Environnement Canada Environment Canada

www.ec.gc.ca

Freshwater Quality Indicator

Data Sources and Methods

March 2011

Cat. #: En4-144/1-2011E-PDF
ISBN: 978-1-100-17976-6

Canada

Table of Contents

Acronyms

BCMELP – British Columbia Ministry of Environment

BCMOE – British Columbia Ministry of Environment

BCMWLAP – British Columbia Ministry of Water, Land and Air Protection

CCME – Canadian Council of Ministers of the Environment

CESI – Canadian Environmental Sustainability Indicators

EC – Environment Canada

INAC – Indian and Northern Affairs Canada

MDDEP – Ministère du Développement durable, de l'Environnement et des Parcs

NHN – National Hydrometric Network

NRCan – Natural Resources Canada

NRTEE – National Round Table on the Environment and the Economy

NPRI – National Pollutant Release Inventory

OECD – Organisation for Economic Co-operation and Development

OMOE – Ontario Ministry of the Environment

PPWB – Prairie Provinces Water Board

RAA - rapid assessment approach

SDAC – Standard Drainage Area Classification

US EPA – United States Environmental Protection Agency

WQI – Water Quality Index

YDOE – Yukon Department of Environment

1. Introduction

This report is released under the Canadian Environmental Sustainability Indicators (CESI) initiative. Each indicator reported under CESI has an associated “data sources and methods” report to provide technical detail and other background to facilitate interpretation of each indicator or allow others to conduct further analysis using the CESI data and methods as a starting point.

This report addresses the underlying methods and data for the Freshwater Quality Indicator as published on the CESI website (www.ec.gc.ca/indicateurs-indicators/).

1.1 Changes since the last report

A number of changes have occurred since the last CESI report of the freshwater quality indicator published in May 2009. The following list provides an overview of the changes, which are described in more detail in subsequent sections:

- This year, the core network comprises 176 stations. New stations have been added in Nova Scotia, Saskatchewan, Quebec and Newfoundland-Labrador.
- The total number of stations included is 348 compared to 437 last year. The decrease is due to many jurisdictions choosing to provide scores for core sites only.
- Many jurisdictions have modified their parameter suites. Quebec federal stations and Saskatchewan provincial stations now have metals included in their calculations. British Columbia stations have a more harmonized set of parameters.

2. The Freshwater Quality Indicator

The CESI freshwater quality indicator (WQI) provides the Canadian public, policy analysts and decision makers with information about the status of water quality in Canada for the protection of aquatic life. This information allows Canadians to better understand and evaluate Canada's environmental performance and the impacts of our social and economic decisions on the environment. Socio-economic decisions can include lifestyle and consumer choices, support for various policies, and commercial and industrial developments. By reporting at multiple scales (i.e., nationally, by drainage region and at individual stations), users can focus on their particular region or locale of interest. The freshwater quality indicator provides an overall measure of the ability of water bodies to support aquatic life at selected monitoring stations in Canada. The indicator is calculated using the Water Quality Index endorsed by the Canadian Council of Ministers of the Environment (CCME WQI) (CCME 2001) and is applied as recommended by the National Round Table on Environment and Economy (NRTEE 2003). Given that aquatic life can be influenced by the presence of hundreds of both natural and anthropogenic substances in water, the CCME WQI is a communication tool useful in allowing experts to translate vast amounts of water quality monitoring information into a simple overall rating. In practice, these ratings are based on 4–15 measured substances, usually those of greatest concern for aquatic life.

The WQI summarizes the potential for substances in water to impact aquatic life and is based on existing knowledge about the toxicity and predicted fate and behaviour of chemical substances in the environment. It is not a direct measure of changes to aquatic communities, such as changes in the composition or abundance of benthic invertebrates or fish. Rather, the CCME WQI results provide complementary assessments of aquatic habitat quality.

Using water quality guidelines, the CCME WQI measures the frequency and extent to which selected parameters exceed water quality guidelines at individual monitoring stations. Water quality guidelines are numerical values for physical, chemical, radiological or biological characteristics of water. When these concentrations are exceeded, it is an indication adverse effects on aquatic life may be occurring.[1] Water quality guidelines used in the calculations are those derived for the protection of aquatic life. They include national guidelines developed by the CCME; provincial and site-specific guidelines developed by federal, provincial and territorial partners; and American guidelines developed by the United States Environmental Protection Agency. If a water quality guideline value is exceeded at a given station, there is an increased probability of an adverse effect on aquatic life at that site.

2.1 The CCME Water Quality Index

The CCME WQI relates water quality data to a selected beneficial water use[2] using relevant water quality guidelines as benchmarks. Each index is calculated for an individual monitoring station during a chosen reference period. Water samples collected over this period of time are analyzed for a suite of water quality parameters. The measured values of each parameter are compared to the appropriate water quality guideline (Appendix 1). These are called tests. The percentage of parameters and tests failing to meet the guidelines, as well as the deviation from the guideline for tests that do not meet guidelines, are captured in three factors used in the calculation of the index. These factors are scope (F_1), frequency (F_2), and amplitude (F_3). The index yields a number between 0 and 100. A higher number indicates better water quality. Please refer to the CCME website for more detail about how the CCME WQI is calculated (http://www.ccme.ca/ourwork/water.html?category_id=102).

The index scores rating system

[1] Water quality guidelines are specific to particular water uses such as protection of aquatic life, crop irrigation, livestock watering, drinking water and recreation.

[2] These uses include protection of aquatic life, drinking water, livestock watering, crop irrigation and recreational use (CCME 1999).

The WQI yields a number between 0 and 100 indicating overall water quality for a particular use. Scores are categorized into five groups according to the rating system in Table 1.

Table 1: The rating system for the Freshwater Quality Indicator

Rating	Interpretation
Excellent (95.0 to 100.0)	Water quality measurements never or very rarely exceed water quality guidelines.
Good (80.0 to 94.9)	Water quality measurements rarely exceed water quality guidelines and, usually, by a narrow margin.
Fair (65.0 to 79.9)	Water quality measurements sometimes exceed water quality guidelines and, possibly, by a wide margin.
Marginal (45.0 to 64.9)	Water quality measurements often exceed water quality guidelines and/or exceed the guidelines by a considerable margin.
Poor (0 to 44.9)	Water quality measurements usually exceed water quality guidelines and/or exceed the guidelines by a considerable margin.

Note: These interpretations are adapted from those endorsed by the CCME (2001), based on the initial assessment of over 100 sites by water quality experts in British Columbia (Rocchini and Swain 1995).

2.2 How the CCME Water Quality Index for aquatic life is used

The CCME WQI calculation has been used by many organizations and jurisdictions, including watershed conservation groups and territorial, provincial and federal government agencies, to inform the public, decision makers and relevant stakeholders on the status and trends of water quality in local water bodies (BCMOE 1996; Government of Alberta 2008; Grand River Conservation Authority 2004; Khan et al. 2004; CCME 2005a; Environment Canada 2005a; Lumb et al. 2006; EC et al. 2007). It has also been used to track the effectiveness of remedial measures on local water quality (Glozier et al. 2004; Wright et al. 1999) and to report on the effectiveness of government programs and policies (Government of Alberta 2008).

Although the CCME provides general guidance on how to use the index, practitioners are responsible for deciding which water quality parameters, guidelines and time periods to use, as well as the number of samples to include for a given application of the index. As a result of this flexibility, different approaches have been used to apply the CCME WQI to achieve different objectives. For example, the British Columbia Ministry of the Environment (BCMOE 1996) has compared site-specific guidelines to the most recent three years of data to evaluate the suitability of water quality to support different beneficial uses. Glozier et al. (2004) applied the index using background concentration[3] values from reference sites[4] in Alberta's national parks to assess change in status of and trends for downstream stations. In that report, trends were calculated as rolling values based on five year blocks of samples (e.g., 1983–1987 and 1984-1988), while status was assessed for a 20-year period. In contrast, Wright et al. (1999) used background concentration values from a given time period, rather than reference sites, as benchmarks for the index to assess changes in water quality over time. Site-specific guidelines are developed because of the natural differences that exist among aquatic ecosystems in terms of natural background conditions, chemical interactions between water quality parameters, etc.

As a result of this flexibility in applying the CCME WQI, a protocol for calculating WQI ratings across Canada for the CESI initiative was developed (Environment Canada 2005b). For this release, however, there remains variation in the applications of the WQI among regions within Canada (see Appendix 1). Comparisons of site-specific scores between provinces or regions should be made with caution.

[3] The concentration of a water quality constituent not influenced by human activity.
[4] An area considered to be relatively unaffected by human activity.

2.3 Data preparation and presentation

Data used to calculate the freshwater quality indicator were derived from water samples collected at water quality monitoring stations across the country from 2006 to 2008. Some exceptions exist: for Newfoundland - Labrador, samples from December 2005 or January 2009 were included at some stations to achieve the minimum samples number. Data were combined to calculate a single index value for each site using the CCME WQI formula. The steps below were followed to carry out the calculations:

1. Selection step:
    a. Station selection
    b. Parameter selection
    c. Relevant national, regional or site-specific guideline selection
    d. Number of samples, timing and collection period
2. Calculation step:
    a. Data extraction
    b. Data validation
    c. Index calculation

The index values for each station were classified into the five quality categories of the WQI (Table 1) and presented in a histogram as the freshwater quality indicator for Canada and 16 drainage regions (Pearse et al. 1985).

3. Data source(s)

Water quality data used in the calculation of the freshwater quality indicator were obtained from a number of existing water quality monitoring programs from across the country (Table 2). These programs are managed by federal and provincial departments as well as by federal-provincial agreements. The networks were originally established for a wide range of purposes such as to monitor water quality changes in certain lakes and rivers due to human-derived pollution. Currently, there is no single national water quality monitoring network designed specifically to report the state of Canada's water quality.

Table 2: Monitoring programs providing data on ambient water quality for 2006 to 2008

Province/territory	Monitoring program	Organization(s)
Alberta	Long-term River Network monitoring program	Alberta Environment
Alberta	Prairie Provinces Water Board	Environment Canada, Alberta Environment
British Columbia	Canada–British Columbia Water Quality Monitoring Agreement	British Columbia Ministry of Environment, Environment Canada
British Columbia and Yukon	Federal Water Quality Monitoring Program	Environment Canada, Parks Canada
Manitoba	Prairie Provinces Water Board, Canada–Manitoba Water Quality Monitoring Agreement	Environment Canada, Manitoba Water Stewardship
	International Red River Board, Federal Water Quality Monitoring Program	International Red River Board, including Environment Canada and Manitoba Water Stewardship
	Ambient water quality monitoring network	Manitoba Water Stewardship
New Brunswick	Canada–New Brunswick Water Quality Monitoring Agreement	Environment Canada, New Brunswick Department of Environment
	Long-range Transport of Atmospheric Pollutants Program	Environment Canada
	Surface water monitoring network, National Parks project	New Brunswick Department of Environment
Newfoundland and Labrador	Canada–Newfoundland and Labrador Water Quality Monitoring Agreement	Environment Canada, Newfoundland and Labrador Department of Environment and Conservation, Parks Canada
Nova Scotia	Long-range Transport of Atmospheric Pollutants Program	Environment Canada
	Pockwock-Bowater Watershed Study	Nova Scotia Environment
	Canadian Wildlife Service, park survey, Maritimes	Environment Canada
Ontario	Provincial Water Quality Monitoring Network	Ontario Ministry of the Environment
Prince Edward Island	Canada–Prince Edward Island Water Quality Agreement	Environment Canada, Prince Edward Island Department of Environment, Energy and Forestry
Quebec	Réseau-Rivières	Ministère du Développement durable, de l'Environnement et des Parcs du Québec
	The State of the St. Lawrence Monitoring Program	Environment Canada

Province/territory	Monitoring program	Organization(s)
Saskatchewan	Prairie Provinces Water Board	Environment Canada, Saskatchewan Ministry of Environment
	Souris River Bilateral Agreement, Federal Water Quality Monitoring Program	International Souris River Board, including Environment Canada and Manitoba Water Stewardship
	Saskatchewan Ministry of Environment Surface Water Quality Monitoring Program	Saskatchewan Ministry of Environment
Northwest Territories and Nunavut	Northwest Territories–Nunavut extensive water quality monitoring network; Northern Energy MC Aquatic Quality Program—Northwest Territories portion of Mackenzie River Basin; Alberta–Northwest Territories transboundary rivers water quality monitoring program; Environment Canada–Parks Canada Northern bioregion national parks programs (seven national parks in Northwest Territories–Nunavut–northern Yukon: Nahanni, Tuktut Nogait, Aulavik, Ivvavik, Quttinirpaaq, Auyuittuq, Ukkusiksalik); Environment Canada–Fisheries and Oceans Canada Lower Hornaday River water quality monitoring program; Indian and Northern Affairs Canada water quality programs in Northwest Territories basins with Northern Development (Coppermine, Yellowknife, Lockhart, Slave, Hay, Liard, Peel, Snare, Burnside River basins)	Environment Canada, Indian and Northern Affairs Canada, Parks Canada, Fisheries and Oceans Canada, Alberta Environment, Government of Northwest Territories (Environment and Natural Resources), Government of Nunavut (Department of Environment)
Yukon	Canada-Yukon Water Quality Monitoring Network	Yukon Environment, Environment Canada

Each program monitors a specific array of parameters designed to suit the program's objectives. These monitoring programs track ambient concentrations[5] of a range of parameters that can include major ions[6] (e.g., chloride and sulphate), nutrients (e.g., phosphorus and nitrogen), metals (e.g., mercury), organic compounds including pesticides and industrial chemicals, and other parameters (e.g., dissolved oxygen, suspended solids and pH). Sampling frequencies also differ among networks due to differences in program requirements, resource constraints, and ease of access to sites.

[5] Concentration of substances in the aquatic environment, as opposed to effluent discharges.

[6] Positively or negatively charged molecules that occur in water as a result of geochemical weathering of rocks, surface runoff and atmospheric deposition. The eight major ions—calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulphate and chloride—account for most of the total dissolved solids in surface waters.

3.1 Station selection

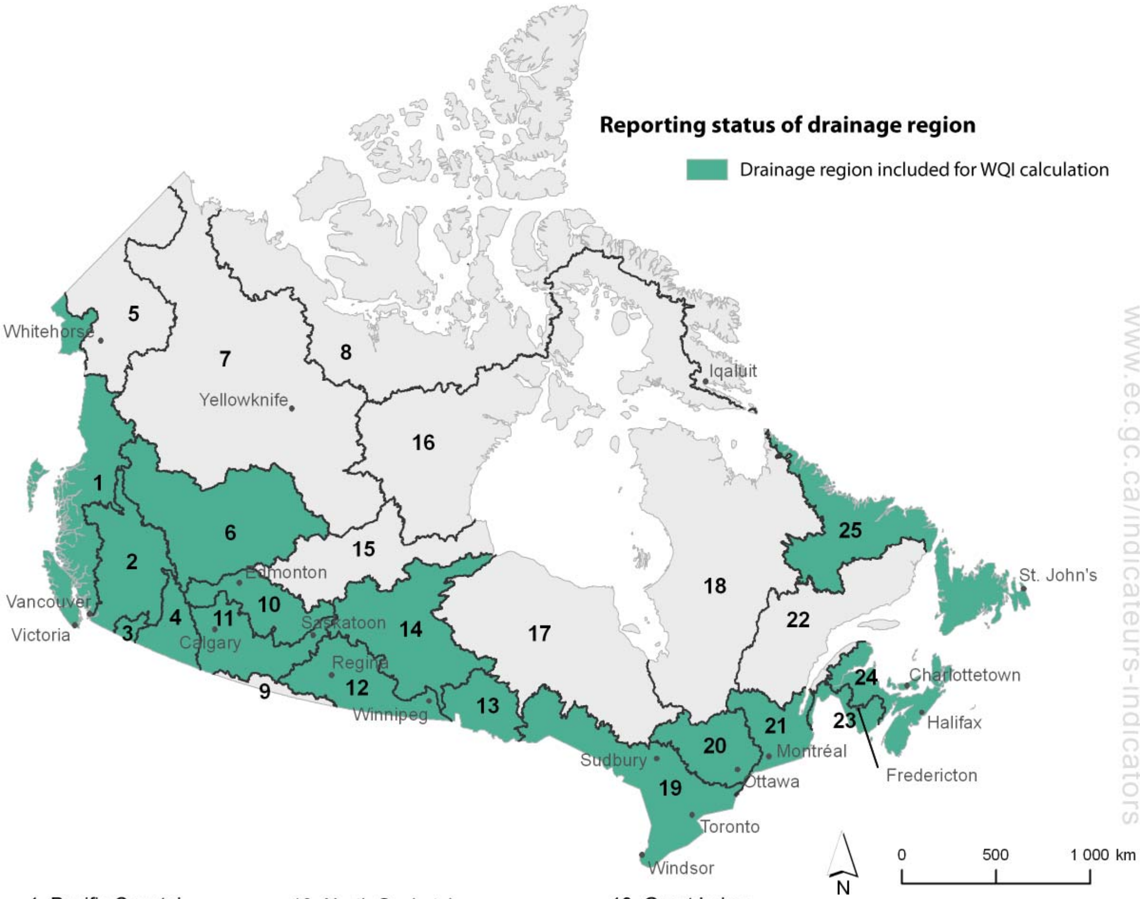
Data from 348 water quality monitoring stations were available for reporting on water quality status across Canada. From this pool of stations, 176 were selected to create a core network to improve the spatial representation among drainage regions and reduce redundancy between stations. The geographic extent for the core network was defined based on hydrology and on the type of direct human pressures on water quality. This station design ensures the core sites are representative of water quality across Canada and reduces overlap among stations. How the core sites were selected is detailed below. The remaining 172 river stations, called “local sites”, were used along with the core sites for local reporting. More information about the monitoring stations included in the WQI can be found in the CESI WQI Interactive Mapping application (http://maps-cartes.ec.gc.ca/indicators-indicateurs/default.aspx?lang=en).

A- Defining geographic extent

In past WQI reports, the “North line” was used to highlight differences in sampling intensity and in the number of stations between northern and southern Canada (see Data Sources and Methods 2008 or prior). In 2009, Canada’s 25 drainage regions were used to define the geographic extent of the stations used to calculate the national freshwater quality indicator (Figure 1).

In Canada, there are five ocean drainage areas, 25 drainage regions and 974 sub-sub-drainage areas. The drainage regions in this classification are based on the major river basins defined by Pearse et al. (1985) to represent Canada’s hydrology. These drainage basin regions can be built up from the sub-sub-drainage areas defined in the Standard Drainage Area Classification (SDAC) 2003 (Statistics Canada, 2009). The ocean drainage areas are based on the ocean drainage areas defined in the *National Scale Frameworks Hydrology - Drainage Areas, Canada, Version 5*. The 25 drainage regions are named and numbered as are the ocean drainage areas and the sub-sub-drainage areas. Of this pool of drainage regions, a subset of 16 regions was selected based on potential human-derived pressure on water quality in these regions. These pressures include population density, agricultural land use and pollutant releases from point sources, such as industry or mining. The selection process resulted in the removal of 18 stations from the national histogram because they lay outside the 16 drainage regions used for reporting.

Figure 1. Geographic extent of the 16 drainage regions in the more populated regions of Canada used to report the national freshwater quality indicator



1. Pacific Coastal
2. Fraser Lower-Mainland
3. Okanagan - Similkameen
4. Columbia
5. Yukon
6. Peace - Athabasca
7. Lower Mackenzie
8. Arctic Coast - Islands
9. Missouri
10. North Saskatchewan
11. South Saskatchewan
12. Assiniboine - Red
13. Winnipeg
14. Lower Saskatchewan - Nelson
15. Churchill
16. Keewatin - Southern Baffin
17. Northern Ontario
18. Northern Quebec
19. Great Lakes
20. Ottawa
21. St. Lawrence
22. North Shore - Gaspé
23. Saint John - St. Croix
24. Maritime Coastal
25. Newfoundland and Labrador

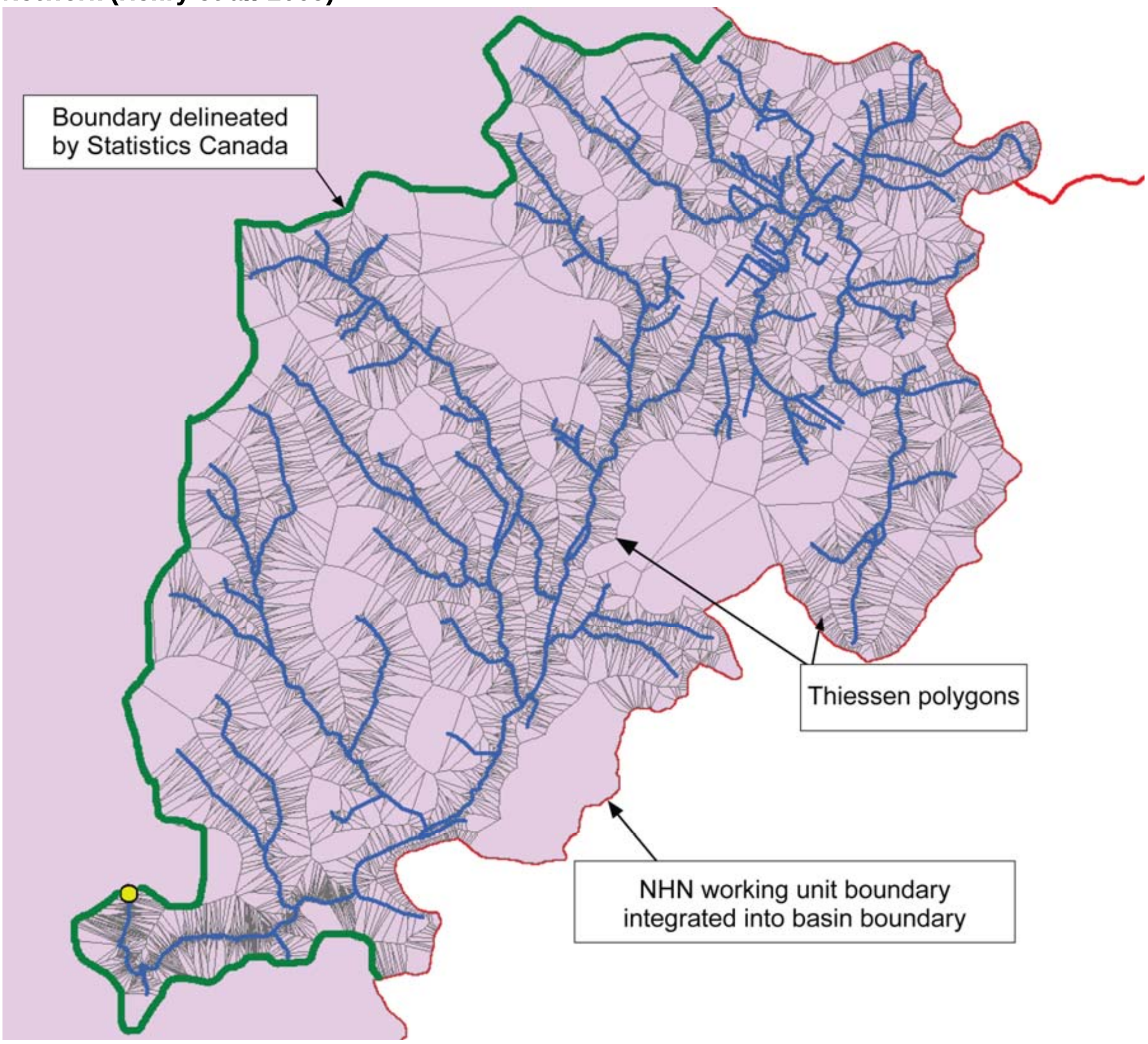
B- Defining geographic coverage of stations

The drainage area for all stations was delineated using flow direction and work unit[7] (WU) data layers from the National Hydrometric Network (NHN; work by Henry et al. 2009). For each station, the upstream hydrometric network was determined by selecting the appropriate arc and tracing the full upstream network by following the flow direction contained in the NHN layer. These upstream networks, and their adjacent networks, were used to create Thiessen[8] polygons to delineate a portion of the basin boundaries (Figure 2). When the boundaries intersected with the NHN work unit boundaries, these points were selected and integrated as the basin boundary. If the network extended beyond the work unit, the adjacent work units were also captured in the drainage area.

[7] The NHN work unit is a drainage area delimited by the drainage area covered by the NHN dataset. These work units do not necessarily represent official boundaries for watersheds or drainage areas. For more information about the NHN work units, please see: www.geobase.ca/geobase/en/data/nhn/units.html

[8] A Thiessen polygon is a set of regions surrounding points on a plane such that all locations within any given region are closer to one of the points than to any other point.

Figure 2. Example of how a drainage basin was delineated using the National Hydrometric Network (Henry et al. 2009)



C- Reducing station redundancy

The overlap of drainage areas was reduced so stations used to calculate the national and regional indicators were independent of each other. This overlap is a problem in many areas, especially on large rivers, as many stations are downstream of one another or on main tributaries. Within the established geographic extent, there were 213 stations with overlapping drainage areas. In basins where more than one station overlapped, the most downstream station was retained, as this station is impacted by the maximum area in the river basin and thus reflects the cumulative impact of all upstream stresses.

Fourteen large rivers were selected because they have high water yields and/or large basin areas. These rivers were chosen because, in cases such as the Athabasca or North Saskatchewan rivers, water travels thousands of kilometres between an upstream and downstream stations and water quality naturally changes along the way. Within these large river systems, stations representing the upper, mid and lower portions of the river were retained, as well as the most downstream stations on each of the tributaries.

D- Classifying stations

A further selection of stations was carried out for each drainage region to create a suite of stations that is proportionally representative of the main human pressures in the overall drainage region and to balance coverage among drainage regions. For example, drainage regions with a high proportion of undisturbed land should have more stations in undisturbed area than basins in agricultural regions. To make this selection, information was compiled for all stations to characterize their drainage areas, including drainage region area, water yield (Bemrose et al. 2009), population (Statistics Canada's *2006 Census of Population*), location of mines (NRCan's *2006 Mine Inventory*), pollutant releases from industrial and commercial facilities (NPRI 2007), agricultural activity (Statistics Canada's *Census of Agriculture 2006*), and land coverage (NRCan 2005a; NRCan 2005b).

Based on this analysis, each station was classified into one of four categories:

- Agricultural: if the station had >20% of agricultural land cover;
- Mining: if there was at least one mine
- Remote: if the station had > 95% of undisturbed land cover
- Mixed urban, agricultural and industrial if the population density > 25 persons/km^2

For water quality monitoring stations added this year, hence not included in the classification exercise, we asked the responsible organization to provide the classification based on their knowledge of the station.

E- Final station selection

In more heavily monitored drainage regions, water quality monitoring stations had to be further pared down. To do this, the length of historical data records, the potential for new human developments, the availability of complementary monitoring and the ease of data access were considered when choosing the sites. In all, 176 core sites were chosen from the pool of 348 stations (Figure 3). These stations are well distributed among the populated sections of southern Canada (Table 3) and across drainage regions while retaining the pattern of monitoring intensity found across Canada (Table 4).

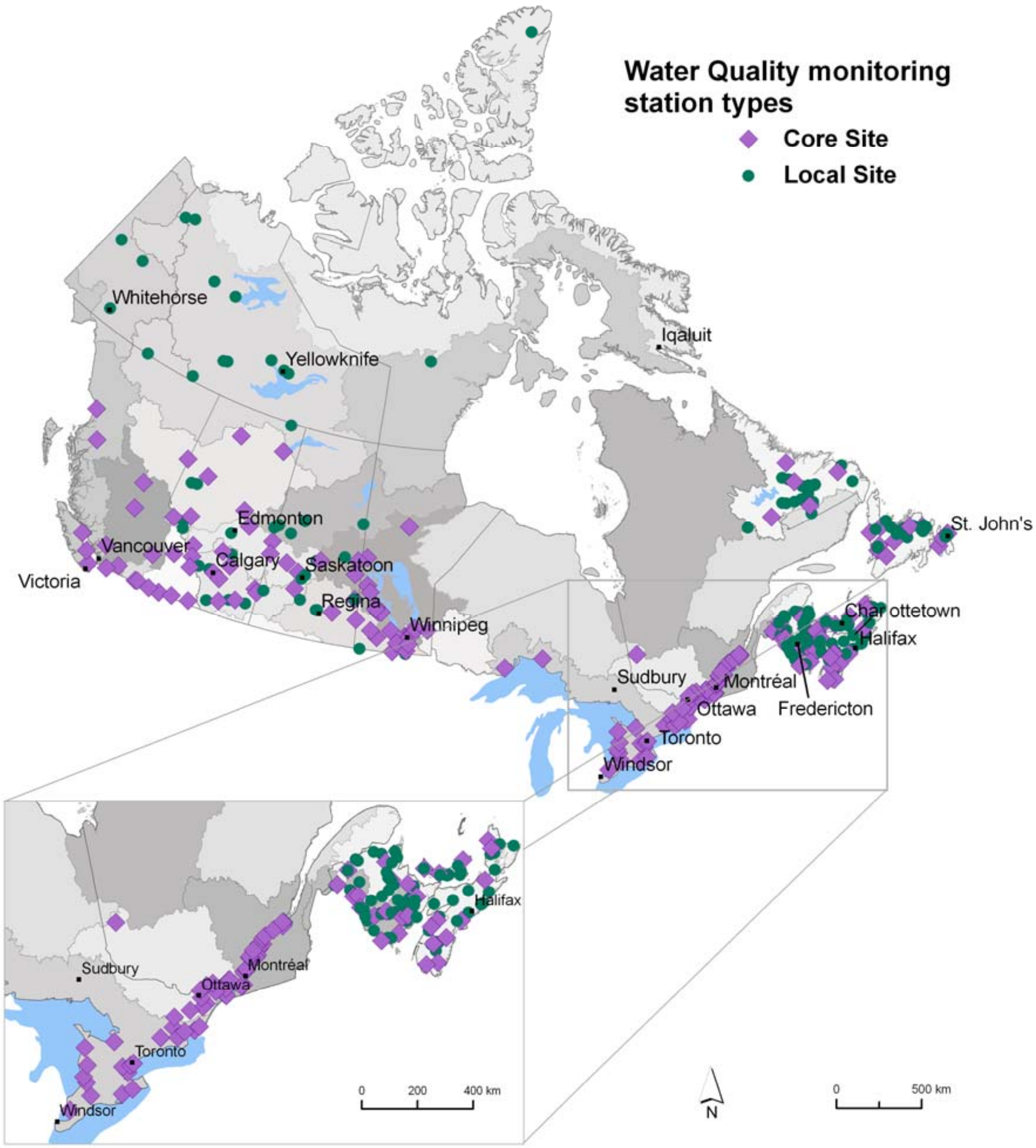
Table 3: Number of core and local sites in each jurisdiction in the 2010 water quality indicator

Province	Core sites	Local sites	Total sites
Yukon	0	4	4
British Columbia	22	0	22
Northwest Territories	0	10	10
Alberta	17	13	30
Saskatchewan	10	14	24
Manitoba	21	2	23
Ontario	30	0	30
Quebec	31	0	31
Nunavut	0	2	2
New Brunswick	15	42	57
Nova Scotia	10	20	30
Prince Edward Island	3	7	10
Newfoundland and Labrador	17	58	75

Table 4: Number of core sites in each drainage region in the 2010 water quality indicator.

Drainage region	Core sites
Pacific Coastal	6
Fraser – Lower Mainland	6
Okanagan – Similkameen	2
Columbia	7
Yukon	0
Peace – Athabasca	6
Lower Mackenzie	0
North Saskatchewan	7
South Saskatchewan	10
Assiniboine – Red	13
Winnipeg	1
Lower Saskatchewan – Nelson	12
Churchill	0
Keewatin – Southern Baffin	0
Northern Ontario	0
Great Lakes	19
Ottawa River	12
St. Lawrence	30
Saint John – St. Croix	10
Maritime Coastal	18
Newfoundland – Labrador	17

Figure 3. Water quality monitoring sites used to calculate the water quality indicator for 2006 to 2008



3.2 Parameter selection

The parameters used in the WQI calculations are chosen to reflect the main human-derived water quality stressors across Canada. These stressors include urban development, agriculture, forestry, mining, smelting, pulp and paper mills and other industrial facilities, deposition of atmospheric pollutants and dams (Environment Canada 2001).

Decisions about which parameters are used in the national WQI are made by provincial, territorial and federal water quality experts (Table 5). Decisions are based on knowledge about which local stressors potentially affect water quality in the region or at each stations. Only parameters relevant to the protection of aquatic life are included. This selection excludes bacterial counts, for example, which are primarily of concern for human health. For all jurisdictions, except British Columbia, a common suite of parameters is applied to all stations within the jurisdiction or monitoring program. Site-specific parameter selections are made in British Columbia, with dissolved oxygen, phosphorus, pH and water temperature included wherever available.

Table 5: Parameters used for the water quality index calculation for core/local sites in each province and territory

Parameter	BC	AB	SK	MB	ON	QC	NB	NS	PE	NL	YT	NT	NU
Alkalinity	B (2)												
Aluminium		A											
Ammonia		A	A	B (18)	A		A					A	A
Arsenic	B (6)	A	A	A		A	A				B (2)	B (3)	
Cadmium	B (14)	B (19)											
Chloride	B (2)	B (8)	A	B (3)	A		A	A		A		A	A
Chlorophyll a						A							
Chromium	B (6)			B (18)	A						B(1)	B (5)	
Copper	B (18)	A	B (20)	A		B (4)	A	A		A	A	A	A
Cyanide	B (2)												
Dissolved Oxygen	B (4)	B (27)	B (21)	A			A	B (25)	A	B (49)			
Fluoride	B (2)												
Iron	B (2)			B (18)			A	A		A		A	A
Lead	B (17)	A	A	A				B (28)		A	B (2)	A	A
Manganese	B (1)												
Mercury						B (4)							
Molybdenum	B (2)												
Nickel	B (4)	B (8)	B (21)	A	A	B (4)				A			
Nitrate	B (3)			B (18)	A		A	B (24)	A	A	B (1)		
Nitrite	B (1)										B (1)		
Nitrate+Nitrite	B (1)					A						A	
pH	A	B (8)	A	A	A	B (28)	A	A	A	A	A	B (13)	A
Phosphorus	A	A	A	A	A	A	A	A	A	A	B (2)	A	A
Pesticide - 2 4 D		B (24)	B (21)	B (20)									
Pesticide - Atrazine						B (3)							
Pesticide - Bentazone						B (3)							
Pesticide - Dicamba						B (3)							
Pesticide - Metalochlor						B (3)							
Pesticide - MCPA		B (24)	B (21)	B (20)									
Selenium	B (5)										B (1)		
Silver	B (9)										B (2)		
Sulphate	B (2)												
Temperature	A										A		
Thallium	B (2)												
Total Nitrogen	B (16)	A	A								B (2)		
Total Suspended Solids				B (18)									
Turbidity	B (1)					A	A						
Uranium	B (1)												
Zinc	B (19)	A	A	A	A	B (4)	A	A		A	A	B (13)	A

Notes: Parameters marked with "A" were used at all stations in the province or territory. Those marked with "B" were only used at selected stations. The number in brackets beside the B represents the number of stations at which this parameter was used.

3.3 Water quality guideline selection

Nationally, water quality guidelines are developed using science-based protocols endorsed by the CCME (CCME 2007a). Typically, water quality guidelines are based on laboratory toxicity studies showing effects on various forms of aquatic life (e.g., fish, invertebrates, plants) using different concentrations of a constituent in water. Generic, national water quality guidelines are often conservative so to provide a high level of protection to aquatic life. This protection is incorporated through the use of uncertainty factors chosen based on the quality and availability of toxicological information for the substance. Natural concentrations of some substances may exceed these water quality guidelines.

Calculation of the freshwater quality indicator relies largely on the use of existing long-term (chronic) water quality guidelines for the protection of aquatic life. In a few instances, guidelines were applied for short-term (acute) exposure.[9] Regional water quality experts select water quality guidelines on a site-specific or jurisdictional basis from the suite of generic water quality guidelines available from a range of sources[10] and from existing site-specific guidelines for parameters of local interest (Appendix 1). The principle behind guideline selection is to choose those that are "locally relevant," meaning appropriate to local aquatic life. Background concentrations of naturally-occurring substances and other characteristics of water, such as hardness and temperature, can affect the toxicity of some substances of concern. For more information on the selection of guidelines, see the Technical Guidance document for WQI practitioners (GoC 2008).

Some provinces and territories have directly adopted the CCME water quality guidelines for their needs, while others have developed their own water quality guidelines using protocols similar to those of the CCME. In the Northwest Territories and some Nunavut rivers, the upper range of local natural background concentrations for selected parameters was statistically estimated and found to be greater than recommended water quality guidelines. In these cases, site-specific guidelines based on background concentration procedures (CCME 2003) were used.

The rapid assessment approach (RAA)[11] is another site-specific method used to derive water quality guidelines for areas with naturally high concentrations of parameters that fluctuate with water turbidity. The RAA uses long-term monitoring data, not toxicity studies, to determine locally-relevant water quality guidelines. This approach was applied to many parameters for stations in British Columbia.

3.4 Sample numbers, timing and collection period

Annual fluctuations in weather and hydrology can have a considerable impact on water quality and, consequently, on the resulting index ratings when applied for individual years. Thus, ratings were calculated using three years of data to dampen temporal variability and reflect a more general state of water quality. This year's freshwater quality indicator was calculated using water quality data from 2006 to 2008, the years for which the most recent data are available from all monitoring programs.

Minimum sample numbers for the three-year reporting period were established for river, lake and northern stations (Table 6). Stations not meeting these minimum sample numbers were excluded from the national reporting of the WQI.

[9] In Quebec, the guideline used for turbidity is for short-term (acute) exposure.
[10] Sources include the Prairie Provinces Water Board (PPWB) 1992; Ontario Ministry of the Environment (OMOE) 1994; CCME 1999; Alberta Environment 1999; BCMOE 2001; Quebec's Ministère du Développement durable, de l'Environnement et des Parcs (MDDEP) 2006; Williamson 2002; and United States Environmental Protection Agency (US EPA) 2005.
[11] See GoC, 2008

Table 6: Sample frequency requirements for WQI application

Water body	Minimum requirements
Lakes	6 samples over the 2006 to 2008 period
Rivers	12 samples over the 2006 to 2008 period
Northern rivers	9 samples over the 2006 to 2008 period

In rivers and streams, surface sampling is considered to be representative of the water column, which is normally well mixed. However, sampling may need to be repeated more often throughout the year to capture water quality variability. The CCME technical guidance document (CCME 2001) recommends a minimum of four samples per year based on the original testing of the index (Rocchini and Swain 1995). This sampling scheme accounts for seasonal and hydrological variability.

Five stations in Manitoba have 11 rather than 12 samples for the 2006-2008 period. These stations are located in remote locations and the parameter measurements did not show large variation. These stations were included in the indicator to ensure national representativity. Similarly, certain stations in New Brunswick did not have the minimum sampling requirements, but these stations were included in the indicator given they did not show large variation.

In northern and remote locations, routine water sampling can be costly and challenging; it is sometimes dangerous and difficult to access stations and weather conditions can be extreme. As a result, monitoring stations are sampled less frequently. In addition, a sensitivity analysis conducted on several northern rivers revealed having nine samples rather than the required minimum of 12 samples over a three-year period did not produce WQI scores that differed significantly (Glozier et al., pers. comm.[12]). For these reasons, the minimum sampling frequency for rivers in the North was reduced from the 12 used in southern Canada to 9 for the 2006 to 2008 period.

3.5 Data management, calculation and verification

Water quality data from each of the monitoring programs are stored in provincial or federal databases managed by the respective environment departments. Basic station information (e.g., station name and location) and water quality data were extracted from available databases by regional and provincial data providers and transferred to the “WQI calculator,” a program that calculates WQI ratings. The WQI calculator allows users to select input parameters, water quality guidelines and sample periods, and includes options allowing water quality guidelines to be calculated based on water hardness, pH or temperature, where appropriate.

Data quality assurance and control is important for all monitoring programs. Unusually high or low values in the WQI datasets are double-checked and confirmed through consultation with the data provider. A check for data entry errors is also performed by ensuring reported units are correct, consulting stream flow and meteorological records and/or comparing with the concentrations of other parameters in the dataset (e.g., turbidity, hardness, total suspended solids, major ions) that could explain unusually high or low concentrations. Unless an error is identified, unusually high or low values are left in the dataset. When the original dataset provided is modified, the data provider is consulted.

After validation of the dataset, calculations are verified and peer reviewed. Environment Canada experts transfer station information, WQI ratings and details on the calculation (i.e., data source, parameters, guidelines, sample numbers and dates, and contact information) into templates for incorporation into a central database. Station data are reviewed by staff in the Water Quality Monitoring and Surveillance Division and the Information and Indicators Division of Environmental Canada to ensure the number of samples, timing and locations meet methodological requirements.

---

[12] Glozier, N., L. Lévesque, and D. Halliwell. Personal communication. Environment Canada. March 2005.

These data are used to generate the freshwater quality histograms and maps of monitoring station locations. A final verification of the ratings and calculation methods (i.e., parameters included, guidelines used, site information) compiled into the national database for each station is carried out by each data provider to detect any errors introduced during information integration.

4. Caveats and limitations

4.1 Station selection

The current collection of monitoring networks from which the freshwater quality data were extracted was designed to respond to specific federal, provincial or regional needs. The networks were not intended to be representative of water quality in Canada as a whole and all its watersheds. The majority of monitoring stations in the local sites data set are located in populated areas and areas where it is thought water quality is affected by human stressors, such as acid rain deposition, dams and industries (e.g., pulp and paper and mines), urban development or agriculture.

The selection of a core set of stations is a means of selecting stations that are more representative of the portion of Canada where the majority of Canadians live. Even after *a priori* geographical criteria were applied to station selection, water quality monitoring stations used in this report do not cover all geographic areas with potential water quality issues or problems across Canada. One obvious under-represented area is Canada's North, which is increasingly being developed and is already showing the effects of climate change.

4.2 Parameter selection

The type and number of parameters included in the WQI calculations differed across water quality monitoring stations and jurisdictions (Tables 6 and 7). For more information on the selection of parameters, see the Technical Guidance document for WQI practitioners (GoC 2008). This flexibility in the WQI allows local and regional water quality concerns and objectives of the monitoring programs to be reflected in the WQI rankings. However, differences in parameter selection among jurisdictions and stations make comparing stations for national aggregation difficult. When the WQI was established, it was recommended between 4 and 15 parameters be included in the WQI calculations (Environment Canada 2005b). A sensitivity analysis has shown the use of approximately 10 parameters yields the most stable WQI scores (Painter and Waltho 2005).

Variation among stations with respect to parameter selection also occurs because not all possible stressors are sampled everywhere because of the random nature of some releases (e.g., unknown or accidental spills), the tracking of substances in other media, such as sediment or fish tissue, provide more reliable measures and the high cost of measuring some parameters on a routine basis (e.g., organic substances).

For the Pacific and Yukon Region, metal values are removed from the WQI calculation when conditions at a given station are highly turbid and where relationships between turbidity and a given metal have been established. The rationale for this decision is the expectation that high metal concentrations measured during such events are due to sediments suspended during high river flows. These metals are not considered available for biological uptake, and, as such, likely do not pose the same risk to aquatic life as dissolved metals.

4.3 Water quality guideline selection

Appendix 1 provides a list of water quality guidelines used by each jurisdiction to calculate the WQI. Water quality guideline exceedances can occur naturally. Human influence is not the only cause of water quality guideline exceedances. Natural exceedances can happen when river flows increase causing sediments to be suspended and along with them various metals and nutrients. Parameters can also exceed water quality guidelines in areas naturally rich in a given metal or nutrient.

In most cases, metal guidelines are calculated using total (or extractable) rather than dissolved metal concentrations. Metals in unfiltered water may be bound to particulates or colloidal molecules making them less bioavailable than suggested by the concentration measured as total metals. However, under different environmental conditions part of the bound fraction may become bioavailable and pose a threat to aquatic life. For the WQI, we use water quality guidelines for total metals as they provide a higher degree of protection for aquatic life than those available for dissolved metals. However, by being conservative, guidelines will be exceeded more often even when the risk is likely minimal.

4.4 Sample timing and frequency

There is variation in timing and frequency of sampling among monitoring programs (Table 7). Some programs are more intensive to capture the full range of variability and seasonality inherent at each station. Other programs are less intensive, more opportunistic and/or random due to resource constraints and the remote nature of some stations. It is currently not known whether this variation poses a problem or creates a bias for the overall indicator. The three-year time period selected as the basis for the indicator helps reduce the potential for some stations to "misrepresent" water quality on an annual basis and accounts for high or low annual water levels which may affect concentrations.

A sensitivity analysis conducted on several northern rivers revealed that having nine samples rather than the required minimum of 12 over a three-year period did not produce WQI scores that were significantly different (Glozier et al., pers. comm.[13]). Another sensitivity analysis for southern Ontario streams suggested that more than 12 samples over three years could be required to produce reliable calculations (Painter and Waltho 2005).

Table 7: Minimum and maximum number of samples for stations by drainage region, 2006-2008.

Drainage region	Core site minimum sample count	Core site maximum sample count	Local site minimum sample count	Local site maximum sample count
Pacific Coastal	26	137	26	137
Fraser – Lower Mainland	29	36	29	36
Okanagan – Similkameen	31	36	31	36
Columbia	26	137	26	137
Yukon	0	0	26	32
Peace – Athabasca	34	39	12	36
Lower Mackenzie	0	0	7	33
North Saskatchewan	14	36	36	36
South Saskatchewan	12	36	35	36
Assiniboine – Red	12	36	11	36
Winnipeg	34	34	0	0
Lower Saskatchewan – Nelson	11	36	10	36
Churchill	0	0	12	36
Keewatin – Southern Baffin	0	0	9	9
Great Lakes	20	60	0	0
Ottawa River	18	56	0	0
St. Lawrence	15	54	0	0
Saint John – St. Croix	11	12	11	12
Maritime Coastal	12	36	12	36
Newfoundland – Labrador	9	38	9	38

[13] Glozier, N., L. Lévesque, and D. Halliwell. Personal communication. Environment Canada. March 2005.

4.5 Data quality

Water quality data exist at three levels: individual samples taken at monitoring stations; the combination of individual samples to calculate a WQI score for a particular station; and the aggregated dataset of all WQI values from the selected stations across the country (see Section 2.3.3).

It is inevitable that errors occur in individual sample results. The most common errors can occur in the field due to sample contamination or mislabelling. In the lab, errors can occur when samples are misidentified, concentrations miscalculated, through analytical mistakes or during data entry. Each monitoring program follows standardized methods for sample collection in the field to ensure reliability of measurements. Chemical analyses are undertaken in Canadian laboratories accredited by the Canadian Association for Laboratory Accreditation or the Canadian Standards Council ensuring analytical methods are up to standard and proper quality assurance / quality control procedures are in place. Additional reviews are conducted on raw data and WQI calculations and final validation is made by Environment Canada's water quality monitoring staff in regional offices.

5. Data sources and methods for accompanying measure: Nutrients in freshwater

Nitrogen and phosphorus are naturally occurring elements essential for all living organisms, and are often found in growth-limiting concentrations in aquatic environments. An oversupply of nutrients in a lake or river can result in eutrophication of a water body through excessive aquatic plant growth. The subsequent decay of excess plant material can lead to anoxia or reduced amounts of oxygen available for fish and other aquatic animals. Other negative repercussions include clogged intake pipes, impaired navigation and a reduction in the aesthetic and recreational value of Canada's lakes and rivers. Algal growths can also be toxic, killing livestock and resulting in the closure of shellfish-growing areas.

The natural level of phosphorus in water is influenced by the amounts and types of rock and soil in a given area. Water bodies in regions with a thick soil layer, such as the Prairies, have naturally high phosphorus levels compared to water bodies in areas with a thin soil layer, such as the Canadian Shield. Nitrate is the most stable form of nitrogen. It is formed naturally in the decay of plants and animals in water and is present in animal waste. It acts as a nutrient at low concentrations but can become toxic at high concentrations. Agricultural runoff containing organic or synthetic fertilizers, as well as municipal and industrial wastewater discharges, are the main human sources of nutrients in lakes and rivers.

5.1 How is the measure calculated

A trend analyses were conducted using phosphorus and nitrogen measurements from Federal and Federal-Provincial surface freshwater monitoring stations. Phosphorus measurements include total phosphorus (75 stations) and total dissolved phosphorus (39 stations). Nitrogen measurements include total nitrogen (52 stations) and nitrate (NO_3) (84 stations). A monitoring station was included if data were available for a minimum of 10 years between 1990 and 2006. For phosphorus, 114 stations were considered and 136 stations were considered for nitrogen. In areas where there is a high density of stations, such as the Atlantic Provinces, a representative subset was selected to create a general picture of nutrient concentrations based on data availability, land use, sampling frequency and/or spatial distribution.

Monitoring was conducted by several federal departments including Environment Canada, Parks Canada and Indian and Northern Affairs Canada, and by provincial/territorial departments under federal-provincial/territorial monitoring programs. All of these agencies have standardized sampling protocols designed to minimize errors introduced by sampling methods and preservation techniques. Samples were analyzed for nutrients using nationally accepted methods at certified laboratories across Canada. Laboratories were accredited by the Canadian Association for Laboratory Accreditation.

A Mann Kendall test was performed to detect long-term trends in nitrogen and phosphorus concentrations. When seasonality was detected using a Kruskal-Wallis test, Seasonal Kendall test was used. Non-parametric tests allowed the inclusion of non-normal datasets and reduced the influence of extreme outliers.

Once the significance and direction of tests were determined for all stations, a national chart was created by summing all stations in each of increasing, decreasing or no trend categories. A sum of the stations in each result category was also compiled for Canada's ocean drainage basins.

As data come from multiple monitoring programs and databases, a common data quality assurance and quality control approach was taken to address outliers, censored data (i.e., observations below detection limits) and changes in analytical methods over time.

5.2 Caveats and limitations

The monitoring programs were not specifically designed to be spatially representative of Canada or the ocean drainage basins as a whole. Moreover, monitoring stations do not cover all areas where excess nutrients are an issue. Data availability is the main determinant for station selection. All stations were equally weighted regardless of location or water discharge.

5.3 Data source(s)

Environment Canada. 2010. Phosphorus in Canada's Aquatic Ecosystems. www.ec.gc.ca/eaudouce-freshwater/default.asp?lang=En&n=B61C9777-1

Personal Communication. 2010. V. Mercier, Atlantic Fresh Quality Monitoring Office, Environment Canada.

6. References

Alberta Environment. 1999. Surface Water Quality Guidelines for Use in Alberta. Science and Standards Branch, Alberta Environment, Edmonton, Alberta. Available from: http://www.environment.gov.ab.ca/info/library/5713.pdf

[BCMOE] British Columbia Ministry of Environment. 1996. *British Columbia Water Quality Status Report.* April 1996. Environmental Protection Division, British Columbia Ministry of Environment, Victoria, British Columbia. Available from: ww.env.gov.bc.ca/wat/wq/public/bcwqsr/bcwqsr1.html

[BCMOE] British Columbia Ministry of Environment. 2001. *British Columbia Approved Water Quality Guidelines (criteria) 1998 Edition*. Environmental Protection Division, British Columbia Ministry of Environment, Victoria, British Columbia.

[BCMWLAP] British Columbia Ministry of Water, Land and Air Protection. 2004. "Water Quality Assessment and Objectives for the Elk River for the Purpose of National Reporting." Technical Appendix, Draft December 2004. Victoria, British Columbia.

Bemrose, R., L. Kemp, M. Henry, and F. Soulard. 2009. *The Water Yield for Canada as a Thirty-year Average (1971 to 2000): Concepts, Methodology and Initial Results*. Environment Accounts and Statistics Analytical and Technical Paper Series. Statistics Canada Catalogue no. 16-001-MWE2009007.

Butcher, G.A. 1992. *Lower Columbia River, Hugh Keenleyside Dam to Birchbank: Water Quality Assessment and Objectives: Overview Report.* Water Quality Branch, British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia. Available from: www.env.gov.bc.ca/wat/wq/objectives/birchbank/birchbank.html.

[CCME] Canadian Council of Ministers of the Environment. 1999. *Canadian Environmental Quality Guidelines*. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.

[CCME] Canadian Council of Ministers of the Environment. 2001. Canadian water quality guidelines for the protection of aquatic life: CCME Water Quality Index 1.0, User's manual In: *Canadian Environmental Quality Guidelines.* 1999. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba. Available from: www.ccme.ca/assets/pdf/wqi_usermanualfctsht_e.pdf

[CCME] Canadian Council of Ministers of the Environment. 2003. *Canadian Water Quality Guidelines for Protection of Aquatic Life – Guidance for Site-Specific Application of Water Quality Guidelines in Canada and Procedures for Deriving Numerical Water Quality Objectives*. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.

[CCME] Canadian Council of Ministers of the Environment. 2005a. *Application and Testing of the CCME Water Quality Index for Selected Water Bodies in Atlantic Canada.* Prepared by Environment Canada, New Brunswick Department of Environment and Local Government, Newfoundland and Labrador Department of Environment and Conservation, Nova Scotia Department of Environment and Labour, and Prince Edward Island Department of Fisheries, Aquaculture and Environment for Water Quality Task Group, Canadian Council of Ministers of the Environment, Winnipeg, Manitoba. Available from: www.ec.gc.ca/soer-ree/English/resource_network/status_report_e.cfm

[CCME] Canadian Council of Ministers of the Environment. 2005b. *Canadian Environmental Quality Guidelines.* Update 5.0. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba. Available from: www.ccme.ca/publications/ceqg_rcqe.html

[CCME] Canadian Council of Ministers of the Environment. 2007a. A protocol for the derivation of water quality guidelines for the protection of aquatic life 2007. In: *Canadian Environmental Quality Guidelines*, 1999,. Canadian Council of Ministers of the Environment, 1999, Winnipeg.

[CCME] Canadian Council of Ministers of the Environment. 2007b. Canadian water quality guidelines for the protection of aquatic life: Summary table. Updated December 2007. In: Canadian environmental quality guidelines, 1999, Canadian Council of Monitors of the Environment, Winnipeg.

Dodds, W.K., J.R. Jones, and E. Welch. 1998. Suggested classification of stream trophic state: distributions of temperate stream types by chlorophyll, total nitrogen, and phosphorus. *Water Research*, 32: 1455–1462.

Environment Canada. 2001. *Threats to Sources of Drinking Water and Aquatic Ecosystem Health in Canada.* National Water Research Institute, Burlington, Ontario. 72 pp.

Environment Canada. 2005a. *Proceedings of the 2nd CCME National Workshop on the Water Quality Index — Towards a Nationally Consistent Water Quality Indicator for Canada*, February 15–18, 2005.

Environment Canada. 2005b. *Initial Guidance for Calculating the Water Quality Index (WQI) for the Environment and Sustainable Development Indicators, Water Quality Indicator.* 17 pp.

Environment Canada. 2005c. *Recommended Water Quality Guidelines for the Protection of Aquatic Life for Use in the 2005 National Water Quality Indicators under the Canadian Environmental Sustainability Indicators (CESI) Initiative* [draft]. National Guidelines and Standards Office, Environment Canada, Gatineau, Quebec.

Environment Canada. 2005d. *Site-specific Water Quality Guidelines for the Dezadeash River at Haines Junction for the Purpose of National Reporting*. Prepared by Tri-Star Environmental Consulting, May 2005.

Environment Canada. 2005e. *Site-specific Water Quality Guidelines for the Beaver River at Park Gate Highway 1 for the Purpose of National Reporting*. Prepared by Tri-Star Environmental Consulting, May 2005.

Environment Canada. 2005f. *Site-specific Water Quality Guidelines for the Liard River at Upper Crossing for the Purpose of National Reporting*. Prepared by Tri-Star Environmental Consulting, May 2005.

Environment Canada. 2005g. *Site-specific Water Quality Guidelines for the Kicking Horse River above Field, BC, for the Purpose of National Reporting*. Prepared by Tri-Star Environmental Consulting, May 2005.

Environment Canada. 2005h. *Site-specific Water Quality Guidelines for the Kootenay River at Kootenay Crossing for the Purpose of National Reporting*. Prepared by Tri-Star Environmental Consulting, May 2005.

Environment Canada. 2005i. *Site-specific Water Quality Guidelines for the Skeena River at Usk for the Purpose of National Reporting*. Prepared by Tri-Star Environmental Consulting, May 2005.

Environment Canada. 2005j. *Site-specific Water Quality Guidelines for the Sumas River at the International Border for the Purpose of National Reporting*. Prepared by Tri-Star Environmental Consulting, May 2005.

Environment Canada, 2007. *Technical guidance document for Water Quality Index practitioners reporting under the Canadian Environmental Sustainability Indicators (CESI) initiative – 2007 update.* Unpublished draft. Ottawa, Ontario.

[EC, BCMOE, YDOE] Environment Canada, British Columbia Ministry of Environment, Yukon Department of Environment. 2007. *British Columbia and Yukon Territory Water Quality Report (2001–2004): An Application of the Canadian Water Quality Index.* Environment Canada, Vancouver, British Columbia.

Fidler, L.E., and G.G. Oliver. 2001. *Water Quality Guidelines for Temperature, Overview Report. Water, Air and Climate Change Branch, British Columbia Ministry of Water, Land and Air*

Protection, Victoria, British Columbia. Available from: www.env.gov.bc.ca/wat/wq/BCguidelines/temptech/temperature.html

Glozier, N.E., R.W. Crosley, L.A. Mottle, and D.B. Donald. 2004. *Water Quality Characteristics and Trends for Banff and Jasper National Parks: 1973–2002.* Ecological Science Division, Environmental Conservation Branch, Environment Canada, Saskatoon, Saskatchewan.

Government of Alberta. 2008. *Measuring up: Progress Report on the Government of Alberta Business Plan. Annual Report 2007-2008*. Government of Alberta, Edmonton, Alberta.

[GoC] Government of Canada. 2008. Technical guidance document for water quality index practitioners reporting under the Canadian environmental sustainability indicators (CESI) initiative. Prepared by Environment Canada and Statistics Canada. Ottawa, ON. 48 p.

Grand River Conservation Authority. 2004. *Grand River Conservation Authority 2004 Fall Report.* Grand River Conservation Authority, Cambridge, Ontario.

Gwanikar, S., S. Cross, D. MacDonald, J.R. Brown, D.Q. Tao, and T. Berger, 1998. *Salmon River: Water Quality Assessment and Recommended Objectives*. Technical Appendix – Volume 1. Environment Canada, Vancouver, British Columbia.

Henry, M., Soulard, F., and Larocque, H. 2009. *Canadian Environmental Sustainability Indicators: Water Quality Index Representivity Report*. Environment Accounts and Statistics Division, Statistics Canada.

Khan, A.A., R. Paterson, and H. Khan. 2004. Modification and application of the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) for the communication of drinking water quality data in Newfoundland and Labrador. *Canadian Water Quality Research Journal*, 39(3): 285–293.

Lumb, A., D. Halliwell, and T.C. Sharma. 2006. Application of CCME Water Quality Index to monitor water quality: A case study of the Mackenzie River basin, Canada. *Environmental Monitoring and Assessment*, 113: 411–429.

Manitoba Conservation. 2002. *Manitoba Water Quality Standards, Objectives and Guidelines*. Water Quality Management Section, Water Branch, Manitoba Conservation, Winnipeg, Manitoba. Available from: www.gov.mb.ca/waterstewardship/water_quality/quality/website_notice_mwqsog_2002.html.

[MDDEP] Ministère du Développement durable, de l'Environnement et des Parcs. 2006. *Critères de qualité de l'eau de surface au Québec.* Ministère du Développement durable, de l'Environnement et des Parcs du Québec, Québec, Quebec. Available from: http://www.mddep.gouv.qc.ca/eau/criteres_eau/fondements.htm

Nagpal, N.K. 1987. *Water Quality Criteria for Lead, Overview Report.* Water Management Branch, British Columbia Ministry of Environment and Parks, Victoria, British Columbia. Available from: www.env.gov.bc.ca/wat/wq/BCguidelines/lead/lead.html

Nagpal, N.K. 1999. *Water Quality Criteria for Zinc, Overview Report.* Water, Air and Climate Change Branch, British Columbia Ministry of Environment and Parks, Victoria, British Columbia. Available from: www.env.gov.bc.ca/wat/wq/BCguidelines/zinc/zinc.html

Nagpal, N.K. 2001a. *Ambient Water Quality Guidelines for Manganese, Overview Report.* Water, Air and Climate Change Branch, British Columbia Ministry of Environment and Parks, Victoria, British Columbia. Available from: www.env.gov.bc.ca/wat/wq/BCguidelines/manganese/manganese.html

Nagpal, N.K. 2001b. *Ambient Water Quality Guidelines for Selenium, Overview Report.* Water, Air and Climate change Branch, British Columbia Ministry of Water, Land and Air Protection, Victoria, British Columbia. Available from: www.env.gov.bc.ca/wat/wq/BCguidelines/selenium/selenium.html

Nagpal, N.K., D.A. Levy, and D.D. MacDonald. 2003. *Ambient Water Quality Guidelines for Chloride, Overview Report.* Water, Air and Climate Change Branch, British Columbia Ministry of Water, Land and Air Protection, Victoria, British Columbia. Available from: http://www.env.gov.bc.ca/wat/wq/BCguidelines/chloride/chloride.html

Nagpal, N.K., L.W. Pommen, and L.G. Swain. 2006. *A Compendium of Working Water Quality Guidelines for British Columbia.* Science and Information Branch, British Columbia Ministry of Environment, Victoria, British Columbia [updated August 2006]. Available from: http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html

[NPRI] National Pollutant Release Inventory. 2007. Environment Canada. Available from: www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=4A577BB9-1

Nordin, R.N., and L.W. Pommen. 1986. *Water Quality Criteria for Nitrogen (Nitrate, Nitrite, and Ammonia).* Water Management Branch, British Columbia Ministry of Environment and Parks, Victoria, British Columbia. Available from: http://www.env.gov.bc.ca/wat/wq/BCguidelines/nitrogen/nitrogen.html

[NRTEE] National Round Table on the Environment and the Economy. 2003. *Environment and Sustainable Development Indicators for Canada.* National Round Table on the Environment and the Economy, Ottawa, Ontario.

[OECD] Organisation for Economic Co-operation and Development. 1982. *Eutrophication of Waters: Monitoring, Assessment and Control.* Organisation for Economic Co-operation and Development, Paris. 154 pp.

[OMOE] Ontario Ministry of the Environment. 1994. *Water Management Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy* [reprinted February 1999]. Ontario Ministry of the Environment. 67 pp. Available from: http://www.ene.gov.on.ca/envision/gp/3303e.pdf.

Painter, S., and J. Waltho. 2005. *Test Driving the Canadian Water Quality Index.* Ecosystem Health Division, Environmental Conservation Branch, Ontario Region, Environment Canada.

Pearse, P.H., F. Bertrand and J.W. MacLaren. 1985. *Currents of Change: Final Report of the Inquiry on Federal Water Policy.* Environment Canada. Ottawa, ON.

[PPWB] Prairie Provinces Water Board. 1992. *Master Agreement on Apportionment. Schedule E: Agreement on Water Quality*. Prairie Provinces Water Board, Regina, Saskatchewan.

Rocchini, R., and L.G. Swain. 1995. *The British Columbia Water Quality Index.* Water Quality Branch, Environmental Protection Department, British Columbia Ministry of Environment, Land and Parks, Victoria, British Columbia. 13 pp.

Singleton, H.J. 1987. *Water Quality Criteria for Copper: Overview Report.* Water Management Branch, British Columbia Ministry of Environment and Parks, Victoria, British Columbia. Available from: www.env.gov.bc.ca/wat/wq/BCguidelines/copper/copper.html

Singleton, H.J. 2000. *Ambient Water Quality Guidelines for Sulphate: Overview Report.* Water Management Branch, British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia. Available from: www.env.gov.bc.ca/wat/wq/BCguidelines/sulphate/index.html

Statistics Canada. 2009. Standard Drainage Areas Classification (SDAC) 2003. Available from: www.statcan.gc.ca/subjects-sujets/standard-norme/sdac-ctad/sdac-ctad-eng.htm

Swain, L.G., and R. Girard. 1987. *Talka-Nechako Area, Nechako River Water Quality Assessment and Objectives: Overview Report.* Water Management Branch, British Columbia Ministry of Environment and Parks, Victoria, British Columbia. Available from: www.env.gov.bc.ca/wat/wq/objectives/nechako/nechako.html

Swain, L.G. 1990. *Okanagan Area, Similkameen River Sub-basin: Water Quality Assessment and Objectives: First Update, Overview Report.* Water Management Branch, British Columbia Ministry of Environment, Victoria, British Columbia. Available from: www.env.gov.bc.ca/wat/wq/objectives/similkameen2/similkameen2.html

Swain, L.G., D.G. Walton, and W. Obedkof. 1997. *Water Quality Assessment and Objectives for the Fraser River from Moose Lake to Hope, Summary Report.* Water Quality Branch, British Columbia Ministry of Environment, Lands, and Parks, Water Management Branch, Victoria, British Columbia. Available from: www.env.gov.bc.ca/wat/wq/objectives/frasermoose/moose.html

[US EPA] United States Environmental Protection Agency. 2005. *Current National Recommended Water Quality Criteria.* United States Environmental Protection Agency. Available from: www.epa.gov/waterscience/criteria/wqcriteria.html

Warrington, P.D. 1995. *Ambient Water Quality Criteria for Fluoride, Overview Report.* Water Management Branch, British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia. Available from: www.env.gov.bc.ca/wat/wq/BCguidelines/fluoride/fluoride.html

Williamson, D.A. 2002. *Manitoba Water Quality Standards, Objectives and Guidelines.* Manitoba Water Stewardship, Winnipeg, Manitoba (Manitoba Conservation Report 2002-11).

Wright, C.R., K.A. Saffran, A.-M. Anderson, R.D. Neilson, N.D. MacAlpine, and S.E. Cooke. 1999. *A Water Quality Index for Agricultural Streams in Alberta: The Alberta Agricultural Water Quality Index (AAWQI).* Prepared for the Alberta Environmentally Sustainable Agriculture Program. Alberta Agriculture, Food and Rural Development, Edmonton, Alberta.

6.1 Further reading

[BCMELP] British Columbia Ministry of Environment, Lands and Parks. 1997. *Ambient Water Quality Criteria for Dissolved Oxygen.* Water Management Branch, British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia.

Brown, J., D. MacDonald, B. McNaughton, and S. Mitchell. 1997*. Lower Columbia River from Birchbank to International Border: Water Quality Assessment and Recommended Objectives.* Environment Canada and British Columbia Ministry of Environment, Lands and Parks.

Butcher, G.A. 1987. *Peace River Area: Peace River Mainstream: Water Quality Assessment and Objectives: Technical Appendix*. British Columbia Ministry of Environment and Parks, Victoria, British Columbia.

Butcher, G.A. 1988. *Water Quality Criteria for Aluminum: Technical Appendix*. Water Quality Unit, Resource Quality Section, Water Management Branch, British Columbia Ministry of Environment and Parks, Victoria, British Columbia.

Butcher, G.A. 1992. *Lower Columbia River, Hugh Keenleyside Dam to Birchbank: Water Quality Assessment and Objectives: Technical Appendix*. British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia.

Gwanikar, S., S. Cross, D. MacDonald, J.R. Brown, D.Q. Tao, and T. Berger.1998. *Salmon River: Water Quality Assessment and Recommended Objectives.* Environment Canada, Vancouver, British Columbia.

Holmes, D.W., and R.N. Nordin. 1992. *Thompson River Water Quality Assessment and Objectives.* British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia.

Holms, G.B., and L.G. Swain. 1985. *Fraser–Delta Area: Fraser River Sub-basin from Hope to Kanaka Creek: Water Quality Assessment and Objectives.* British Columbia Ministry of Environment, Victoria, British Columbia.

Howell, K., and N.K. Nagpal. 2001. *Water Quality Guidelines for Selenium: Technical Appendix*. Water Protection Branch, British Columbia Ministry of Water, Land and Air Protection, Victoria, British Columbia.

Kangasniemi, B.J. 1989. *Campbell River Area: Middle Quinsam Lake Sub-basin: Water Quality Assessment and Objectives: Technical Appendix*. Water Management Branch, British Columbia Ministry of Environment, Victoria, British Columbia.

Levy, D.A., D.D. MacDonald, and N.K. Nagpal. 1981. *Ambient Water Quality Guidelines for Chloride.* Water, Air and Climate Change Branch, British Columbia Ministry of Water, Land and Air Protection, Victoria, British Columbia.

McKean, C. 1989. *Cowichan–Koksilah Rivers Water Quality Assessment and Objectives: Technical Appendix*. British Columbia Ministry of Environment, Victoria, British Columbia.

McKean, C., and N.K. Nagpal. 1991. *Ambient Water Quality Criteria for pH: Technical Appendix*. Water Management Division, British Columbia Ministry of Environment, Victoria, British Columbia.

Nagpal, N.K. 1981. *Ambient Water Quality Guidelines for Zinc.* Environment and Resource Management Department, Water Management Branch, British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia.

[NRCan] Natural Resources Canada. 2005a. Land Cover Map of Canada 2005 at 250m, Natural Resources Canada and Canada Center for Remote Sensing.

[NRCan] Natural Resources Canada. 2005b. Multi-Temporal Land Cover Maps of Canada using NOAA AVHRR 1-km data from 1985-2005, Natural Resources Canada and Canada Center for Remote Sensing.

Nordin, R.N. 2001. *Water Quality Criteria for Nutrients and Algae. Overview Report.* Resource Quality Section, Water Management Branch, British Columbia Ministry of Environment. Victoria, British Columbia.

Pearse, P.H., F. Bertrand and J.W. MacLaren. 1985. *Currents of Change: Final Report of the Inquiry on Federal Water Policy.* Environment Canada, Ottawa; Natural Resources Canada, GeoAccess Division, 2003, 1:1 Million Digital Drainage Area Framework, version 4.8b, Ottawa.

Reimer, P.S. 1999. *Environmental Effects of Manganese and Proposed Guidelines to Protect Freshwater Life in British Columbia.* Department of Chemical and Bio-Resource Engineering, University of British Columbia, Vancouver, British Columbia.

Singleton, H.J. 1986. *Water Quality Criteria for Cyanide: Technical Appendix*. Water Management Branch, British Columbia Ministry of Environment and Parks, Victoria, British Columbia.

Swain, L.G., D.G. Walton, and W. Obedkof. 1997. *Water Quality Assessment and Objectives for the Fraser River from Moose Lake to Hope.* British Columbia Ministry of Environment, Lands, and Parks, Water Management Branch, Victoria, British Columbia.

Swain, L.G. 1990. *Okanagan Area, Similkameen River Sub-basin: Water Quality Assessment and Objectives: Technical Appendix First Update*. British Columbia Ministry of Environment, Victoria, British Columbia.

Appendix 1: Water quality guidelines used in each jurisdiction

Parameter	Form	Guideline description[1]	Unit	Source
Alberta				
Aluminium[2]	Dissolved	5 at pH < 6.5; 100 at pH > 6.5	µg/L	CCME 2005b
Ammonia	Un-ionized	0.019	mg/L	CCME 2005b Environment Canada 2005c
Arsenic	Total	5	µg/L	CCME 2005b
Cadmium[2]	Total	e^(1.0166*ln[hardness]−3.924)	µg/L	US EPA 2005
Chloride	Dissolved	150	mg/L	BCMOE 2001 Environment Canada 2005c
Copper[2]	Total	7	µg/L	Alberta Environment 1999
Copper[3]	Total	2, for hardness 0-90 mg/L; e^(0.8545*ln[hardness]−1.465)* 0.2, for hardness > 90 mg/L	µg/L	CCME 2005b
Dissolved oxygen		6.5	mg/L	Alberta Environment 1999
Lead	Total	e^(1.273*ln[hardness]−4.705)	µg/L	CCME 2005b Environment Canada 2005c
Mercury[2]	(Total) inorganic	0.026	µg/L	CCME 2005b
Nickel	Total	e^(0.76[ln(hardness)]+1.06)	µg/L	CCME 2005b
Nitrogen	Total	1	mg/L	Alberta Environment 1999
Pesticides	2,4-D	4	µg/L	CCME 2005b
Pesticides	MCPA	2.6	µg/L	CCME 2005b
pH[3]		6.5-9.0	n/a	CCME 2005b
Phosphorus	Total	0.05	mg/L	Alberta Environment 1999
Selenium[2]	Total	2	µg/L	BCMOE 2001 Environment Canada 2005c
Zinc	Total	7.5, for hardness ≤ 90 mg/L; 7.5 + 0.75*(hardness−90), for hardness > 90 mg/L $CaCO_3$	µg/L	BCMOE 2001 Environment Canada 2005c

Parameter	Form	Guideline description[1]	Unit	Source
British Columbia[4]				
Alkalinity		20	mg/L ($CaCO_3$)	Nagpal et al. 2006
Antimony	Total	20	µg/L	Nagpal et al. 2006
Arsenic	Total	5	µg/L	CCME 2005b
Cadmium	Total	≤ 10^0.86[log(hardness)]−3.2, when > 50mg/L $CaCO_3$; ≤ 0.019, when < 50 mg/L $CaCO_3$, SSG	µg/L	CCME 2005b Environment Canada 2005c Environment Canada 2005d
Cadmium	Extractable	SSG	µg/L	CCME 2005b Butcher 1992
Chloride	Total or dissolved	SSG	mg/L	Nagpal et al. 2003
Chromium	Total	SSG	µg/L	Environment Canada 2005c Environment Canada 2005e Butcher 1992 Environment Canada 2005f CCME 2005b Environment Canada 2005g Environment Canada 2005h Swain 1990 Environment Canada 2005i
Chromium	Extractable	SSG	µg/L	BCMOE 1992
Copper	Total	SSG	µg/L	Environment Canada 2005c Singleton 1987 BCMWLAP 2004 Swain et al. 1997 Environment Canada 2005i
Copper	Extractable	SSG	µg/L	Butcher 1992 Singleton 1987
Copper	Dissolved	SSG	µg/L	Swain 1990
Cyanide	Total	SSG	µg/L	CCME 2005b Swain 1990
Cyanide	Weak acid dissociable	5	µg/L	CCME 2005b
Dissolved oxygen		SSG	mg/L	Environment Canada 2005c Environment Canada 2005j CCME 2005b Gwanikar et al. 1998 Swain and Girard 1987
Fluoride	Total	0.30	mg/L	Warrington 1995
Iron	Total	300	µg/L	CCME 2005b

Parameter	Form	Guideline description[1]	Unit	Source
Lead	Total or extractable	SSG	µg/L	Nagpal 1987 Environment Canada 2005c
Manganese	Total or dissolved	SSG	µg/L	Nagpal 2001a Swain 1990 CCME 2005b
Molybdenum	Total	SSG	µg/L	CCME 2005b Swain 1990
Nickel	Total	SSG	µg/L	Environment Canada 2005c Swain 1990
Nitrate	Total dissolved (as N)	2.93	mg/L	CCME 2005b
Nitrite	Total (as N)	0.02	mg/L	Nordin and Pommen 1986
Nitrogen	Total or total dissolved	SSG	mg/L	CCME 2005b Environment Canada 2005c
Nitrate + nitrite	Dissolved	2.93	mg/L	CCME 2005b
pH		SSG	n/a	CCME 2005b Swain 1990 Butcher 1992 Gwanikar et al. 1998
Phosphorus	Total or total dissolved	SSG	mg/L	Environment Canada 2005c OMOE 1994
Selenium	Total or dissolved	2	µg/L	Nagpal 2001b
Silver	Total	SSG	µg/L	Environment Canada 2005c
Sulphate	Dissolved	50	mg/L	Singleton 2000
Temperature		SSG	°C	Fidler and Oliver 2001 Environment Canada 2005c Gwanikar et al. 1998
Thallium	Total or extractable	0.8	µg/L	CCME 2005b
Zinc	Total or extractable	SSG	µg/L	Nagpal 1999 Environment Canada 2005c Swain 1990 Environment Canada 2005i Butcher 1992

Parameter	Form	Guideline description[1]	Unit	Source
Manitoba				
Ammonia[2]	Total (as N)	Calculation based on pH and temperature	mg/L	US EPA 2005
Ammonia[3]	Un-ionized	0.019	mg/L	CCME 2005b
Arsenic[2]	Total or extractable	0.15	mg/L	US EPA 2005
Arsenic[3]	Total	5	µg/L	CCME 2005b
Cadmium[2]	Total or extractable	e^(0.7852*ln[hardness]−2.715) where hardness = mg/L as $CaCO_3$	µg/L	US EPA 2005
Chloride[3]	Dissolved	150	mg/L	BCMOE 2001 Environment Canada 2005c
Copper[2]	Total or extractable	e^(0.8545*ln[hardness]−1.702) where hardness = mg/L as $CaCO_3$	µg/L	US EPA 2005
Copper[3]	Total	2, for hardness 0-90 mg/L; e^(0.8545*ln[hardness]−1.465)* 0.2, for hardness > 90 mg/L	µg/L	CCME 2005c US EPA 2005
Dissolved oxygen[2]		5	mg/L	US EPA 2005
Dissolved oxygen[3]		6.5	mg/L	PPWB 1992 Alberta Environment 1999
Iron[2]	Total or extractable	0.3	µg/L	CCME 2005b Environment Canada 2005c
Lead	Total or extractable	e^(1.273*ln[hardness]−4.705)	µg/L	CCME 2005b Environment Canada 2005c
Nickel[3]	Total	e^(0.76*ln[hardness]+1.06)	µg/L	CCME 2005b Environment Canada 2005c
Nickel[2]	Total or extractable	e^(0.8460*ln[hardness]+0.0584), where hardness = mg/L $CaCO_3$	µg/L	US EPA 2005
Nitrate[2]	Total (as N)	2.9	mg/L	CCME 2005b Environment Canada 2005c
Nitrogen[3]	Total	1	mg/L	Alberta Environment 1999
Pesticides	MCPA	2.6	µg/L	CCME 2005b
Pesticides	2,4-D	4	µg/L	CCME 2005b
pH		6.5–9.0	n/a	CCME 2005b
Phosphorus	Total	0.05 (rivers); 0.025 (lakes)	mg/L	PPWB 1992 Alberta Environment 1999 Manitoba Conservation 2002
Total suspended solids[2]		25	mg/L	Manitoba Conservation 2002
Zinc[3]	Total	7.5, for hardness ≤ 90 mg/L; 7.5 + 0.75*(hardness−90), for hardness > 90 mg/L $CaCO_3$	µg/L	BCMOE 2001 Environment Canada 2005c
Zinc[2]	Total or extractable	e^(0.8473*ln[hardness]+0.884), where hardness = mg/L as $CaCO_3$	µg/L	US EPA 2005

Parameter	Form	Guideline description[1]	Unit	Source
New Brunswick				
Ammonia	Un-ionized	0.019	mg/L	CCME 2005b Environment Canada 2005c
Chloride	Dissolved	150	mg/L	BCMOE 2001 Environment Canada 2005c
Copper	Total	2, for hardness < 60 mg/L $CaCO_3$; e^(0.8545*ln[hardness]−1.465)*0.2, for hardness > 60 mg/L	µg/L	BCMOE 2001
Iron	Dissolved	300	µg/L	CCME 2005b Environment Canada 2005c
Nickel	Total	e^(0.76*ln[hardness]+1.06)	µg/L	CCME 2005b Environment Canada 2005c
Nitrate	Total	2.9	mg/L	CCME 2005b Environment Canada 2005c
Oxygen	Dissolved	6.5	mg/L	CCME 2005b Environment Canada 2005c
pH		6.5–9.0	n/a	CCME 2005b
Phosphorus	Total	0.03 (rivers); 0.02 (lakes)	mg/L	Dodds et al. 1998
Turbidity		10 (SSG)	NTU	Environment Canada 2005c
Zinc	Total	7.5 for hardness < 90 mg/L; 7.5 + 0.75*(hardness−90) for hardness > 90 mg/L	µg/L	BCMOE 2001 Environment Canada 2005c

Parameter	Form	Guideline description[1]	Unit	Source
Newfoundland and Labrador				
Chloride	Dissolved	150	mg/L	BCMOE 2001 Environment Canada 2005c
Copper[5]	Total	2, for [$CaCO_3$] = 0–120 mg/L; 3, for [$CaCO_3$] = 120–180 mg/L; 4, for [$CaCO_3$] > 180 mg/L	µg/L	CCME 2005b
Oxygen	Dissolved	9.5	mg/L	CCME 2005b Environment Canada 2005c
Iron[5]	Total	300	µg/L	CCME 2005b Environment Canada 2005c
Lead[5]	Total	1, for [$CaCO_3$] = 0–60 mg/L; 2, for [$CaCO_3$] = 60–120 mg/L; 4, for [$CaCO_3$] = 120–180 mg/L; 7, for [$CaCO_3$] > 180 mg/L	µg/L	CCME 2005b
Nickel[5]	Total	25, for [$CaCO_3$] = 0–60 mg/L; 65, for [$CaCO_3$] = 60–120 mg/L; 110, for [$CaCO_3$] = 120–180 mg/L; 150, for [$CaCO_3$] > 180 mg/L	µg/L	CCME 2005b
Nitrate[2]	Total (as N)	2.9	mg/L	CCME 2005b Environment Canada 2005c
pH		5-9.0	n/a	CCME 2005b
Phosphorus	Total	0.03 (rivers)	mg/L	Dodds et al. 1998
Zinc[5]	Total	30	µg/L	CCME 2005b

Parameter	Form	Guideline description[1]	Unit	Source
Northwest Territories and Nunavut				
Ammonia	Dissolved	SSG for lotic sites (mean + 2SD) and 0.019 for lentic-lotic sites	mg/L	CCME 2005b
Arsenic	Total	SSG (mean + 2 SD)	µg/L	INAC
Chloride	Dissolved	SSG for lotic sites (mean + 2SD) and 150 for lentic-lotic sites	mg/L	CCME 2005b
Chromium	Total	SSG (mean + 2 SD)	µg/L	INAC
Copper	Total	SSG for lotic sites (mean + 2SD) and for lentic-lotic sites: 2, for [$CaCO_3$] = 0–120 mg/L; 3, for [$CaCO_3$] = 120–180 mg/L; 4, for [$CaCO_3$] > 180 mg/L	µg/L	CCME 2005b
Iron	Total	SSG for lotic sites (mean + 2SD) and 300 for lentic-lotic sites	µg/L	CCME 2005b
Lead	Total	SSG for lotic sites (mean + 2SD) and for lentic-lotic sites: 1, for [$CaCO_3$] = 0–60 mg/L; 2, for [$CaCO_3$] = 60–120 mg/L; 4, for [$CaCO_3$] = 120–180 mg/L; 7, for [$CaCO_3$] > 180 mg/L	µg/L	CCME 2005b
Nitrite	Dissolved	SSG (mean + 2 SD)	mg/L	INAC
Nitrite-nitrate	Dissolved	SSG for lotic sites (mean + 2SD) and 2.93 (lentic-lotic sites)	mg/L	CCME 2005b
Oxygen	Dissolved	5	mg/L	CCME 2005b
pH		SSG for lotic sites (mean + 2SD) and 6.5-9.0 for lentic-lotic sites)	pH units	CCME 2005b
Phosphorus	Total	SSG for lotic sites (mean + 2SD) and 0.03 (lentic-lotic sites)	mg/L	Dodds et al. 1998
Zinc	Total	SSG for lotic sites (mean + 2SD) and 30 for lentic-lotic sites	µg/L	CCME 2005b

Parameter	Form	Guideline description[1]	Unit	Source
Nova Scotia				
Chloride	Dissolved	150	mg/L	BCMOE 2001 Environment Canada 2005c
Copper[5]	Total	2, for [$CaCO_3$] = 0–120 mg/L; 3, for [$CaCO_3$] = 120–180 mg/L; 4, for [$CaCO_3$] > 180 mg/L	µg/L	CCME 2005b
Iron	Extractable	300	µg/L	CCME 2005b Environment Canada 2005c
Lead[5]	Total	1, for [$CaCO_3$] = 0–60 mg/L; 2, for [$CaCO_3$] = 60–120 mg/L; 4, for [$CaCO_3$] = 120–180 mg/L; 7, for [$CaCO_3$] > 180 mg/L	µg/L	CCME 2005b
Nickel	Total	e^(0.76*ln[hardness]+1.06)	µg/L	CCME 2005b Environment Canada 2005c
Nitrate	Total (as N)	2.9	mg/L	CCME 2005b
pH		6.5–9.0	n/a	CCME 2005b
Phosphorus	Total	0.03 (rivers); 0.02 (lakes)	mg/L	Dodds et al. 1998
Zinc	Total	7.5 for hardness < 90 mg/L; 7.5 + 0.75*(hardness–90) for hardness > 90 mg/L	µg/L	BCMOE 2001 Environment Canada 2005c

Parameter	Form	Guideline description[1]	Unit	Source
Ontario				
Ammonia	Un-ionized	0.019	mg/L	CCME 2005b Environment Canada 2005c
Chloride	Dissolved	150	mg/L	BCMOE 2001 Environment Canada 2005c
Chromium	Total	2	µg/L	CCME 2005b (guideline for Cr(VI) adjusted to total chromium)
Nickel	Total	e^(0.76*ln[hardness]+1.06)	µg/L	CCME 2005b Environment Canada 2005c
Nitrate	Total (as N)	2.93	mg/L	CCME 2005b
Phosphorus	Total	0.03	mg/L	OMOE 1994
Zinc	Total	7.5, for hardness < 90 mg/L; 7.5 + 0.75*(hardness−90), for hardness > 90 mg/L $CaCO_3$	µg/L	BCMOE 2001 Environment Canada 2005c

Parameter	Form	Guideline description[1]	Unit	Source
Prince Edward Island				
Ammonia	Un-ionized	0.019	mg/L	CCME 2005b Environment Canada 2005c
Nitrate	Dissolved (as N)	2.93	mg/L	CCME 2005b Environment Canada 2005c
pH		6.5–9.0	n/a	CCME 2005b
Phosphorus	Total	0.03	mg/L	Dodds et al. 1998
Suspended sediments	Total	29 (SSG)	mg/L	CCME 2005b Environment Canada 2005c

Parameter	Form	Guideline description[1]	Unit	Source
Quebec				
Ammonia	Total (as N)	0.05	mg/L	MDDEP 2006
Atrazine	Total	1.8	ug/L	CCME 2005b
Bentazone	Total	510	ug/L	CCME 2005b
Chlorophyll a		8	mg/m3	OECD 1982
Copper[5]	Total	2, for [$CaCO_3$] = 0–120 mg/L; 3, for [$CaCO_3$] = 120–180 mg/L; 4, for [$CaCO_3$] > 180 mg/L	µg/L	CCME 2005b
Dicamba	Total	10	ug/L	CCME 2005b
Metolachlore	Total	7.8	ug/L	CCME 2005b
Mercury	Total	26	ng/L	CCME 2005b Environment Canada 2005c
Nitrite+nitrate	Total (as N)	2.93	mg/L	CCME 2005b Environment Canada 2005c
pH		>6.5; <9.0	n/a	MDDEP 2006
Phosphorus	Total	0.03	mg/L	MDDEP 2006
Nickel	Total	e^(0.76*ln[hardness]+1.06)	µg/L	CCME 2005b Environment Canada 2005c
Turbidity		10	NTU	MDDEP 2006
Zinc	Total	7.5, for hardness < 90 mg/L; 7.5 + 0.75*(hardness−90), for hardness > 90 mg/L $CaCO_3$	µg/L	BCMOE 2001 Environment Canada 2005c

Parameter	Form	Guideline description[1]	Unit	Source
Saskatchewan				
Ammonia	Un-ionized	0.019	mg/L	CCME 2005b Environment Canada 2005c
Arsenic	Total	5	µg/L	CCME 2005b
Chloride	Dissolved	150	mg/L	BCMOE 2001 Environment Canada 2005c
Copper	Total	2, for hardness 0-90 mg/L; e^(0.8545*ln[hardness]−1.465)* 0.2, for hardness > 90 mg/L	µg/L	CCME 2005b Environment Canada 2005c
Oxygen	Dissolved	6.5	mg/L	PPWB 1992 Alberta Environment 1999
Lead	Total	e^(1.273*ln[hardness]−4.705)	µg/L	CCME 2005b Environment Canada 2005c
Nickel	Total	e^(0.76*ln[hardness]+1.06)	µg/L	CCME 2005b Environment Canada 2005c
Nitrogen	Total	1	mg/L	Alberta Environment 1999
Pesticides	MCPA	2.6	µg/L	CCME 2005b
Pesticides	2,4-D	4	µg/L	CCME 2005b
pH		6.5–9.0	n/a	CCME 2005b
Phosphorus	Total	0.05	mg/L	PPWB 1992 Alberta Environment 1999
Zinc	Total	7.5, for hardness ≤ 90 mg/L; 7.5 + 0.75*(hardness−90), for hardness > 90 mg/L $CaCO_3$	µg/L	BCMOE 2001 Environment Canada 2005c

Parameter	Form	Guideline description[1]	Unit	Source
Yukon[4]				
Arsenic	Total	5	µg/L	CCME 2007b
Chromium	Total	SSG	µg/L	Environment Canada 2005f
Copper	Total	$0.2^{(e(0.8545(\ln[hardness])-1.465)}$ when $CaCO_3$ > 90mg/L , 1 when $CaCO_3$ < 90 mg/L	µg/L	GoC, 2008
Lead	Total	$e^{(1.273[\ln^*(hardness)]-4.705)}$ when $CaCO_3$ > 50mg/L, 1ug/L when $CaCO_3$ < 50mg/L	µg/L	GoC, 2008
Nitrate	dissolved (as N)	2.93	mg/L	CCME 2007b
Nitrogen	Total Dissolved	0.7	mg/L	GoC, 2008
Nitrite	Total (as N)	0.02	mg/L	Nordin and Pommen 1986
pH		6.5-9		CCME 2007b
Phosphorus	Total	0.025	mg/L	GoC, 2008
Selenium	Total	0.2	ug/L	GoC, 2008
Silver	Total	0.05 when $CaCO_3$ < 100mg/L, 1.9 when $CaCO_3$ > 100mg/L	µg/L	GoC, 2008
Temperature		SSG	˚C	GoC, 2008
Zinc	Total	7.5 when $CaCO_3$ < 90 mg/L, 7.5 + 0.75*(hardness-90) when $CaCO_3$ > 90mg/L	µg/L	GoC, 2008

Notes: (1) SSG means that different site-specific guidelines or formulas were used at different sites (specific site information available on request).
(2) Applies to stations monitored by provincial monitoring programs.
(3) Applies to stations monitored under federal monitoring programs and the Prairie Provinces Water Board.
(4) British Columbia and Yukon parameter selections were site-specific.
(5) Sites in Labrador had either total or extractable metals used in calculation of the WQI due to modification in sampling program.