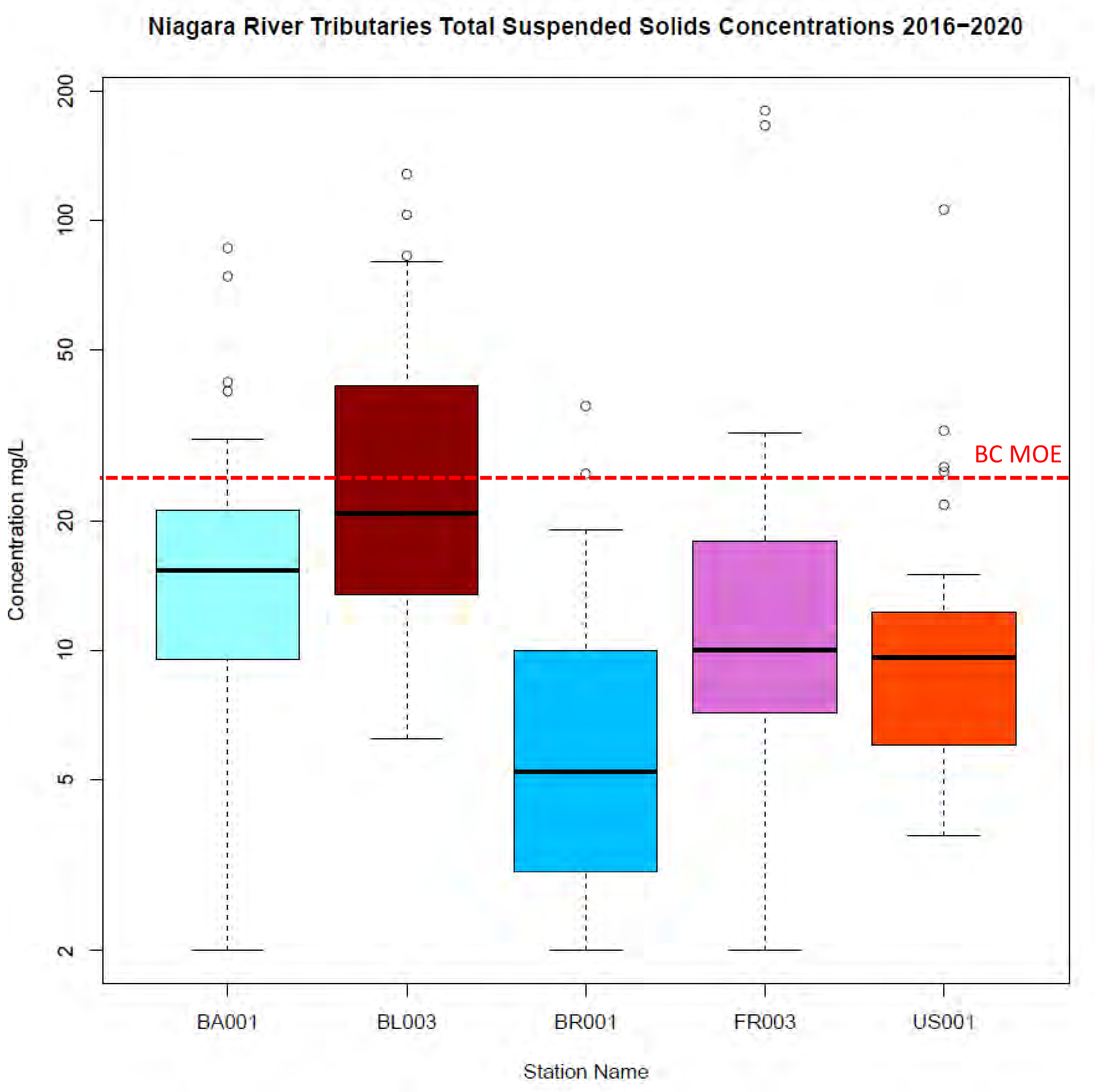
Welland River Watershed Total Suspended Solids Concentrations 2016−2020
Concentration mg/L
500
50
10
5
1
BC MOE
WR00A
WR000
WR001
WR002
WR020
WR003
WR004
WR005
WR006
WR007
WR009B
WR010
WR011
WR012
Station


Welland River Tributaries Total Suspended Solids Concentrations 2016−2020
Concentration mg/L
1000
500
200
100
50
20
10
5
2
BC MOE
BF001
BU001
BV001
CO001
DR001
EL001
GR001
LY003
MI001
MR001
OS001
OS002
PR001
TC001
TE001
Station

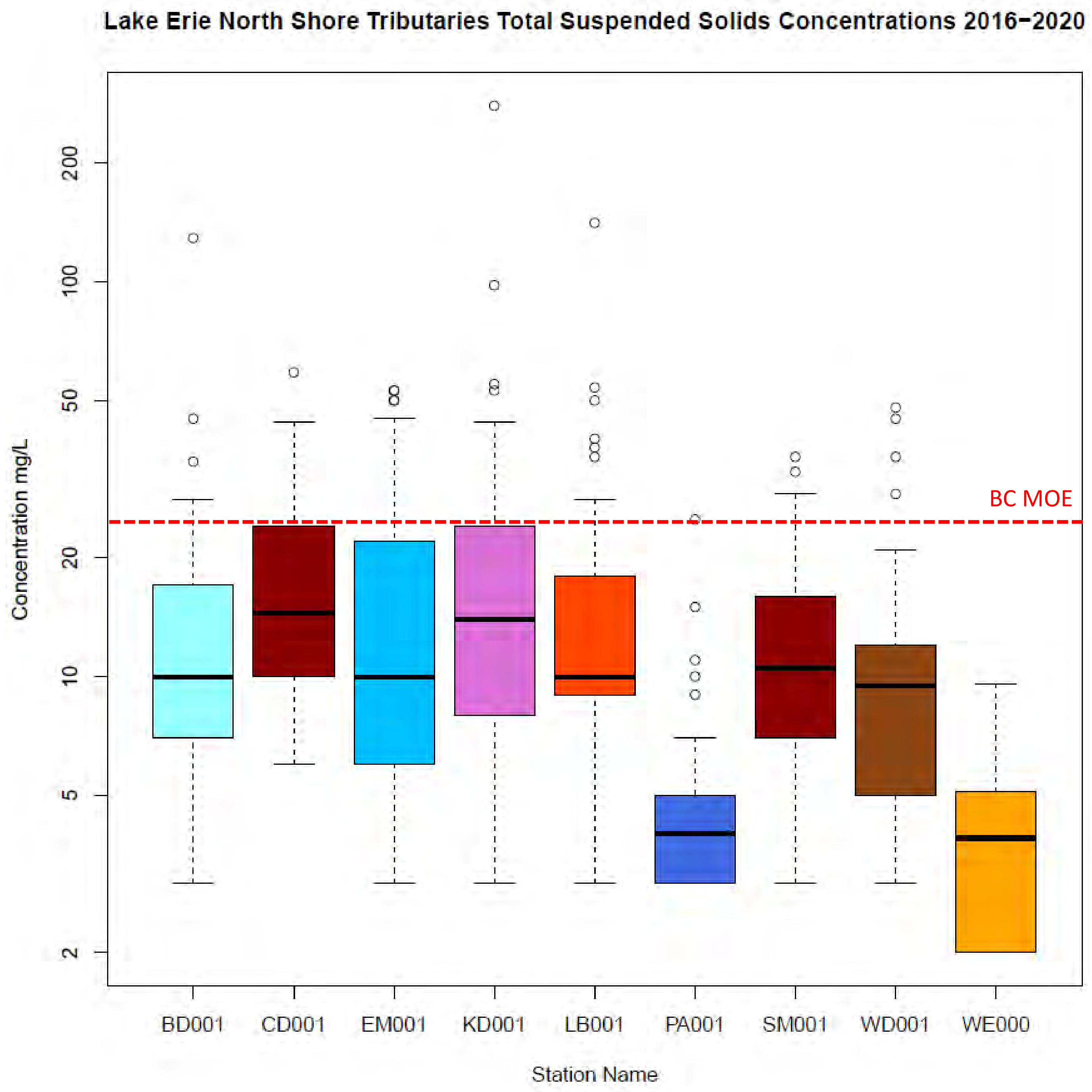

Twenty Mile Creek Watershed Total Suspended Solids Concentrations 2016−2020
Concentration mg/L
200
100
50
20
10
5
2
BC MOE
GV001
NC001
SP001
TN001
TN002
TN003
TN003A
TN004
TN006
Station Name



Lake Ontario South Shore Tributaries Total Suspended Solids Concentrations 2016−2020
Concentration mg/L
500
50
10
5
1
BC MOE
TW001
TW002
TW003
TW004
TW005
TW006
TW008
TW007
BE004
SH002
RC001
FA001
TW009
OM001
TM001
FU004
SI001
EI001
WE001
WC001
FF001
SX001
ET001
PD001
BT001
TH001
FM001
Station



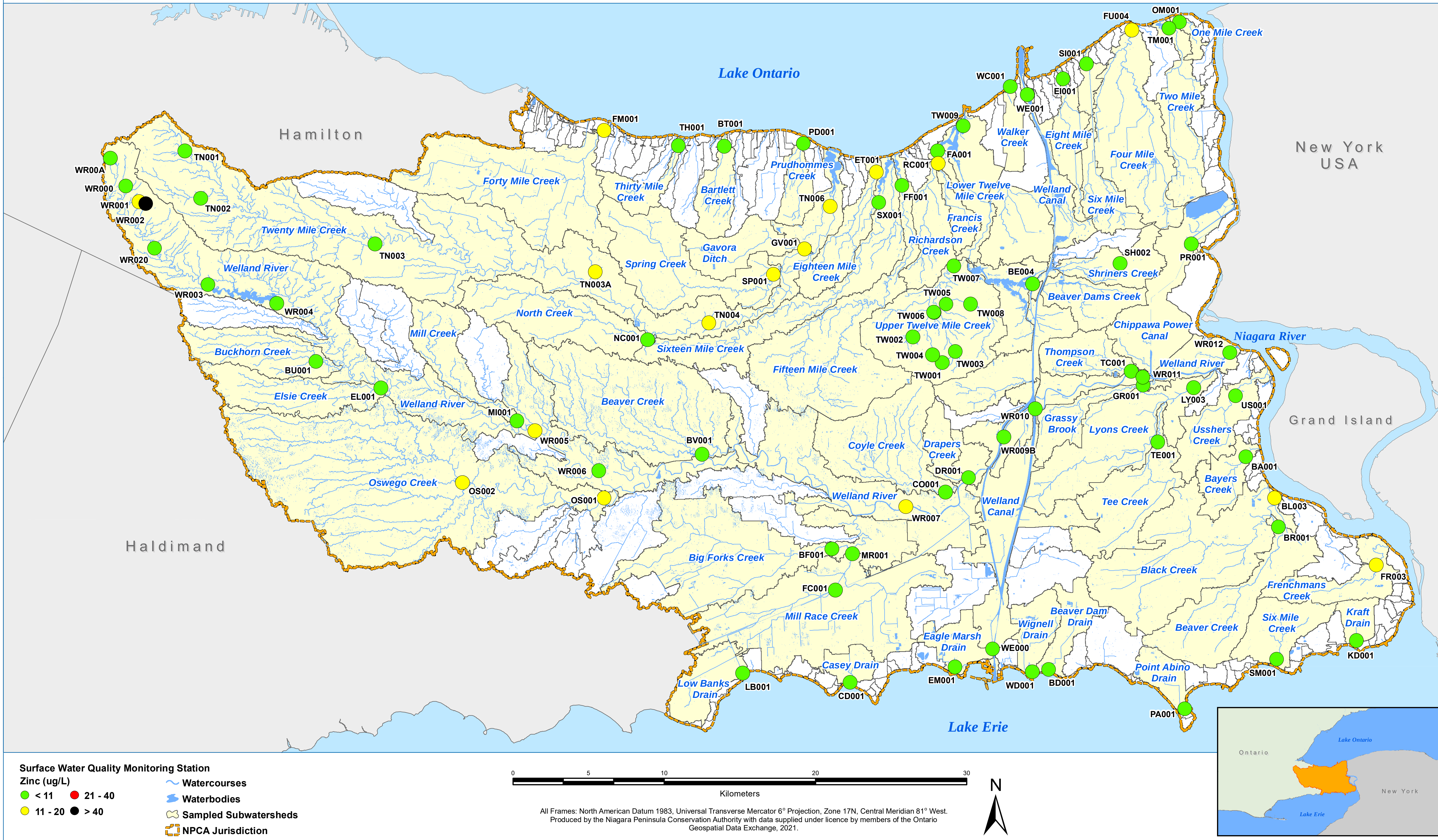
Niagara River Tributaries Total Suspended Solids Concentrations 2016−2020
Concentration mg/L
200
100
50
20
10
5
2
BC MOE
BA001
BL003
BR001
FR003
US001
Station Name


Lake Erie North Shore Tributaries Total Suspended Solids Concentrations 2016−2020
Concentration mg/L
200
100
50
20
10
5
2
BC MOE
BD001
CD001
EM001
KD001
LB001
PA001
SM001
WD001
WE000
Station Name

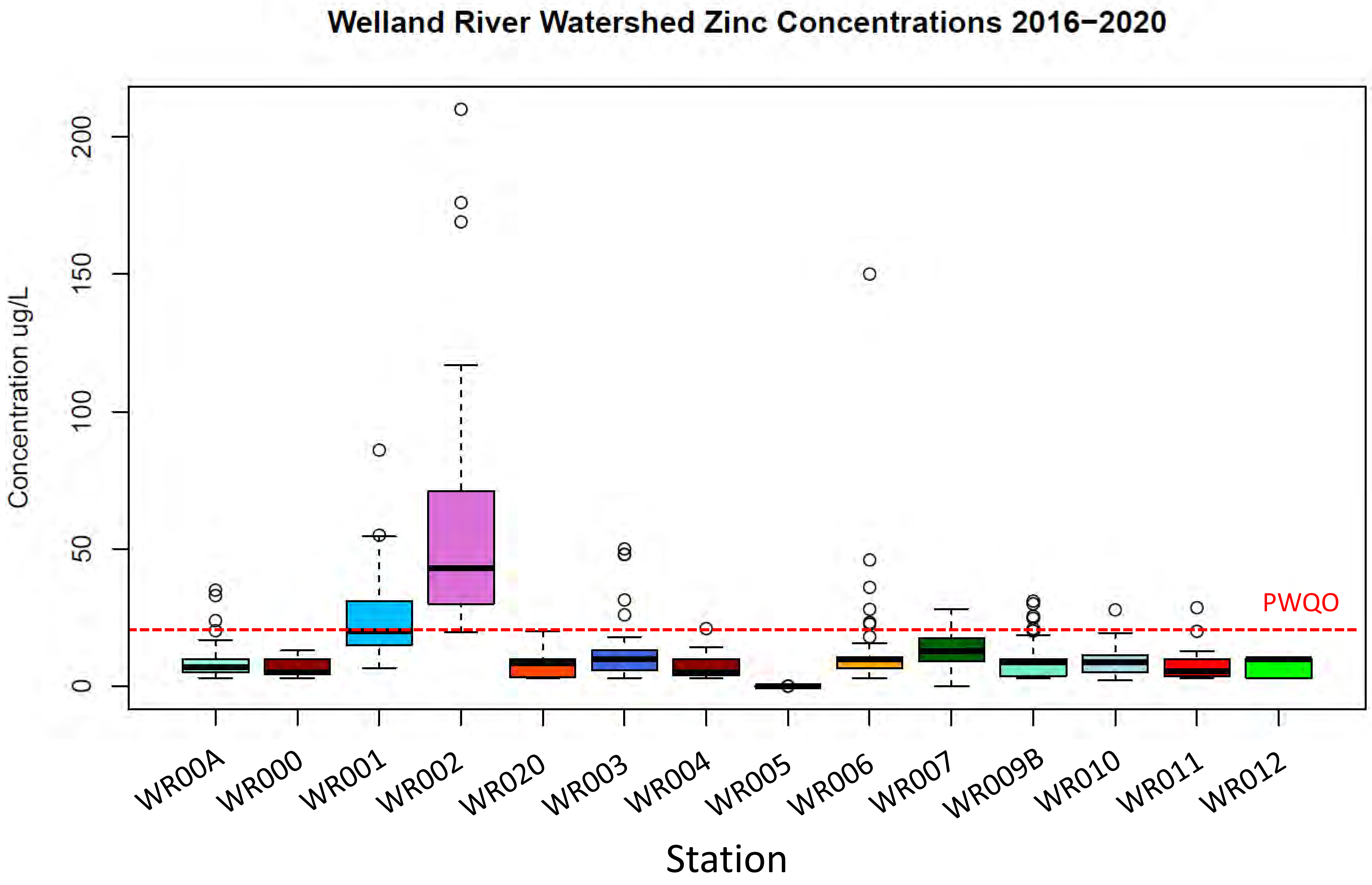
Appendix I

NIAGARA PENINSULA CONSERVATION AUTHORITY

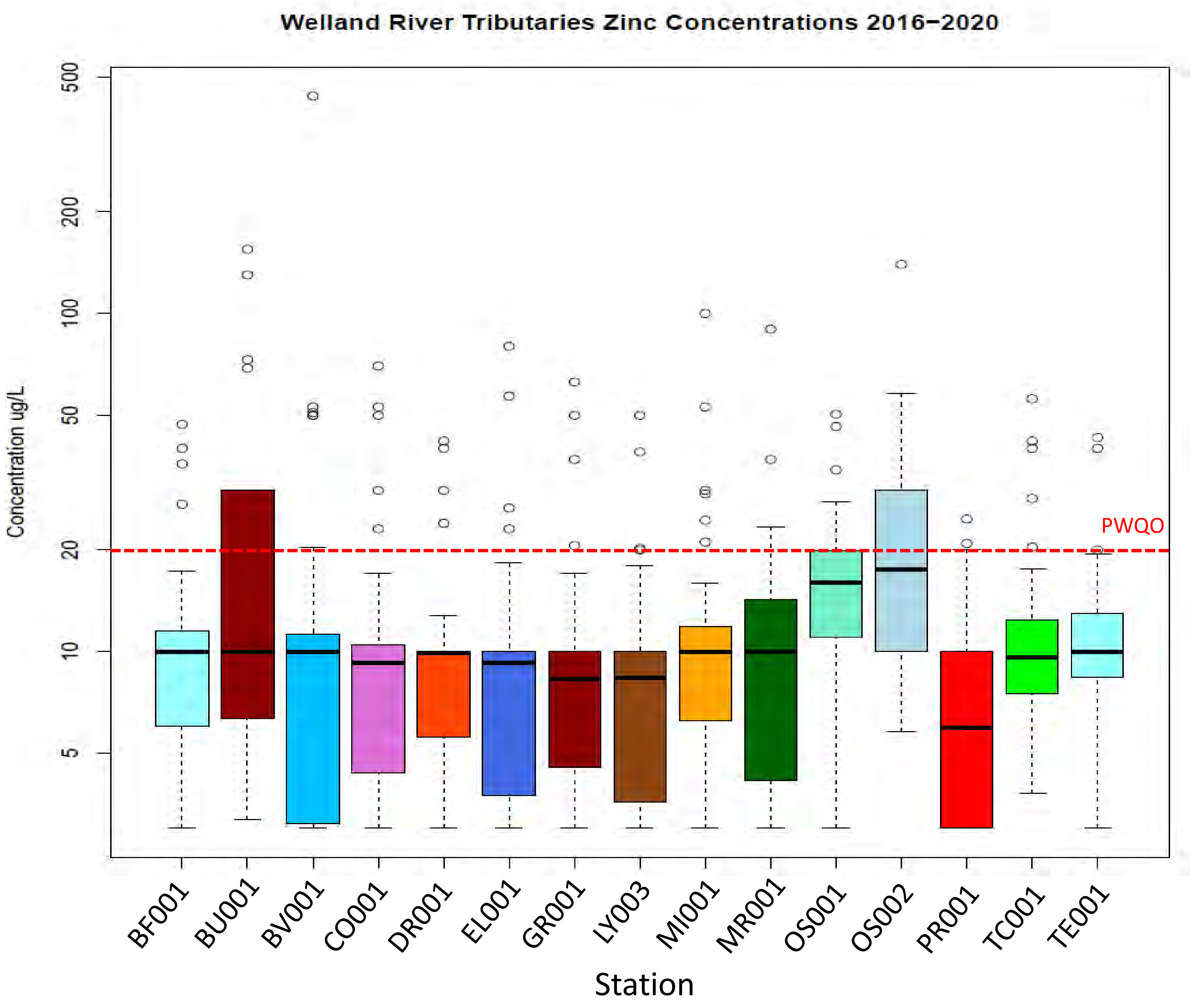
Median Zinc Concentrations 2016 - 2020



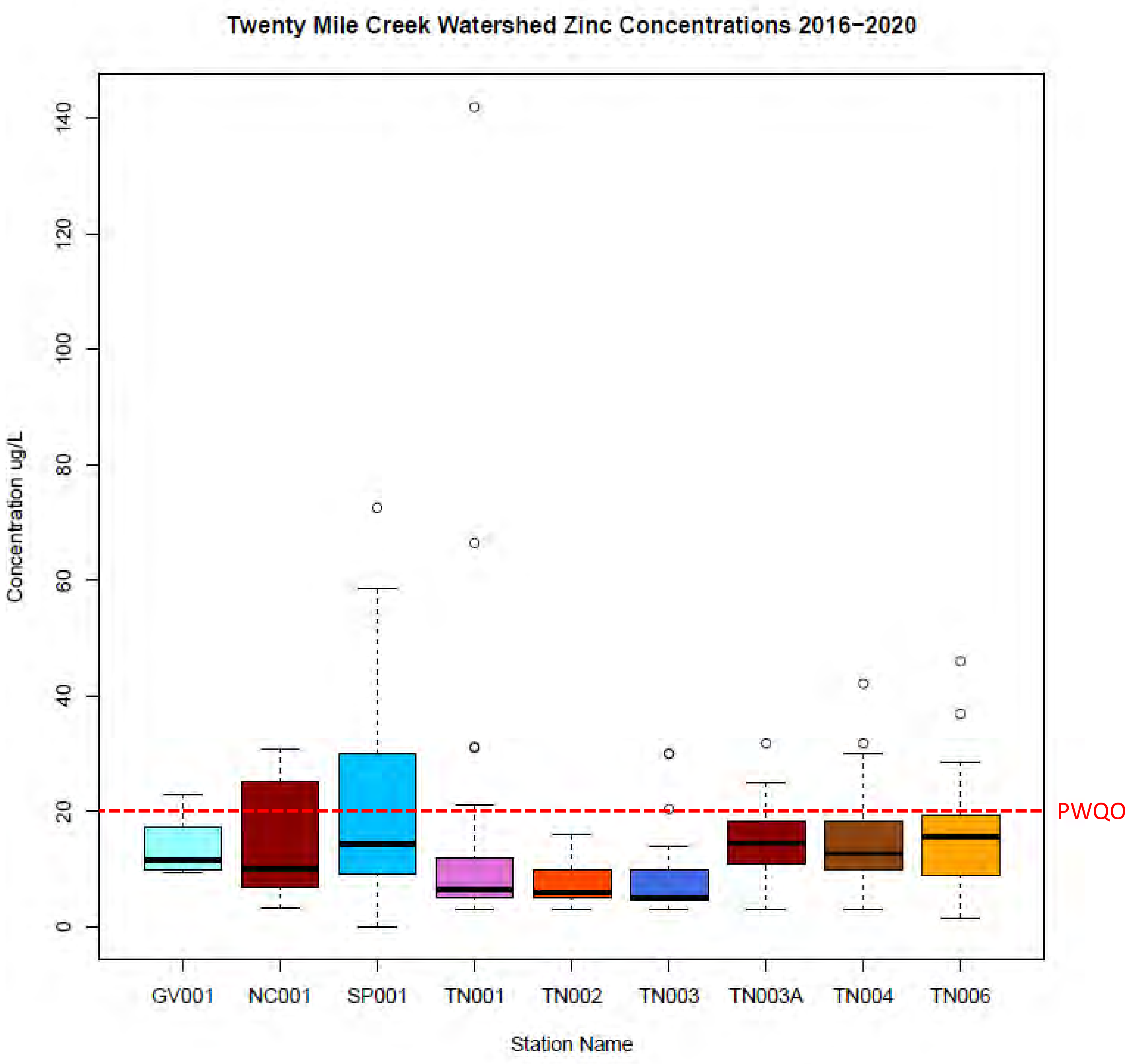
All Frames: North American Datum 1983, Universal Transverse Mercator 6° Projection, Zone 17N, Central Meridian 81° West.
Produced by the Niagara Peninsula Conservation Authority with data supplied under licence by members of the Ontario Geospatial Data Exchange, 2021.

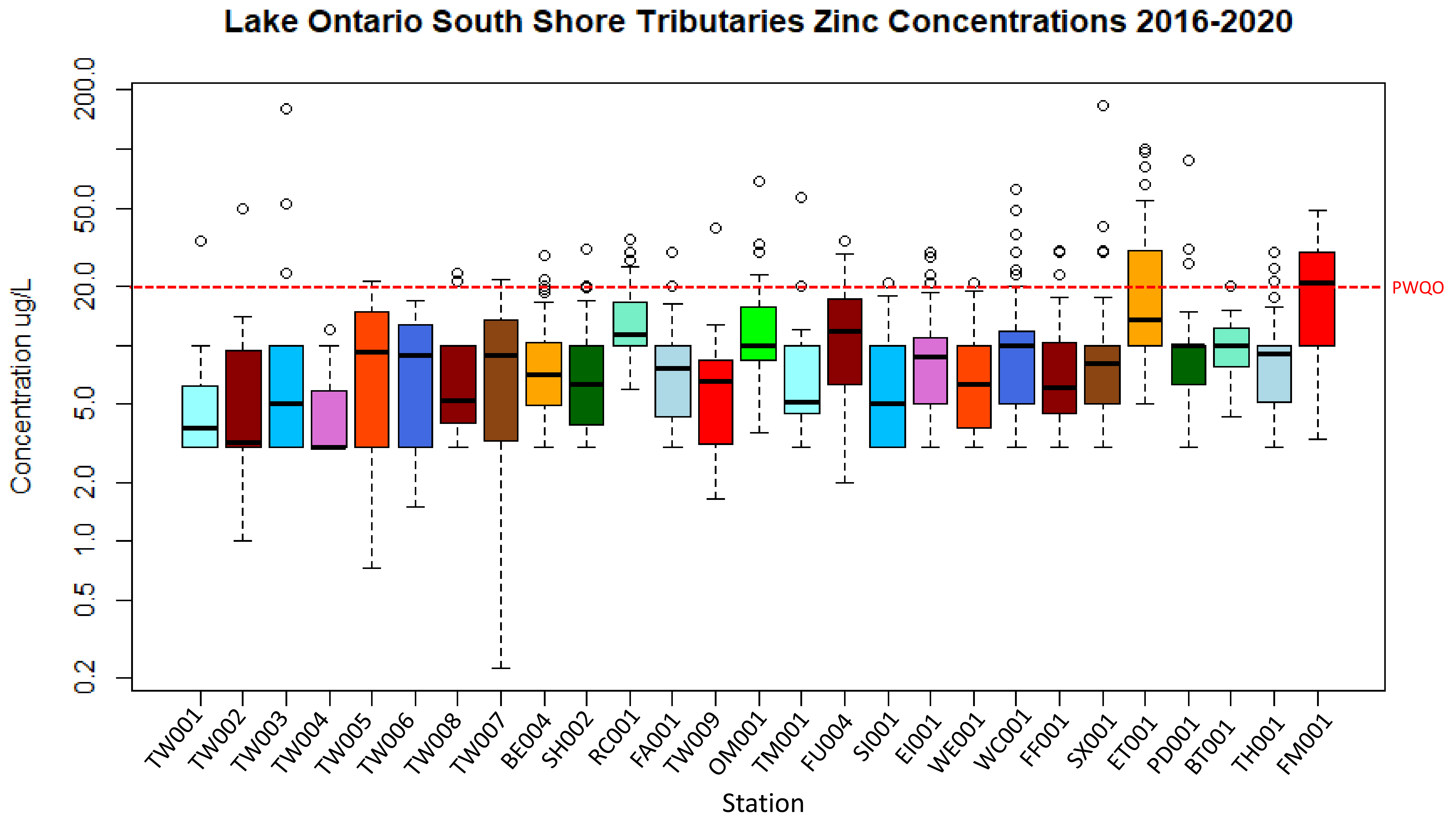


Welland River Watershed Zinc Concentrations 2016−2020
Concentration ug/L
0
50
100
150
200
PWQO
WR00A
WR000
WR001
WR002
WR020
WR003
WR004
WR005
WR006
WR007
WR009B
WR010
WR011
WR012
Station

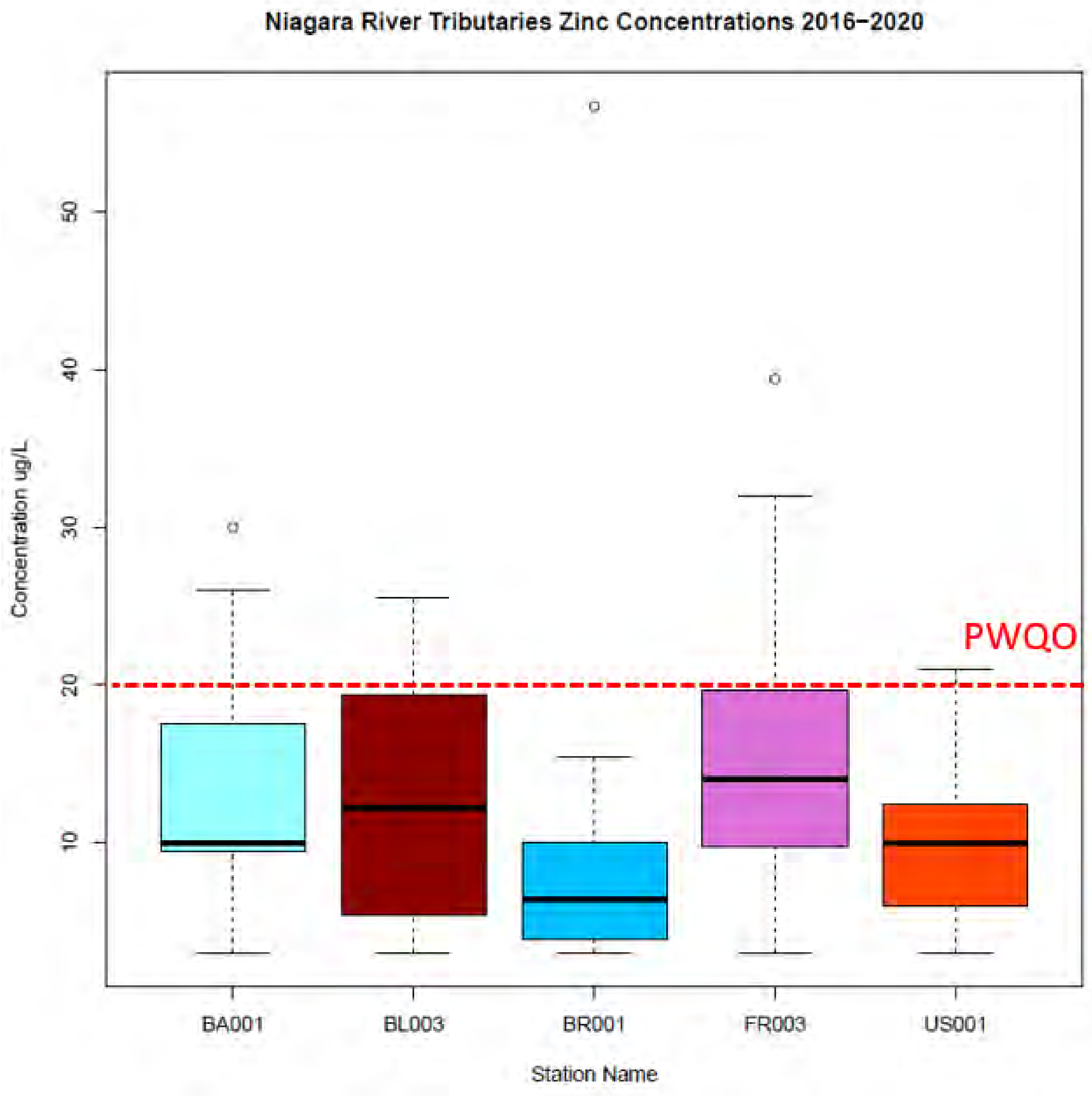


Welland River Tributaries Zinc Concentrations 2016−2020
Concentration ug/L
500
200
100
50
20
10
5
PWQO
BF001
BU001
BV001
CO001
DR001
EL001
GR001
LY003
MI001
MR001
OS001
OS002
PR001
TC001
TE001
Station

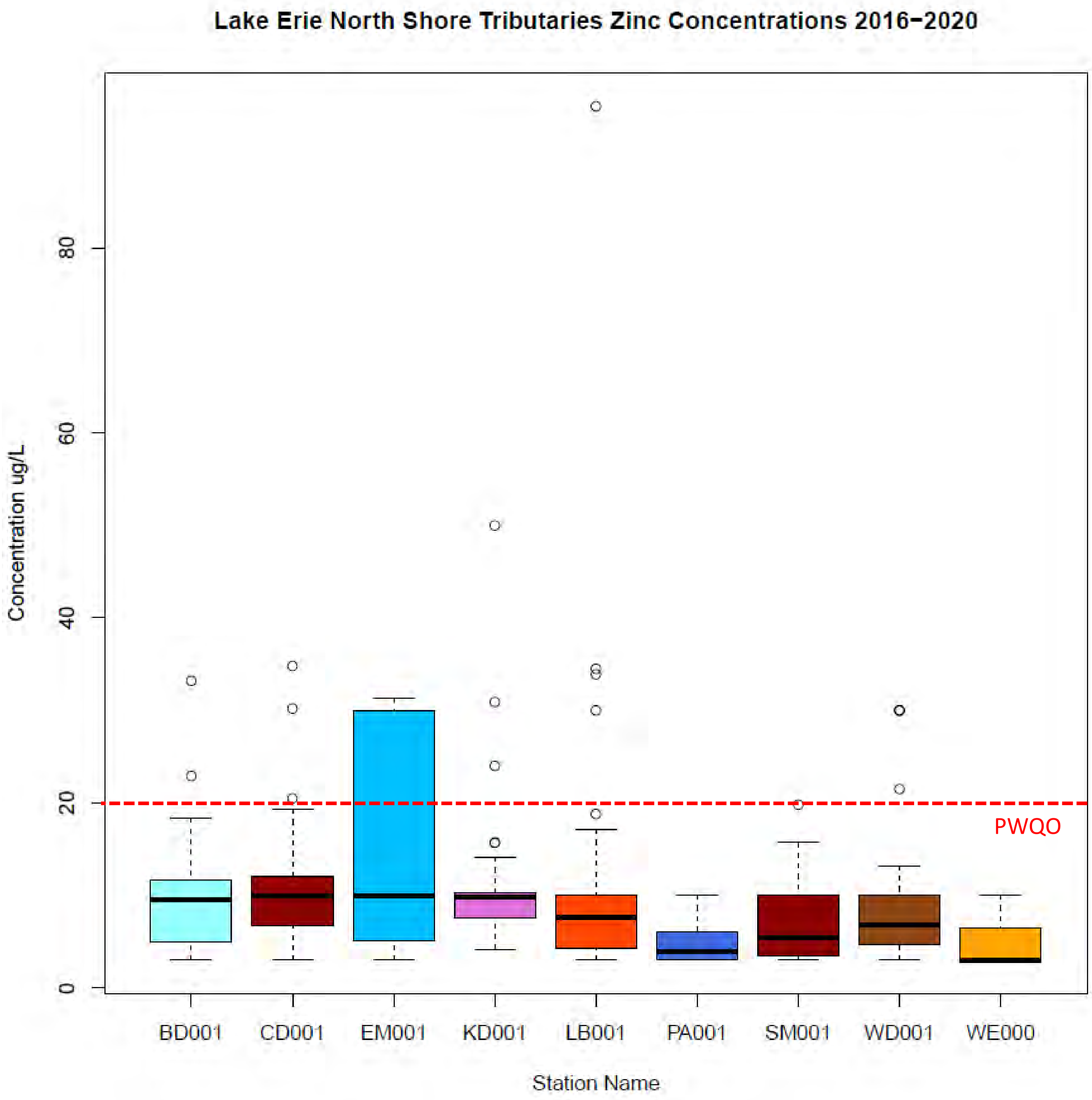

Twenty Mile Creek Watershed Zinc Concentrations 2016−2020
Concentration ug/L
0
20
40
60
80
100
120
140
PWQO
GV001
NC001
SP001
TN001
TN002
TN003
TN003A
TN004
TN006
Station Name



Lake Ontario South Shore Tributaries Zinc Concentrations 2016-2020
Concentration ug/L
200.0
50.0
20.0
5.0
2.0
1.0
0.5
0.2
PWQO
TW001
TW002
TW003
TW004
TW005
TW006
TW008
TW007
BE004
SH002
RC001
FA001
TW009
OM001
TM001
FU004
SI001
EI001
WE001
WC001
FF001
SX001
ET001
PD001
BT001
TH001
FM001
Station



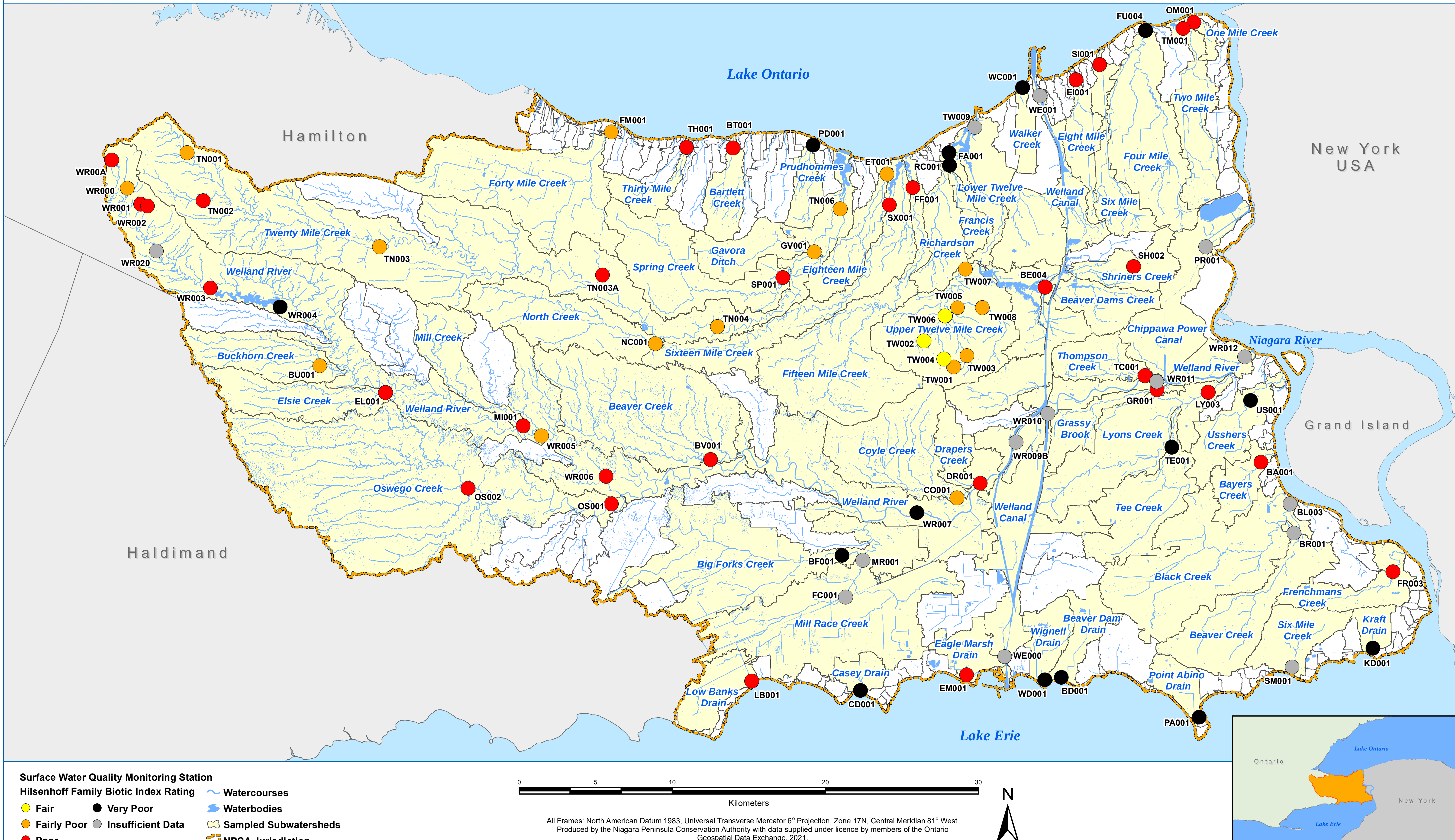
Niagara River Tributaries Zinc Concentrations 2016−2020
Concentration ug/L
10
20
30
40
50
PWQO
BA001
BL003
BR001
FR003
US001
Station Name



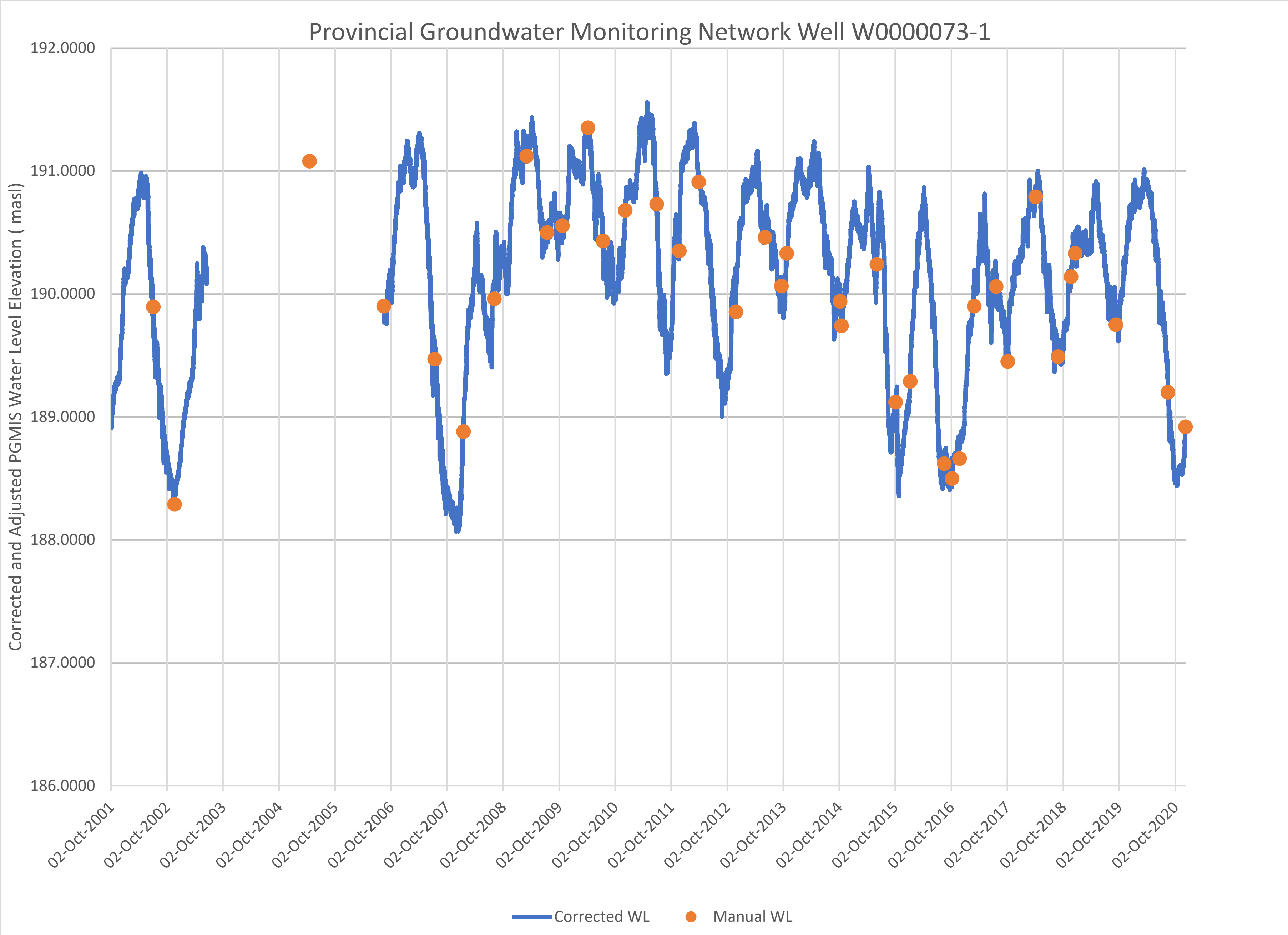
Lake Erie North Shore Tributaries Zinc Concentrations 2016−2020
Concentration ug/L
0
20
40
60
80
PWQO
BD001
CD001
EM001
KD001
LB001
PA001
SM001
WD001
WE000
Station Name

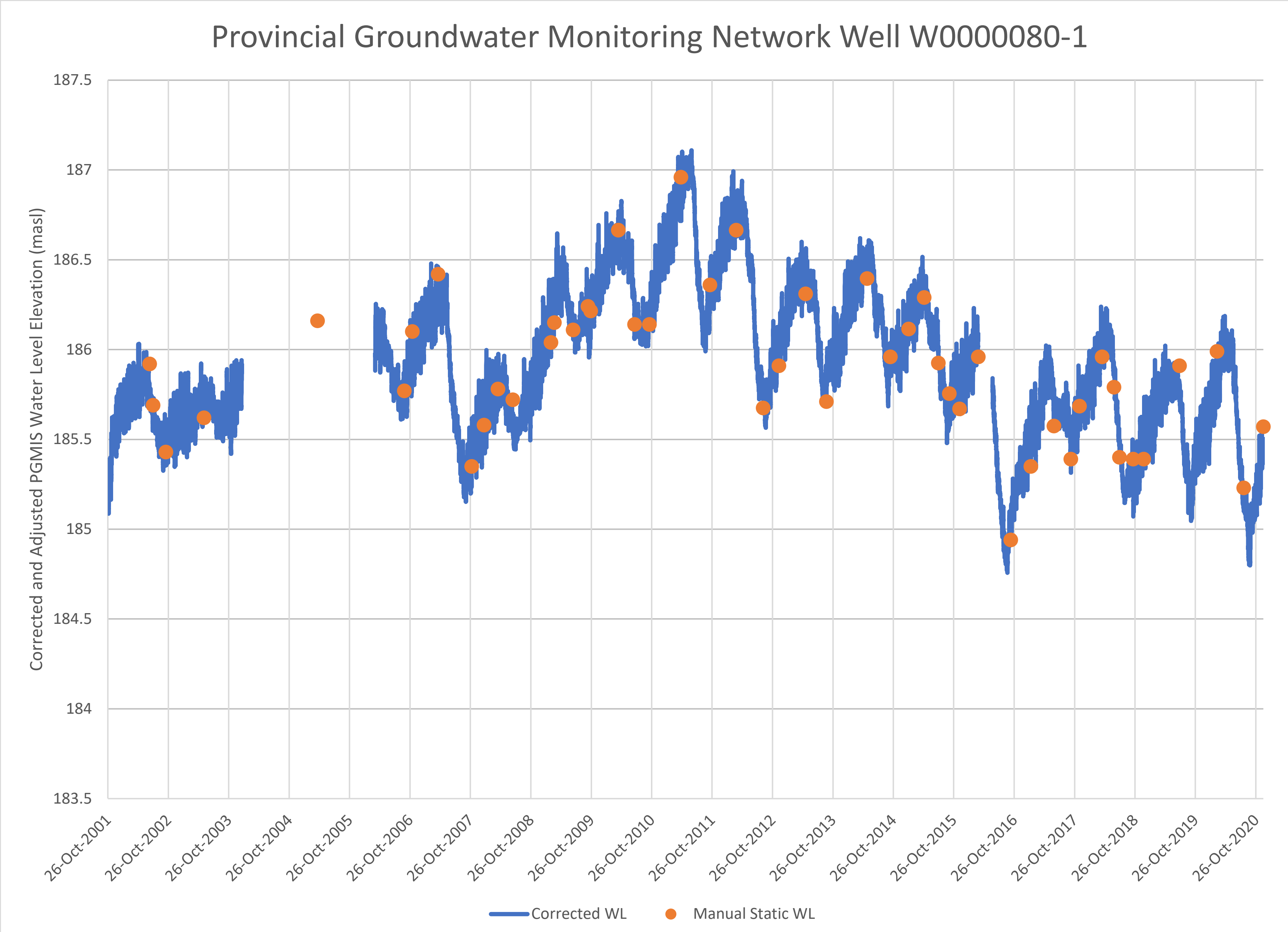
Appendix J

Hilsenhoff Family Biotic Index 2016 - 2020

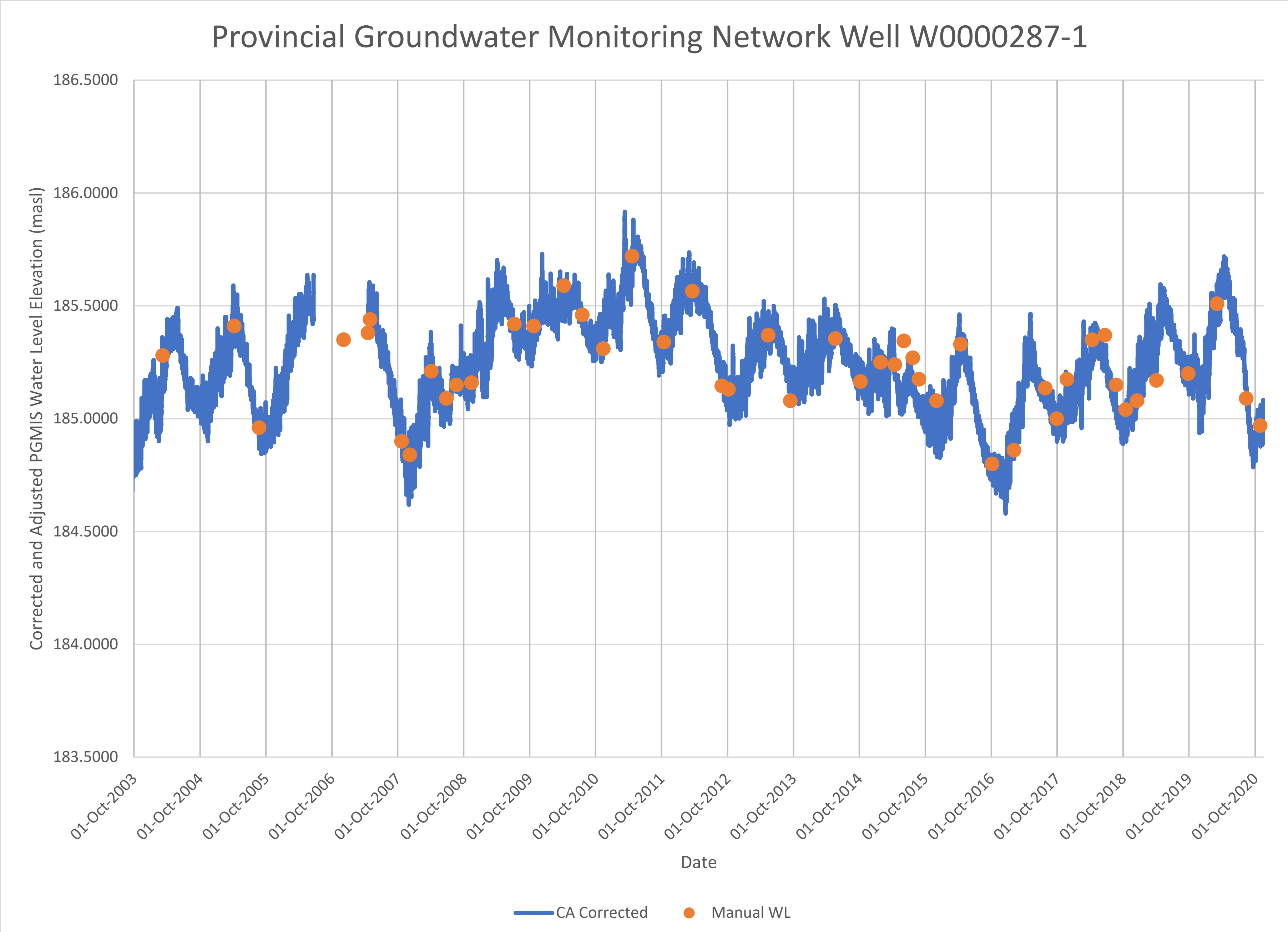


Appendix K

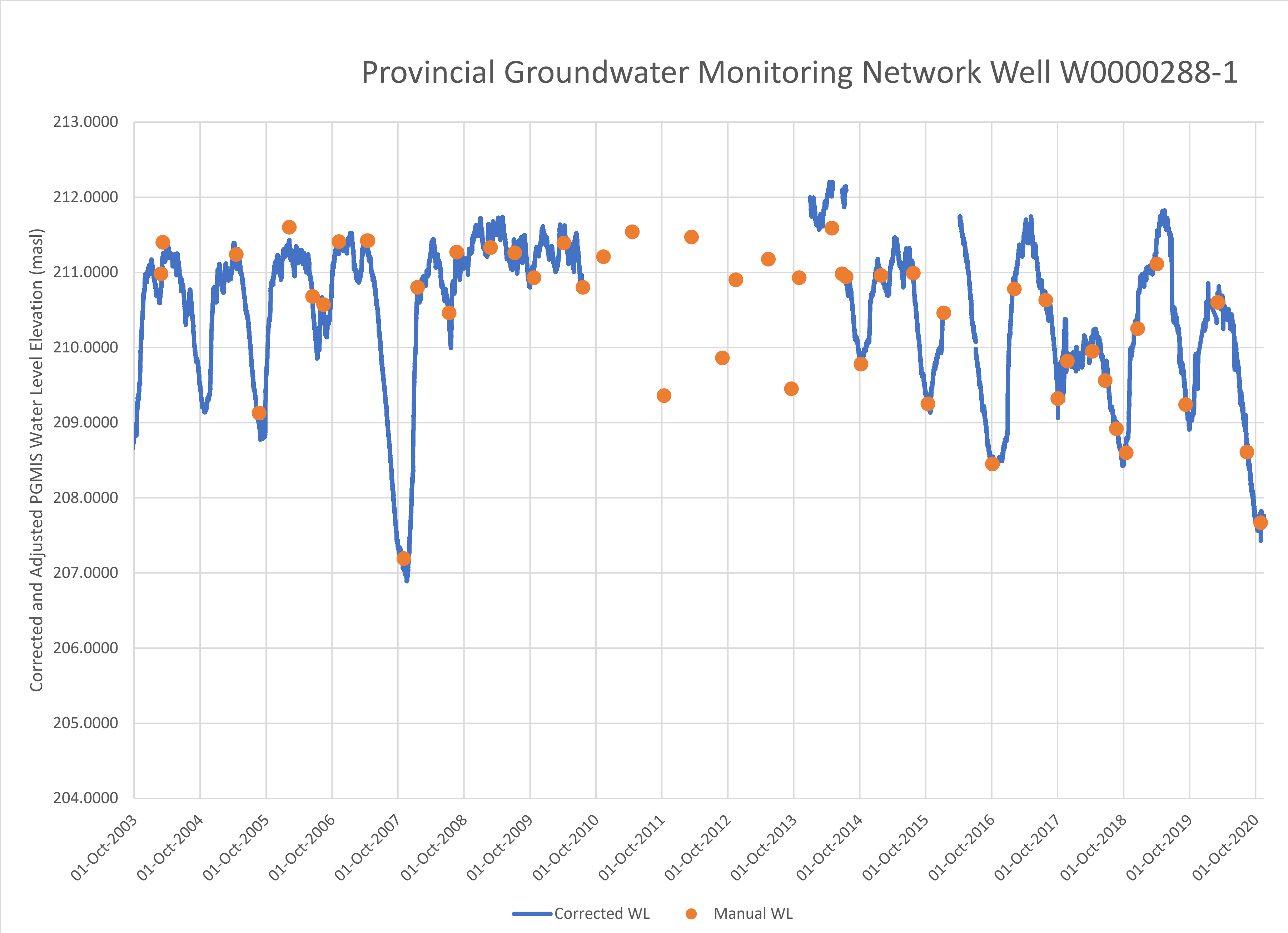

Provincial Groundwater Monitoring Network Well W0000073-1
Corrected and Adjusted PGMIS Water Level Elevation (masl)
192.0000
191.0000
190.0000
189.0000
188.0000
187.0000
186.0000
02-Oct-2001
02-Oct-2002
02-Oct-2003
02-Oct-2004
02-Oct-2005
02-Oct-2006
02-Oct-2007
02-Oct-2008
02-Oct-2009
02-Oct-2010
02-Oct-2011
02-Oct-2012
02-Oct-2013
02-Oct-2014
02-Oct-2015
02-Oct-2016
02-Oct-2017
02-Oct-2018
02-Oct-2019
02-Oct-2020
Corrected WL
Manual WL

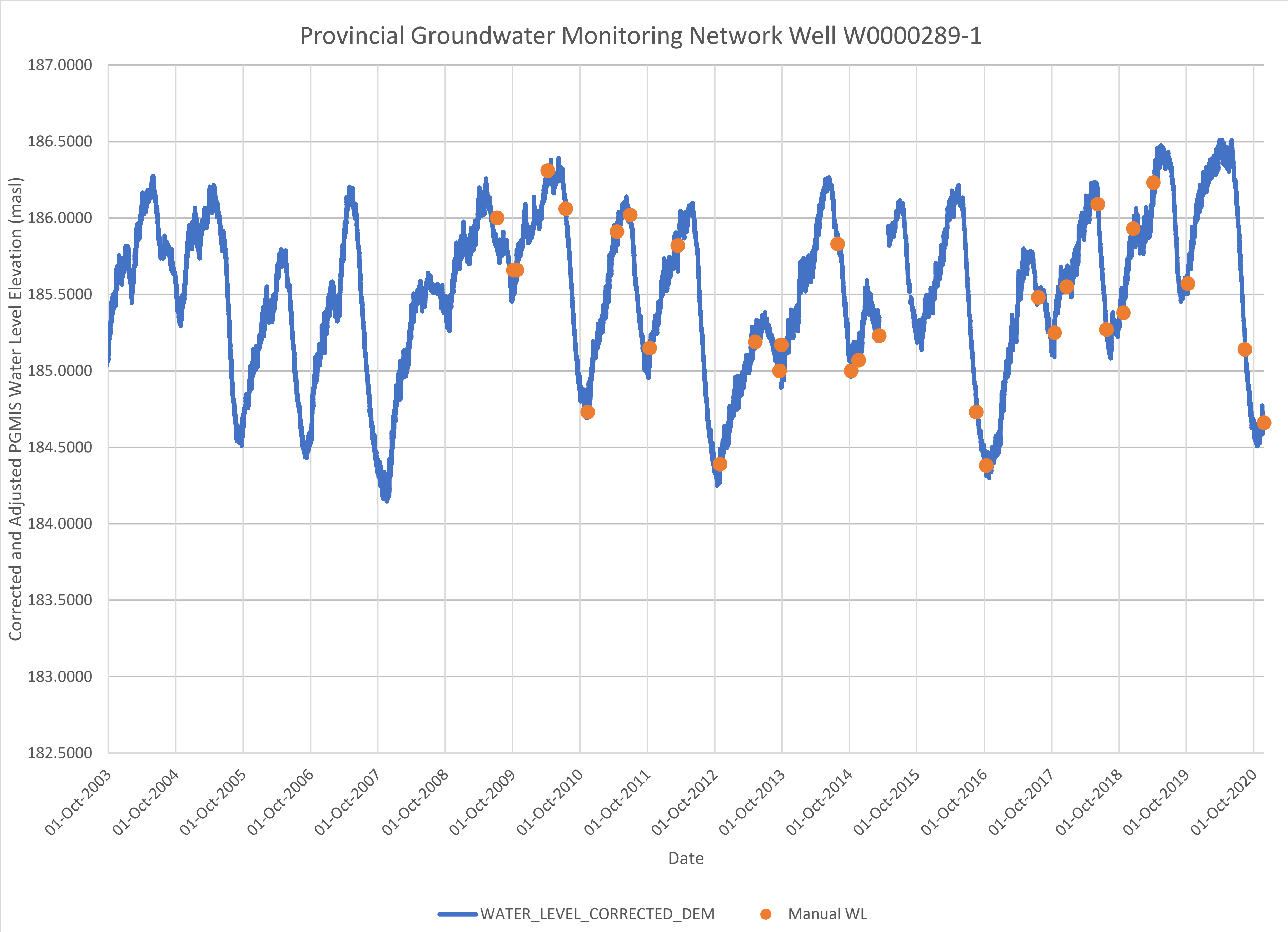


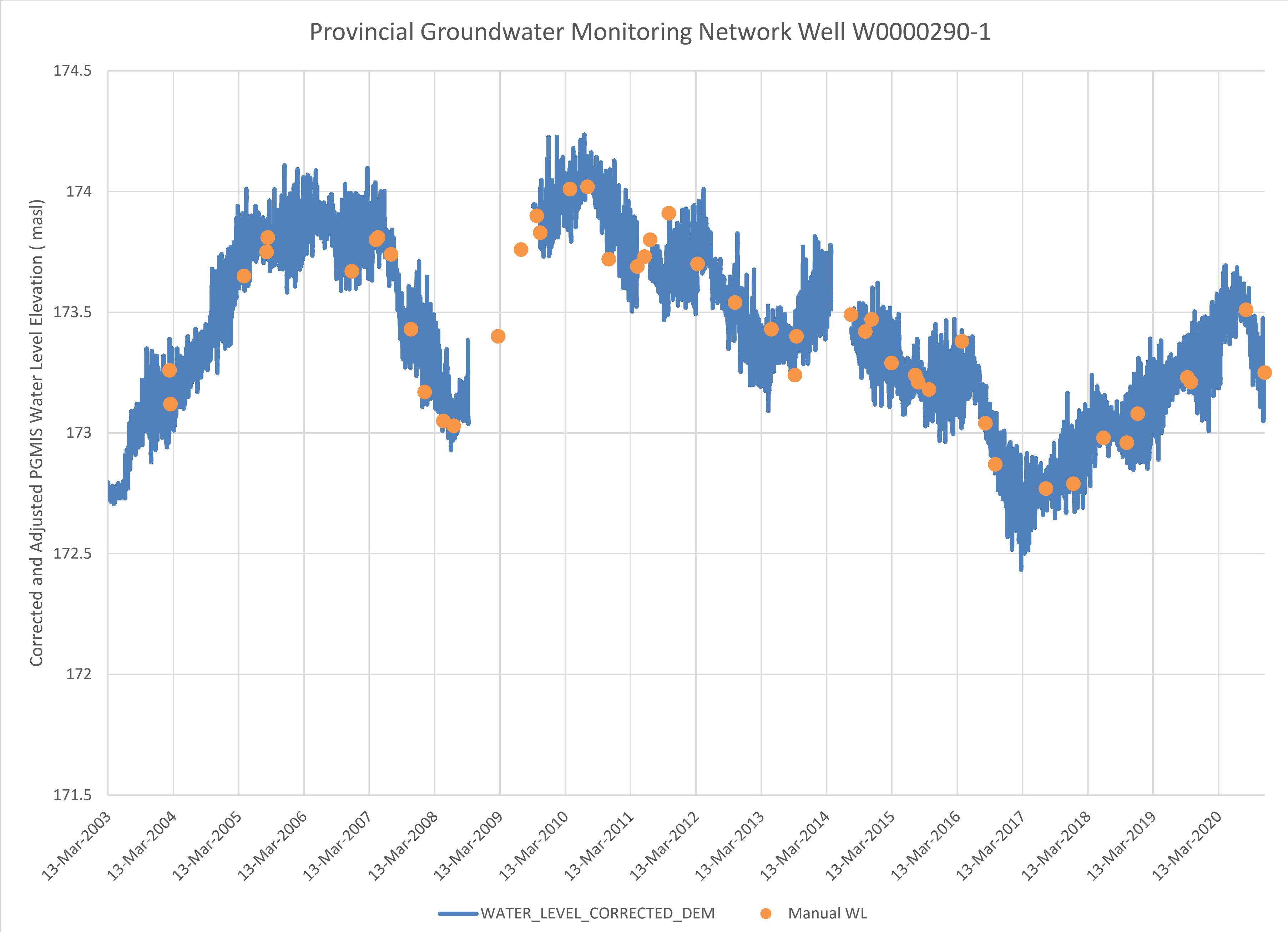
Provincial Groundwater Monitoring Network Well W0000080-1
Corrected and Adjusted PGMIS Water Level Elevation (masl)
187.5
187
186.5
186
185.5
185
184.5
184
183.5
26-Oct-2001
26-Oct-2002
26-Oct-2003
26-Oct-2004
26-Oct-2005
26-Oct-2006
26-Oct-2007
26-Oct-2008
26-Oct-2009
26-Oct-2010
26-Oct-2011
26-Oct-2012
26-Oct-2013
26-Oct-2014
26-Oct-2015
26-Oct-2016
26-Oct-2017
26-Oct-2018
26-Oct-2019
26-Oct-2020
Corrected WL
Manual Static WL



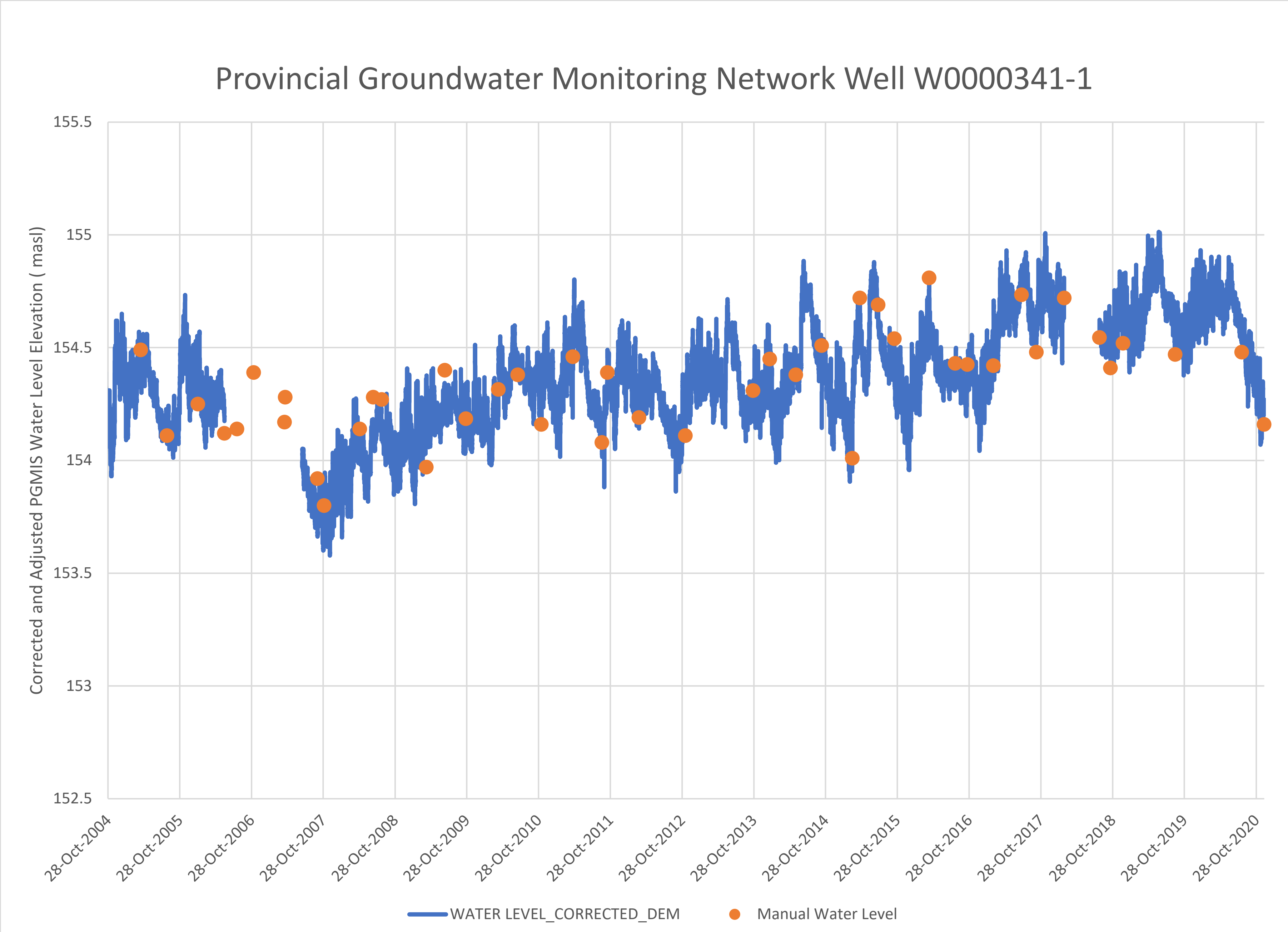
Provincial Groundwater Monitoring Network Well W0000287-1
Corrected and Adjusted PGMIS Water Level Elevation (masl)
186.5000
186.0000
185.5000
185.0000
184.5000
184.0000
183.5000
01-Oct-2003
01-Oct-2004
01-Oct-2005
01-Oct-2006
01-Oct-2007
01-Oct-2008
01-Oct-2009
01-Oct-2010
01-Oct-2011
01-Oct-2012
01-Oct-2013
01-Oct-2014
01-Oct-2015
01-Oct-2016
01-Oct-2017
01-Oct-2018
01-Oct-2019
01-Oct-2020
Date
CA Corrected
Manual WL

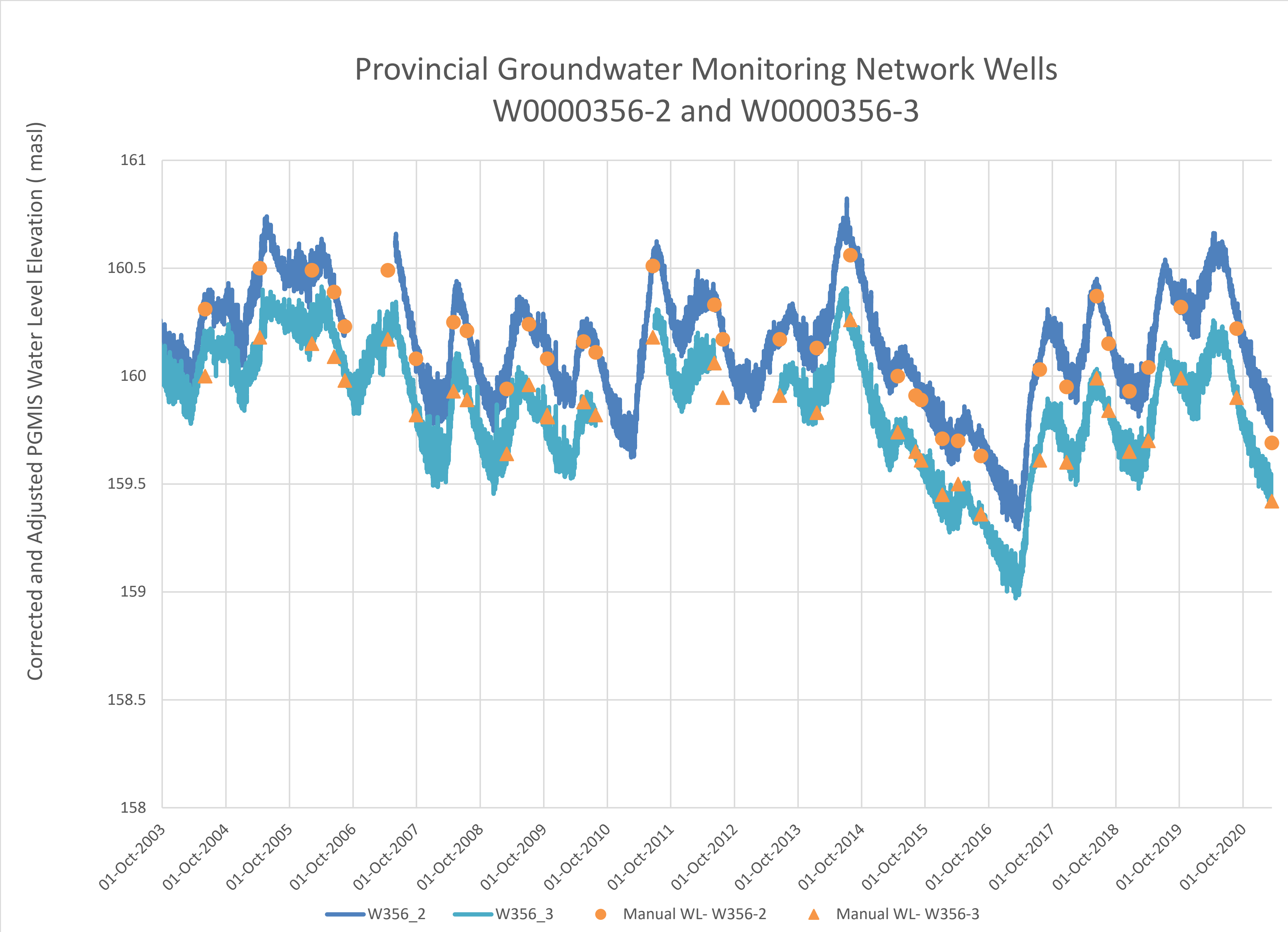

Provincial Groundwater Monitoring Network Well W0000288-1
Corrected and Adjusted PGMIS Water Level Elevation (masl)
213.0000
212.0000
211.0000
210.0000
209.0000
208.0000
207.0000
206.0000
205.0000
204.0000
01-Oct-2003
01-Oct-2004
01-Oct-2005
01-Oct-2006
01-Oct-2007
01-Oct-2008
01-Oct-2009
01-Oct-2010
01-Oct-2011
01-Oct-2012
01-Oct-2013
01-Oct-2014
01-Oct-2015
01-Oct-2016
01-Oct-2017
01-Oct-2018
01-Oct-2019
01-Oct-2020
Corrected WL
Manual WL

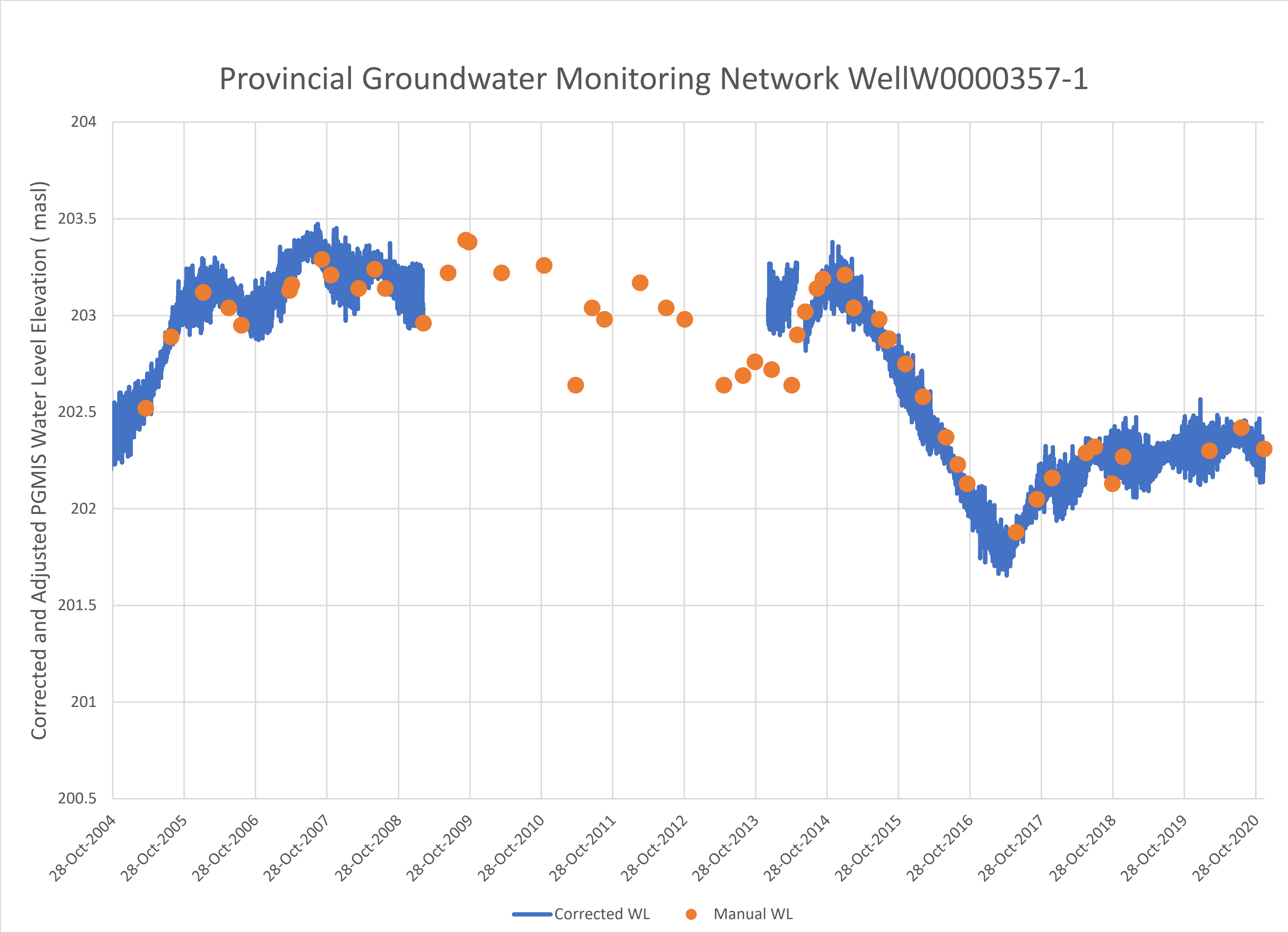

Provincial Groundwater Monitoring Network Well W0000289-1
Corrected and Adjusted PGMIS Water Level Elevation (masl)
187.0000
186.5000
186.0000
185.5000
185.0000
184.5000
184.0000
183.5000
183.0000
182.5000
01-Oct-2003
01-Oct-2004
01-Oct-2005
01-Oct-2006
01-Oct-2007
01-Oct-2008
01-Oct-2009
01-Oct-2010
01-Oct-2011
01-Oct-2012
01-Oct-2013
01-Oct-2014
01-Oct-2015
01-Oct-2016
01-Oct-2017
01-Oct-2018
01-Oct-2019
01-Oct-2020
Date
WATER_LEVEL_CORRECTED_DEM
Manual WL



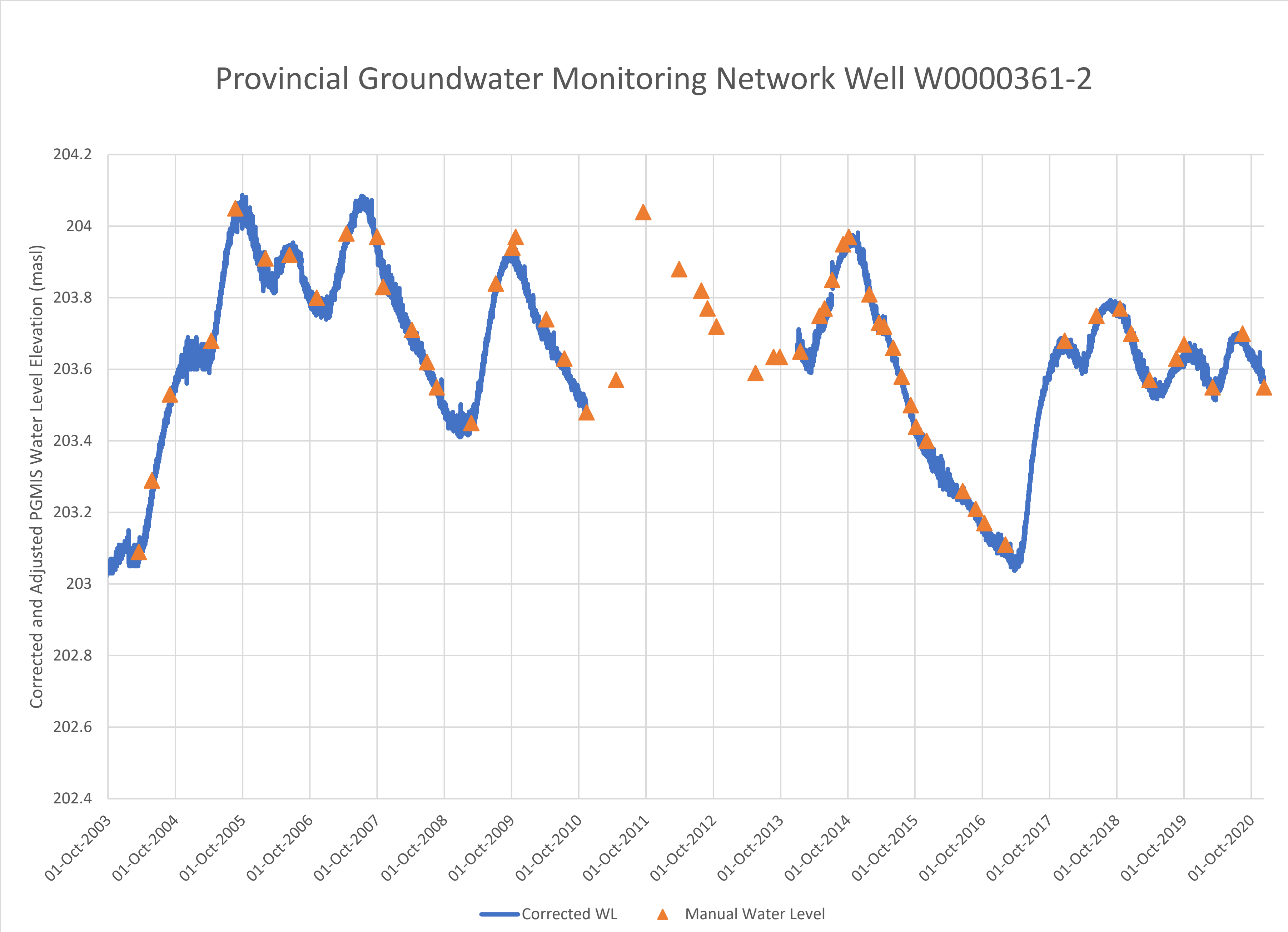
Provincial Groundwater Monitoring Network Well W0000290-1
Corrected and Adjusted PGMIS Water Level Elevation (masl)
174.5
174
173.5
173
172.5
172
171.5
13-Mar-2003
13-Mar-2004
13-Mar-2005
13-Mar-2006
13-Mar-2007
13-Mar-2008
13-Mar-2009
13-Mar-2010
13-Mar-2011
13-Mar-2012
13-Mar-2013
13-Mar-2014
13-Mar-2015
13-Mar-2016
13-Mar-2017
13-Mar-2018
13-Mar-2019
13-Mar-2020
WATER_LEVEL_CORRECTED_DEM
Manual WL


Provincial Groundwater Monitoring Network Well W0000341-1
Corrected and Adjusted PGMIS Water Level Elevation (masl)
155.5
155
154.5
154
153.5
153
152.5
28-Oct-2004
28-Oct-2005
28-Oct-2006
28-Oct-2007
28-Oct-2008
28-Oct-2009
28-Oct-2010
28-Oct-2011
28-Oct-2012
28-Oct-2013
28-Oct-2014
28-Oct-2015
28-Oct-2016
28-Oct-2017
28-Oct-2018
28-Oct-2019
28-Oct-2020
WATER LEVEL_CORRECTED_DEM
Manual Water Level

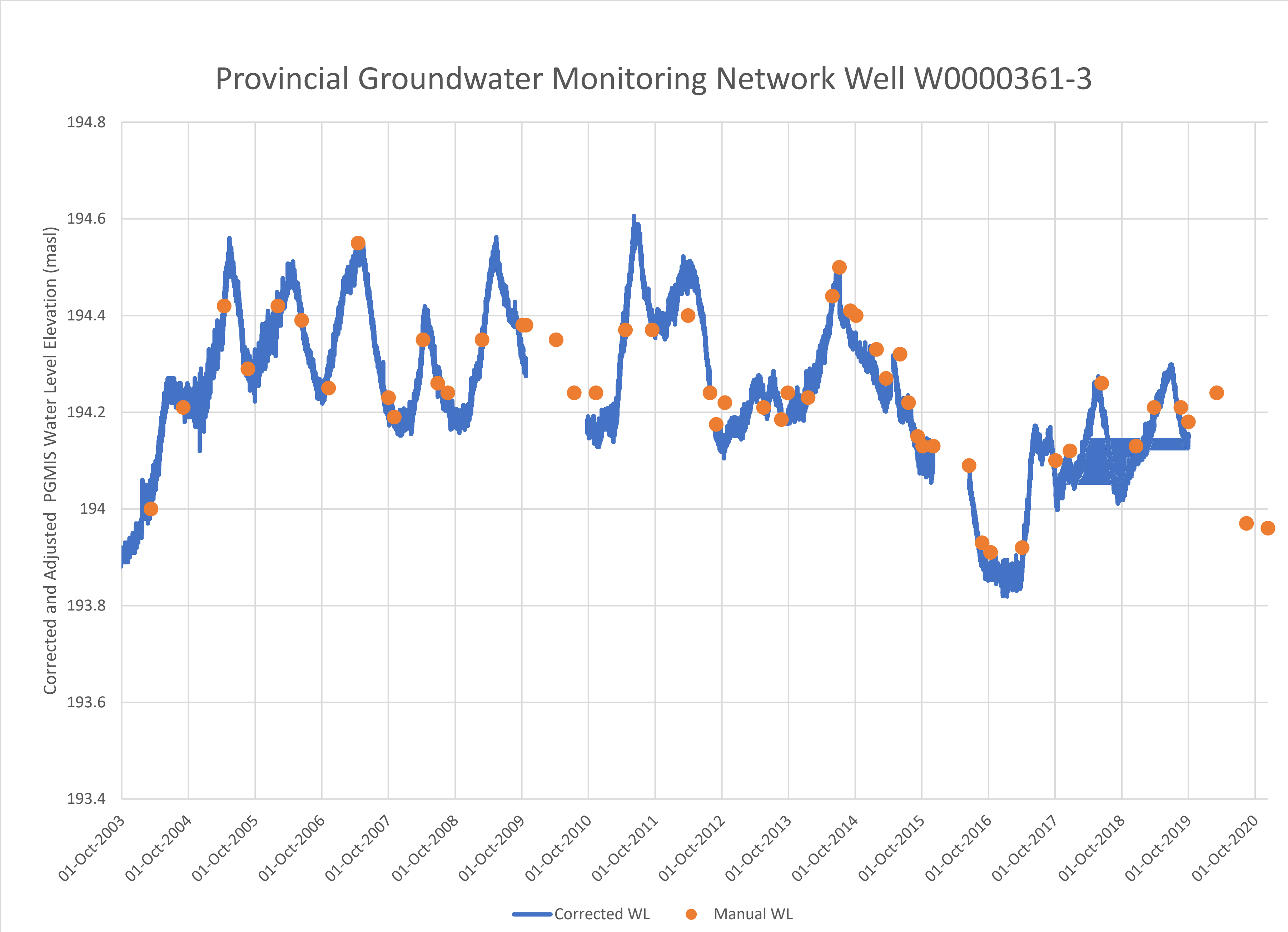

Provincial Groundwater Monitoring Network Wells
W0000356-2 and W0000356-3
Corrected and Adjusted PGMIS Water Level Elevation (masl)
161
160.5
160
159.5
159
158.5
158
01-Oct-2003
01-Oct-2004
01-Oct-2005
01-Oct-2006
01-Oct-2007
01-Oct-2008
01-Oct-2009
01-Oct-2010
01-Oct-2011
01-Oct-2012
01-Oct-2013
01-Oct-2014
01-Oct-2015
01-Oct-2016
01-Oct-2017
01-Oct-2018
01-Oct-2019
01-Oct-2020
W356_2
W356_3
Manual WL- W356-2
Manual WL- W356-3



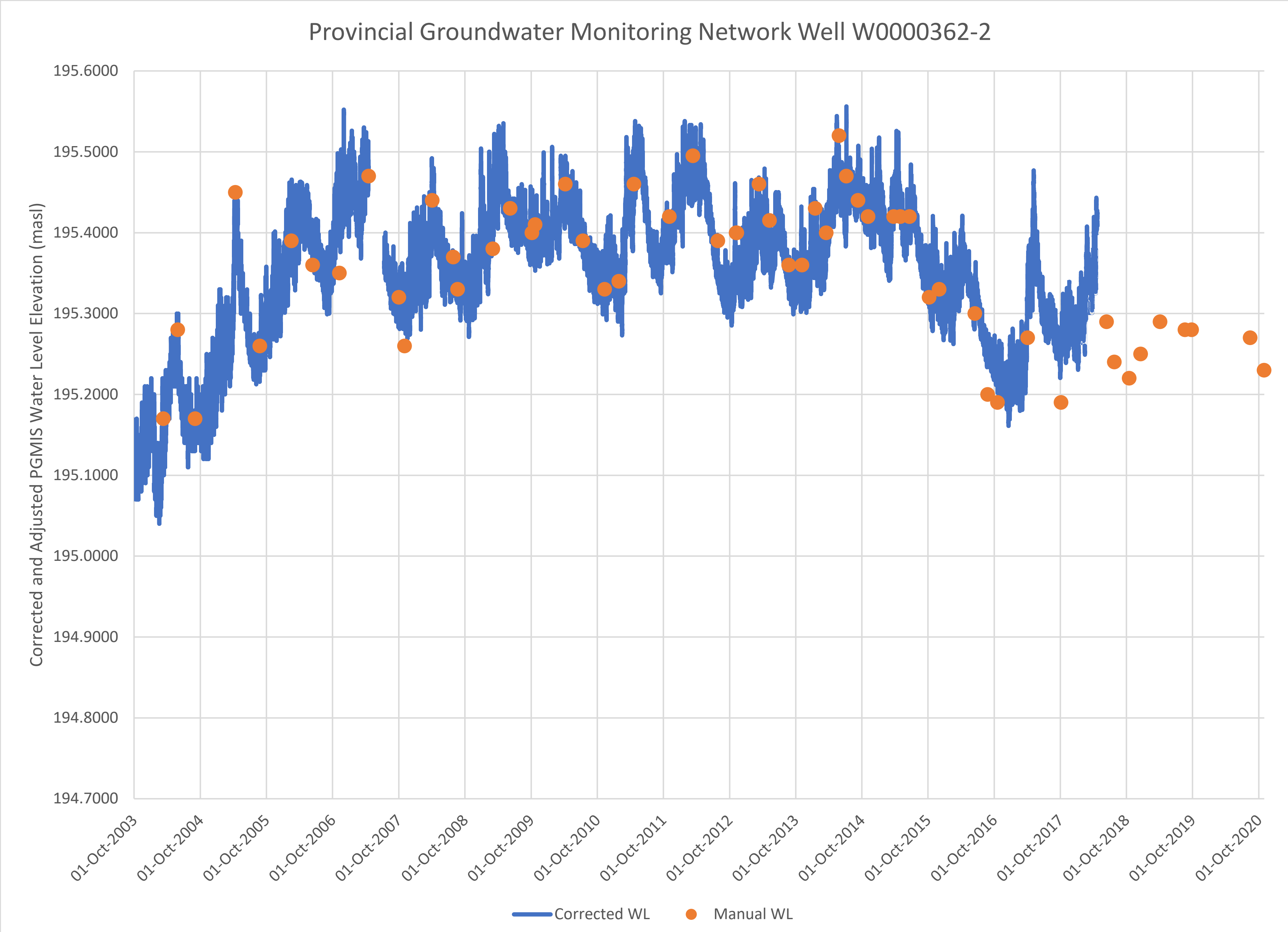
Provincial Groundwater Monitoring Network WellW0000357-1
Corrected and Adjusted PGMIS Water Level Elevation (masl)
204
203.5
203
202.5
202
201.5
201
200.5
28-Oct-2004
28-Oct-2005
28-Oct-2006
28-Oct-2007
28-Oct-2008
28-Oct-2009
28-Oct-2010
28-Oct-2011
28-Oct-2012
28-Oct-2013
28-Oct-2014
28-Oct-2015
28-Oct-2016
28-Oct-2017
28-Oct-2018
28-Oct-2019
28-Oct-2020
Corrected WL
Manual WL



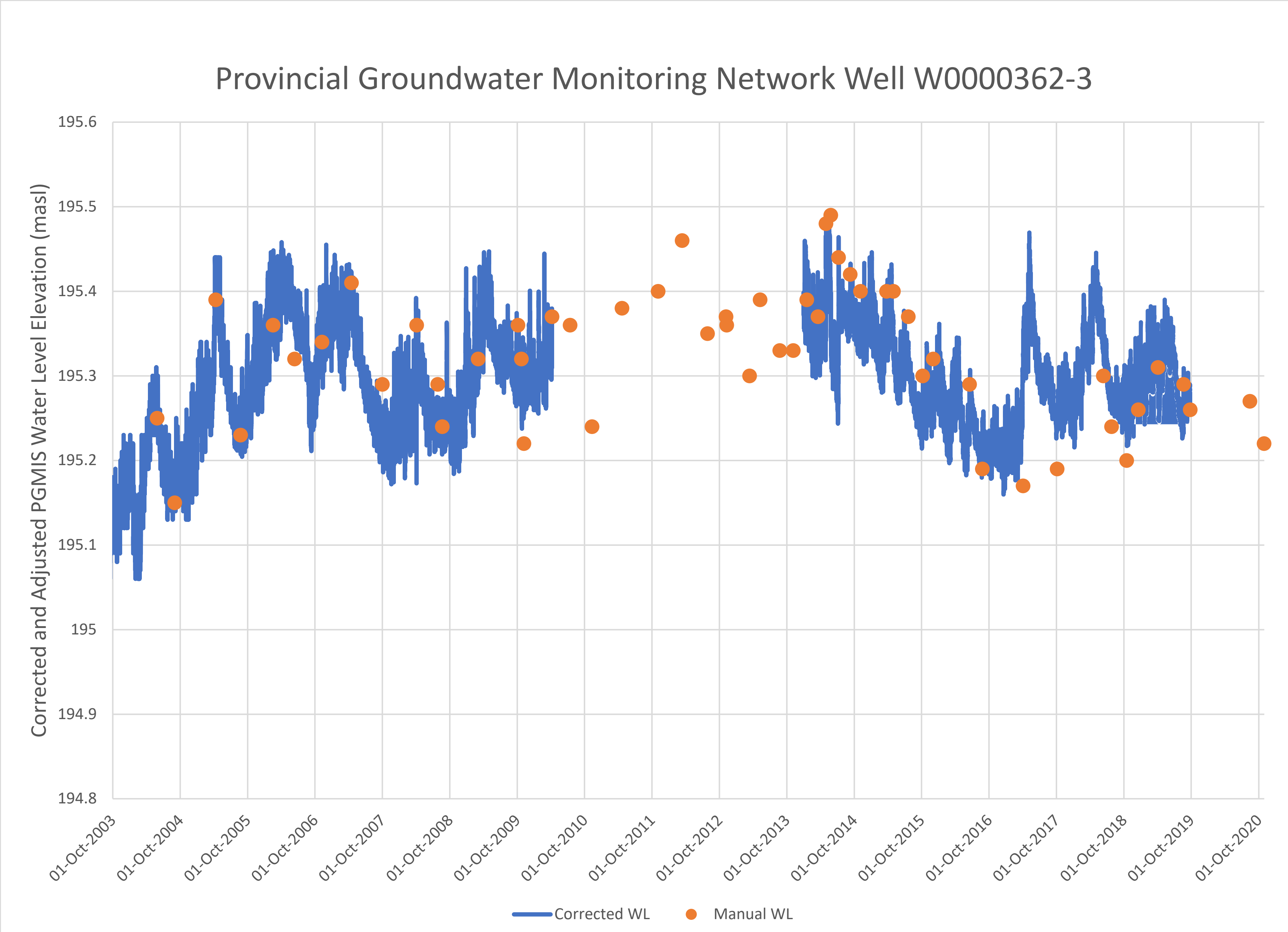
Provincial Groundwater Monitoring Network Well W0000361-2
Corrected and Adjusted PGMIS Water Level Elevation (masl)
204.2
204
203.8
203.6
203.4
203.2
203
202.8
202.6
202.4
01-Oct-2003
01-Oct-2004
01-Oct-2005
01-Oct-2006
01-Oct-2007
01-Oct-2008
01-Oct-2009
01-Oct-2010
01-Oct-2011
01-Oct-2012
01-Oct-2013
01-Oct-2014
01-Oct-2015
01-Oct-2016
01-Oct-2017
01-Oct-2018
01-Oct-2019
01-Oct-2020
Corrected WL
Manual Water Level



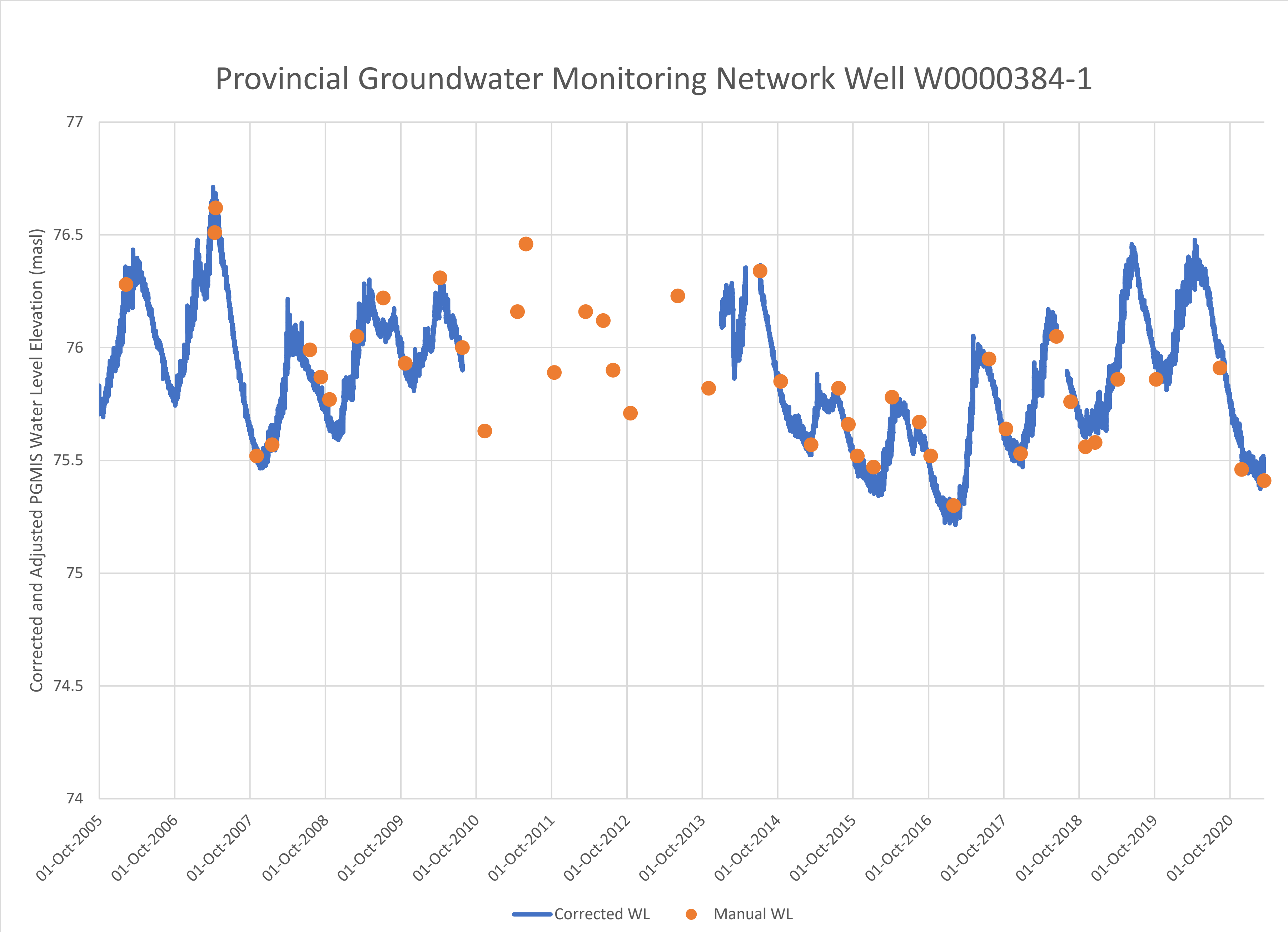
Provincial Groundwater Monitoring Network Well W0000361-3
Corrected and Adjusted PGMIS Water Level Elevation (masl)
194.8
194.6
194.4
194.2
194
193.8
193.6
193.4
01-Oct-2003
01-Oct-2004
01-Oct-2005
01-Oct-2006
01-Oct-2007
01-Oct-2008
01-Oct-2009
01-Oct-2010
01-Oct-2011
01-Oct-2012
01-Oct-2013
01-Oct-2014
01-Oct-2015
01-Oct-2016
01-Oct-2017
01-Oct-2018
01-Oct-2019
01-Oct-2020
Corrected WL
Manual WL

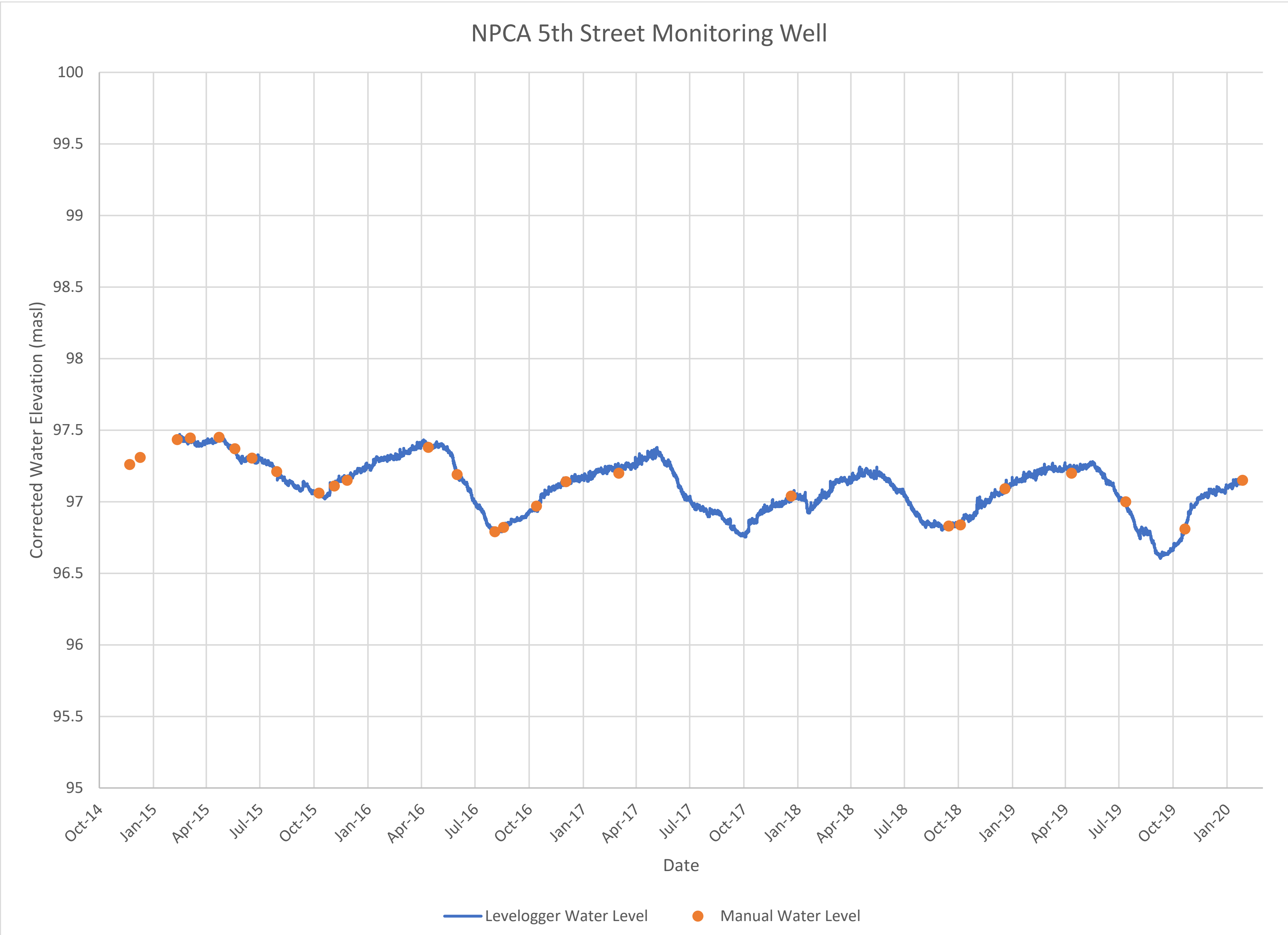


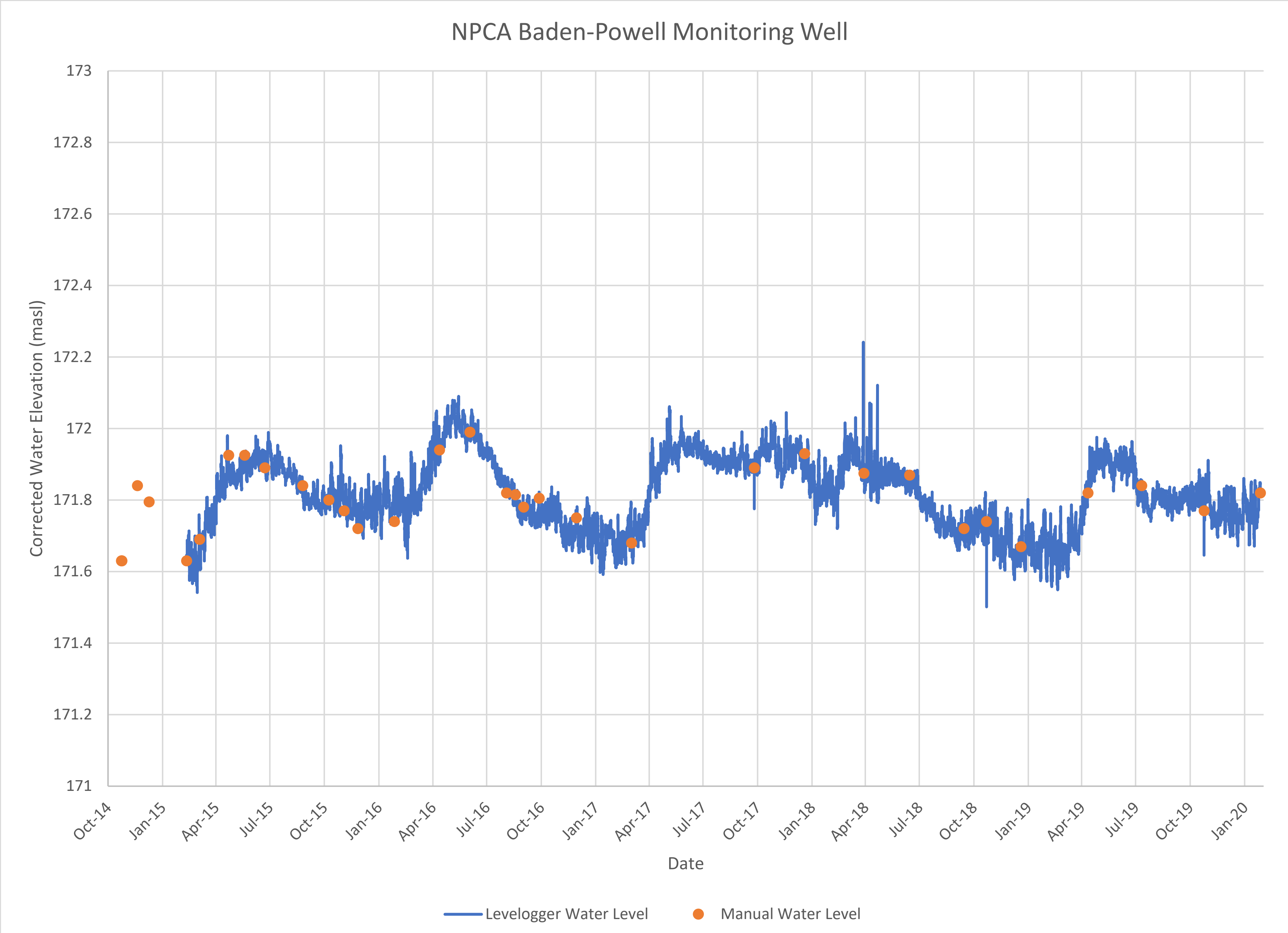
Provincial Groundwater Monitoring Network Well W0000362-2
Corrected and Adjusted PGMIS Water Level Elevation (masl)
195.6000
195.5000
195.4000
195.3000
195.2000
195.1000
195.0000
194.9000
194.8000
194.7000
01-Oct-2003
01-Oct-2004
01-Oct-2005
01-Oct-2006
01-Oct-2007
01-Oct-2008
01-Oct-2009
01-Oct-2010
01-Oct-2011
01-Oct-2012
01-Oct-2013
01-Oct-2014
01-Oct-2015
01-Oct-2016
01-Oct-2017
01-Oct-2018
01-Oct-2019
01-Oct-2020
Corrected WL
Manual WL



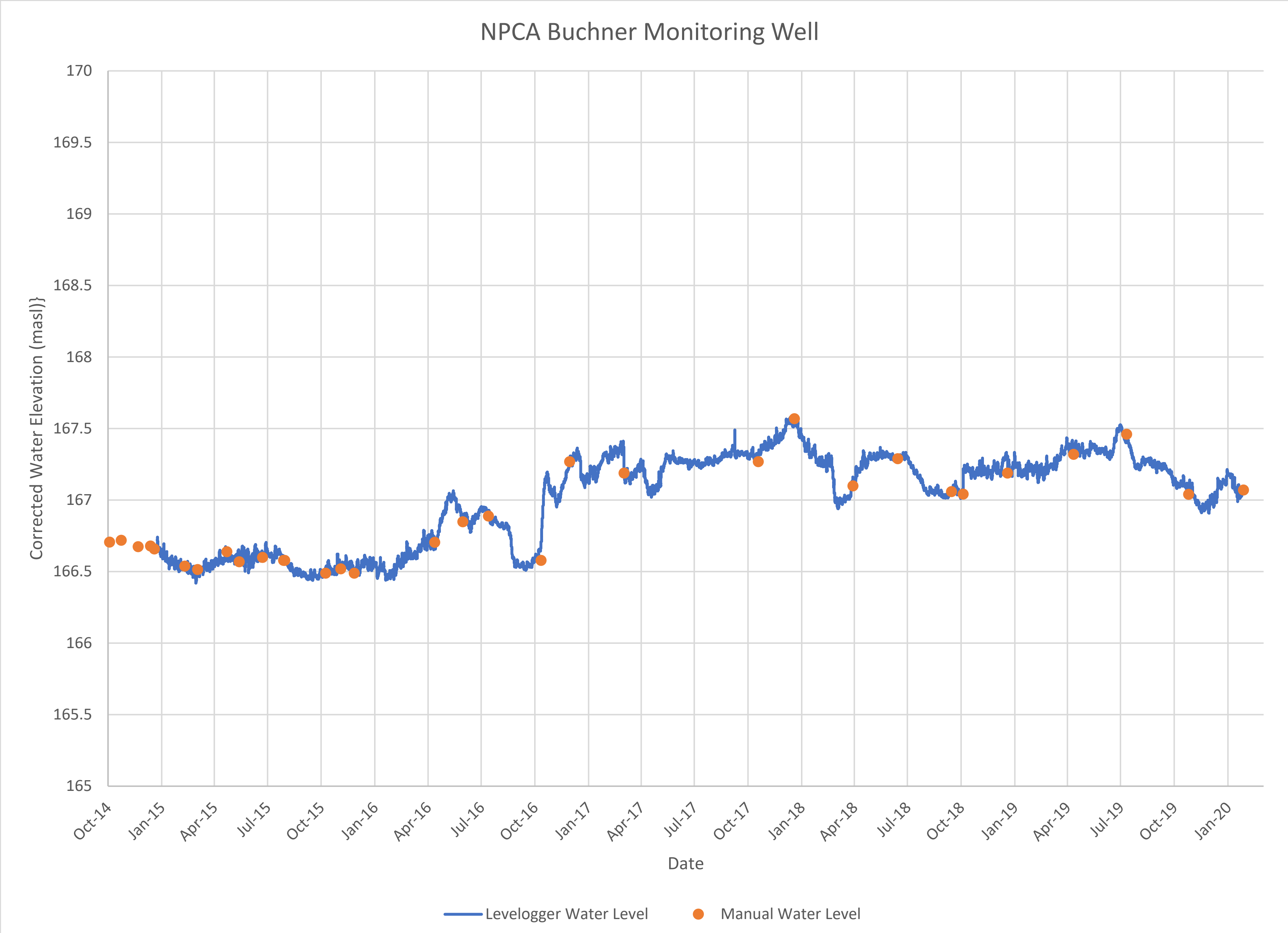
Provincial Groundwater Monitoring Network Well W0000362-3
Corrected and Adjusted PGMIS Water Level Elevation (masl)
195.6
195.5
195.4
195.3
195.2
195.1
195
194.9
194.8
01-Oct-2003
01-Oct-2004
01-Oct-2005
01-Oct-2006
01-Oct-2007
01-Oct-2008
01-Oct-2009
01-Oct-2010
01-Oct-2011
01-Oct-2012
01-Oct-2013
01-Oct-2014
01-Oct-2015
01-Oct-2016
01-Oct-2017
01-Oct-2018
01-Oct-2019
01-Oct-2020
Corrected WL
Manual WL

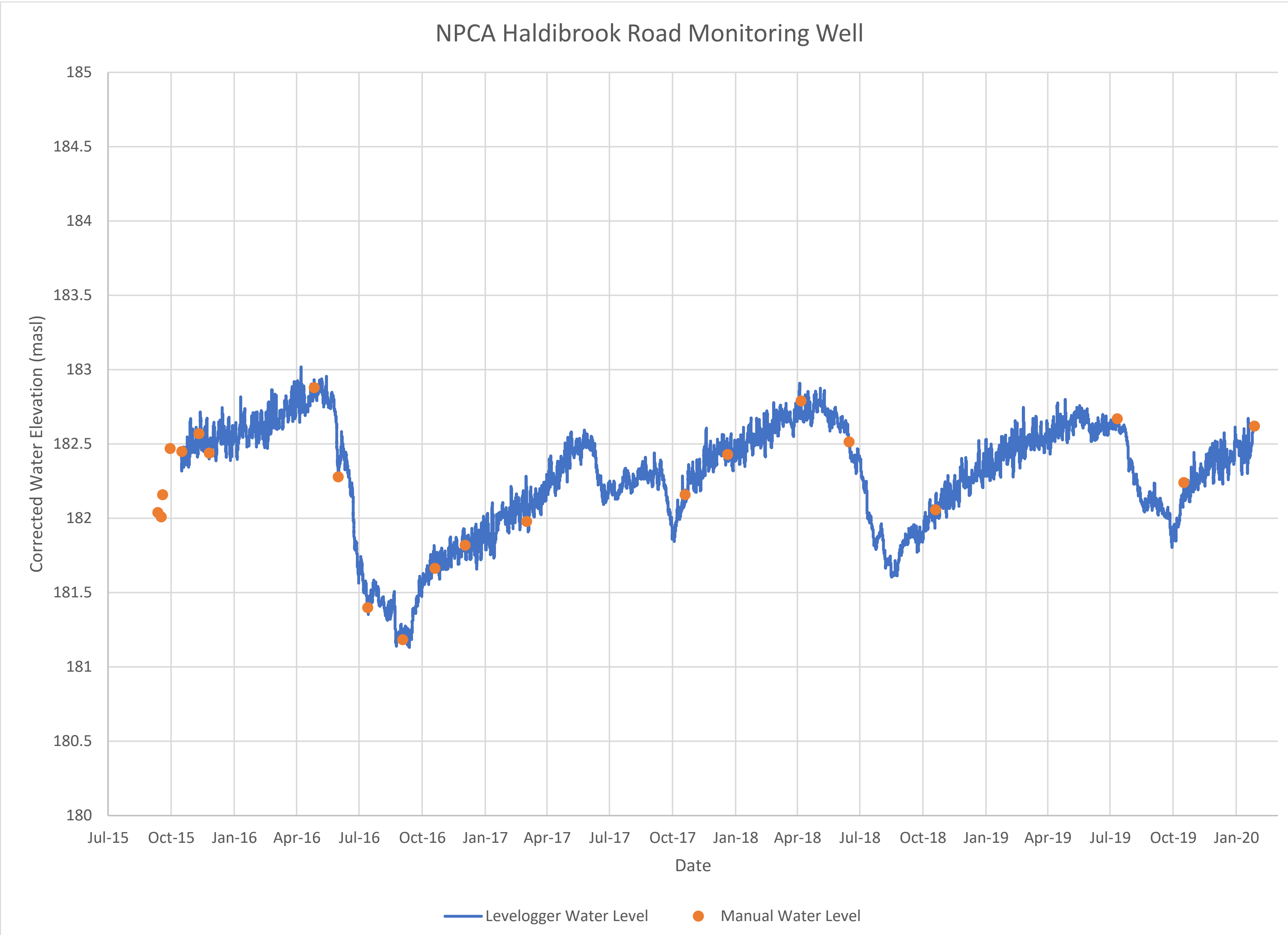

Provincial Groundwater Monitoring Network Well W0000384-1
Corrected and Adjusted PGMIS Water Level Elevation (masl)
77
76.5
76
75.5
75
74.5
74
01-Oct-2005
01-Oct-2006
01-Oct-2007
01-Oct-2008
01-Oct-2009
01-Oct-2010
01-Oct-2011
01-Oct-2012
01-Oct-2013
01-Oct-2014
01-Oct-2015
01-Oct-2016
01-Oct-2017
01-Oct-2018
01-Oct-2019
01-Oct-2020
Corrected WL
Manual WL


NPCA 5th Street Monitoring Well
100
99.5
99
98.5
98
97.5
97
96.5
96
95.5
95
Corrected Water Elevation (masl)
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level

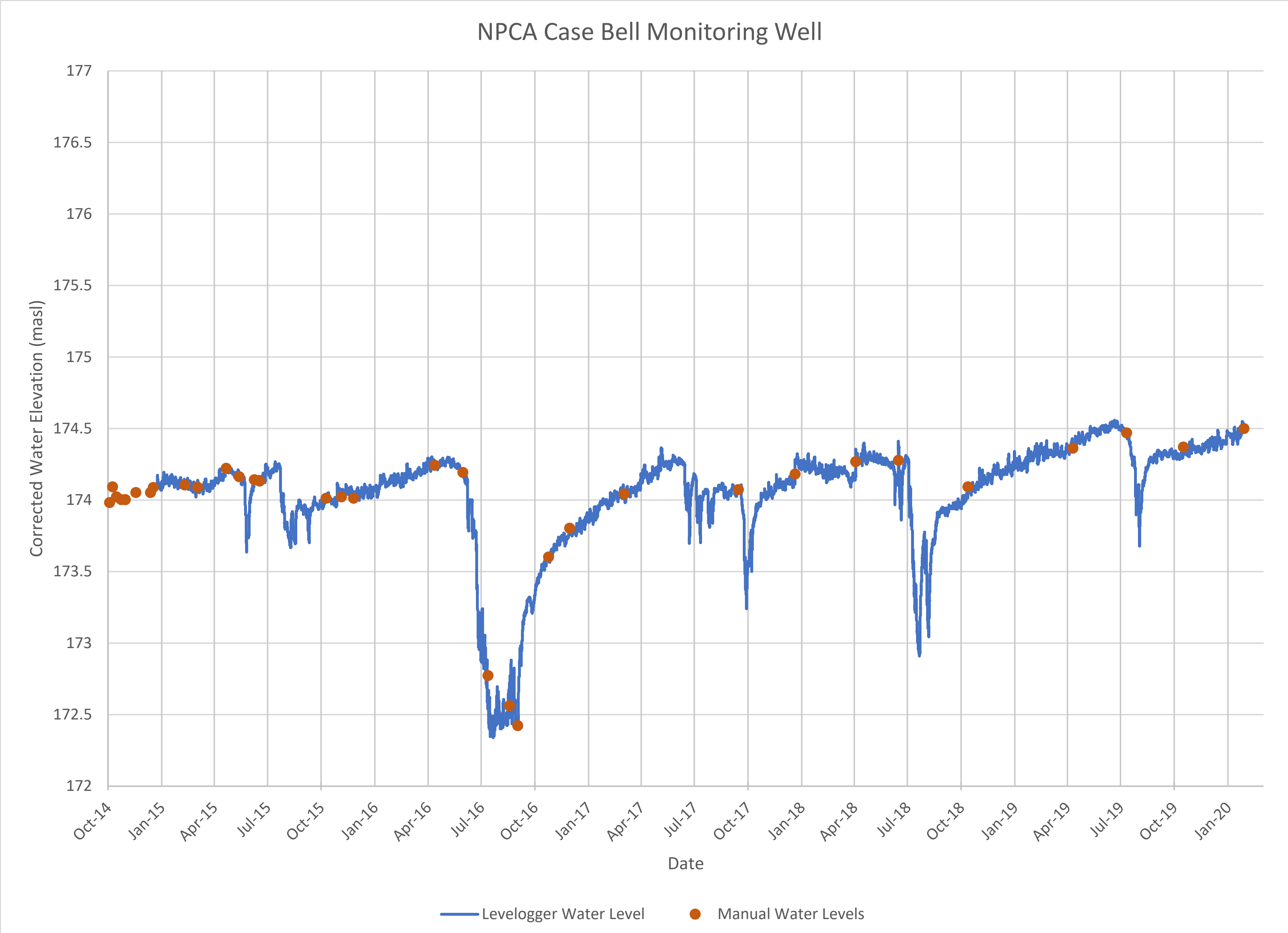


NPCA Baden-Powell Monitoring Well
Corrected Water Elevation (masl)
173
172.8
172.6
172.4
172.2
172
171.8
171.6
171.4
171.2
171
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level

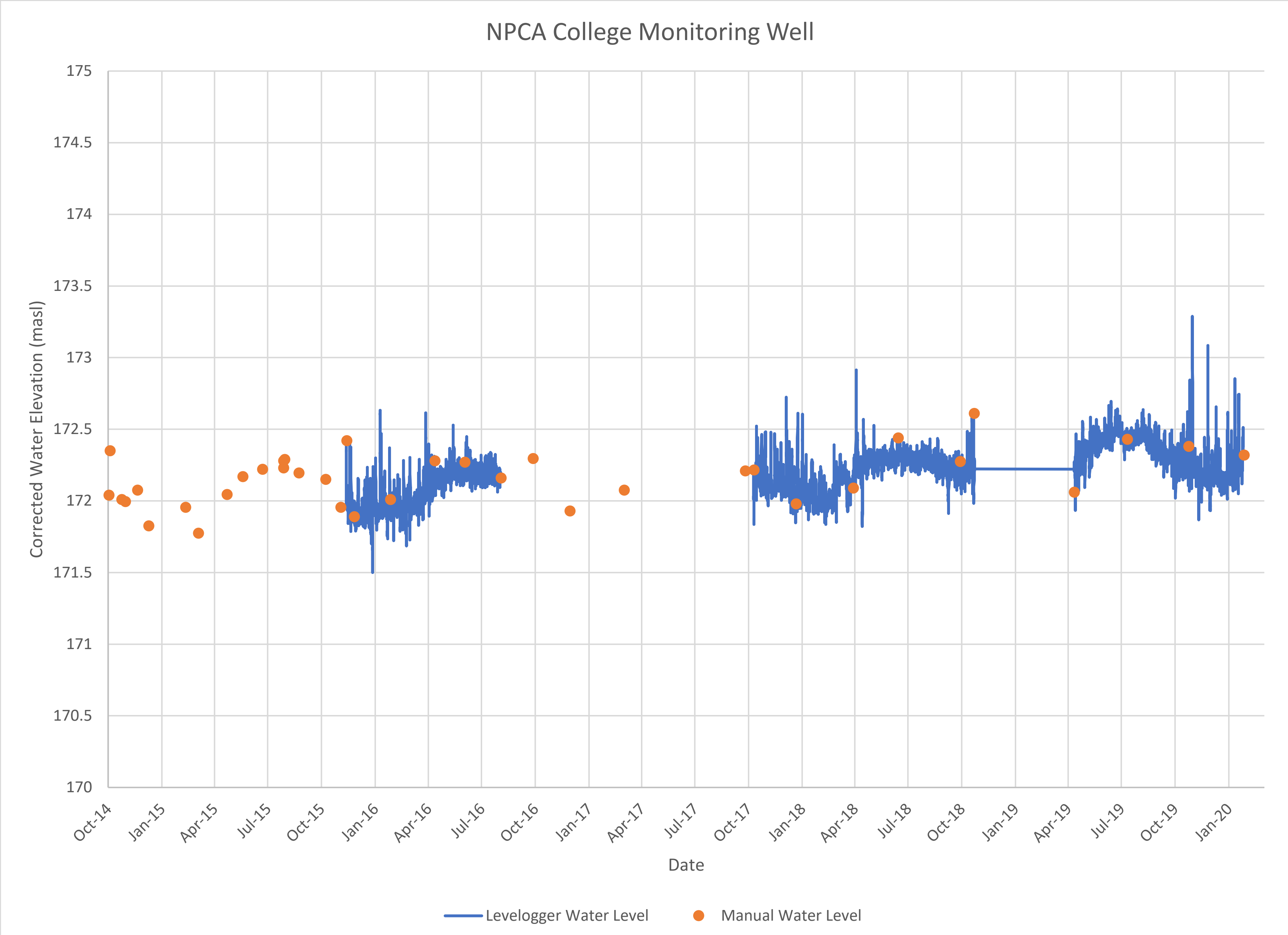

NPCA Buchner Monitoring Well
Corrected Water Elevation (masl)}
170
169.5
169
168.5
168
167.5
167
166.5
166
165.5
165
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level

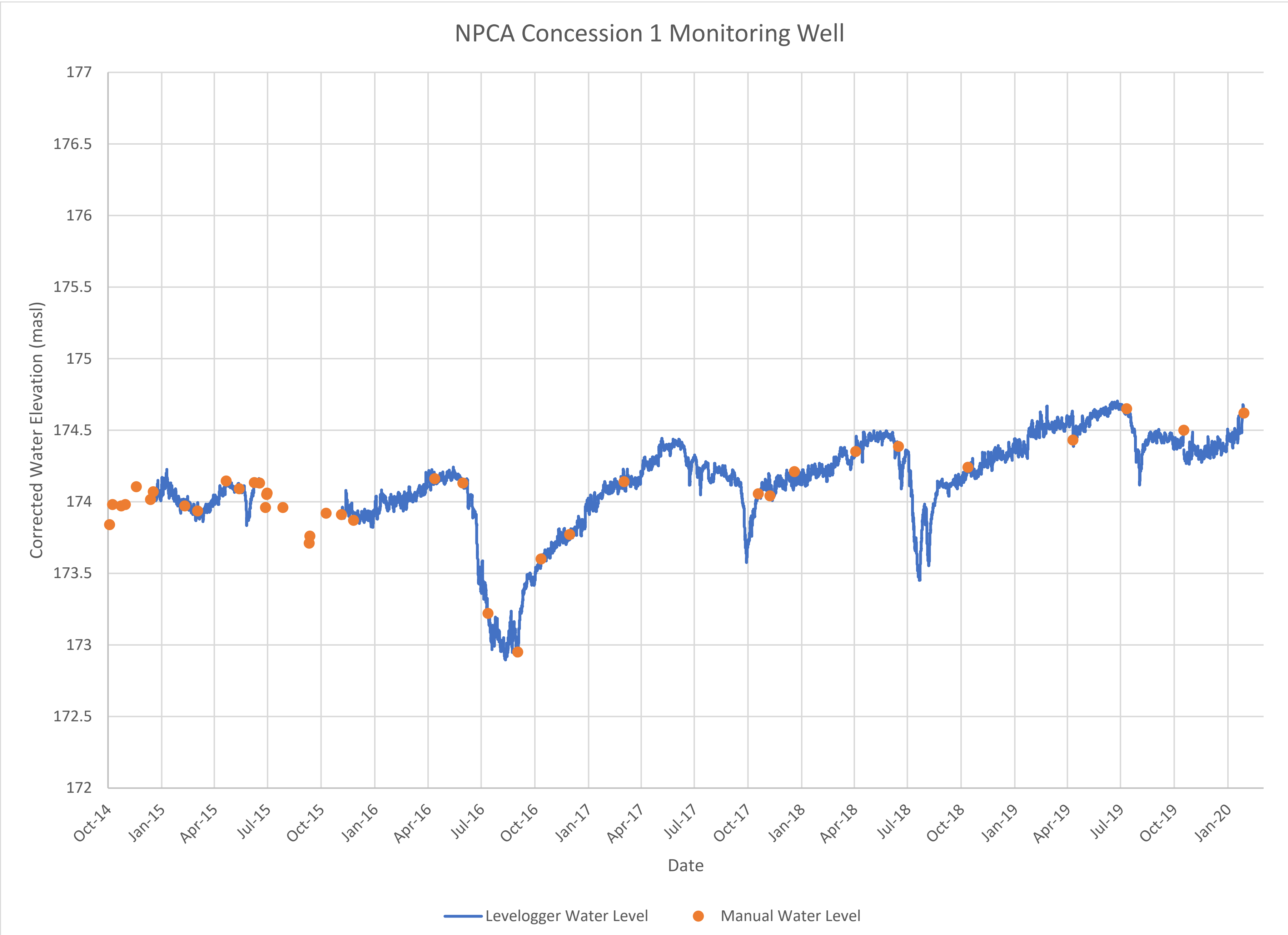


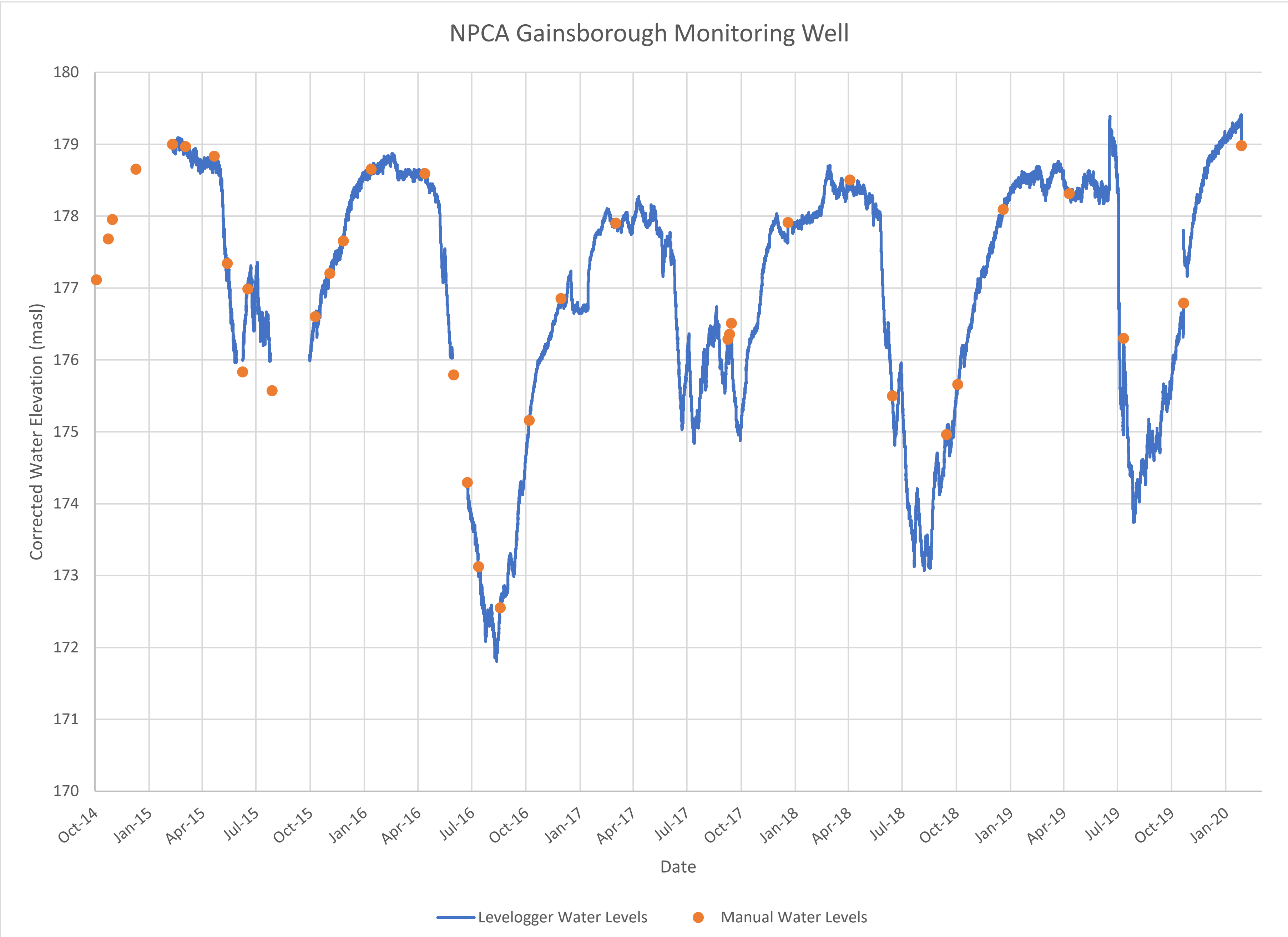
NPCA Haldibrook Road Monitoring Well
185
184.5
184
183.5
183
182.5
182
181.5
181
180.5
180
Corrected Water Elevation (masl)
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level



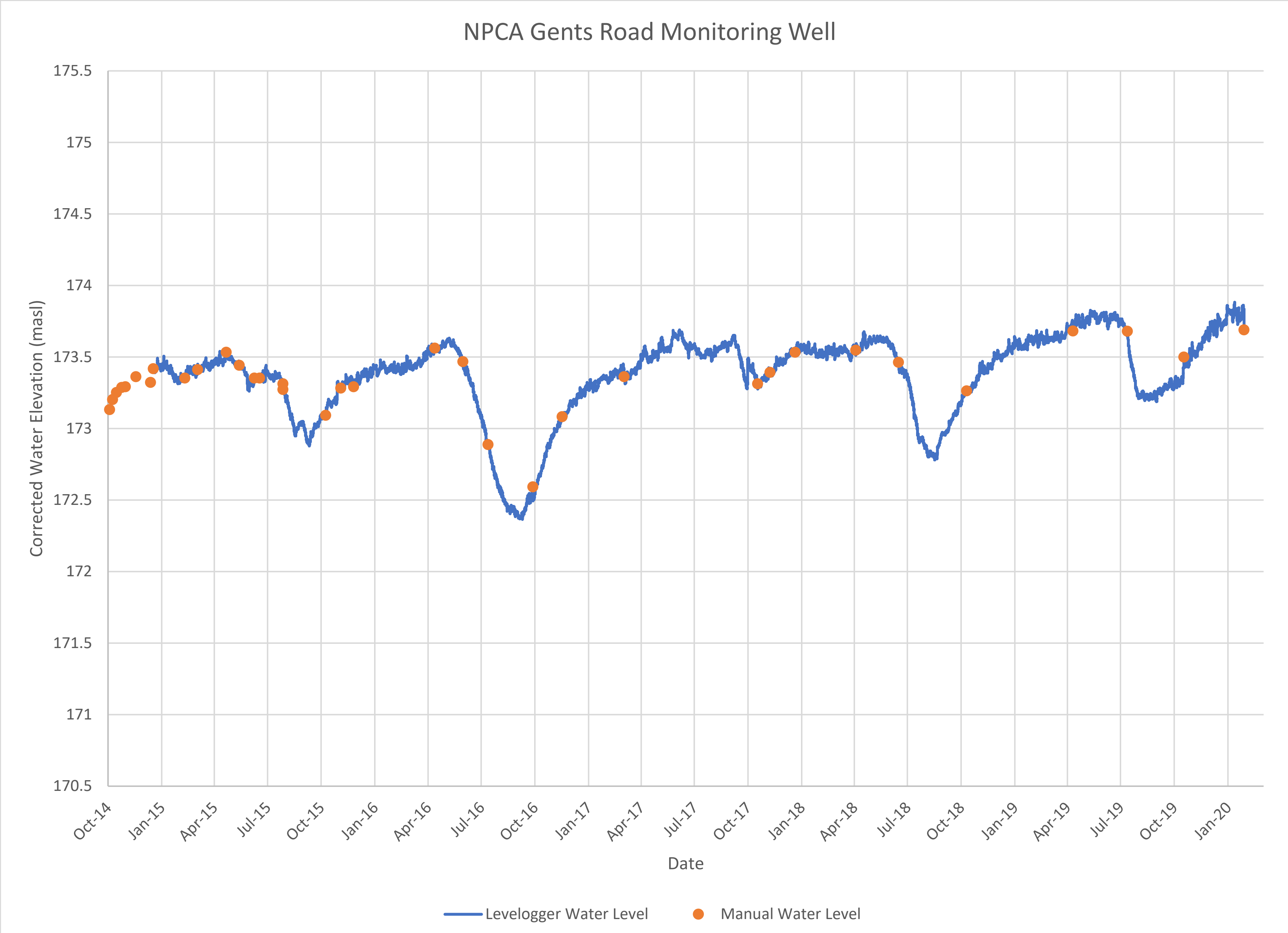
NPCA Case Bell Monitoring Well
Corrected Water Elevation (masl)
177
176.5
176
175.5
175
174.5
174
173.5
173
172.5
172
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Levels

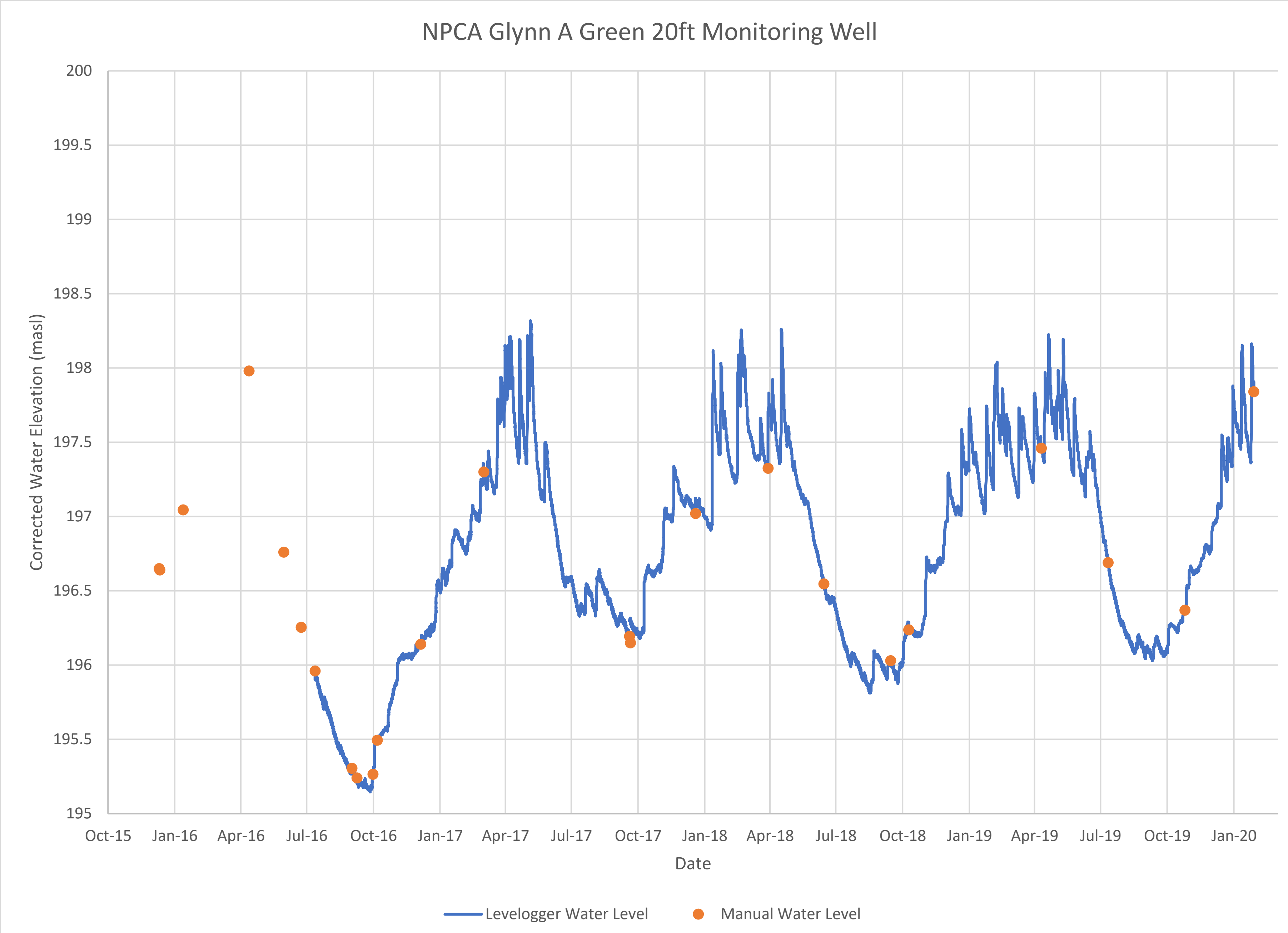

NPCA College Monitoring Well
175
174.5
174
173.5
173
172.5
172
171.5
171
170.5
170
Corrected Water Elevation (masl)
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level


NPCA Concession 1 Monitoring Well
Corrected Water Elevation (masl)
177
176.5
176
175.5
175
174.5
174
173.5
173
172.5
172
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level

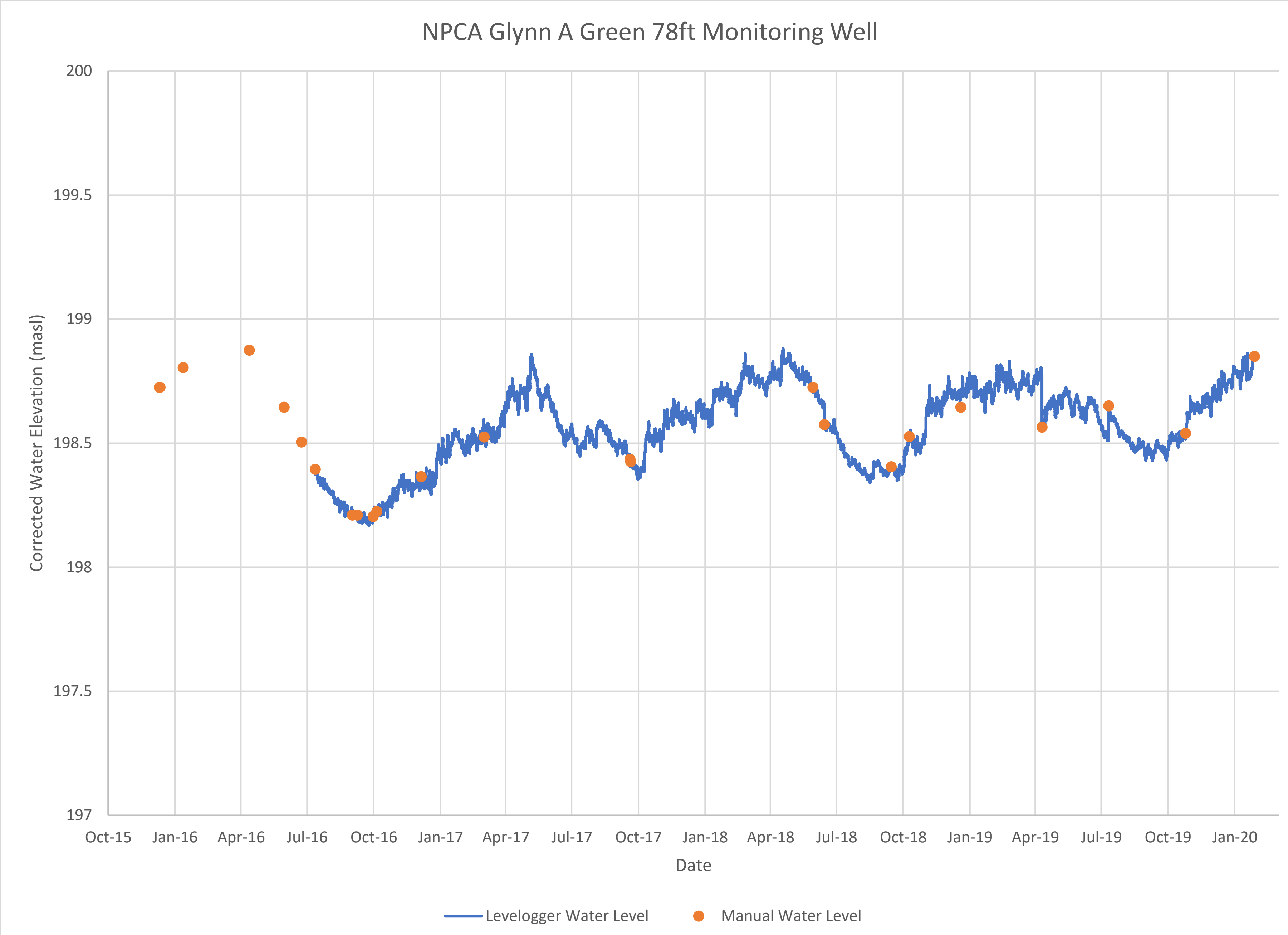


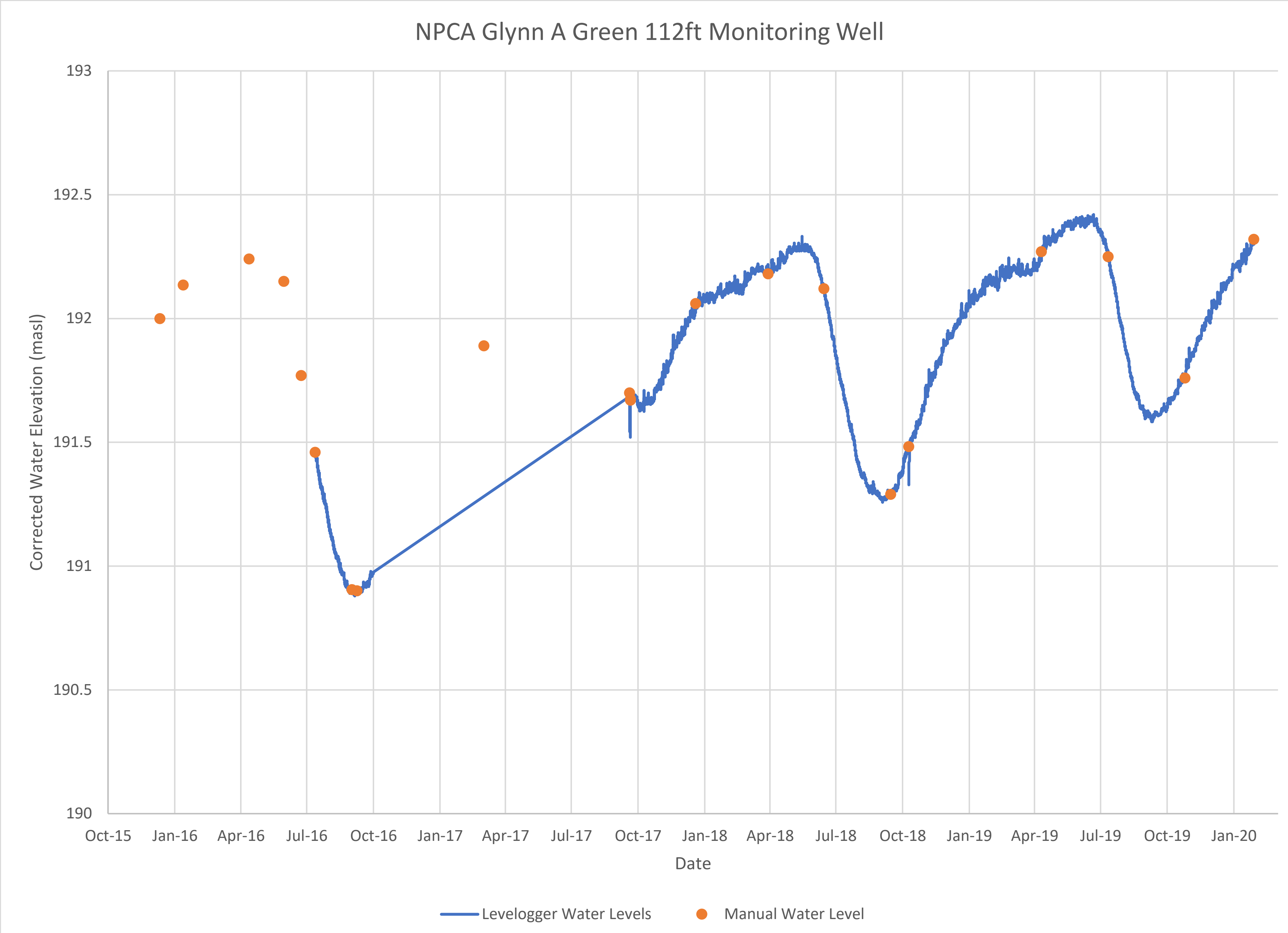
NPCA Gainsborough Monitoring Well
Corrected Water Elevation (masl)
180
179
178
177
176
175
174
173
172
171
170
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Levels
Manual Water Levels


NPCA Gents Road Monitoring Well
Corrected Water Elevation (masl)
175.5
175
174.5
174
173.5
173
172.5
172
171.5
171
170.5
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level

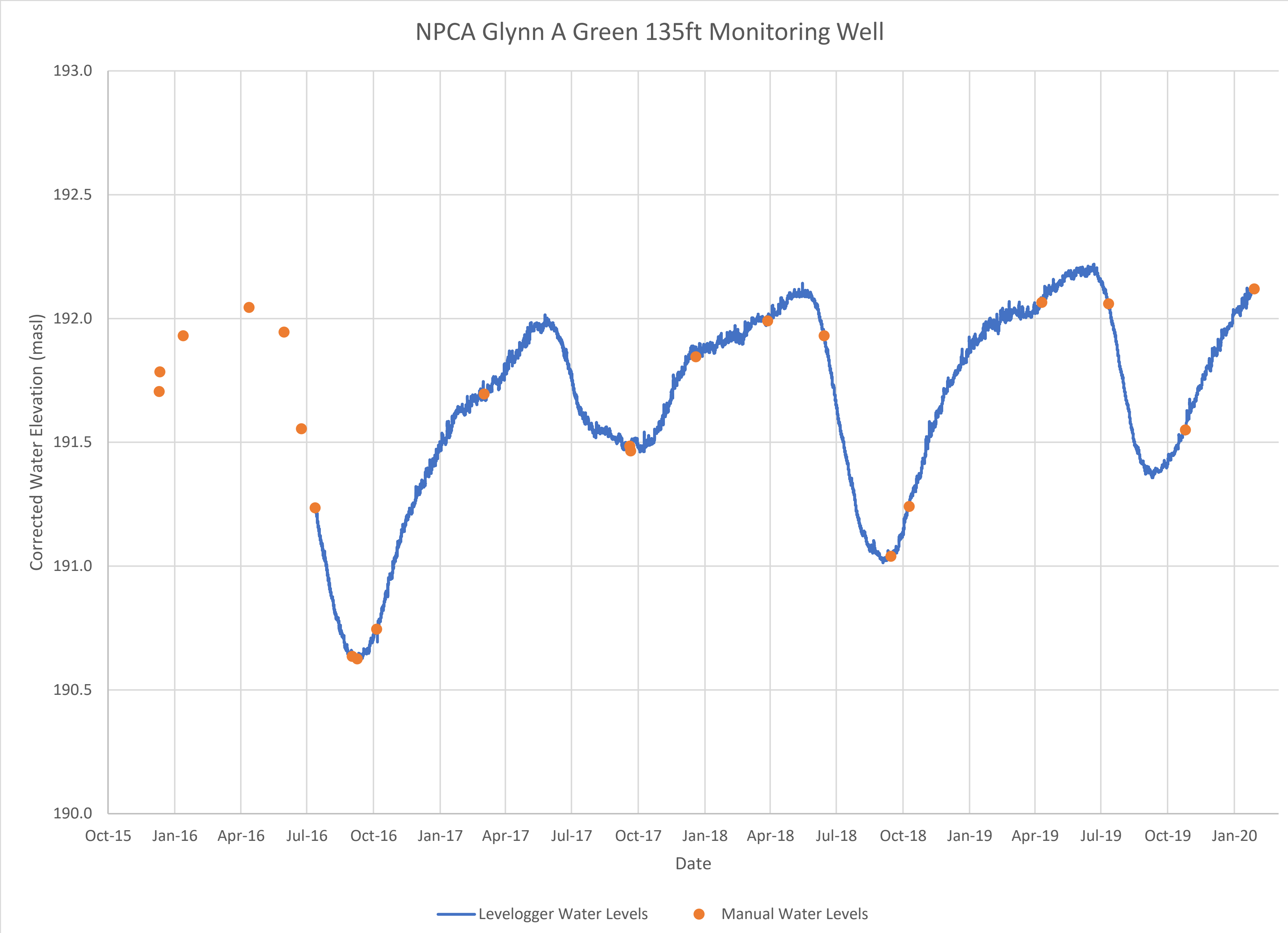


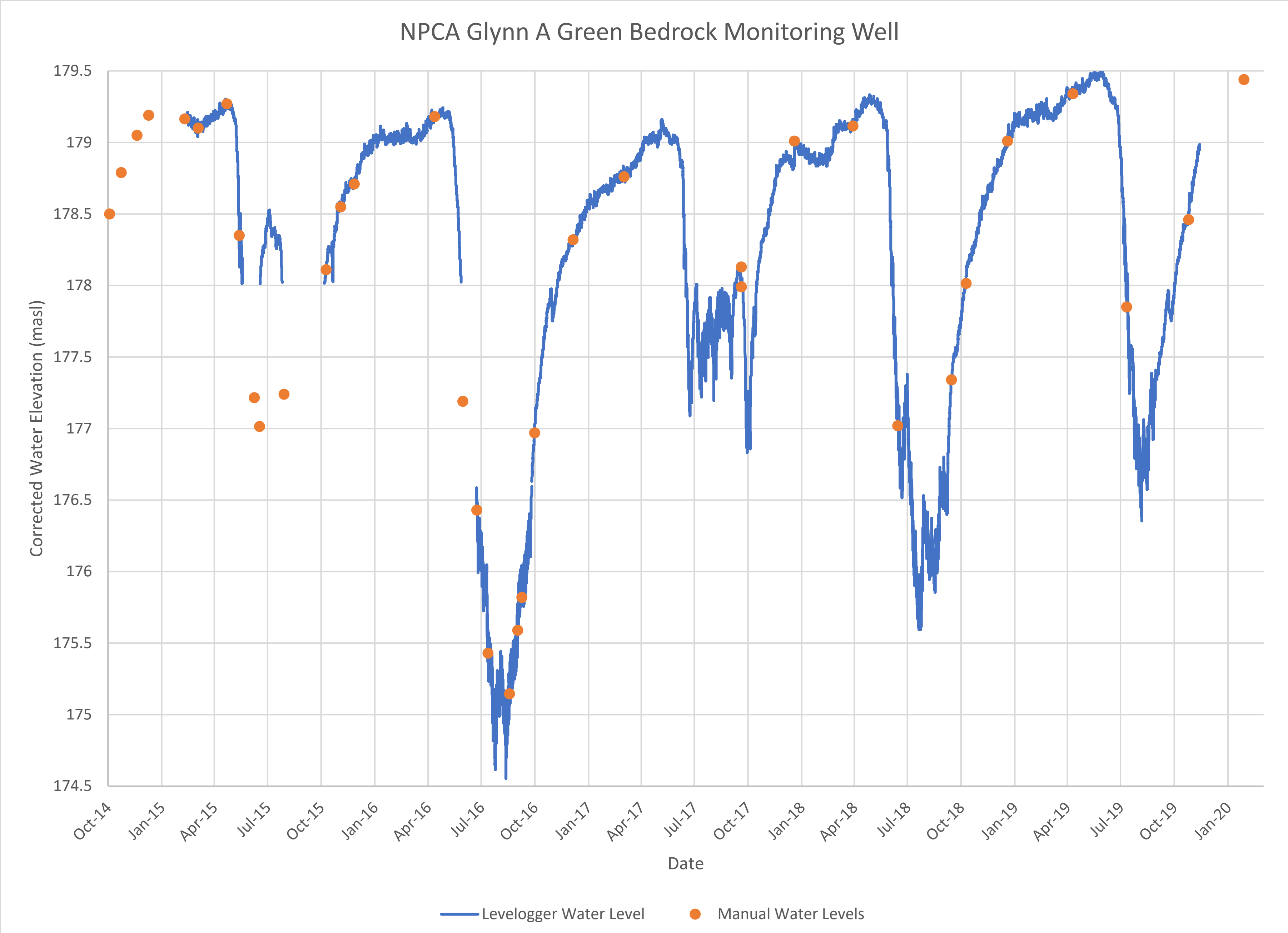
NPCA Glynn A Green 20ft Monitoring Well
Corrected Water Elevation (masl)
200
199.5
199
198.5
198
197.5
197
196.5
196
195.5
195
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level


NPCA Glynn A Green 78ft Monitoring Well
Corrected Water Elevation (masl)
200
199.5
199
198.5
198
197.5
197
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level

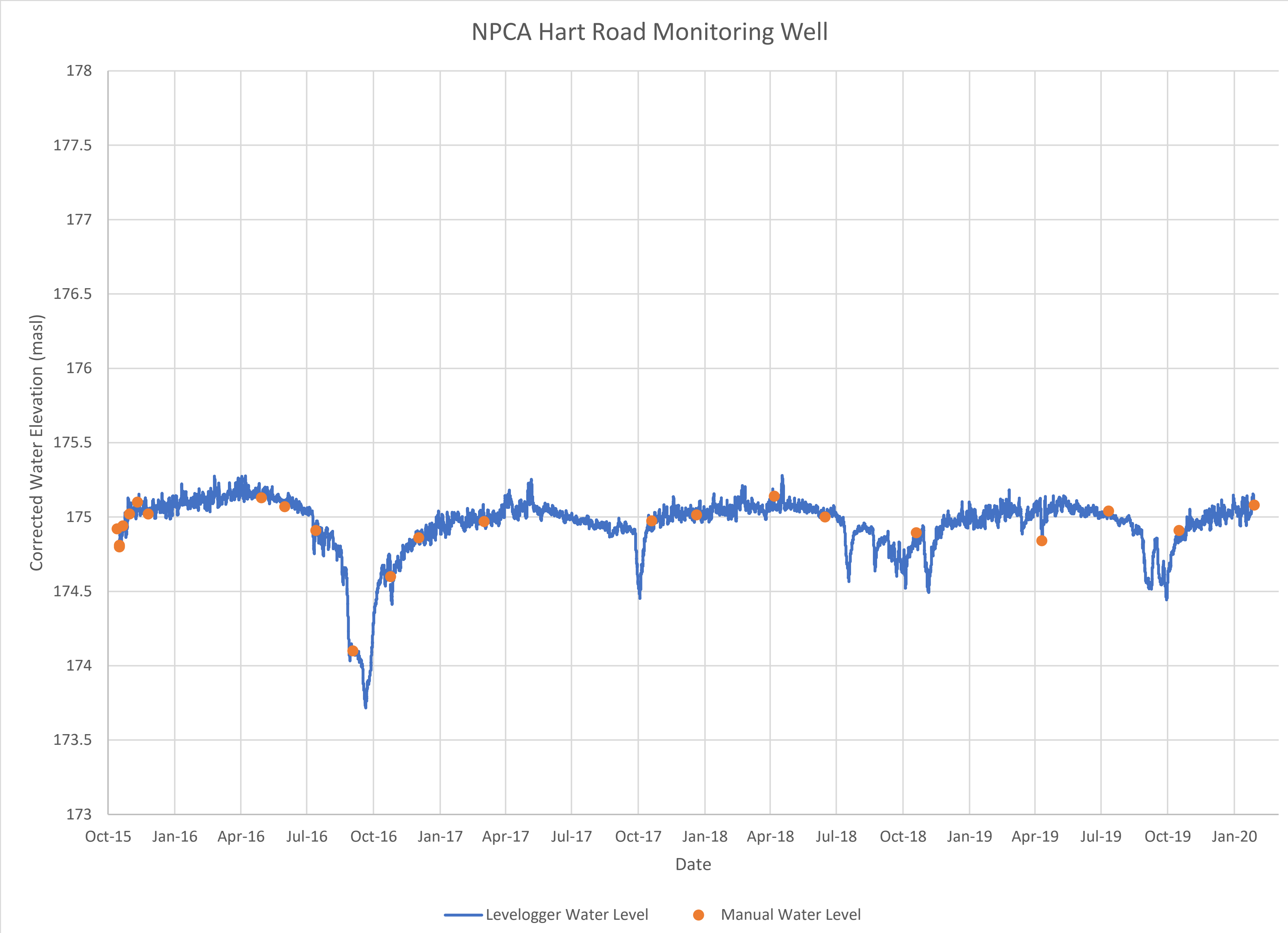


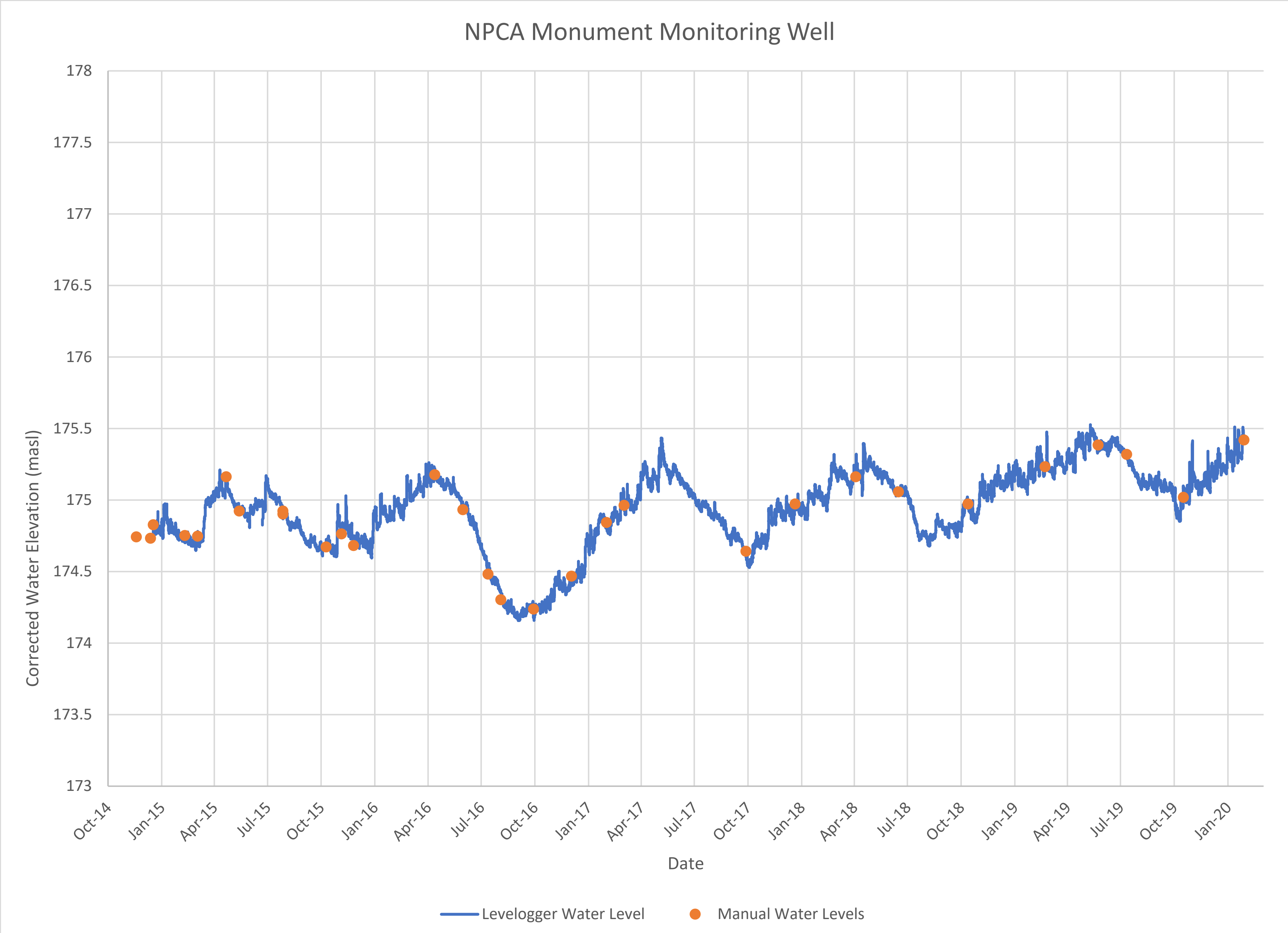
NPCA Glynn A Green 112ft Monitoring Well
Corrected Water Elevation (masl)
193
192.5
192
191.5
191
190.5
190
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Levels
Manual Water Level

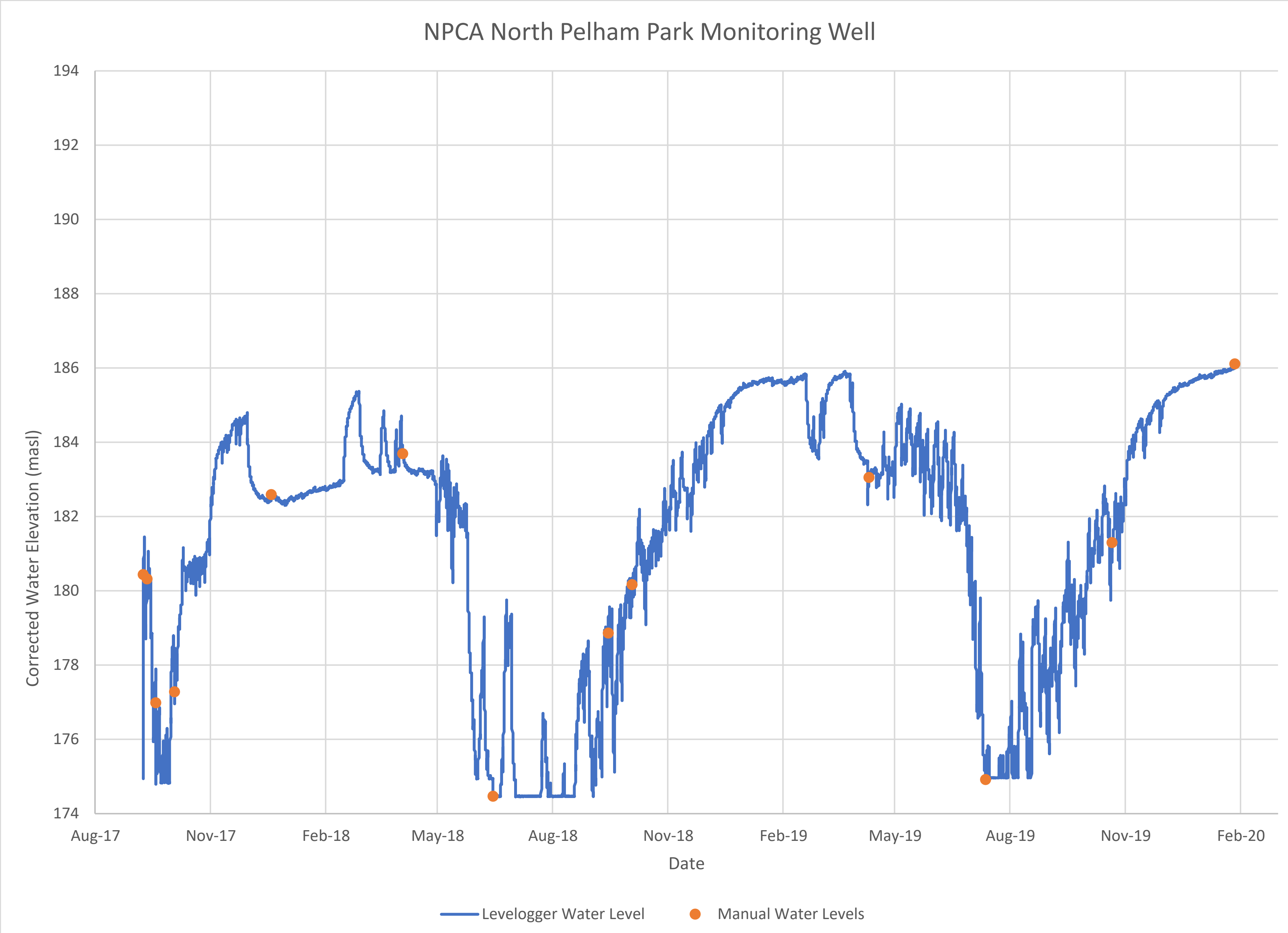

NPCA Glynn A Green 135ft Monitoring Well
Corrected Water Elevation (masl)
193.0
192.5
192.0
191.5
191.0
190.5
190.0
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Levels
Manual Water Levels



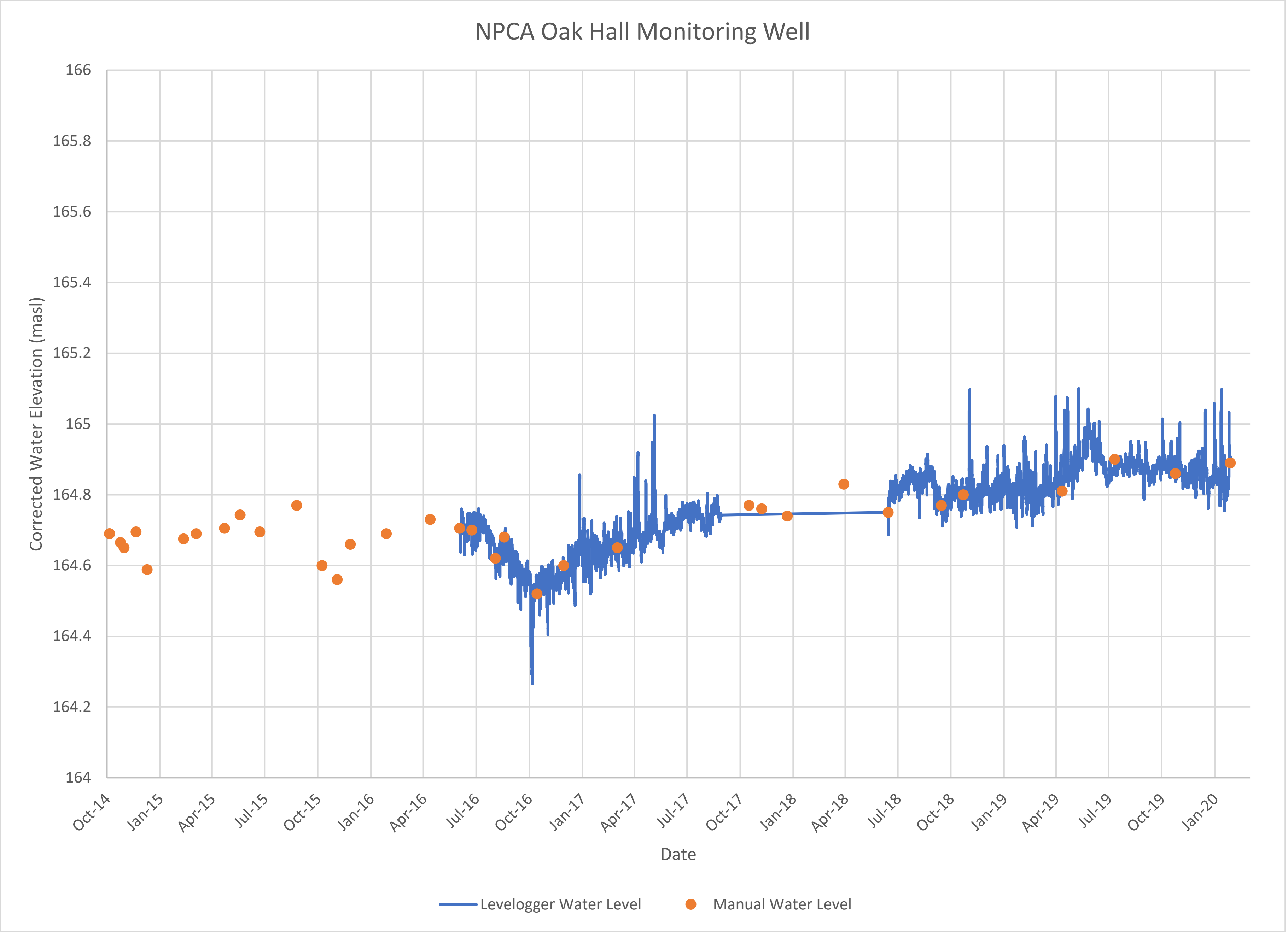
NPCA Glynn A Green Bedrock Monitoring Well
Corrected Water Elevation (masl)
179.5
179
178.5
178
177.5
177
176.5
176
175.5
175
174.5
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Levels


NPCA Hart Road Monitoring Well
Corrected Water Elevation (masl)
178
177.5
177
176.5
176
175.5
175
174.5
174
173.5
173
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level

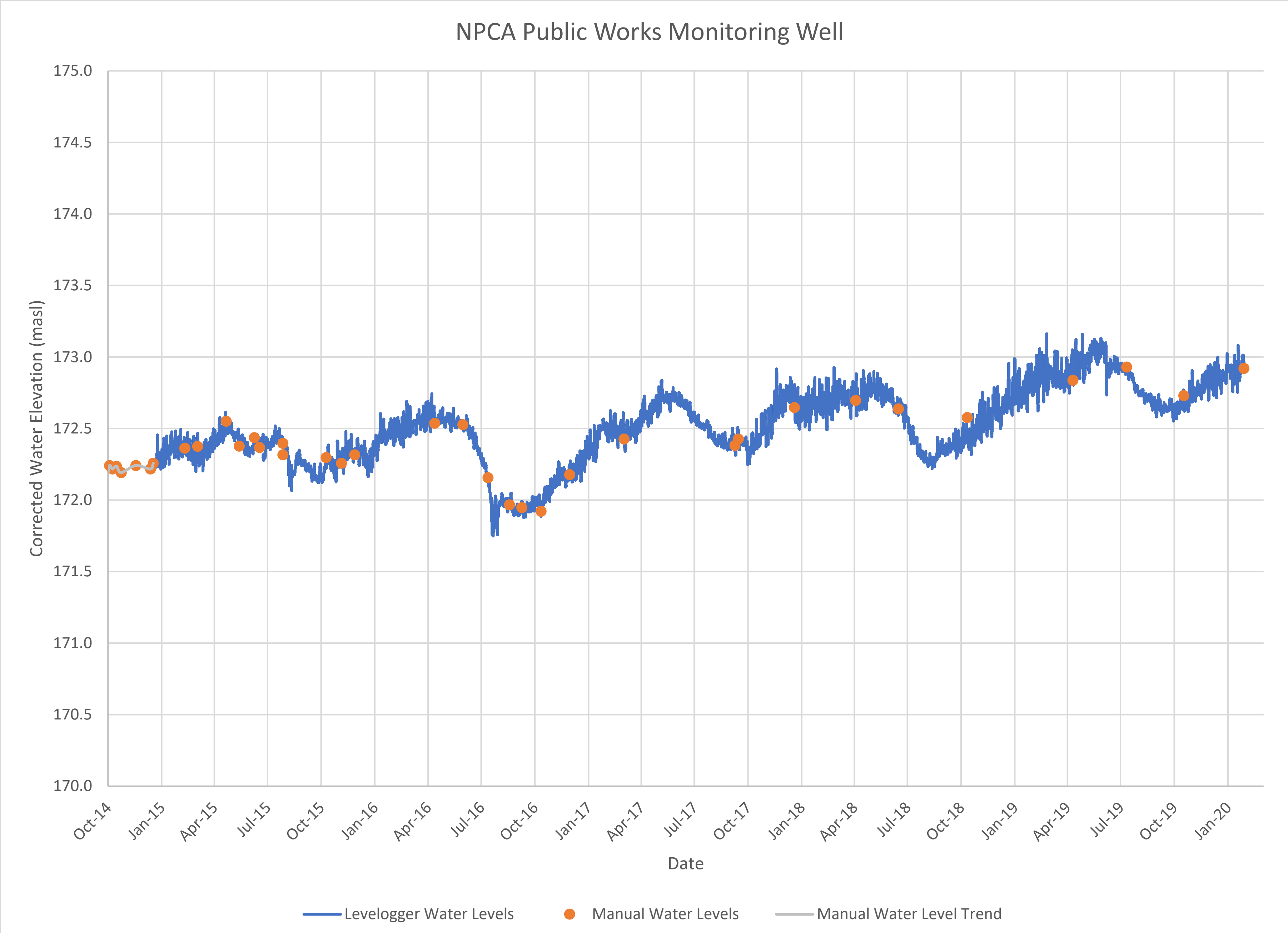

NPCA Monument Monitoring Well
Corrected Water Elevation (masl)
178
177.5
177
176.5
176
175.5
175
174.5
174
173.5
173
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Levels

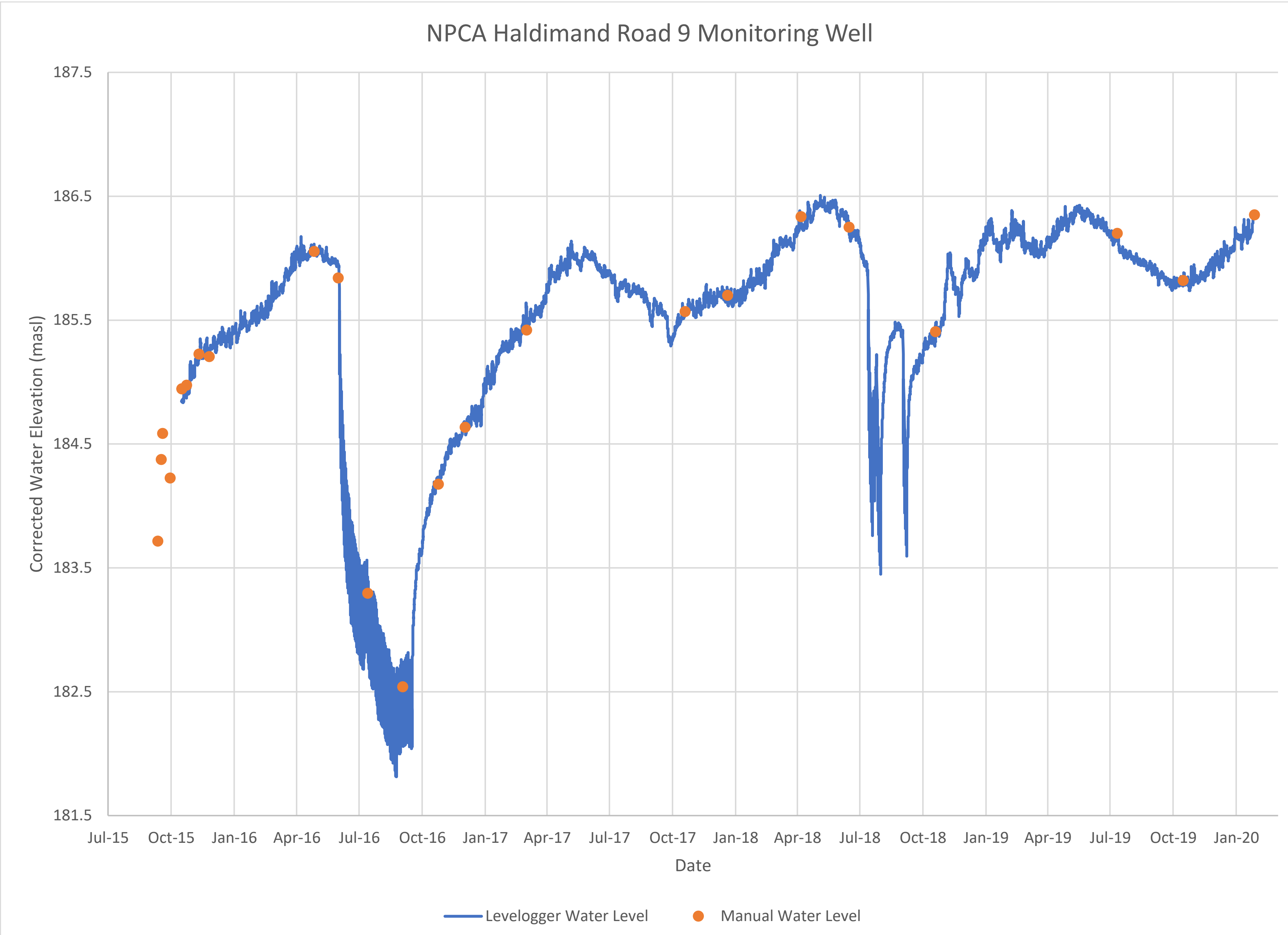


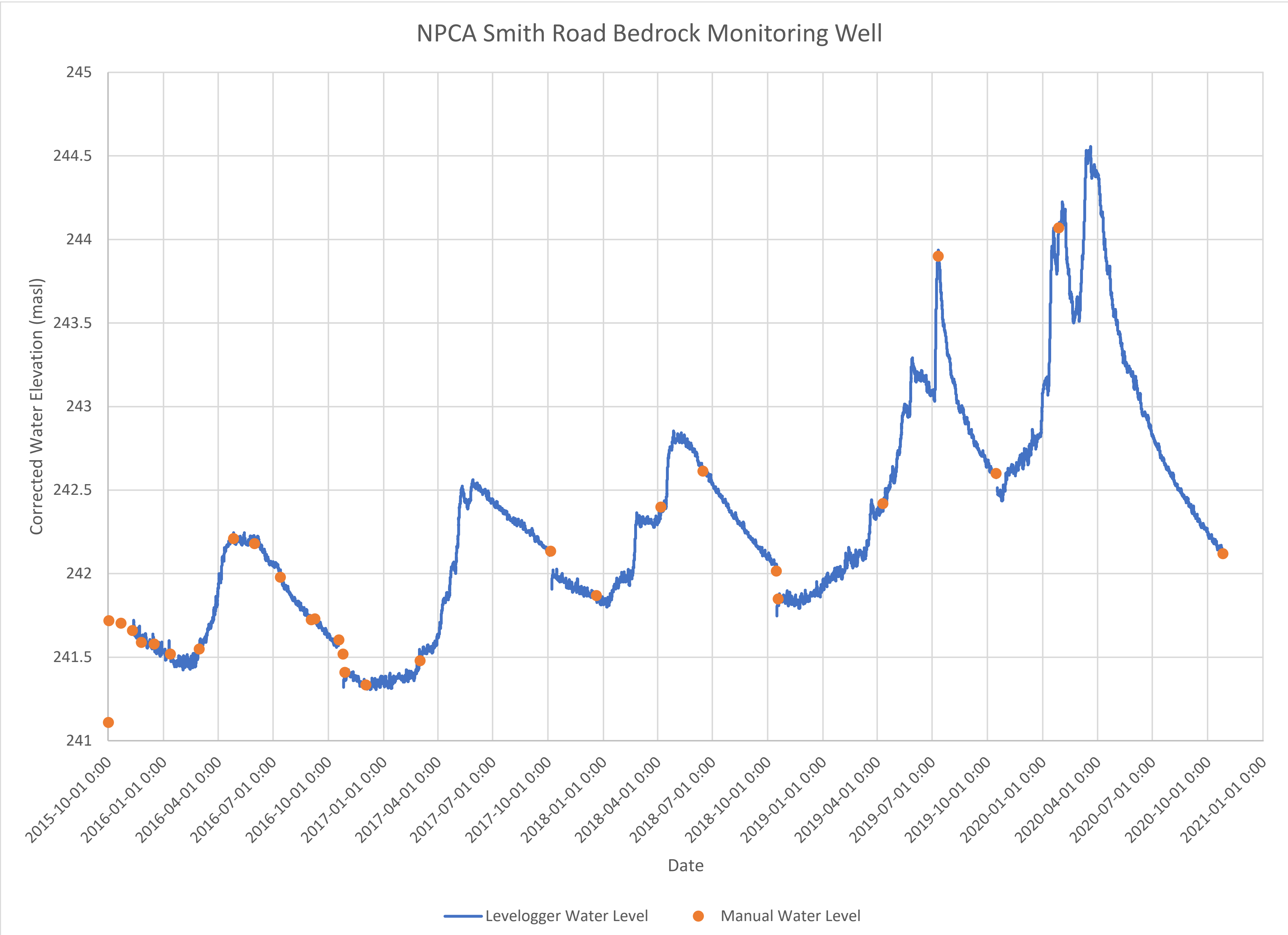
NPCA North Pelham Park Monitoring Well
Corrected Water Elevation (masl)
194
192
190
188
186
184
182
180
178
176
174
Aug-17
Nov-17
Feb-18
May-18
Aug-18
Nov-18
Feb-19
May-19
Aug-19
Nov-19
Feb-20
Date
Levelogger Water Level
Manual Water Levels



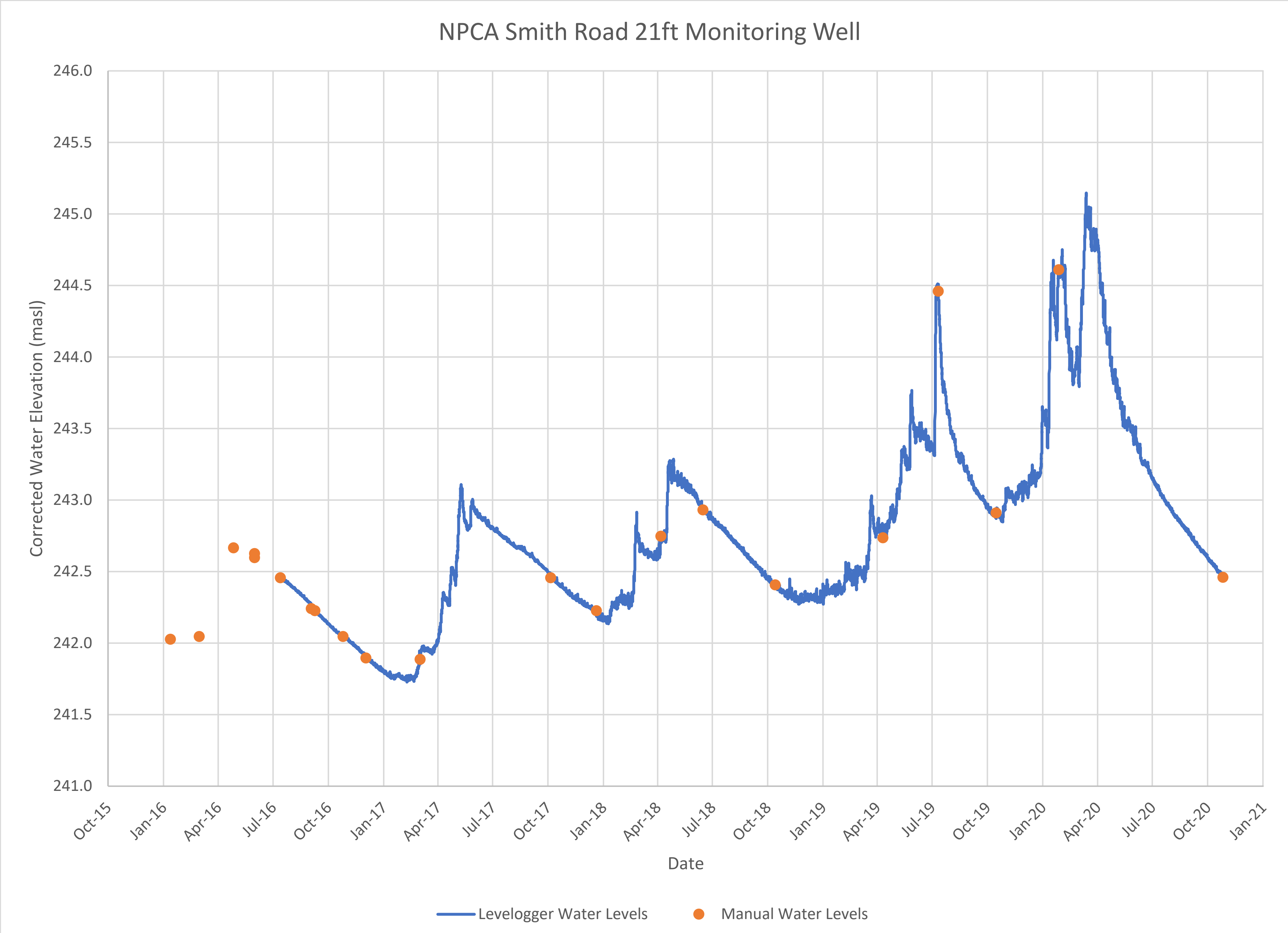
NPCA Oak Hall Monitoring Well
Corrected Water Elevation (masl)
166
165.8
165.6
165.4
165.2
165
164.8
164.6
164.4
164.2
164
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level


NPCA Public Works Monitoring Well
175.0
174.5
174.0
173.5
173.0
172.5
172.0
171.5
171.0
170.5
170.0
Corrected Water Elevation (masl)
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Levels
Manual Water Levels
Manual Water Level Trend

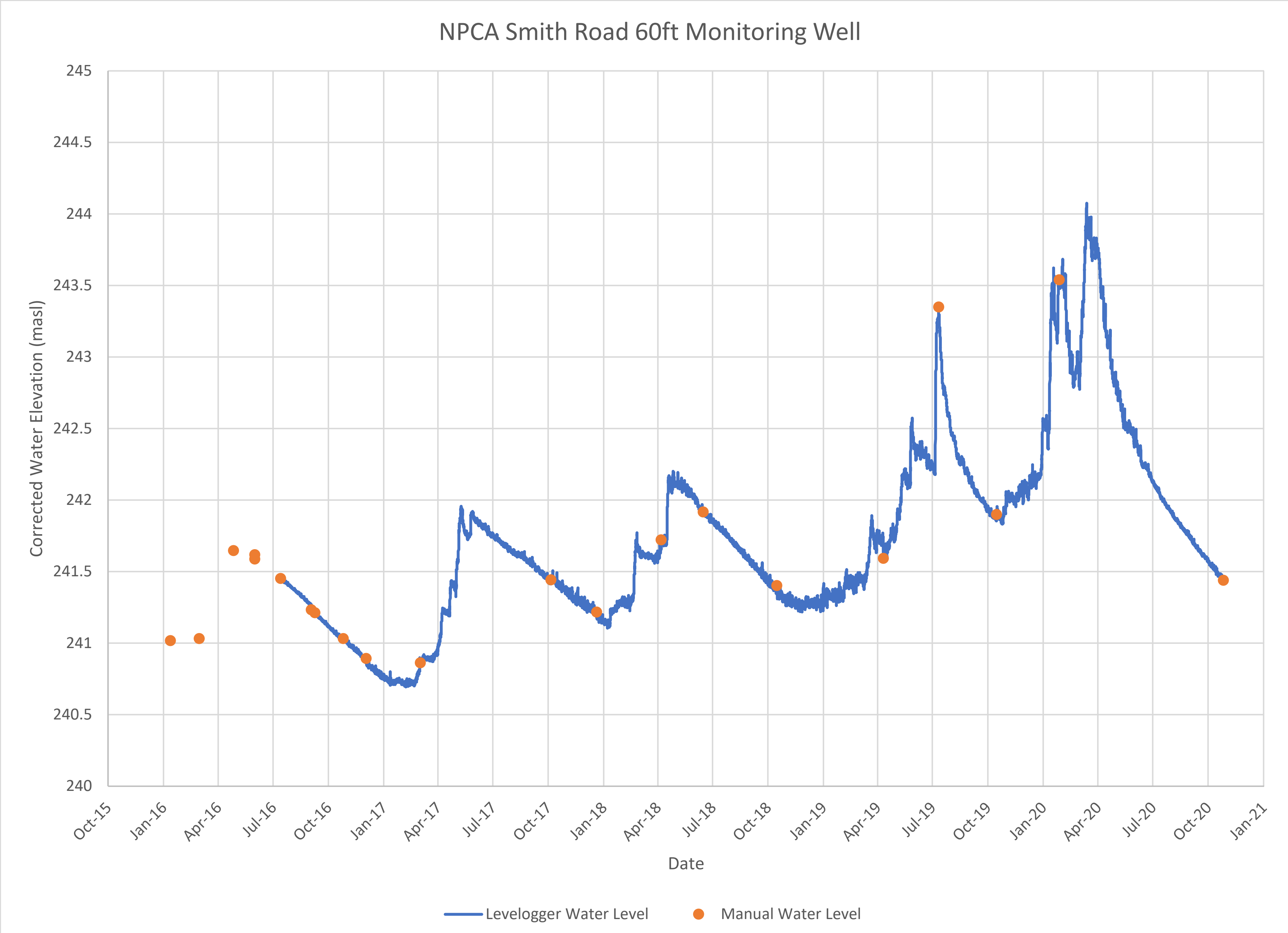

NPCA Haldimand Road 9 Monitoring Well
187.5
186.5
185.5
184.5
183.5
182.5
181.5
Corrected Water Elevation (masl)
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level

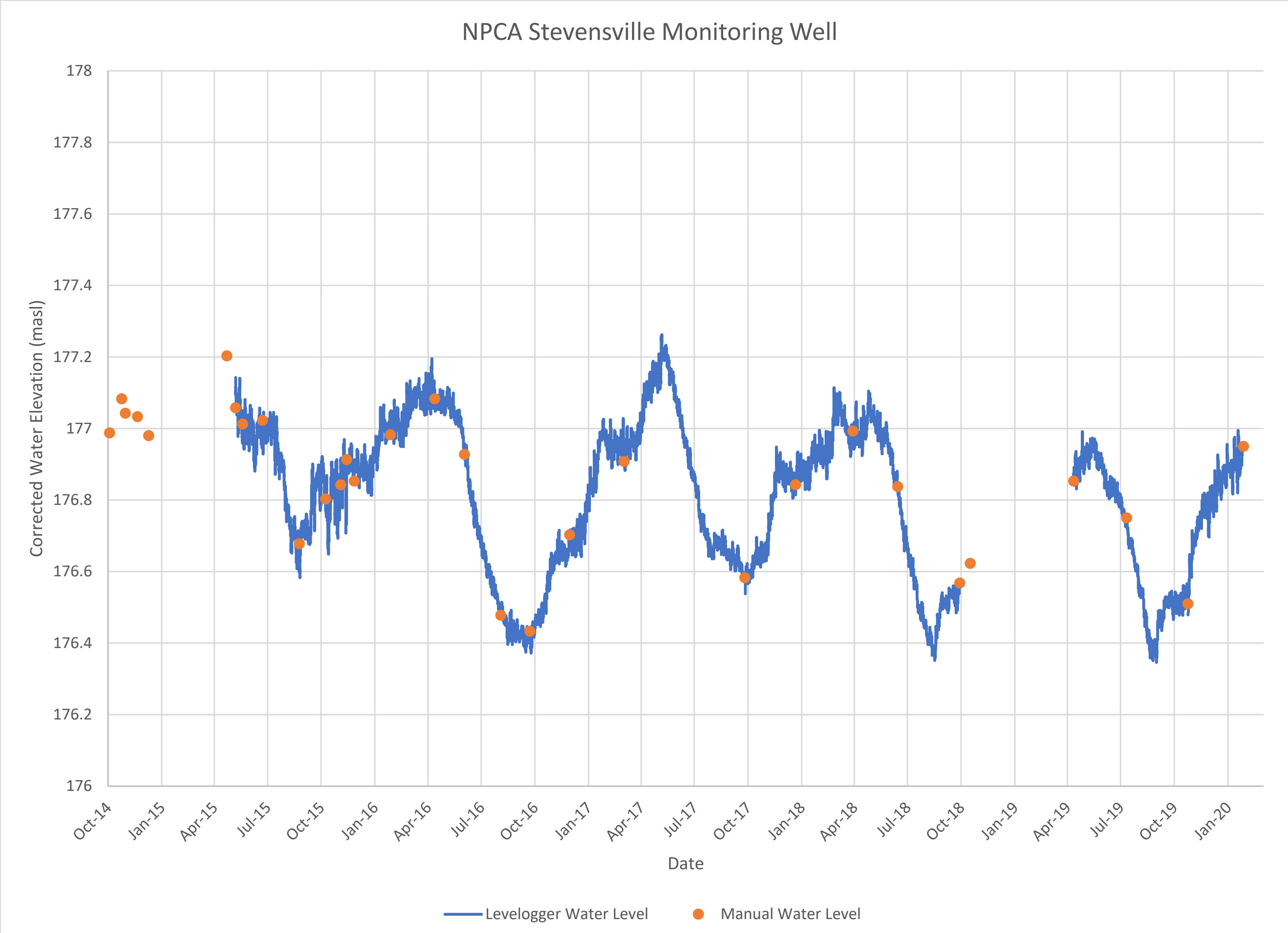


NPCA Smith Road Bedrock Monitoring Well
Corrected Water Elevation (masl)
245
244.5
244
243.5
243
242.5
242
241.5
241
2015-10-01 0:00
2016-01-01 0:00
2016-04-01 0:00
2016-07-01 0:00
2016-10-01 0:00
2017-01-01 0:00
2017-04-01 0:00
2017-07-01 0:00
2017-10-01 0:00
2018-01-01 0:00
2018-04-01 0:00
2018-07-01 0:00
2018-10-01 0:00
2019-01-01 0:00
2019-04-01 0:00
2019-07-01 0:00
2019-10-01 0:00
2020-01-01 0:00
2020-04-01 0:00
2020-07-01 0:00
2020-10-01 0:00
2021-01-01 0:00
Date
Levelogger Water Level
Manual Water Level

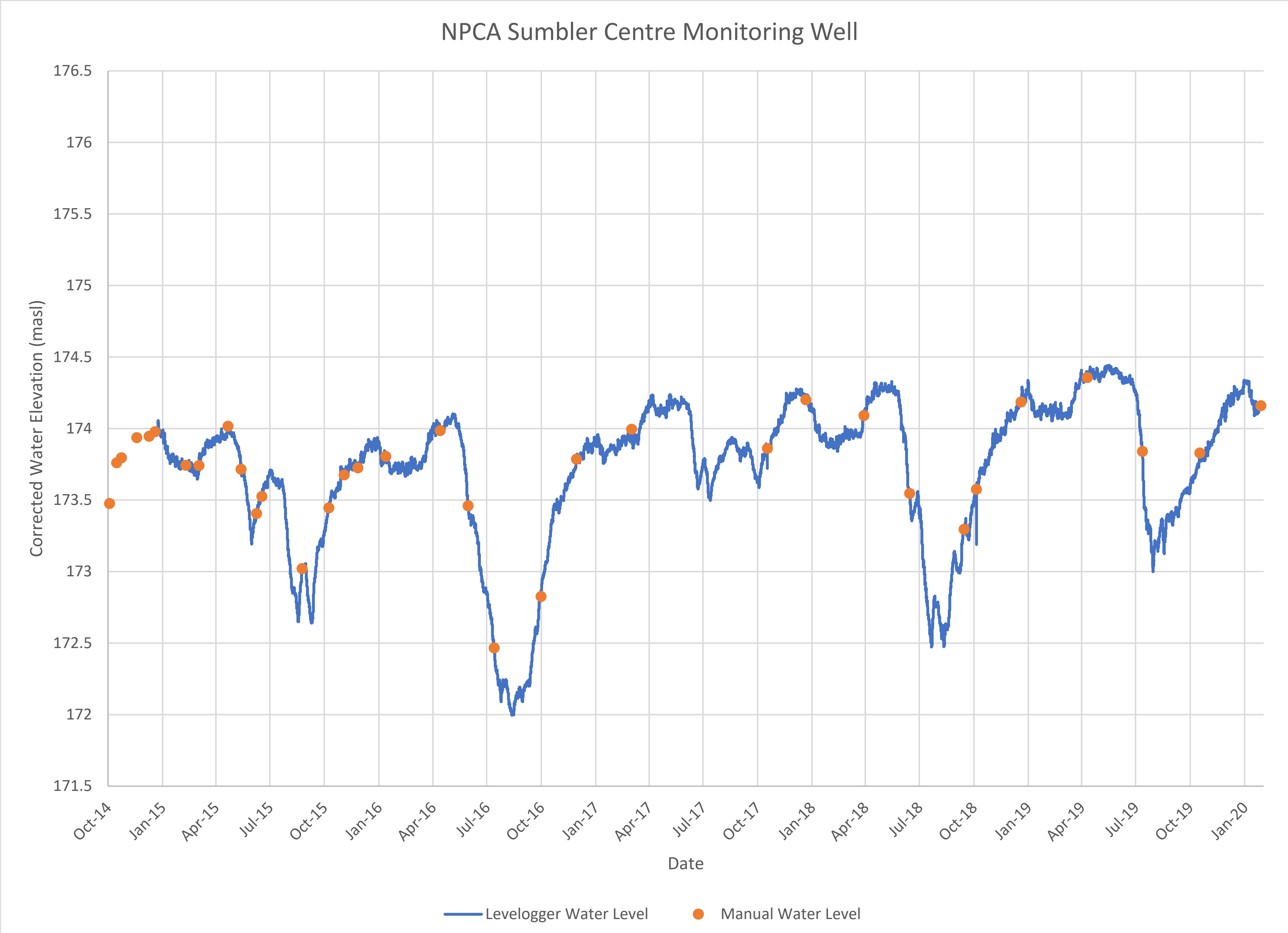


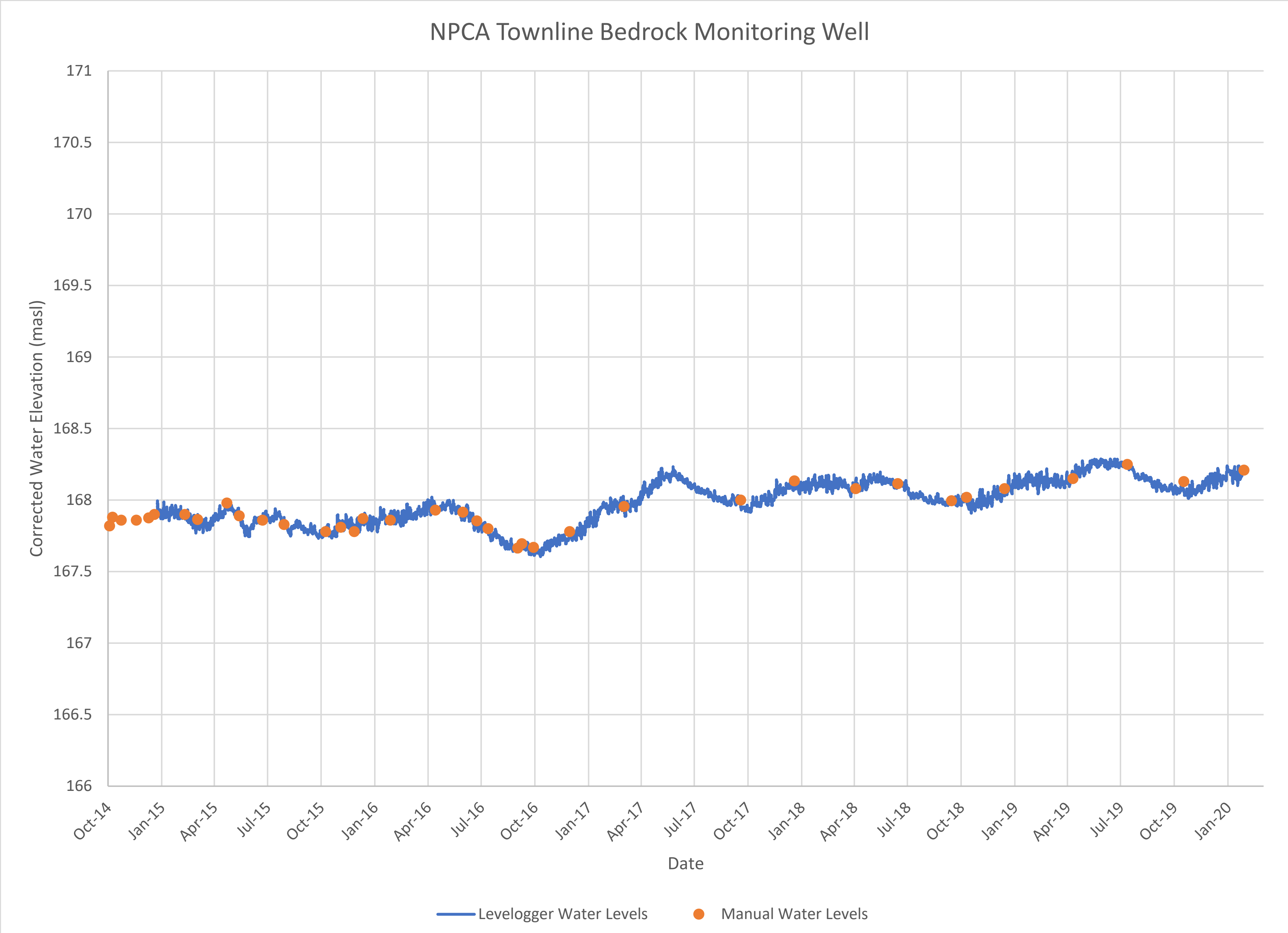
NPCA Smith Road 21ft Monitoring Well
Corrected Water Elevation (masl)
246.0
245.5
245.0
244.5
244.0
243.5
243.0
242.5
242.0
241.5
241.0
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Apr-20
Jul-20
Oct-20
Jan-21
Date
Levelogger Water Levels
Manual Water Levels


NPCA Smith Road 60ft Monitoring Well
Corrected Water Elevation (masl)
245
244.5
244
243.5
243
242.5
242
241.5
241
240.5
240
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Apr-20
Jul-20
Oct-20
Jan-21
Date
Levelogger Water Level
Manual Water Level

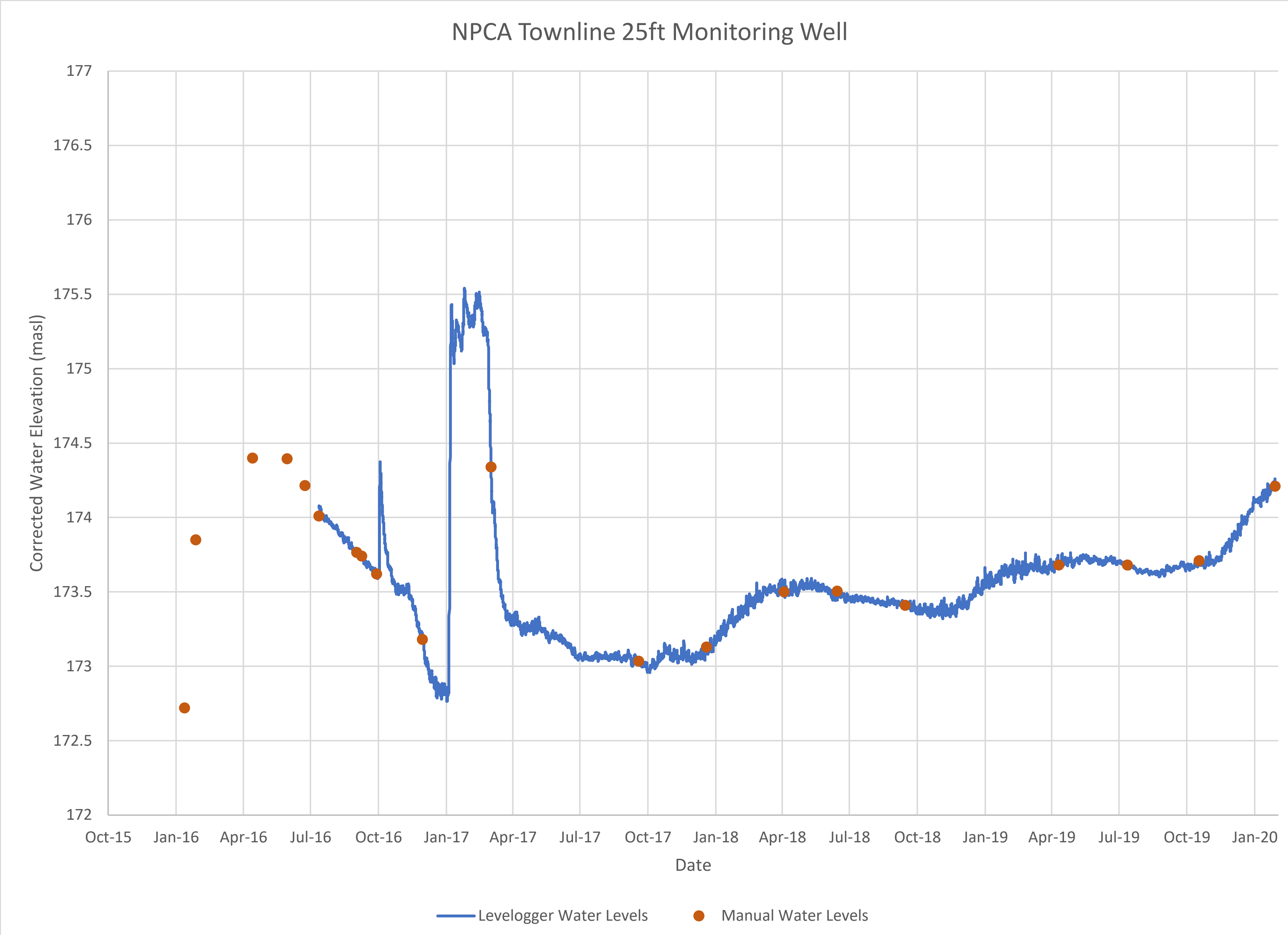


NPCA Stevensville Monitoring Well
Corrected Water Elevation (masl)
178
177.8
177.6
177.4
177.2
177
176.8
176.6
176.4
176.2
176
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level

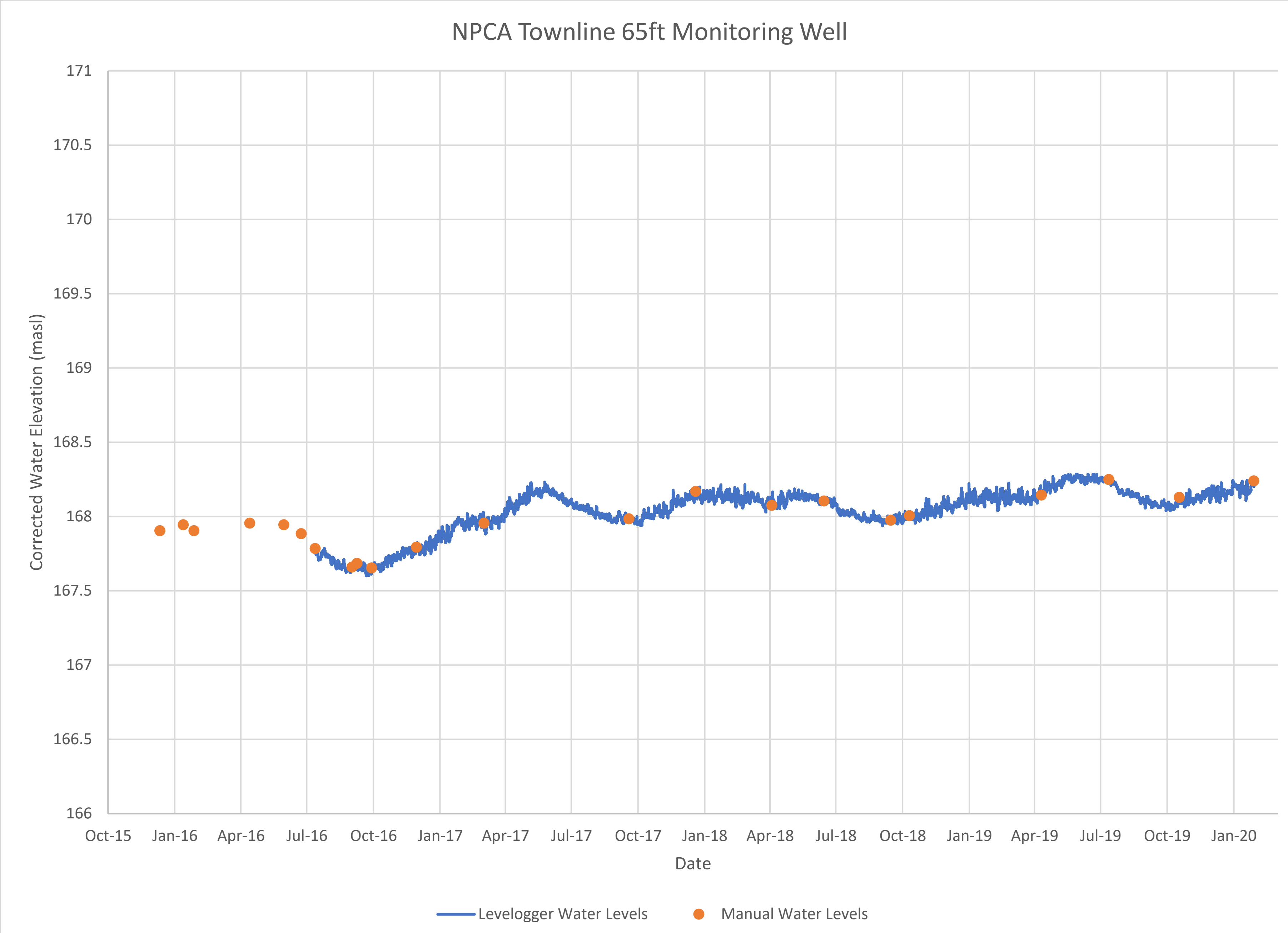

NPCA Sumbler Centre Monitoring Well
Corrected Water Elevation (masl)
176.5
176
175.5
175
174.5
174
173.5
173
172.5
172
171.5
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level



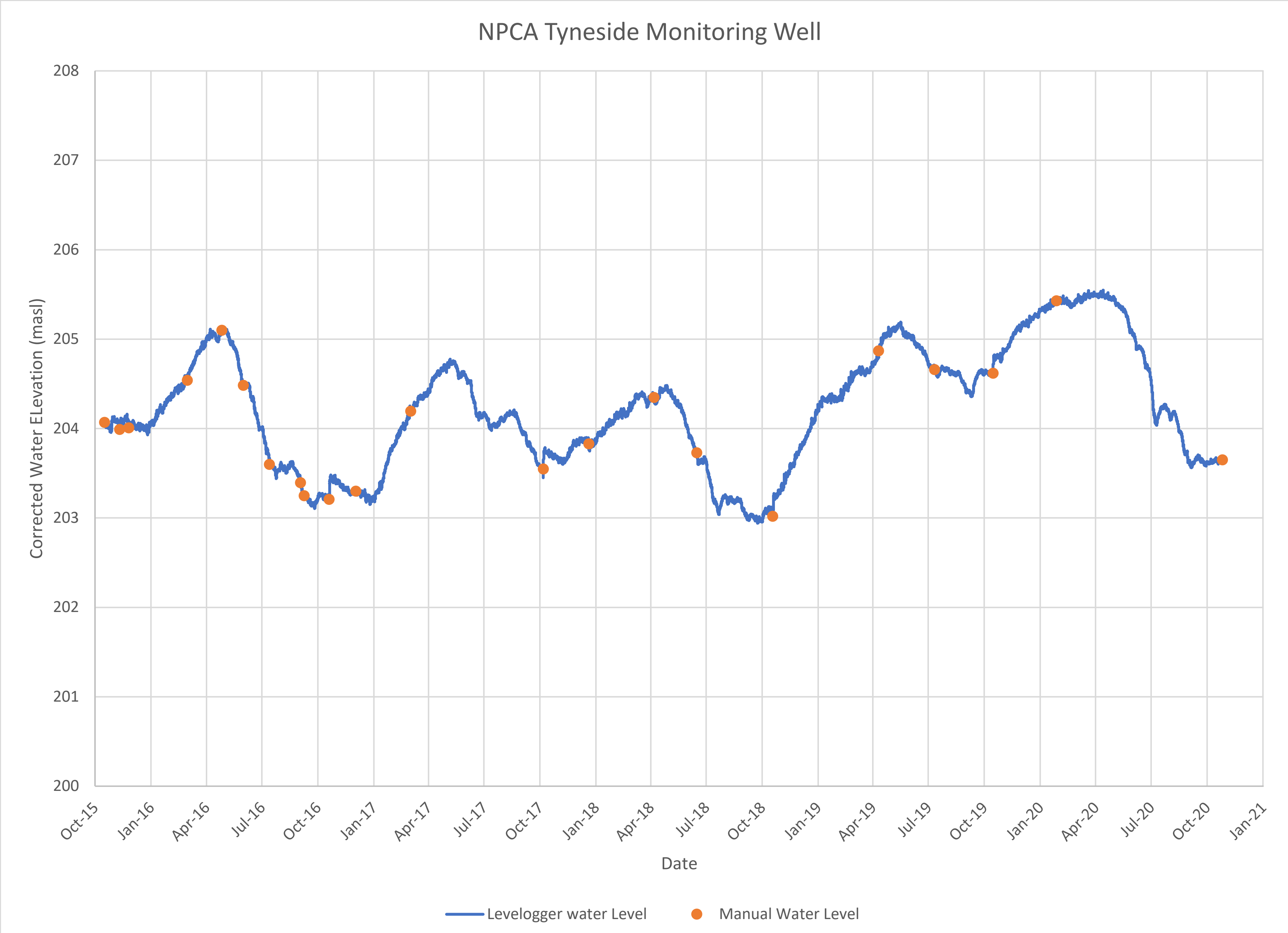
NPCA Townline Bedrock Monitoring Well
Corrected Water Elevation (masl)
171
170.5
170
169.5
169
168.5
168
167.5
167
166.5
166
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Levels
Manual Water Levels



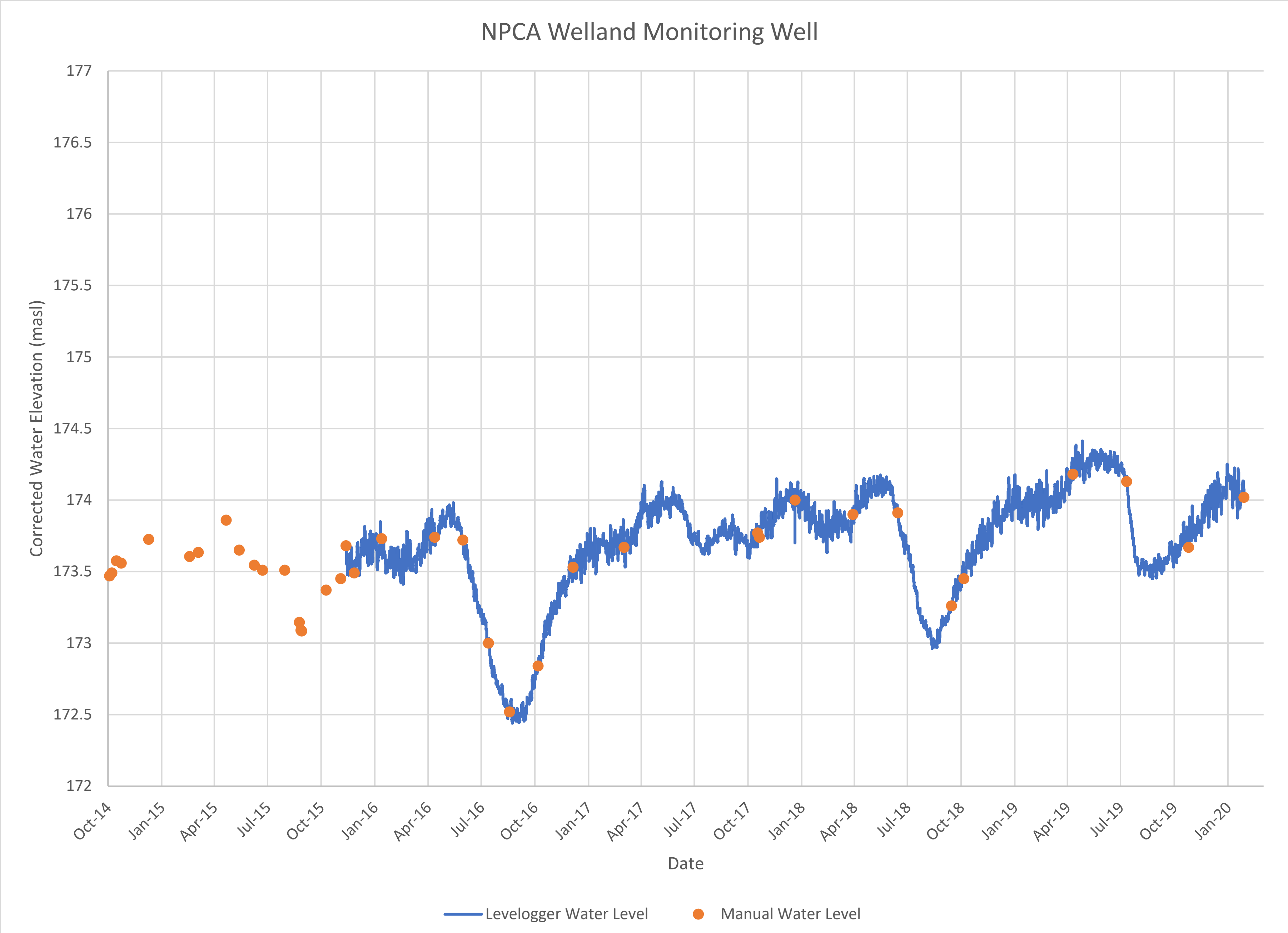
NPCA Townline 25ft Monitoring Well
Corrected Water Elevation (masl)
177
176.5
176
175.5
175
174.5
174
173.5
173
172.5
172
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Levels
Manual Water Levels



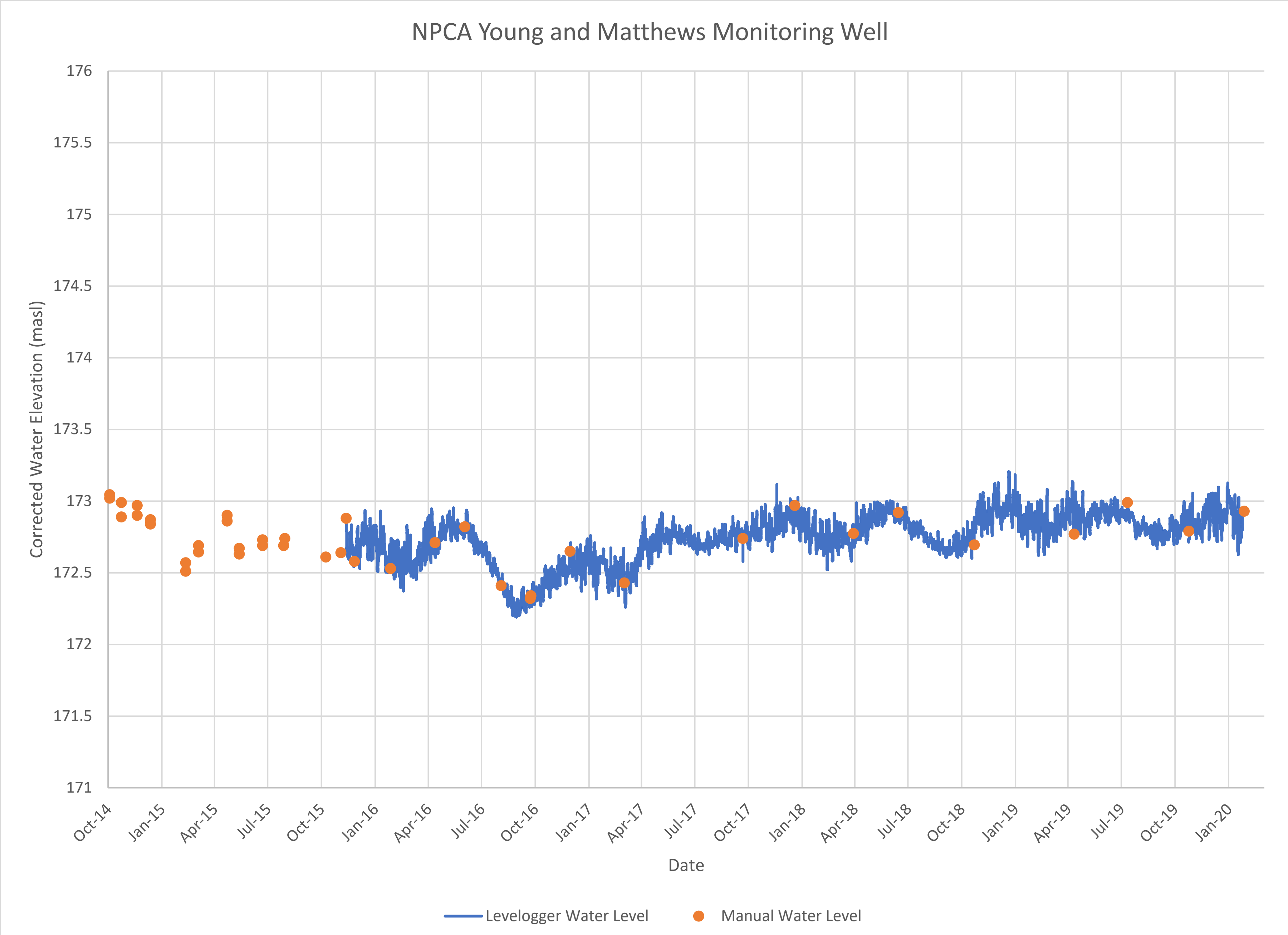
NPCA Townline 65ft Monitoring Well
171
170.5
170
169.5
169
168.5
168
167.5
167
166.5
166
Corrected Water Elevation (masl)
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Levels
Manual Water Levels



NPCA Tyneside Monitoring Well
Corrected Water ELevation (masl)
208
207
206
205
204
203
202
201
200
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Apr-20
Jul-20
Oct-20
Jan-21
Date
Levelogger water Level
Manual Water Level



NPCA Welland Monitoring Well
Corrected Water Elevation (masl)
177
176.5
176
175.5
175
174.5
174
173.5
173
172.5
172
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level


NPCA Young and Matthews Monitoring Well
Corrected Water Elevation (masl)
176
175.5
175
174.5
174
173.5
173
172.5
172
171.5
171
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Date
Levelogger Water Level
Manual Water Level

Appendix L

Upper Twelve Mile Creek Temperature Monitoring: 2020 Summary Report

NIAGARA PENINSULA CONSERVATION AUTHORITY, 2021

Table of Contents

List of Figures

List of Tables

Upper Twelve Mile Creek Temperature Monitoring

2020 Summary Report

1.0 Introduction

The following report is the yearly update on the Niagara Peninsula Conservation Authority's stream temperature monitoring program in the Upper Twelve Mile Creek subwatershed.

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 the Fonthill Kame Delta Complex in Pelham, Ontario. The creek runs north through urbanized St. Catharines and empties into Lake Ontario at Port Dalhousie. The Upper Twelve Mile Creek tributaries are groundwater fed. The St. John's and Effingham Tributaries, located in the Upper Twelve watershed, are the only identified coldwater streams in Niagara and are therefore the only stream supporting naturally reproducing Brook Trout *Salvelinus fontinalis* (**Figure 1**) in Niagara.

Figure 1: Brook Trout (*Salvelinus fontinalis*) and a Hobo Water Temperature Logger

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 (Coker *et al.* 2001). 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˚C 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 stream water quality. Water temperature, a key indicator and attribute of Brook Trout habitat health and viability, is easily monitored using temperature dataloggers.

Prior studies found that most upper tributaries fall within the healthy range for Brook Trout. Moving downstream leads to higher stream temperatures and eventually temperatures out of the optimal range for Brook Trout.

2.0 Objectives

The objectives of the 2020 temperature monitoring study are to:

- Update the yearly temperature monitoring program of the Upper Twelve Mile Creek.
- Identify and classify the thermal regime for selected locations.
- Identify sites that exceed the optimal range and/or lethal limit for Brook Trout.
- Identify any alarming changes that may be occurring.
- Identify locations that require restoration and stewardship.

3.0 Methodology

Nine stream locations were monitored in 2020. 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.

Onset HOBO Water Temp Pro dataloggers **Figure 1** were deployed at seven locations. Stream temperature data for the remaining two locations was downloaded from NPCA stream flow stations. The locations can be found below in **Table 1**. Loggers were deployed in June 2020 and collected in November 2020, recording at one-hour intervals. **Figure 2** below shows station locations on a map within Twelve Mile Creek.

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. Sulphur Spring Drive data were taken from a stream gauge operated by the NPCA in Effingham. This was also the source of air temperature data. TW007 stream temperature was taken from a stream gauge operated by the NPCA on First Street Louth in St. Catharines.

A monthly maintenance schedule was implemented for this study. Temperature loggers were cleaned and downloaded monthly to ensure they were in working order and to make sure they remained submerged. The data is downloaded via HOBOware Pro Software and then organized into excel worksheets with air temperature data. The boxplots are used to show here the data lies in relation to the Brook Trout's optimum temperature range. The box represents where 50% of the temperature values fall and the whiskers represent the minimum and maximum values that were recorded. The red line represents the lethal limit of 24°C for Brook Trout and the blue line represents the maximum of the optimum temperature range of 13 °C to 17 °C.

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 16:00 hours from June to September 10. This method determines whether a watercourse is to be classified as coldwater, coolwater or warmwater. For this study, the monitoring period has been expanded from June 6th to September 10th. This protocol approximates the classification.

Table 4: 2020 Monitoring locations

Station	Watershed	UTM Coordinates	Location Description
TW000	St. Johns	639434, 4767542	Small headwater tributary located in Marlene Stewart Streit Park
TW001	St. Johns	639604, 4768717	St. John's branch on Pelham Street near Overholt Road
TW002	Effingham	637665, 4770341	Effingham branch on Effingham Street, upstream of Sulphur Spring Drive
Sulphur Spring Drive	Effingham	638301, 4771206	Effingham branch located on Sulphur Spring Drive, downstream of TW002
TW003	St. Johns	640455, 4769347	St. Johns branch located on private property near McSherry Lane.
TW004	Effingham	638942, 4769132	Effingham branch located on Metler Road near Haist Street, downstream of golf course
TW005	St. Johns	639056, 4771938	St. Johns branch located on Roland Road, near the confluence of both branches
TW006	Effingham	639021, 4771975	Effingham branch located on Roland Road, near the confluence of both branches
TW007	Main branch	640329, 4775029	Main branch near First Street Louth, downstream of Short Hills Provincial Park

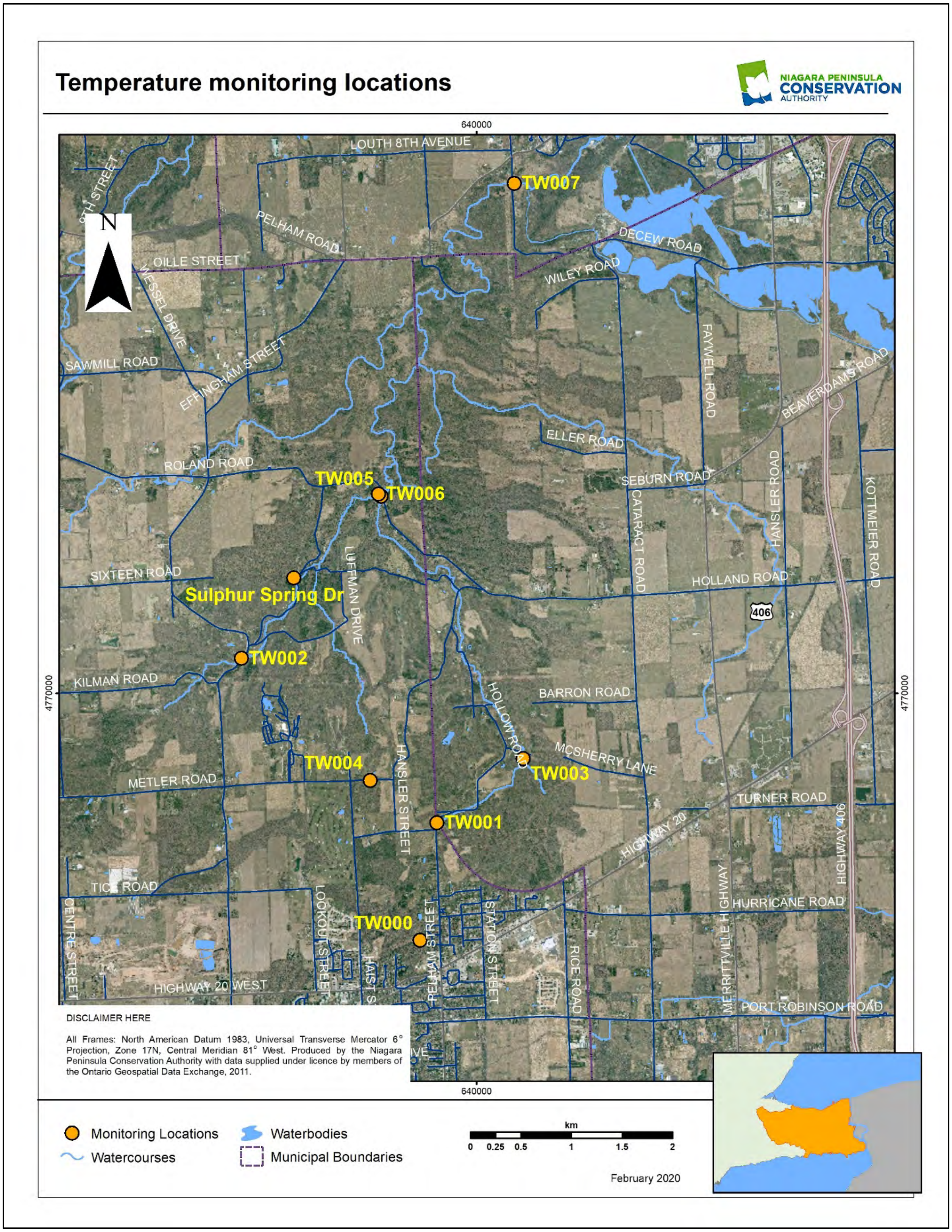


Figure 2: Map of temperature monitoring locations

4.0 Results

Table 5: Summary of 2020 summer data

Stations	Mean Temperature (°C)	Minimum Temperature (°C)	Median Temperature (°C)	Maximum Temperature (°C)	Percentage of time temperature was out of optimal range	Maximum consecutive hours over lethal limit
TW000	13.34	9.85	13.26	20.51	0.39	0
TW001	14.81	9.46	15.65	22.51	46.97	0
TW002	15.09	11.37	15.08	19.77	18.43	0
Sulphur Spring Dr	15.61	8.93	15.89	20.94	23.59	0
TW003	14.81	9.24	14.89	19.96	10.29	0
TW004	16.03	10.27	16.15	20.75	28.24	0
TW005	17.58	9.49	17.99	23.02	55.64	0
TW006	17.63	8.92	18.06	24.03	54.86	1
TW007	19.54	9.97	20.18	26.41	67.80	16

Table 2 above displays a summary of all data collected for the 2020 field season. In total, 3332 data points were collected at all stations between June and October. Maximum temperatures exceeded the lethal limit at two locations: TW006 and TW007. The lethal limit was exceeded for extended periods of time at TW007. The longest periods of time were 15 hours and 16 hours (on two occasions) over 24°C. More than half of the data collected was over the optimal range at TW005, TW006, and TW007. TW001 was out of optimal range for close to 50% of the time. TW000 was out of optimal range for less than 1% of the study period. TW002, Sulphur Spring Drive, TW003, and TW004 were outside of the optimal range for less than 30% of the study period.

4.1 St. Johns tributaries and main branch

St. Johns tributaries and the main branch of the Upper Twelve Mile Creek watershed were monitored for a total of five stations. **Figure 3** below shows a box and whisker diagram of the five locations for the 2020 field season. The main branch at TW007 (1st Street Louth) exceeded the lethal limit and is above the optimal range for most data collected. TW005 and TW001 data falls above the optimal range. TW000 and TW003 fall within the optimal range.

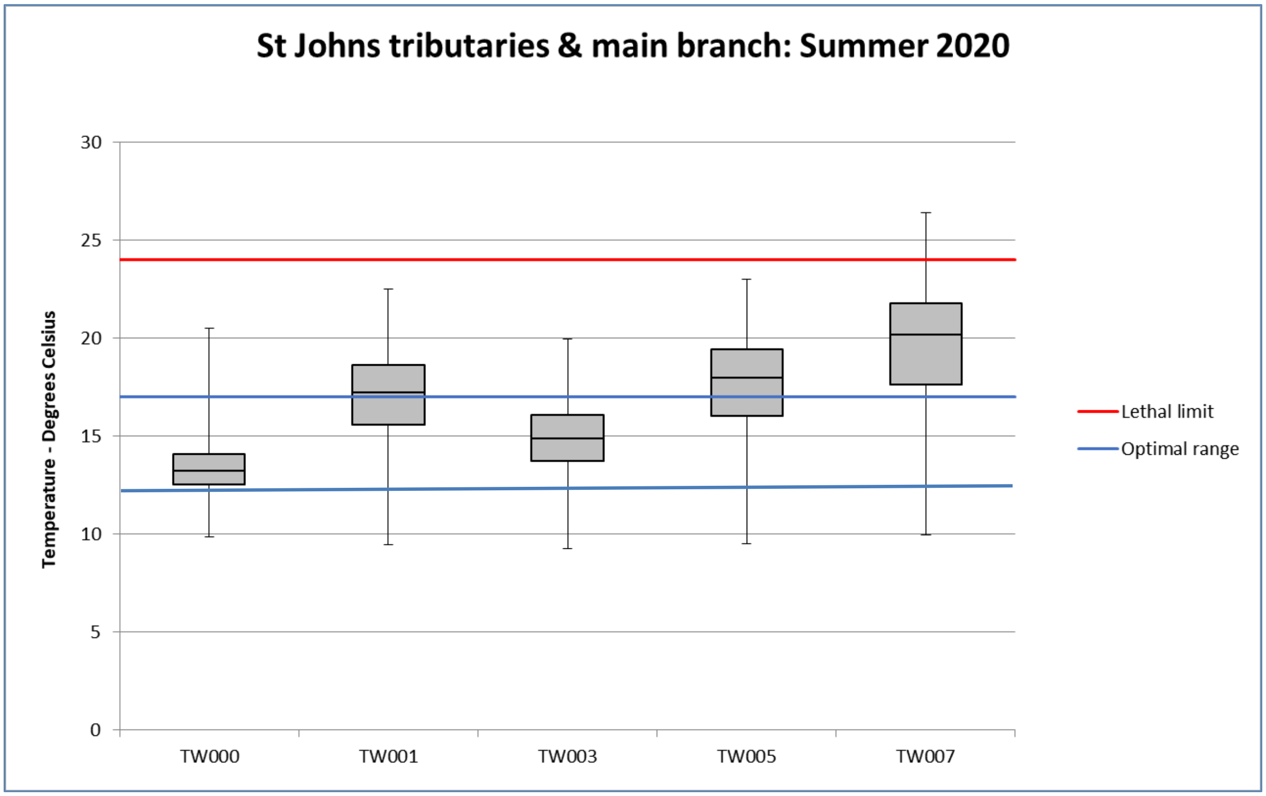


Figure 3: Box and whisker plot for St. Johns tributaries and main branch

Figure 4 below is a scatter plot nomogram that represents the classification of stream thermal stability. Maximum daily air temperature is plotted against the corresponding water temperature at 16:00hrs from June 6th to September 30th. This nomogram is created based on the protocol outlined by Stoneman and Jones (1996).

The nomogram for St Johns and the main branch of Twelve Mile Creek shows that TW000 and TW003 can be classified as coldwater in 2020. TW001 and TW005 are classified as coolwater. TW007 (main branch) is classified as warmwater. The classifications are determined by where the majority of data fit into the graph below.

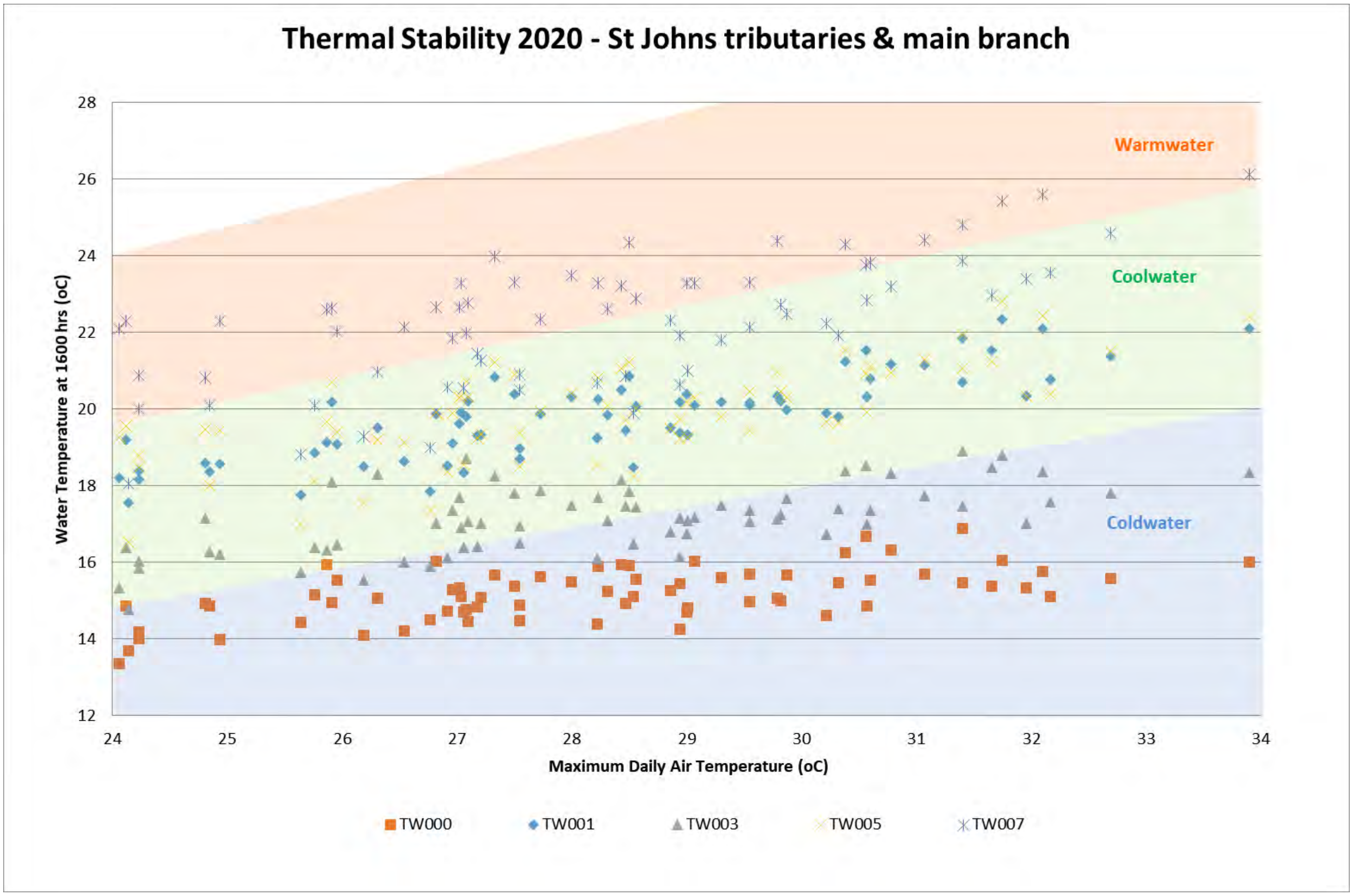


Figure 4: Thermal stability nomograms for St. Johns and main branch

4.2 Effingham tributaries

Stream temperature was monitored at four locations in the Effingham branch of Twelve Mile Creek. **Figure 5** below is a boxplot from the four stations with optimal range and lethal limit plotted. TW002, Sulphur Spring Drive, and TW004 fall mostly within the optimal range with maximum stream temperatures well below the lethal limit. TW006 near the confluence of both branches sits slightly higher with a significant portion of data falling above the optimal range. The maximum temperature for TW006 falls slightly above the lethal limit.

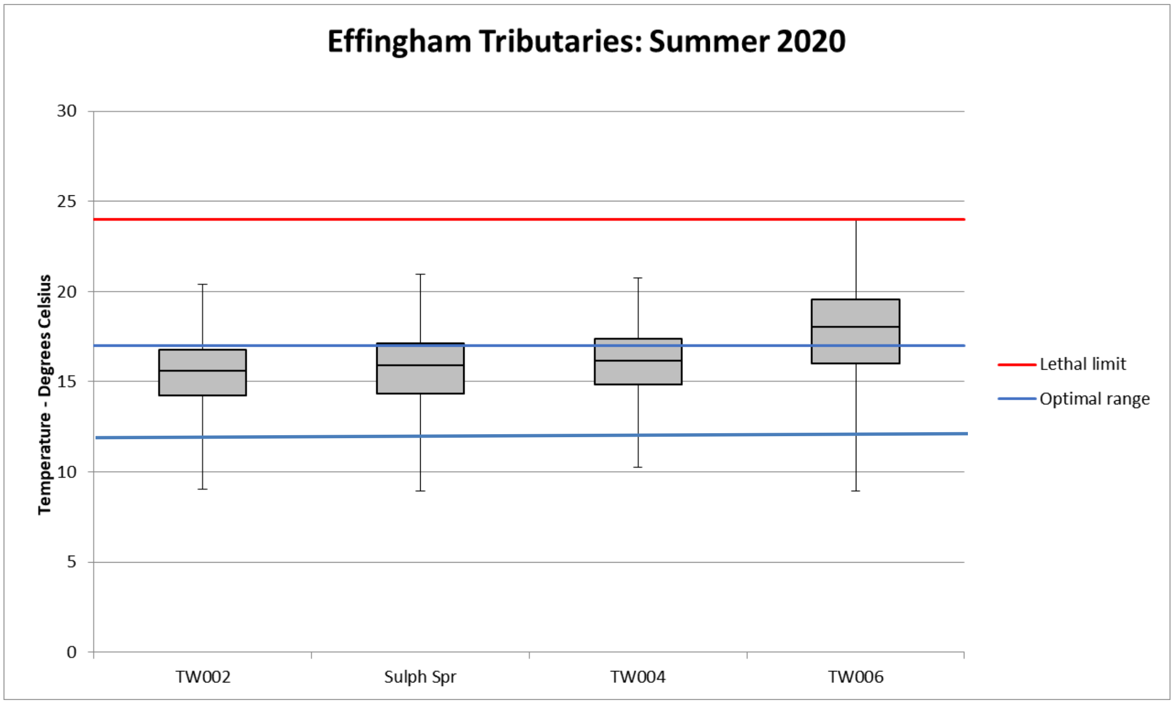


Figure 5: Box and whisker plot for Effingham tributaries

Figure 6 below is the scatter plot nomogram of thermal stability for the Effingham branch. The same protocol was followed as above. Based on summer 2020 data, TW002 and Sulphur Spring Drive are classified as coldwater while TW004 and TW006 are classified as coolwater.

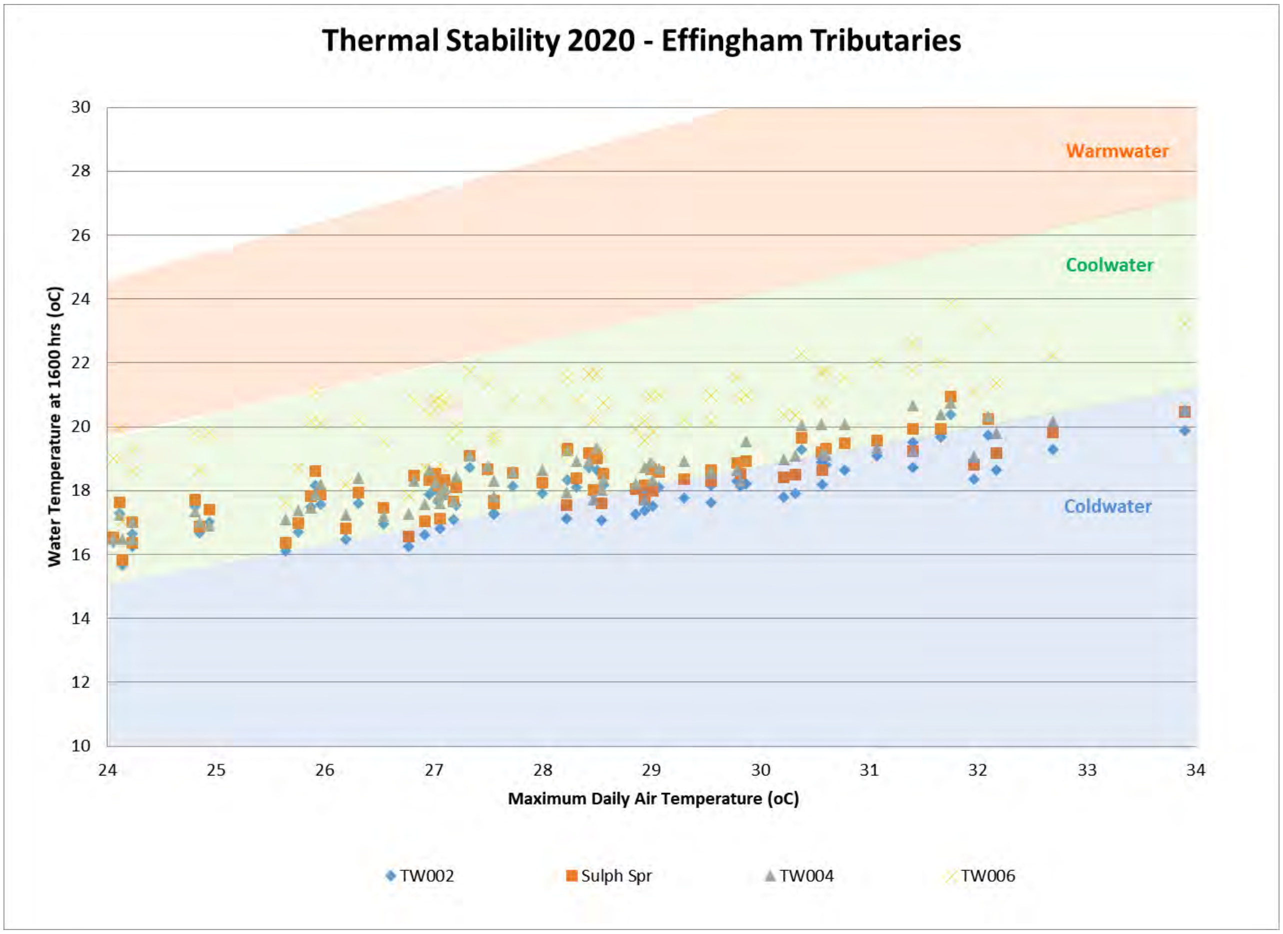


Figure 6: Thermal stability nomograms for the Effingham branch

4.3 Summary of results

Table 3 below is a summary of stream classifications between 2011 and 2020. The summary shows both classifications according to nomograms and indicates whether the maximum temperature exceeded the lethal limit for that summer (marked X). In 2020, TW006 and TW007 exceeded the lethal limit. TW000 and TW003 are both classified as coldwater. TW003 is classified as coldwater in 2020 for the first time since 2015 and TW007 continues to be classified as a warmwater.

Table 6: Stream classification summary 2011-2020. Grey indicates no data, blue indicates coldwater, green indicates coolwater, and red indicates warmwater classifications. X marks indicate that the maximum temperature that year was over the lethal limit for Brook Trout.

	Sanctuary	TW000	TW001	TW002	Sulphur Spring Dr	TW003	TW004	TW005	TW006	TW007
2011	Grey	Blue	Green X	Green	Grey	Green	Green	Green X	Green X	Green X
2013	Grey	Blue	Green X	Green	Grey	Blue	Green	Green X	Green X	Red X
2014	Blue	Blue	Green	Blue	Grey	Blue	Blue	Green	Green	Grey
2015	Grey	Blue	Green	Green	Grey	Blue	Green	Green	Green	Grey
2016	Blue	Blue	Green	Green	Green	Green	Green	Green	Green	Red X
2017	Grey	Blue	Green	Green	Green	Green	Green	Green	Green	Green X
2018	Grey	Blue	Green	Green	Green	Green	Green	Green	Green	Grey
2019	Grey	Blue	Green	Green	Green	Blue	Green	Green	Green	Red X
2020	Grey	Blue	Green	Blue	Blue	Blue	Green	Green	Green X	Red X

Figure 7 displays mean stream temperatures since temperature monitoring began in 2006. In some cases, the data has not been consistently collected at all locations. Mean temperatures appear to go up during hotter summers in all cases and drop back down during cooler, wetter years. Overall, no significant pattern up or down appears in the mean temperatures.

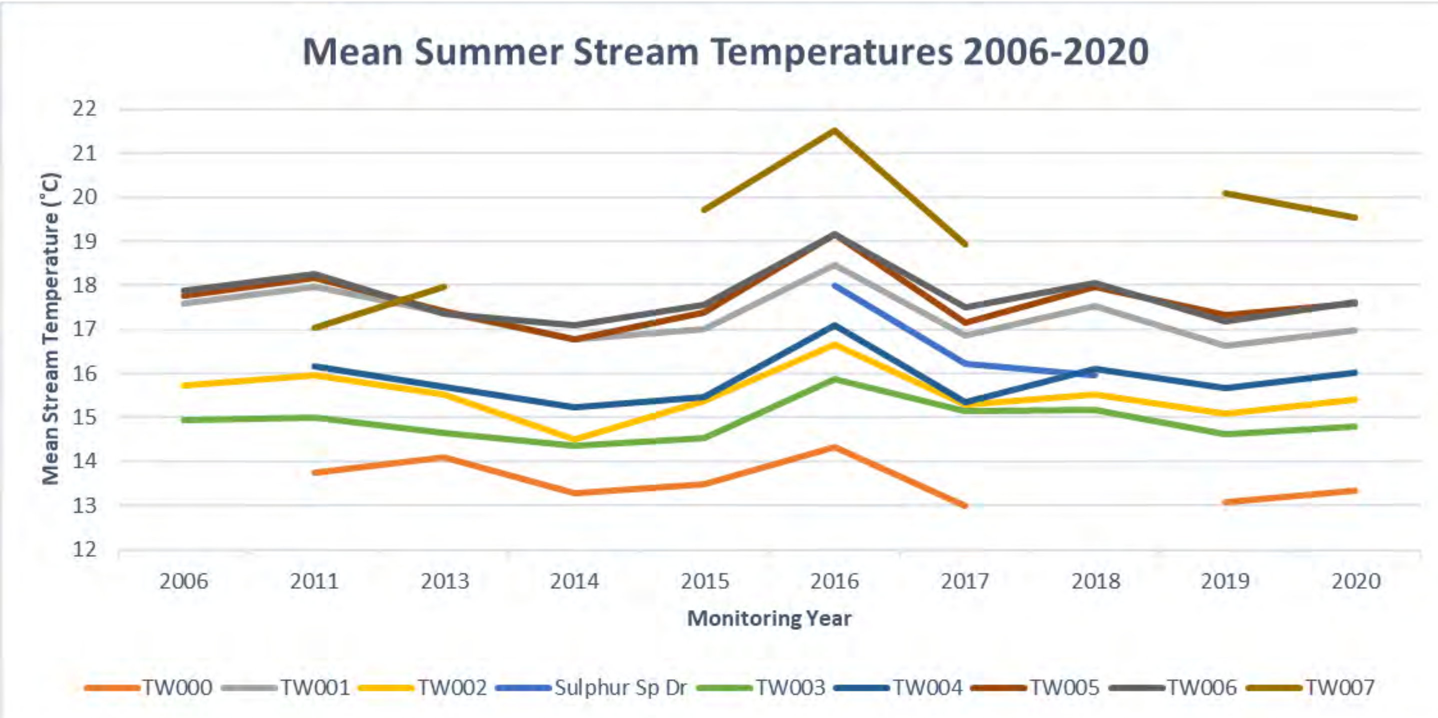


Figure 7: Mean stream temperatures recorded since 2006

5.0 Analysis

There are no obvious patterns emerging in the data, with most results being stable. Stream classifications remained consistent except for TW002, and Sulphur Spring Drive locations being classified as coldwater in 2020. TW006 experienced a short period of time above the lethal limit for Brook Trout for the first time since 2013.

Mean stream temperatures are stable except for an abnormally warm and dry summer in 2016. Streams that are classified as coldwater (TW000, TW003) appear to respond slightly less to warmer summers, perhaps being protected by the shaded woodlots they are in or are regulated by more groundwater influence than downstream locations. Downstream locations are the accumulation of upstream land uses and tend to be wider creeks, in some cases being exposed to more sunlight.

TW005 and TW006 remain a concern as they typically hover around, or above optimal range and the maximum temperature is near the lethal limit. In 2020, no significant amount of time was spent above the lethal limit at either site, however, more than half time recorded was spent above the optimal range (**Table 2** above). On Roland Road, these two tributaries combine into one branch and enters Short Hills Provincial Park. Based on the temperature monitoring at these two locations, there is some concern for Upper Twelve Mile Creek as it runs through the park as it is entering already at elevated temperatures in the summer.

TW001 is typically a concern as that location tends to be elevated relative to the monitoring locations around it. This is due to upstream land uses (ponds) that artificially warm this location.

This location is classified as coolwater, however, with the ponds upstream it could be in danger of further warming over time.

TW007 (main branch) remains unsuitable for Brook Trout. The upper tributaries are considered suitable based on thermal stability data, however, some locations such as TW001, TW005, and TW006 are close to being considered unsuitable.

6.0 Conclusion

Some tributaries in the Upper Twelve Mile Creek watershed are capable of supporting Brook Trout based on temperatures monitoring alone. Downstream, the main branch is not considered suitable. Some locations are above the optimal range and would cause some stress to Brook Trout. Overall, the upper tributaries are considered safe as they are classified coldwater or coolwater.

Downstream locations are at risk of higher temperatures due to widening of the banks and exposure to sunlight. As the creek enters Short Hills Provincial Park at Roland Road, it is above the optimal range for over 50% of the time. While the park offers significant riparian vegetation and shade, the creek continues to widen due to erosion and bank instability in the park, eventually exiting at the final monitoring location at First Street Louth. At this location, the creek is now classified as warmwater and unsuitable for Brook Trout.

Significant stream rehabilitation is required within Short Hills Provincial Park and upstream to ensure that the stream temperatures are in the optimal range for Brook Trout. Current tributaries that are considered suitable must be protected from degradation, and downstream locations must be stabilized.

7.0 Recommendations

- It is recommended that the NPCA continue annual temperature monitoring at current network stations.
- It is recommended that the NPCA initiate stream erosion monitoring of critical locations that may be contributing thermal pollution.
- It is recommended that the NPCA participate in undertaking fish studies in the Upper 12 Mile Creek tributaries to better understand the distribution and status of resident Brook Trout populations and to help focus restoration efforts.
- It is recommended that the NPCA continue to coordinate with local stakeholders and landowners to share information, address data gaps and identify opportunities to improve the watershed.
- It is recommended that the NPCA participate in undertaking fish studies in the Upper 12 Mile Creek tributaries to better understand the distribution and status of resident Brook Trout populations and to help focus restoration efforts.

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.

Environment Canada, (2019). Historical data. Retrieved from http://www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html

Niagara Peninsula Conservation Authority, (2020). NPCA Water Quality Monitoring Program: Summary report of the year 2019*.* Niagara Peninsula Conservation Authority, Welland, Ontario.

Stoneman, Christine, and Michael Jones, (1996). A simple method to classify stream thermal stability with single observations of daily maximum water and air temperatures. North American Journal of Fisheries Management, 16: 728-737.