Sub-Indicator: Water Quality in Tributaries

Note: As with previous reports, the current water quality status assessment is updated using the most recent available Canadian water quality data. Due to the intensive nature of the trend analysis, the short- and long- term trends will be updated every other SOGL report. As such, this sub-indicator report assesses the same range of data as the SOGL 2022 Water Quality in Tributaries sub-indicator report for the trend portion only. Please see the methods and individual assessments for more information.

Overall Assessment – Canadian Only

Status (2018-2022): Fair

Trends:

10-Year Trend (2010 - 2019): No Trend

Long-term Trend (1970 - 2019): No Trend

Rationale: The overall status is based on the Water Quality Index (WQI) which was computed for 72 Canadian tributaries to the Great Lakes spanning a gradient of land cover/uses from forestry to agricultural and urban to determine current water quality status. The WQI is based on eight water quality constituents (ammonia, chloride, copper, iron, nitrate, nitrite, total phosphorus and zinc). The overall water quality status of tributaries to the Great Lakes varies considerably in this large geographic region but can be described as Fair if taking the average WQI from all 72 tributaries (WQIavg=62, WQIrange=18 - 93). This overall assessment could be biased since Lake Superior and the northern portion of Lake Huron is currently underrepresented. Broken down by category, 17% of the tributaries were categorized as having Good water quality, 64% as Fair, and 19% as Poor.

A separate analysis for a different selection of water quality sites (n=133) was conducted analyzing 10-year- and long- term trends for three water quality constituents (nitrate, total phosphorus and chloride). The 10-year trend is reported as No Trend. Trend results for three parameters for the entire Great Lakes Basin indicate mixed trends for this time period at most sites. Long-term trends are mixed, with the majority of trend sites showing increasing chloride concentrations, no trend in nitrate concentrations and decreasing total phosphorus concentrations, however, it should be noted that Lake Superior and Lake Huron are underrepresented.

Lake-by-Lake Assessment – Canadian Only

Lake Superior

Status (2018-2022): Undetermined

10-Year Trend: Undetermined

Long-term Trend (*see Table 3 for time period used; varies by site*): Undetermined

Rationale: The average WQI score for three tributaries was 81. WQI scores ranged from 73 to 93 (Fair to Good). There were only a few sites monitored and all three sites were clustered near Thunder Bay, therefore it is difficult to assign an overall lake assessment value based on so few tributaries.

Lake Michigan – Not Applicable (assessment is Canadian only)

Status: Not Applicable

10-Year Trend: Not Applicable

Long-term Trend: Not Applicable

Rationale: No tributaries to Lake Michigan are monitored by the Ontario Provincial Water Quality Monitoring Network (PWQMN)

Lake Huron

Status (2018-2022): Fair

10-Year Trend: No Trend

Long-term Trend (*see Table 3 for time period used; varies by site*): No Trend

Rationale: The average WQI score for 20 tributaries was 74. WQI scores ranged from 54 to 81 (Fair to Good). The 10-year trend is reported as No Trend: majority of sites show no trend for both total phosphorus and nitrate while just under half of trend sites show an increasing chloride trend. Long-term trends are mixed and therefore there is no clear overall trend: most sites show a decreasing trend for total phosphorus, no trend for nitrate, and an increasing trend for chloride concentrations.

Lake Erie

Status (2018-2022): Poor

10-Year Trend: No Trend

Long-term Trend (*see Table 3 for time period used; varies by site*): No Trend

Rationale: The average WQI score for 15 tributaries was 43. WQI scores ranged from 18 to 65 (Poor to Fair). The 10-year trend is reported as No Trend since the majority of trend sites are showing no trend for all three parameters tested (total phosphorus, nitrate, and chloride). Long-term trends are mixed and therefore there is no clear overall trend: the majority of trend sites show decreasing trends in total phosphorus concentrations, no trend in nitrate concentrations, and increasing trends in chloride concentrations. While this assessment is limited to the Canadian portion of the Lake Erie basin, stream information from the Ohio waters of the Lake Erie basin are included in the Discussion section below.

Lake Ontario and the St. Lawrence River

Status (2018-2022): Fair

10-Year Trend: No Trend

Long-term Trend (*see Table 3 for time period used; varies by site*): No Trend

Rationale: The average WQI score for 34 tributaries was 62. WQI scores ranged from 27 to 100 (Poor to Good). The 10-year trend is reported as No Trend: majority of sites show no trend for both total phosphorus and nitrate while just over half of trend sites show an increasing chloride trend. Long-term trends are mixed and therefore there is no clear overall trend: the majority of trend sites show decreasing total phosphorus concentrations, no trend for nitrate concentrations, and increasing chloride concentrations.

Status Assessment Definitions

The calculated WQI values fit into five categories that describe water quality conditions as used by the Canadian

Council of Ministers of the Environment (CCME):

Excellent (95-100);

Good (80-94);

Fair (65-79);

Marginal (45-64); and

Poor (0-44).

For this sub-indicator, the five original categories developed by CCME were dissolved into three descriptive categories:

Good: 80-100

Fair: 45-79

Poor: 0-44

Trend Assessment Definitions

Improving: Metrics show a change toward more acceptable condition.

Unchanging: Metrics generally show no overall change in condition and generally exhibit low inter-annual variability.

Deteriorating: Metrics show a change away from acceptable condition.

Undetermined: Insufficient data to report on a trend.

No Trend: Metrics are showing mixed trends and therefore do not show a clear overall trend, and/or metrics generally show no statistically significant improving or deteriorating conditions and exhibit high inter-annual variability.

Endpoints and/or Targets

Desirable outcomes are the absence of undesirable water quality conditions in streams. The Water Quality Index (WQI) score is from 0 to 100 with rankings for poor, fair and good. The category ranges describe sites where the water quality complies with criteria virtually all of the time (Good) or hardly any of the time (Poor).

Sub-Indicator Purpose

The purpose of this sub-indicator is to communicate water quality status relative to guidelines based on eight water quality parameters (ammonia, chloride, copper, iron, nitrate, nitrite, total phosphorus and zinc) and also to determine short-term and long-term trends in three water quality parameters (nitrate, total phosphorus and chloride) to support the evaluation of aquatic ecosystem health in Great Lakes tributaries.

Ecosystem Objective

The surface waters in the Great Lakes Basin should be of a quality that is protective of aquatic life and healthy aquatic ecosystems.

This sub-indicator best supports work towards General Objective #6 and #4 of the 2012 Great Lakes Water Quality Agreement. General Objective #6 states that the Waters of the Great Lakes should "be free from nutrients that directly or indirectly enter the water as a result of human activity, in amounts that promote growth of algae and cyanobacteria that interfere with aquatic ecosystem health, or human use of the ecosystem". General Objective #4 states that the Waters of the Great Lakes should "be free from pollutants in quantities or concentrations that could be harmful to human health, wildlife, or aquatic organisms, through direct exposure or indirect exposure through the food chain".

Methods

Current status

Water Quality Index (WQI) calculations for 72 Ontario tributaries to the Great Lakes were computed using monitoring data from the Provincial Water Quality Monitoring Network (PWQMN) (Figures 1-2); https://data.ontario.ca/dataset/provincial-stream-water-quality-monitoring-network) for the period 2018-2022.

The WQI provides a mathematical framework for synthesizing water quality monitoring results for multiple samples and parameters into a single value representing overall water quality conditions at a given site. The WQI is based on three measures (factors) of compliance with water quality criteria (guidelines and objectives) for the protection of aquatic life.

Scope: measures the percentage of the number of parameters that comply with water quality criteria

Frequency: measures the percentage of individual water quality tests that comply with criteria

Magnitude: measures by how much criteria are exceeded

The three factors are combined into a single unit-less value between 0 and 100 where higher numbers indicate better water quality. The WQI is computed using the Canadian Council of Ministers of the Environment's Water Quality Index (v. 1.2; CCME 2011a), which is described in detail in CCME (2001a, b).

For the calculation of the WQI, the water quality results are compared with guidelines from the Canadian Council of Ministers of the Environment (CCME)'s Water Quality Guidelines for the Protection of Aquatic Life (CCME, 2011b) or, in the absence of CCME Guidelines, the Ontario Interim Provincial Water Quality Objectives (PWQO) (i.e., for total phosphorus) (OMOE, 1994) (Table 1). All guidelines except for total phosphorus are for the protection of aquatic life whereas the guideline for total phosphorus is to avoid excessive plant growth in rivers and streams.

While the specific parameters that are selected for use in the calculation of the WQI and the number of parameters included may vary by jurisdiction at the discretion of the water quality manager, a minimum of four parameters that are sampled at least four times per year is recommended by CCME (2001) for calculating the WQI. Considerations for selecting parameters should include:

1. If parameters are relevant to the water body that is being assessed;
2. Whether the parameters are comparable to a water quality criterion such as the CCME's Water Quality Guidelines for the Protection of Aquatic Life;

3. If an appropriate number of samples (measurements) have been collected at each site at a suitable frequency for each parameter; and
4. If it is possible to maintain consistency in calculating and reporting the WQI within and between jurisdictions.

The parameters selected to calculate the WQI for this report will be at the discretion of the agencies collecting and analyzing the data, considering the above and ensuring consistency with criteria used in previous SOGL reports. The index was calculated at sites with five years of data and a minimum of 10 observations for the following eight parameters: ammonia (unionized), chloride, copper, iron, nitrates, nitrites, total phosphorus and zinc. These eight parameters were selected because they were consistently monitored at all sites used in this assessment and can all be compared to water quality criterion. These eight parameters also reflect a range of issues/stressors in the watershed. Nutrients (nitrate, nitrite, un-ionized ammonia and total phosphorus) are included as higher concentrations can be indicative of both urban and agricultural influences and can contribute to nutrient enrichment. Chloride is an important indicator of urban disturbance in watersheds; the main anthropogenic source is the application of road salts during the winter months. Elevated levels of metals (copper, iron and zinc) can be toxic to aquatic organisms and are usually indicative of urban / industrial sources in the watershed. Inland stream water quality results for these parameters were acquired from the Ontario Provincial Water Quality Monitoring Network (PWQMN) (OMOE, 2013).

Water quality data are typically collected from March to November, although limited winter data do exist at selected sites, over several years as they represent environmental exposure during various climatic regimes (wet/dry; warm/cool) that might stress biological communities.

The WQI was calculated for the most downstream monitoring site for streams draining to the Great Lakes, including tributaries to the Great Lake connecting channels and the St. Lawrence River as an indication of water quality entering the Great Lakes.

Because the WQI synthesizes multiple water quality parameters into one value, comparing WQI values across time may not be the best indicator of changes in water quality. This version of the sub-indicator report includes a separate assessment of water quality trends in Great Lakes tributaries.

Short and long-term trends

In the previous SOGL report (2022), short and long-term trend analyses were introduced to the Water Quality in Tributary sub-indicator report. This sub-indicator uses a robust trend method that first determines the relationship between stream water quality and streamflow and then determines the trend on the residuals of this relationship. This determines trends in water quality independent of the trend in streamflow. This method is time-intensive and therefore the short- and long- term trends will be updated every other SOGL report. As such, this version reports the same short- and long- term trends as the 2022 report. It is generally not expected that water quality changes greatly from one year to another.

A separate analysis was conducted to determine short- and long- term trends; results are shown in Table 2 and Figure 3. The WQI (explained above) was used to determine current water quality status. Trends were determined for Great Lakes tributaries by using a flow-adjusted Mann Kendall trend test at suitable sites. To remove any influences of flow on trends, the method described in Helsel et al., (2020) was used. A LOWESS model was fitted to concentration against flow and a Mann Kendall Trend Test was used on the residuals from this model. Long-term trends were analyzed for the complete record at each station, starting from 1970 onwards. The complete record varies for each station and is not consistent across sites. Please see Table 3 for the period used for each site for long-term trends. 10-year trends were assessed for the period: 2010-2019.

The criteria used for the selection of WQI sites (noted in the sub-section above) differed from the criteria used to select sites for the short- and long- term trend analyses. As such, a different selection of sites were used for the trend analyses (see Figure 3) compared to the sites used for the WQI calculation (see Figure 1). While only downstream (i.e., closest to the outlet) PWQMN sites were selected for the WQI used for the current status, the criteria were expanded for sites suitable for trend analyses. Long-term sites (>= 10 years of data) that were co-located at or near a Water Survey of Canada hydrometric gauge (HYDAT) (https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/monitoring/survey/data-products-services/national-archive-hydat.html) were used in the analysis. Further, any sites with gaps in the long-term record greater than 1/3 were removed from the analysis. Three water quality parameters were used in these trend assessments: total phosphorus, nitrate and chloride. Time period for long-term trends varies by site and parameter based on data availability (see Table 3).

Discussion

Background

The Ontario Ministry of the Environment, Conservation and Park's Provincial Water Quality Monitoring Network (PWQMN) measures water quality in rivers and streams at hundreds of sites across Ontario in partnership with Ontario's Conservation Authorities. Most of these sites are located in the Great Lakes Basin, and many are located at or near the outlets of tributaries to the Great Lakes. Stream water samples are collected on an approximately monthly basis from March/April to October/November and delivered to the Ministry of the Environment, Conservation and Park's laboratory where they are analyzed using consistent analytical methods for a standardized suite of water quality indicators. Water quality indicators are selected to indicate the influence of land-use activities (primarily agricultural and urban influences) on stream water quality. For example, chloride is measured as an indicator of the influence of salt loading from winter de-icing. Field measurements including water temperature and pH are also taken at the time of sample collection using portable water quality meters. Water quality data for all stream monitoring sites is available on the Ontario Ministry of the Environment, Conservation and Parks public website (https://data.ontario.ca/dataset/provincial-stream-water-quality-monitoring-network).

Status of Water Quality in the Great Lakes Tributaries

The WQI was computed for 72 Canadian tributaries to the Great Lakes. The overall water quality status of tributaries to the Great Lakes can be described as Fair (WQIavg=62, WQIrange=18-93). Broken down by category: 17% of the tributaries were categorized as having Good water quality, 64% as Fair, and 19% were Poor (Figures 1 and 2).

Good water quality was found in certain tributaries to Lakes Huron, Superior, and Ontario and the St. Lawrence River. Poor water quality was found in certain tributaries to Lakes Erie and Ontario. The WQI scores ranged from 18 (Sturgeon River, Lake Erie) to 93 (Current River, Lake Superior and Salmon River, Lake Ontario).

On a lake-by-lake basis, tributaries to Lake Superior can be described as having an Undetermined status. Tributaries to Lakes Huron (WQI_{avg}=74, WQI_{range}=54-81, n=20) and Ontario and St. Lawrence River (WQI_{avg}=62, WQI_{range}=32-93, n=34) can be described as having Fair water quality. Tributaries to Lake Erie (WQI_{avg}=43, WQI_{range}= 18-65, n=15) were categorized as having Poor water quality. The designation of the water quality for tributaries (based on the WQI results) has not changed for any of the Great Lake Basins since the last report.

While this assessment is limited to the Canadian portion of the Lake Erie basin, river and stream data from Ohio waters conducted by the Ohio Lake Erie Commission are available for a variety of chemical and biological

parameters. These monitoring efforts indicate that conditions for parameters like dissolved reactive phosphorus are in fair condition with no overall trend, while stream status for a fish community Index of Biotic Integrity and stream habitat quality are considered fair and good, respectively, and have improving trends (Ohio Lake Erie Commission 2022). Overall, water quality tributary conditions in the U.S. component of Lake Erie range from fair to good and with generally unchanging or improving trends.

10 year- and long- term trends

Short (10-year) and long-term trend analyses for three water quality parameters (total phosphorus, nitrate and chloride) known to be influenced by anthropogenic activities are included with this sub-indicator report to estimate trends in water quality conditions. Assessing a singular trend indication on a basin-level is challenging considering the gradient in land uses/covers in various watersheds within each of the Great Lakes Basin. In many cases, trends are mixed since the concentrations of the different water quality parameters evaluated here often vary in opposite directions over time (Table 2). For Lakes Huron and Ontario, the 10-year trend is reported as No Trend since the majority of sites show no trend for total phosphorus and nitrate. Slightly less than half of the trend sites in Lake Huron and slightly more than half of the trend sites in Lake Ontario had an increasing trend in chloride concentrations in the past 10 years. However, greater than 70% of the sites used in the trend analysis show no trend for total phosphorus and nitrate (Table 2). Long-term trends are mixed and therefore assessed as No Trend: most sites show a decreasing trend for total phosphorus, no trend for nitrate, and increasing trend for chloride. The 10-year trend for Lake Erie is reported as No Trend since the majority of sites are showing no trend for all three parameters tested (total phosphorus, nitrate, and chloride). Long-term trend is reported as No Trend due to mixed trends: majority of sites show a decrease in total phosphorus concentrations, no trend in nitrate concentrations, and increase in chloride concentrations.

There are insufficient monitored sites (under the PWQMN) in the Lake Superior Basin to determine trends in tributary water quality for this basin.

Linkages

The WQI values for the 72 tributaries show a statistically significant negative correlation (Spearman's Rank Correlation; $p<0.001$) with percent of the watershed occupied by human land uses (%agriculture and %urban land covers combined) (Figure 4). This relationship suggests that overall water quality in the Great Lakes tributaries is influenced by human land use where minimally developed watersheds have higher WQI scores than more heavily developed watersheds.

The WQI scores suggest the potential for substances in stream water to impact aquatic life based on compliance with water quality criteria. However, the WQI values are not a direct measure of impacts to aquatic communities, such as changes in fish and benthic invertebrate communities. The WQI values (and the water quality in tributaries) also infer the potential for discharge of nutrients or other substances from tributaries into the Great Lakes and the associated impacts of these discharges, particularly at the tributary mouths and nearshore areas.

It should be noted that there are some linkages that can be made to impacts on aquatic life. Elevated concentrations above water quality criteria for parameters such as nitrates, un-ionized ammonia, chloride and metals indicate potential impacts to aquatic life. For example, freshwater mussels are particularly sensitive to chloride (a component of road salt) exposure compared to other aquatic life, especially during their early life stages (Gillis, 2011). Chloride concentrations in many of our rivers and streams have been increasing since the 1970s. (Todd and Kaltenecker, 2012; Sorichetti et al., 2022, Water Quality in Ontario Report 2014).

Linkages to other sub-indicators in the indicator suite include:

- Cladophora – phosphorus inputs from tributaries can have an effect on *Cladophora* growth.
- Harmful Algal Blooms – nutrient inputs from tributaries contribute to algal blooms in receiving water bodies.
- Groundwater Quality – in areas where groundwater and surface water interact, groundwater may influence water quality.
- Nutrients in Lakes (open water) – tributaries transport nutrients and other constituents to downstream receiving water bodies.
- Treated Drinking Water – where drinking water systems use surface water (rivers) as drinking water sources.

Assessing Data Quality

Data Characteristics	Agree	Neutral or Unknown	Disagree	Not Applicable
Data are documented, validated, or quality-assured by a recognized agency or organization	X			
Data are from a known, reliable and respected generator of data and are traceable to original sources	X			
Geographic coverage and scale of data are appropriate to the Great Lakes Basin	X			
Data obtained from sources within the U.S. are comparable to those from Canada				X
Uncertainty and variability in the data are documented and within acceptable limits for this sub-indicator report*	X			
Data used in assessment are openly available and accessible	Yes	Data can be found here: Provincial Water Quality Monitoring Network - Dataset - Ontario Data Catalogue		

Data Limitations

The WQI is a simple communication tool intended for the public. However, the WQI has its limitations. One potential challenge is combining water quality parameters with different ecological impacts (mixing eutrophication parameters with toxics) into one index value, as opposed to sub-indices to represent issues that have common management expectations (i.e., nutrient management programs targeting both point and non-point source

pollution). Some water quality programs do not have sufficient parameters to use the Index without resulting in the inadvertent influence of one parameter (with few parameters, the influence of one can dominate the final Index score). Some water quality parameters are naturally-occurring in certain areas, such as trace metals, and inclusion in the Index may require the development of site-specific guidelines.

The computed WQI score is dependent on the adequacy of the data and the water chemistry parameters that represent the risk based on the human activities within the watershed. Given the cost of some water quality parameters, they may not be included in routine programs and the Index score may not reflect the entire risk.

Because the WQI can be influenced by factors other than water quality (i.e., the particular parameters selected for the calculation, the number of parameters included, the specific sites used and the water quality criteria for a given jurisdiction), using changes in the WQI scores over time to identify trends can be potentially more indicative of changes based on how the index was calculated than changes in the quality of the water. For this reason, an additional analysis is included to determine trends in specific water quality constituents.

Water quality criteria can be exceeded in areas that are naturally rich in a given nutrient or metal. The calculation of the WQI does not take into account naturally occurring elevated concentrations of some parameters.

Furthermore, the overall status for the entire Great Lakes Basin may not be accurate given the spatial bias in the water quality sites used in this assessment. While there is good spatial coverage for both the Lakes Erie and Ontario watersheds, Lake Superior and the northern shore of Lake Huron are underrepresented.

10 year- and long- term trend analyses were conducted using the Mann Kendall trend test which tests for a monotonic trend in the data. Non-monotonic trends (i.e., two different trends in the same time period) may exist in the data but would not be depicted by the Mann Kendall results. For example, a site showing a no trend result from the Mann Kendall test may in fact have two different and significant trends for the time period in question (e.g. increasing then decreasing or decreasing then increasing).

Most of the PWQMN's monitoring sites are purposefully located where water quality impacts are known or expected, such as areas with a high population or where land is used for agriculture. Minimally-impacted reference watersheds are likely under-represented in this sub-indicator. The sub-indicator also under-represents tributaries to the upper Great Lakes (especially Lake Superior).

For this Water Quality in Tributaries report, the WQI has been computed for Canadian tributaries only.

Additional Information

The WQI is a communication tool that was designed to report complex water quality information about multiple variables in a simplified format. While the WQI can provide a broad overview of water quality, it is not intended to replace rigorous technical analyses of water quality data for water resource management.

This current Water Quality in Tributaries report is a status update from 2022 (ECCC and USEPA, 2022). This report uses the same eight (8) parameters as the previous report. The WQI was recalculated for this report using the most recent water quality monitoring results for these parameters with current water quality criteria. This version of the report includes summary results from trend analyses of individual water quality parameters that were computed in the previous report (ECCC and USEPA, 2022). These trend analyses will be computed every other report.

Data from U.S. Great Lakes tributaries will be explored and considered for potential integration into the Water Quality in Tributaries sub-indicator report in the future.

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Table 1. Water quality criteria for the eight indicators used in the CCME Water Quality Index (WQI) calculations.

Source: Ontario Ministry of the Environment, Conservation and Parks.

Table 2. Summary of short (10 year-) and long-term water quality trends (% of sites) in each of the Great Lakes Basins based on Mann Kendall trend tests (number of sites used in the analysis are shown in square brackets).

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Source: Ontario Ministry of the Environment, Conservation and Parks

Figure 2. CCME Water Quality Index (WQI) values for Canadian Great Lakes tributaries by lake basin.

Source: Ontario Ministry of the Environment, Conservation and Parks

Figure 3. Short- and long-term trends for three water quality parameters (chloride, nitrate, and total phosphorus)

Source: Ontario Ministry of the Environment, Conservation and Parks

Figure 4. CCME Water Quality Index (WQI) values for Canadian Great Lakes tributaries (n=72) versus percent agriculture and urban land uses

Source: Ontario Ministry of the Environment, Conservation and Parks

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Table 1. Water quality criteria for the eight indicators used in the CCME Water Quality Index (WQI) calculations.
Source: Ontario Ministry of the Environment, Conservation and Parks

Parameter	Criterion	Source
Ammonia (un-ionized)	0.0152 mg L^{-1}-N	CCME
Chloride	120 mg L^{-1}	CCME
Copper	2 µg L^{-1} at water hardness of 0-120 mg L^{-1}-$CaCO_3$ 3 µg L^{-1} at water hardness of 120-180 mg L^{-1}-$CaCO_3$ 4 µg L^{-1} at water hardness of >180 mg L^{-1}-$CaCO_3$	CCME
Iron	300 µg L^{-1}	CCME
Nitrate	2.9 mg L^{-1}-N	CCME
Nitrite	0.06 mg L^{-1}-N	CCME
Total Phosphorus	0.03 mg L^{-1}	OMOE
Zinc	30 µg L^{-1}	CCME

Table 2. Summary of short (10 year-) and long-term water quality trends (% of sites) in each of the Great Lakes Basins based on Mann Kendall trend tests (number of sites used in the analysis are shown in square brackets).

	Total phosphorus		Nitrate		Chloride	
	10-year	Long-term	10-year	Long-term	10-year	Long-term
Lake Ontario	[63]	[59]	[62]	[56]	[63]	[57]
Decrease	5	59	5	34	0	5
Increase	24	8	15	25	56	79

No trend	71	32	81	41	44	16
Lake Erie	[38]	[35]	[38]	[35]	[38]	[36]
Decrease	5	66	5	23	0	6
Increase	3	3	18	29	42	78
No trend	92	31	76	49	58	17
Lake Huron	[30]	[28]	[30]	[28]	[30]	[28]
Decrease	10	64	10	21	13	11
Increase	3	7	20	18	47	64
No trend	87	29	70	61	40	25
Lake Superior	[1]		[1]		[1]	
Decrease	0		0		0	
Increase	0		0		0	
No trend	100		100		100	

Table 3. WQI Index results, trend results and time period of record (long-term trends) for individual sites used in analyses. The ↑ symbol indicates an increasing trend, ↓ indicates a decreasing trend, and ↔ indicates no trend.

STATION	Great Lake Basin	WQI	CHLORIDE TREND			NITRATE TREND			TOTAL PHOSPHORUS TREND		
			Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range
04001000302	Erie	35.9	↔	↔	1991 - 2019	↔	↔	1991 - 2019	↔	↔	1991 - 2019
04001301702	Erie		↑			↔	↔	2003 - 2019	↔		
04001302502	Erie		↔	↑	1970 - 2019	↑	↑	1984 - 2019	↔	↓	1970 - 2019
04001302902	Erie		↔	↑	1972 - 2019	↓	↓	1984 - 2019	↔	↓	1972 - 2019
04001304102	Erie		↔	↑	1975 - 2019	↓	↔	1984 - 2019	↔	↔	1975 - 2019
04001304402	Erie		↔	↑	1975 - 2019	↔	↑	1984 - 2019	↔	↔	1975 - 2019
04001305802	Erie		↑	↑	1976 - 2019	↔	↔	1984 - 2019	↔	↓	1976 - 2019
04001306402	Erie		↔			↔			↔		

STATION	Great Lake Basin	WQI	CHLORIDE TREND			NITRATE TREND			TOTAL PHOSPHORUS TREND		
			Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range
04001306602	Erie		↔	↑	1979 - 2019	↔	↑	1984 - 2019	↔	↑	1979 - 2019
04001308002	Erie		↔	↑	1988 - 2019	↔	↔	1988 - 2019	↔	↔	1988 - 2019
04001308102	Erie		↔	↔	2006 - 2016	↔	↓	2006 - 2016	↓	↓	2006 - 2016
04001308202	Erie	53.6									
04001308302	Erie		↑	↑	2005 - 2019	↑	↑	2005 - 2019	↔	↔	2005 - 2019
04001309002	Erie		↔	↑	2006 - 2019	↔	↔	2006 - 2019	↔	↔	2006 - 2019
04002700902	Erie		↔	↔	2006 - 2019	↔	↔	2006 - 2019	↔	↔	2006 - 2019
04002701202	Erie		↑	↑	1975 - 2019	↔	↔	1984 - 2019	↔	↓	1975 - 2019
04002701602	Erie		↑	↔	2002 - 2019	↔	↓	2002 - 2019	↔	↔	2002 - 2019
04002701702	Erie	50.9									
10000100302	Erie	44.1									
10000200202	Erie	35.2	↔	↑	1976 - 2019	↔	↔	1984 - 2019	↔	↓	1976 - 2019
16001800202	Erie	48									
16002700102	Erie	16.3									
16003200102	Erie	37.8									
16007200102	Erie	34.3									
16008700502	Erie		↔	↓	2004 - 2019	↔	↑	2004 - 2019	↔	↓	2004 - 2019
16008701002	Erie	38.3									
16010900702	Erie		↑	↑	1980 - 2019	↑	↑	1984 - 2019	↔	↓	1980 - 2019
16010900802	Erie	49.4	↑	↑	2002 - 2019	↑	↑	2002 - 2019	↔	↓	2002 - 2019
16012401102	Erie	67.8	↔	↔	2002 - 2018	↑	↑	2002 - 2018	↓	↓	2002 - 2018
16012401202	Erie		↑	↑	2002 - 2019	↑	↔	2002 - 2019	↔	↔	2002 - 2019
16015900302	Erie	53.9	↑	↑	1981 - 2019	↑	↑	1995 - 2019	↔	↓	1975 - 2019

STATION	Great Lake Basin	WQI	CHLORIDE TREND			NITRATE TREND			TOTAL PHOSPHORUS TREND		
			Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range
16016400102	Erie	49.5	↔	↑	1970 - 2019	↔	↓	1995 - 2019	↔	↔	1970 - 2019
16018401602	Erie		↔	↓	1970 - 2019	↔	↓	1994 - 2019	↔	↓	1970 - 2019
16018403202	Erie		↔	↑	1970 - 2018	↔	↓	1994 - 2018	↔	↓	1970 - 2018
16018403402	Erie		↑	↑	1970 - 2019	↔			↔	↓	1970 - 2019
16018403502	Erie	37.1									
16018403602	Erie		↑	↑	1972 - 2019	↔	↑	1994 - 2019	↔	↓	1972 - 2019
16018403702	Erie		↑	↑	1972 - 2019	↔	↔	1994 - 2019	↔	↓	1972 - 2019
16018406702	Erie		↔	↑	1978 - 2019	↔			↔	↓	1975 - 2019
16018407402	Erie		↔	↔	2007 - 2019	↔	↔	2007 - 2019	↔		
16018407702	Erie		↔	↑	1980 - 2019	↔	↔	1994 - 2019	↑	↓	1975 - 2019
16018409302	Erie		↑	↑	1977 - 2015	↔	↓	1994 - 2015	↔	↓	1977 - 2015
16018409902	Erie		↑	↑	1978 - 2019	↔	↔	1994 - 2019	↔	↓	1978 - 2019
16018410202	Erie		↑	↑	1979 - 2019	↔	↓	1994 - 2019	↔	↓	1979 - 2019
16018410302	Erie		↔	↑	1980 - 2019	↔	↔	1994 - 2019	↔	↓	1980 - 2019
16018410402	Erie		↔	↑	2006 - 2019	↔	↔	2006 - 2019	↔	↔	2006 - 2019
16018410602	Erie		↑	↑	1980 - 2019	↔	↔	1994 - 2019	↔	↓	1980 - 2019
03001500202	Huron	70.9									
03001600302	Huron	85.5	↓	↑	1975 - 2019	↔	↔	1984 - 2019	↔	↔	1975 - 2019
03001700202	Huron	78.3									
03003000202	Huron	85.6	↔	↑	1975 - 2019	↑	↓	1984 - 2019	↓	↓	1975 - 2019
03003601002	Huron	85.5	↓	↓	2002 - 2019	↑	↔	2002 - 2019	↓	↓	2002 - 2019

STATION	Great Lake Basin	WQI	CHLORIDE TREND			NITRATE TREND			TOTAL PHOSPHORUS TREND		
			Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range
03005300102	Huron	85.4	↑	↔	2006 - 2019	↔	↔	2006 - 2019	↔	↔	2006 - 2019
03005702502	Huron	82.7									
03005702902	Huron		↑	↑	2002 - 2019	↔	↔	2002 - 2019	↔	↓	2002 - 2019
03006600102	Huron	69.4									
03007000302	Huron	78.3									
03007000402	Huron		↔	↔	2002 - 2019	↔	↔	2002 - 2019	↔	↓	2002 - 2019
03007300202	Huron	77.3	↑	↑	2002 - 2019	↑	↑	2002 - 2019	↔	↓	2002 - 2019
03007500202	Huron	85.3									
03007600302	Huron	77	↑	↔	2002 - 2019	↑	↔	2002 - 2019	↔	↔	2002 - 2019
03007600502	Huron	78.1	↑	↑	2002 - 2019	↔	↔	2002 - 2019	↔	↓	2002 - 2019
03007702902	Huron		↔	↑	1977 - 2019	↔	↔	2002 - 2019	↔	↓	1977 - 2019
03007703902	Huron		↑	↑	2002 - 2019	↔	↔	2002 - 2019	↔	↓	2002 - 2019
03013301902	Huron		↔	↑	1974 - 2018	↔	↓	2003 - 2018	↔	↓	1974 - 2018
03013400102	Huron		↑	↑	1970 - 2019	↔	↓	1995 - 2019	↔	↓	1970 - 2019
08002100202	Huron	54.8									
08002201002	Huron		↑	↑	2006 - 2019	↔	↔	2006 - 2019	↔	↔	2006 - 2019
08002201602	Huron		↑	↑	1984 - 2019	↓	↔	1984 - 2019	↓	↑	1984 - 2019
08002202002	Huron		↑	↑	2003 - 2019	↔	↔	2003 - 2019	↔	↓	2003 - 2019
08004000802	Huron	69.8	↔	↑	1975 - 2019	↔	↓	1984 - 2019	↔	↓	1975 - 2019
08005600102	Huron	77.9									
08005600202	Huron		↑	↑	1984 - 2019	↔	↑	1984 - 2019	↔	↓	1984 - 2019
08005600302	Huron		↔	↑	1970 - 2019	↔	↑	1984 - 2019	↔	↓	1970 - 2019

STATION	Great Lake Basin	WQI	CHLORIDE TREND			NITRATE TREND			TOTAL PHOSPHORUS TREND		
			Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range
08005600902	Huron		↑	↑	1970 - 2019	↔	↔	1984 - 2019	↔	↓	1970 - 2019
08005603702	Huron		↔	↔	2004 - 2019	↓	↓	2004 - 2019	↔	↔	2004 - 2019
08007600102	Huron	71									
08010300102	Huron	61.5	↑			↔	↔	2002 - 2019	↔		
08012303002	Huron	63.7	↔	↓	2002 - 2019	↑	↔	2002 - 2019	↔	↔	2002 - 2019
08012305102	Huron		↔	↔	2005 - 2019	↔	↑	2005 - 2019	↔	↔	2005 - 2019
08012305702	Huron		↔	↔	2005 - 2019	↑	↑	2005 - 2019	↑	↑	2005 - 2019
08013500302	Huron	78.3	↓	↑	1970 - 2019	↔	↔	1984 - 2019	↔	↓	1970 - 2019
08013500502	Huron		↔	↔	2002 - 2019	↔	↔	2002 - 2019	↔	↔	2002 - 2019
14002800302	Huron		↔	↑	1977 - 2019	↓	↓	1995 - 2019	↔	↓	1977 - 2019
14002801202	Huron		↑	↓	1976 - 2019	↔			↔	↓	1976 - 2019
14002802802	Huron		↓			↔			↔		
06000300102	Ontario	38.1									
06001700102	Ontario	85.3									
06002400102	Ontario	41.2	↔	↑	1970 - 2019	↔	↔	2003 - 2019	↔	↑	1970 - 2019
06006000702	Ontario	62.7									
06006100102	Ontario	56.4	↔	↑	2002 - 2019	↔	↓	2002 - 2019	↔	↔	2002 - 2019
06006300102	Ontario	59.4									
06006301102	Ontario		↔	↑	1975 - 2019	↔	↓	1994 - 2019	↔	↔	1975 - 2019
06006800102	Ontario	37.6									
06007600302	Ontario		↑	↑	1988 - 2019	↔	↑	1994 - 2019	↔	↓	1988 - 2019
06007600402	Ontario		↔	↑	1970 - 2019	↔	↑	1994 - 2019	↔	↓	1970 - 2019

STATION	Great Lake Basin	WQI	CHLORIDE TREND			NITRATE TREND			TOTAL PHOSPHORUS TREND		
			Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range
06007600802	Ontario		↔	↓	1987 - 2014	↑	↑	1994 - 2014	↓	↓	1987 - 2014
06007601002	Ontario		↑	↑	1982 - 2019	↔	↓	1994 - 2019	↔	↓	1982 - 2019
06007602202	Ontario		↑	↑	1979 - 2019	↓	↔	1994 - 2019	↔	↓	1979 - 2019
06007602302	Ontario		↔	↑	1979 - 2019	↔	↓	1994 - 2019	↔	↑	1979 - 2019
06007605002	Ontario	45.4									
06008000602	Ontario	35.4	↔	↑	2002 - 2019	↔	↔	2002 - 2019	↑	↑	2002 - 2019
06008200302	Ontario	32.9									
06008300902	Ontario		↔			↔	↔	2004 - 2019	↑		
06008301902	Ontario	45.8	↔	↑	1988 - 2019	↔	↓	1994 - 2019	↔	↓	1979 - 2019
06008310302	Ontario		↑	↑	2002 - 2019	↔	↓	2002 - 2019	↔	↓	2002 - 2019
06008310402	Ontario		↑	↑	2002 - 2019	↔	↑	2002 - 2019	↔	↔	2002 - 2019
06008501402	Ontario	26.6	↔	↑	1984 - 2019	↑	↓	1994 - 2019	↑	↓	1979 - 2019
06009701102	Ontario	48.6									
06010400102	Ontario	59.7									
06010800102	Ontario	67.9	↑	↑	1970 - 2018	↓	↓	1994 - 2018	↑	↓	1970 - 2018
06011200302	Ontario	67.5									
06011600102	Ontario	62.6	↑	↑	1970 - 2019	↔			↑	↓	1970 - 2019
06011700302	Ontario	78.3	↑	↑	1973 - 2019	↑	↔	1994 - 2019	↑	↓	1973 - 2019
06012900102	Ontario	78.2									
06012900202	Ontario		↑			↔	↓	2002 - 2019	↔		
06012900502	Ontario		↑	↑	2002 - 2019	↑	↓	2002 - 2019	↔	↔	2002 - 2019

STATION	Great Lake Basin	WQI	CHLORIDE TREND			NITRATE TREND			TOTAL PHOSPHORUS TREND		
			Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range
06013000102	Ontario	71									
06013300402	Ontario	70.7	↑	↑	2002 - 2019	↔	↑	2002 - 2019	↑	↔	2002 - 2019
06013300502	Ontario		↑	↔	2006 - 2019	↔	↓	2006 - 2019	↔	↔	2006 - 2019
06017200102	Ontario		↔			↔			↔		
06018000302	Ontario		↔						↔		
06018300202	Ontario	74.2	↔	↑	1970 - 2019	↔	↑	1994 - 2019	↔	↔	1970 - 2019
09000100502	Ontario	51.2	↔			↔			↔		
09000800502	Ontario	54.4	↔	↔	2002 - 2019	↔	↓	2002 - 2019	↔	↔	2002 - 2019
09000800602	Ontario		↑	↑	2002 - 2019	↔	↓	2002 - 2019	↔	↔	2002 - 2019
09000800702	Ontario		↑	↑	2005 - 2019	↓	↓	2005 - 2019	↓	↓	2005 - 2019
09000902402	Ontario	52.7	↑	↔	2002 - 2019	↔	↓	2002 - 2019	↔	↓	2002 - 2019
12000200402	Ontario	62									
12001700102	Ontario	85.1									
12003100102	Ontario	76.3	↑	↔	1986 - 2019	↔	↔	1994 - 2019	↔	↓	1986 - 2019
12003400102	Ontario	54.8	↑	↑	1989 - 2019	↔	↔	1994 - 2019	↔	↓	1989 - 2019
12007300302	Ontario	61.7	↑	↑	1976 - 2019	↔	↔	1994 - 2019	↔	↓	1976 - 2019
12008600102	Ontario		↑	↔	2003 - 2019	↔	↔	2003 - 2019	↔	↓	2003 - 2019
17002100302	Ontario		↔			↔			↔	↓	1970 - 2019
17002103802	Ontario		↑	↑	1970 - 2019	↑	↑	1995 - 2019	↓	↓	1970 - 2019
17002107102	Ontario		↑	↑	2011 - 2019	↔	↔	2011 - 2019	↔	↔	2011 - 2019
17002107502	Ontario		↑	↑	1972 - 2019	↔	↔	1996 - 2019	↔	↓	1972 - 2019

STATION	Great Lake Basin	WQI	CHLORIDE TREND			NITRATE TREND			TOTAL PHOSPHORUS TREND		
			Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range
17002107702	Ontario		↑	↑	2006 - 2019	↑	↔	2006 - 2019	↔	↔	2006 - 2019
17002109502	Ontario		↔			↔			↑	↔	1976 - 2019
17002112802	Ontario		↔	↔	2002 - 2019	↔	↔	2002 - 2019	↔	↓	2002 - 2019
17002113302	Ontario		↑	↑	2002 - 2019	↔	↔	2002 - 2019	↔	↓	2002 - 2019
17002113702	Ontario		↑	↑	2006 - 2019	↔	↑	2006 - 2019	↑	↔	2006 - 2019
17002114502	Ontario		↑	↔	2007 - 2019	↔	↑	2007 - 2019	↑	↑	2007 - 2019
17002600102	Ontario	100									
17002600602	Ontario		↔	↔	2002 - 2019	↔	↔	2002 - 2019	↔	↓	2002 - 2019
17002600702	Ontario		↔	↔	2006 - 2019	↔	↑	2006 - 2019	↔	↔	2006 - 2019
17002600902	Ontario		↑	↑	1970 - 2017	↔	↔	1994 - 2017	↔	↓	1970 - 2017
17002601302	Ontario		↔	↑	1970 - 2019	↔	↔	1994 - 2019	↔	↓	1970 - 2019
17002601902	Ontario		↔	↑	1970 - 2019	↔	↔	1994 - 2019	↔	↓	1970 - 2019
17003100102	Ontario	92.8	↔	↑	1970 - 2019	↔	↓	1994 - 2019	↑	↓	1970 - 2019
17003500202	Ontario	92.6									
17003700302	Ontario	85.3	↔	↓	1987 - 2019	↑	↓	1994 - 2019	↔	↓	1975 - 2019
18003300302	Ontario		↑	↑	1970 - 2019	↔	↓	1994 - 2019	↔	↓	1970 - 2019
18003303102	Ontario		↑	↑	1972 - 2019	↔	↔	1994 - 2019	↔	↓	1972 - 2019
18003303602	Ontario		↑	↑	1980 - 2019	↑	↔	1994 - 2019	↔	↔	1980 - 2019
18207010002	Ontario			↑	1974 - 2019					↓	1974 - 2019
18207014502	Ontario		↑	↑	1980 - 2016	↔	↑	1986 - 2016	↔	↓	1980 - 2016

STATION	Great Lake Basin	WQI	CHLORIDE TREND			NITRATE TREND			TOTAL PHOSPHORUS TREND		
			Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range	Short-term	Long-term	Long-term range
18337012102	Ontario		↑	↑	1986 - 2019	↔	↔	1994 - 2019	↔	↓	1983 - 2019
18343000102	Ontario		↑	↑	2007 - 2019	↔	↑	2007 - 2019	↔	↔	2007 - 2019
18343000202	Ontario		↔	↑	2007 - 2019	↔	↔	2007 - 2019	↔	↔	2007 - 2019
18343006102	Ontario		↔	↑	1983 - 2019	↑	↔	1994 - 2019	↑	↓	1983 - 2019
18343017502	Ontario		↑	↑	2003 - 2019	↔	↑	2003 - 2019	↔	↔	2003 - 2019
18343023002	Ontario		↑	↑	1988 - 2019	↔	↓	1994 - 2019	↑	↔	1988 - 2019
18343061002	Ontario		↔	↓	2003 - 2019	↔	↑	2003 - 2019	↑	↑	2003 - 2019
18369001002	Ontario		↔	↑	1970 - 2018	↔			↑	↓	1970 - 2018
01010400202	Superior	92.1									
01010500102	Superior	69.9	↔			↔			↔		
01010600202	Superior	75.4									

↑ indicates increasing trend

↓ indicates decreasing trend

↔ indicates no trend

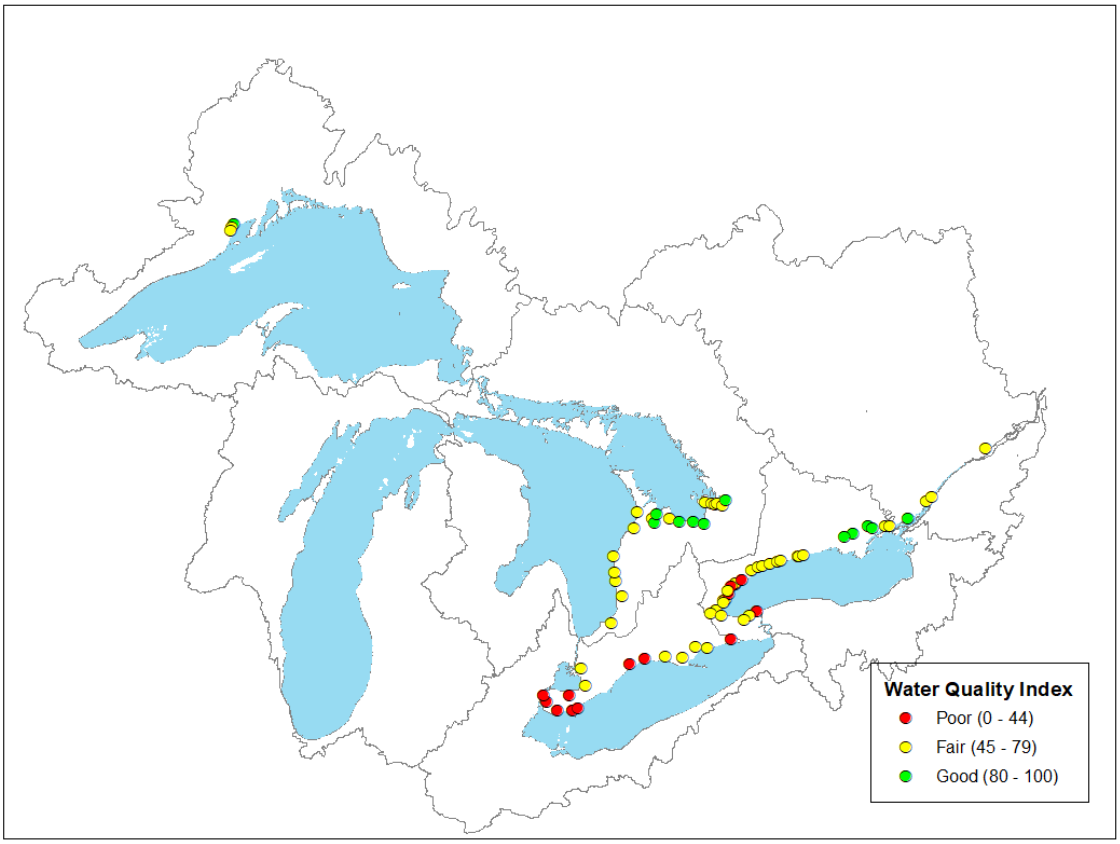

Figure 1. Map showing CCME Water Quality Index (WQI) values for 72 Canadian tributaries to the Great Lakes.

Source: Ontario Ministry of the Environment, Conservation and Parks

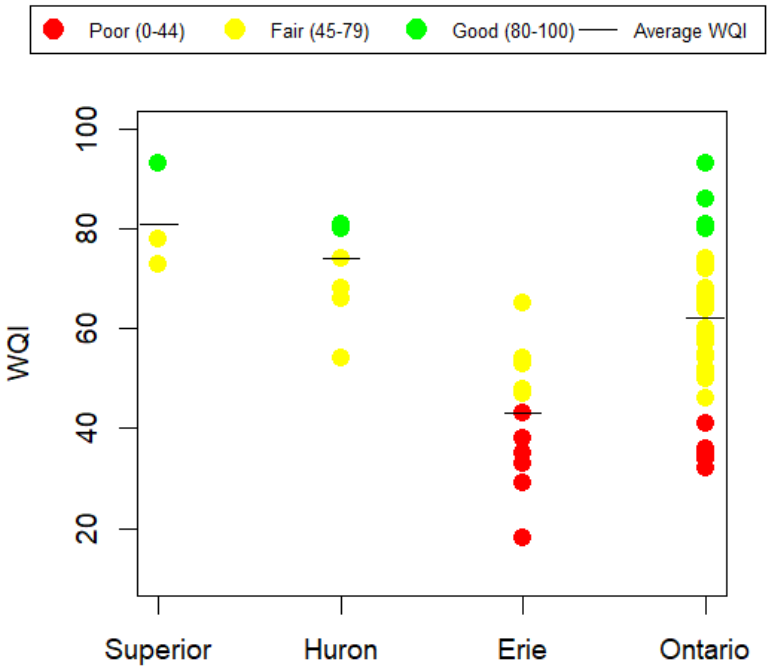

Figure 2. CCME Water Quality Index (WQI) values for Canadian Great Lakes tributaries by lake basin.

Source: Ontario Ministry of the Environment, Conservation and Parks

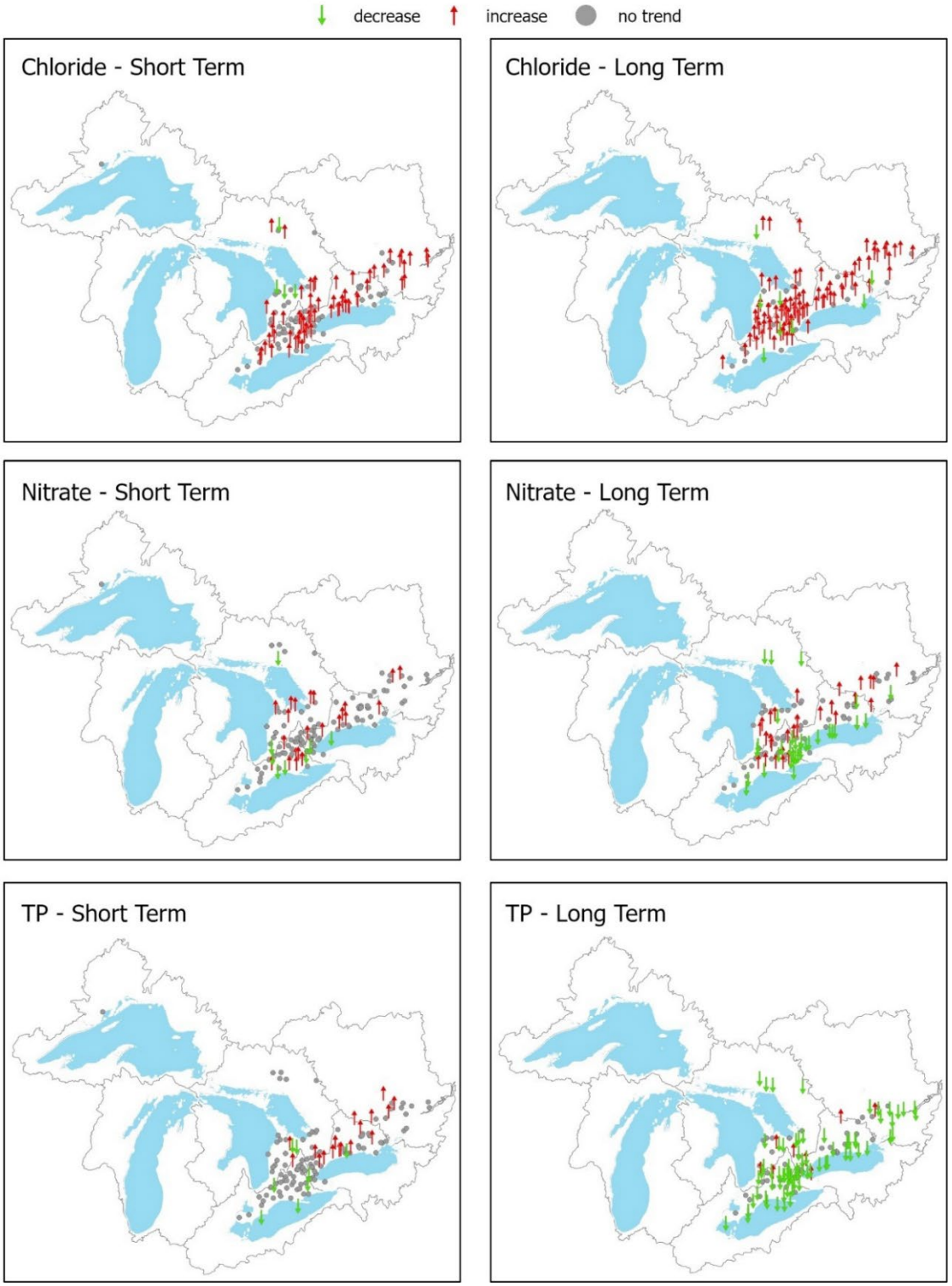

Figure 3. Short- and long-term trends for three water quality parameters (chloride, nitrate, and total phosphorus)

Source: Ontario Ministry of the Environment, Conservation and Parks

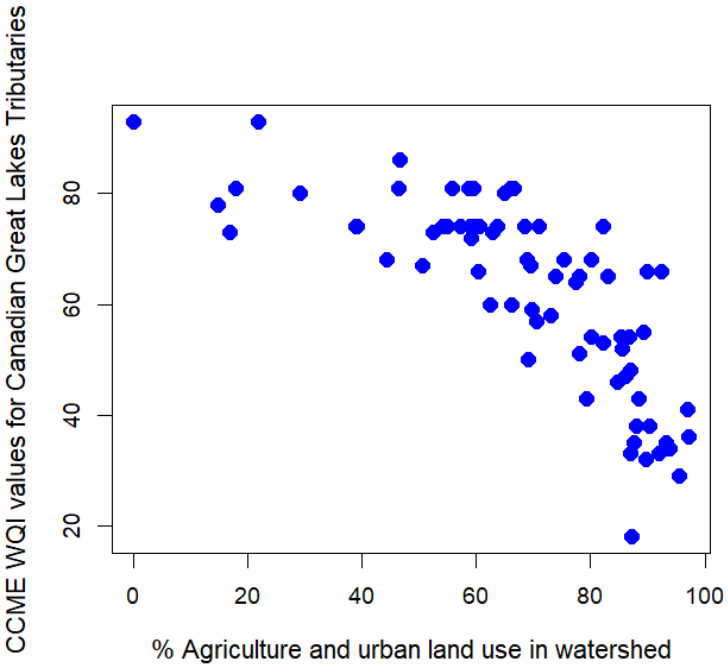

Figure 4. CCME Water Quality Index (WQI) values for Canadian Great Lakes tributaries (n=72) versus percent agriculture and urban land uses

Source: Ontario Ministry of the Environment, Conservation and Parks