Canadian Environmental Sustainability Indicators 2006

Freshwater Quality Indicator

Data Sources and Methods

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Environment Canada
Statistics Canada
Health Canada

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1. Introduction

Canadians' health and their social and economic well-being are fundamentally linked to the quality of their environment. Recognizing this, in 2004, the Government of Canada committed to establishing national indicators of freshwater quality, air quality, and greenhouse gas emissions. The goal of these indicators is to provide Canadians with more regular and reliable information on the state of their environment and how it is linked with human activities. Environment Canada, Statistics Canada, and Health Canada are working together to develop and communicate these indicators. Reflecting the joint responsibility for environmental management in Canada, this effort has benefited from the cooperation and input of the provinces and territories.

This report is part of a suite of documents released under the Canadian Environmental Sustainability Indicators (CESI) initiative.[1] Each indicator reported in a given year under the CESI has an associated "data sources and methods" report to provide technical details and other background to facilitate interpretation of the indicator or allow others to build further analysis using the CESI data and methods as a starting point.

The information in this report should be used to ensure a clear understanding of the basic concepts that define the information provided in the freshwater quality indicator, of the underlying methodology, and of key aspects of the data quality. This information will provide users with a better understanding of the strengths and limitations of the data, and of how they can be effectively used and analysed. The information is of particular importance when making comparisons with data from other indicators, and in drawing conclusions regarding change over time.

This report deals with the underlying methods and data for the freshwater quality indicator as it was reported in 2006.

2. Description of the indicator

The freshwater quality indicator provides an overall measure of the suitability of water bodies to support aquatic life at selected monitoring sites in Canada. The indicator is based on applications of the Water Quality Index (WQI) endorsed by the Canadian Council of Ministers of the Environment (CCME) in 2001 (CCME, 2001). Given that aquatic life can be influenced by the presence of hundreds of both natural and anthropogenic substances in water, the WQI provides a useful tool that allows experts to translate vast amounts of water quality monitoring information into a simple overall rating.

At present, the freshwater quality indicator is presented as southern Canada and northern Canada histograms, and a Great Lakes map of the WQI results from individual water quality monitoring sites across the country. The histogram groups WQI values into five categories: poor, marginal, fair, good, and excellent.

1. http://www.environmentandresources.ca/indicators and www.statcan.ca

The WQI measures the frequency and extent to which selected parameters exceed water quality guidelines at individual monitoring sites. Water quality guidelines are numerical values for physical, chemical, radiological, or biological characteristics of water that indicate that adverse effects may be occurring when exceeded.[2] The water quality guidelines used in the calculations are those defined for the protection of aquatic life. They include national guidelines developed by the CCME, as well as provincial and site-specific guidelines developed by federal, provincial, and territorial partners. If a guideline value is exceeded at a given site, there is an increased probability of an adverse effect on aquatic life at that site.

The WQI reflects the potential for substances to impact aquatic life based on existing knowledge of toxicity and predicted fate and behaviour of chemical substances. It is not a direct measure of changes to aquatic communities, such as changes in the composition or abundance of benthic invertebrates or fish.

In aquatic ecosystems, water quality naturally varies seasonally and annually due to fluctuations in weather such as the timing and amount of precipitation, which affects erosion in the drainage area and water levels and flows. Thus, the WQI is calculated for a period of three years (2002–2004) to dampen the effect of seasonal variability on the WQI score.

3. How the WQI for aquatic life is used

The Canadian Environmental Sustainability Indicators (CESI) 2006 report provides policy analysts and decision makers with national and regional pictures of the status of water quality for the protection of aquatic life.

On a regional level, the CCME WQI has been used by many organizations and jurisdictions, such as 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 local water bodies (British Columbia Ministry of Environment (BCMOE), 1996; Alberta Environment, 2003; Grand River Conservation Authority, 2004; Khan et al., 2004; CCME, 2005a; Environment Canada, 2005a; and Lumb et al., 2006. It has also been used to track the effectiveness of remedial measures on local water quality (Glozier et al., 2004 and Wright et al., 1999) and to report on the effectiveness of government programs and policies (Alberta Environment, 2002).

Although the CCME provides general guidance on using the index (www.ccme.ca), practitioners are responsible for deciding which parameters, guidelines, time periods, and number of samples to include in a given application of the index. As a result of this flexibility, different approaches have been used to apply the index to achieve different objectives. For example, the British Columbia Ministry of the Environment (1996) used site-specific guidelines to evaluate the suitability of water quality to support different beneficial uses, using the most recent three years of data. Glozier et al. (2004) applied the index using background concentration[3] values from reference sites[4] to assess change in status and trends for downstream sites. In this work, trends were calculated as rolling values based on blocks of five years of samples (e.g. 1983–1987 and 1984–1988), while status was

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2. Guidelines are specific to particular water uses, such as protection of aquatic life, crop irrigation, livestock watering, drinking water, and recreation.
3. The concentration of a naturally occurring water quality constituent, not influenced by human activity.
4. An area considered to be relatively unaffected by human activity.

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 differences that exist between different aquatic ecosystems in terms of natural background, chemical interactions between water quality parameters, etc.

As a result of this flexibility in applying the index, a protocol for calculating the WQI ratings across Canada for this initiative was developed (Environment Canada, 2005b). For 2006, however, there remains variation in the applications of the WQI across Canada (see section 6).

4. How the indicator is calculated

The freshwater quality indicator is based on the application of the CCME WQI across Canada at 370 monitoring sites (streams, rivers, and lakes) and 7 basins from the Great Lakes using ambient water quality monitoring data for the 2002–2004 period, and relevant water quality guidelines for the protection of aquatic life. Of the 370 sites, 30 are located in northern Canada and 340 in southern Canada. In addition, water quality was assessed separately for 7 basins of the Great Lakes from surveys conducted in April 2004 and 2005. The resulting ratings are presented in five categories (poor, marginal, fair, good, and excellent) in one national histogram.

4.1 Changes from previous period (2005 report)

A number of changes to the 2005 freshwater quality indicator were undertaken for 2006. The following list provides an overview of these changes, most of which are described in more detail in the subsequent sections:

- Separation of the indicator into north and south portions of Canada, due to differences in intensity of data collection. In 2005, eight sites were located in the area that is defined as the North for 2006.
- In the South, a subset of water quality values from 7 representative lakes was selected from a larger dataset of 62 highly clustered lakes in New Brunswick and Nova Scotia. In 2005, only 18 lakes had met the minimum requirement for sample numbers and were reported as individual sites.
- The addition of 22 new sites in the North and 25 in the South. In the South, there were also 11 fewer sites due to the use of a subset of lakes (see previous bullet) and 11 fewer due to reduced or discontinued monitoring.
- All jurisdictions calculated WQI values using the same F_1 formula. Previously, a slightly different formula was used for sites in the province of Quebec.
- Stations for Quebec's Réseau-Rivières included year-round data in calculations, rather than April to October. This resulted in different ratings for 22 of 115 stations.
- Minimum sampling frequency data requirements were reduced from four times to three times per year for northern locations, based on the results of a sensitivity analysis. Also, an exception was made for including three rivers in New Brunswick that had one sample less than the requirement and three rivers in Manitoba that were sampled three times a year, rather than four, but had a very long data record and local expert opinion confirming the reliability of the WQI scores for this period.

- The Great Lakes assessment included three parameters measured in sediment, as these contaminants are known to endanger aquatic life.

4.2 Formulation of the CCME Water Quality Index

The CCME WQI relates water quality data to the various beneficial uses of water[5] using relevant water quality guidelines as benchmarks. Each index is calculated for an individual monitoring site during a chosen reference period. Water samples collected over this period of time are analyzed for a suite of water quality parameters. Each parameter value is evaluated against the appropriate water quality guideline (Appendix 1). These are called tests. The percentage of parameters, samples, and tests that fail to meet the guidelines, and the deviation (excursion) from the guideline, are captured in three factors—scope, frequency, and amplitude of excursions from water quality guidelines—used to calculate the index (CCME, 2001). The index yields a number between 0 and 100. A higher number indicates better water quality.

CCME WQI formula

$$\text{CCME WQI} = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right)$$

Scope (F_1)

The scope factor represents the percentage of the total number of parameters that fail to meet the water quality guidelines at any time during the reference period.

$$F_1 = \left(\frac{\text{number of failed parameters}}{\text{total number of parameters}} \right) \times 100$$

Frequency (F_2)

The frequency factor represents the percentage of individual tests that fail to meet the water quality guidelines.

$$F_2 = \left(\frac{\text{number of failed tests}}{\text{total number of tests}} \right) \times 100$$

A failed test occurs when an individual parameter value within a sample exceeds the guideline. The total number of failed tests represents the total number of failed parameter values in every sample during the reference period. The total number of tests for an individual site is calculated by multiplying the average number of parameters per sample by the total number of samples during the reference period.

Amplitude (F_3)

5. These uses are: protection of aquatic life, drinking water, livestock watering, crop irrigation, and recreational use (CCME, 1999).

The amplitude factor represents the average deviation of failed test values from their respective guidelines. The relative deviation of a failed test from the guideline is termed an excursion and is calculated as follows:

I. When the test value must not exceed the guideline:

$$\text{excursion}_i = \left(\frac{\text{failed test value}_i}{\text{guideline value}_i}\right) - 1$$

II. When the test value must not fall below the guideline:

$$\text{excursion}_i = \left(\frac{\text{guideline value}_i}{\text{failed test value}_i}\right) - 1$$

The collective amount by which individual tests are out of compliance is calculated as follows:

$$\text{nse} = \frac{\sum_i \text{excursion}_i}{\text{total number of tests}}$$

where nse is the ***n**ormalized **s**um of the **e**xcursions* from the guidelines. The F_3 factor is then calculated by a formula that scales the nse to yield a range between 0 and 100.

$$F_3 = \frac{\text{nse}}{(0.01\text{nse} + 0.01)}$$

The rating system of index values

The WQI yields a number between 0 and 100 that is indicative of the overall water quality for a particular use (Text table 1).

Text table 1 The rating system of the CCME WQI values

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 by a considerable margin.
Poor (0 to 44.9)	Water quality measurements **usually** exceed water quality guidelines and/or 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 several water quality experts in British Columbia (Rocchini and Swain, 1995).

4.3 Data preparation and presentation

The data used to calculate the freshwater quality indicator were derived from water samples collected at sites across the country from 2002 to 2004. Data were combined to calculate a single index value for each site using the equations described in section 4.2. The steps below, which are described in more detail in section 5, were followed in carrying out the calculations:

1. Selection step:
    a. Selection of sites
    b. Selection of parameters
    c. Selection of relevant national, regional, or site-specific guidelines
    d. Number of samples, timing, and collection period
2. Calculation step:
    a. Extraction of data
    b. Validation of data
    c. Calculation of index

The index values for each site were then classified into the five quality categories of the WQI and presented in a histogram as the freshwater quality indicator for northern Canada and southern Canada. The line delineating the North is based on a series of climatic, biotic, and socio-economic aspects (McNiven and Puderer, 2000). WQI values were also derived for seven basins of the Great Lakes and reported separately (see 5.1).

5. Data sources: review and selection

Water quality data used in the calculation of the freshwater quality indicator in the CESI 2006 report were obtained from a number of existing water quality monitoring programs across the country (Text table 2). These programs are managed by federal departments, provincial departments, and under federal-provincial agreements. They were originally established for many different reasons. Currently, there is no national network of water quality monitoring sites designed specifically for the purposes of reporting the state of Canada's water quality in a fully representative way at different geographic scales across Canada.

Text table 2 Monitoring programs that provided data on ambient water quality from 2002 to 2004

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
Manitoba	Prairie Provinces Water Board, Canada–Manitoba Water Quality Monitoring Agreement	Environment Canada, Manitoba Conservation
Manitoba	International Red River Pollution Board, Federal Water Quality Monitoring Program	International Red River Board, including Environment Canada and Manitoba Conservation
Manitoba	Ambient water quality monitoring network	Manitoba Conservation
New Brunswick	Canada–New Brunswick Water/Economy Agreement	Environment Canada, New Brunswick Department of Environment and Local Government
New Brunswick	Long-range Transport of Atmospheric Pollutants	Environment Canada
New Brunswick	Surface water monitoring network	New Brunswick Department of Environment and Local Government
Newfoundland and Labrador	Canada–Newfoundland Water Quality Monitoring Agreement	Environment Canada, Newfoundland and Labrador Department of Environment and Conservation
Nova Scotia	Long-range Transport of Atmospheric Pollutants	Environment Canada
Nova Scotia	Pockwock–Bowater Watershed Study	Nova Scotia Department of Environment and Labour

Province/territory	**Monitoring program**	**Organization(s)**
Nova Scotia	Canadian Wildlife Service, park survey, Maritimes	Environment Canada
Ontario	Provincial Water Quality Monitoring Network	Ontario Ministry of the Environment
Ontario	Great Lakes Surveillance Program	Environment Canada
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
Quebec	The State of the St. Lawrence Monitoring Program	Environment Canada
Saskatchewan	Prairie Provinces Water Board	Environment Canada, Saskatchewan Environment
Saskatchewan	Souris River Bilateral Agreement, Federal Water Quality Monitoring Program	International Souris River Board, including Environment Canada and Manitoba Conservation
Northwest Territories and Nunavut	Northwest Territories-Nunavut extensive water quality monitoring network; Northern Energy MC aquatic quality network—Northwest Territories portion of Mackenzie River Basin; Alberta-Northwest Territories transboundary rivers water quality monitoring program; EC-Parks Canada Northern bioregion national parks programs (seven national parks in Northwest Territories-Nunavut-northern Yukon: Nahanni, Tuktut Nogait, Aulavik, Ivvavik, Quttinirpaaq, Auyuittuq, Ukkusiksalik); EC-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 Sustainable Development)
Nunavut	See above	See above

Each program monitors a specific array of parameters designed to suit the program's objectives and resource constraints. These monitoring programs track ambient concentrations[6] of major ions[7] (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, with program needs, resource constraints, and ease of access to sites being important determinants.

5.1 Site selection

For the freshwater quality indicator in the CESI 2006 report, data from 370 sites across all provinces and territories were selected from the available water quality monitoring sites that met the desired sampling frequency for the 2002 to 2004 period. Different sampling frequency criteria were applied to sites in the North and those in the South (section 5.4).

The Great Lakes are treated separately in the freshwater quality indicator because of their disproportionate size and unique surface water quality monitoring program. For the Great Lakes dataset, the WQI was calculated using data collected by Environment Canada's Great Lakes Surveillance Program. Conducted on a two-year rotation, this program sampled Lake Erie, Lake Huron, and Georgian Bay in April/May 2004, and lakes Ontario and Superior in April/May 2005. Approximately 320 sites were sampled on the Great Lakes, with the sites being divided between the lakes as follows: Lake Ontario (100), Lake Erie (70), Lake Huron and Georgian Bay (90) and Lake Superior (60). Of these sites, approximately 20 percent are sampled for organic parameters. Eighteen water quality parameters and three sediment quality parameters were included in the calculation of the WQI score.

The 62 sites in the acid rain monitoring program in the Atlantic region were grouped into 7 clusters. This was done to reduce the influence on the national indicator of these numerous small and neighbouring sites, all subject to the same specific water quality concern. The sites were grouped into clusters based on their proximity. For the lakes in each cluster, the average WQI score, weighted by lake area, was calculated. The average lake area for each cluster was also calculated. The lake in each cluster with an area and WQI score closest to the average was selected to represent all sites in that cluster. Other sites in the cluster were then cut from the dataset. For those clusters with river sites, one river of average WQI score and flow was selected to represent the rivers of that cluster.

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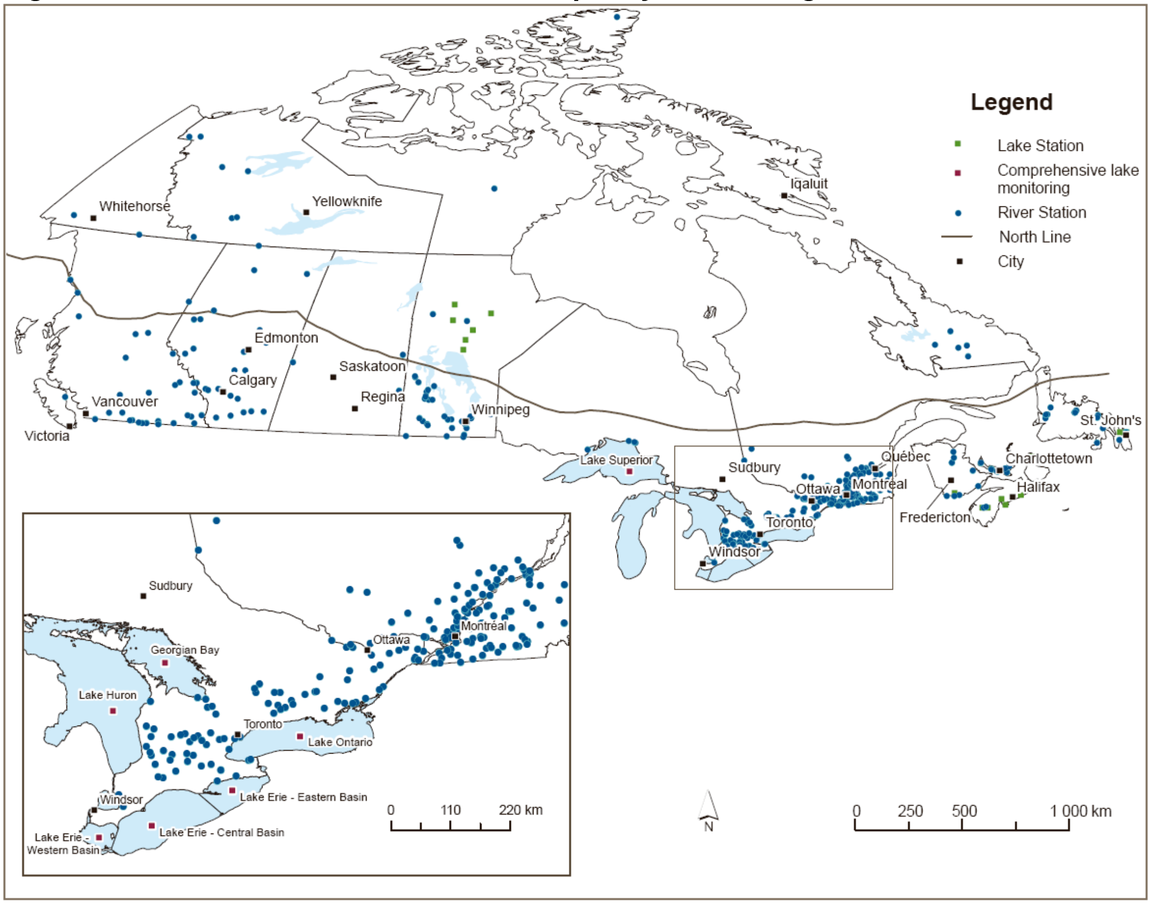
6. Concentration of substances in the aquatic environment, as opposed to effluent discharges.
7. Positively or negatively charged molecules that occur naturally in water as a result of geochemical weathering of rocks, surface runoff, and atmospheric deposition. The eight major ions—calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulphate, and chloride—account for most of the total dissolved solids in surface waters.

Figure 1 Locations of CESI 2006 water quality monitoring sites across Canada



Note: The North Line is defined in McNiven and Puderer (2000).

Sources: Data assembled by Environment Canada from federal, provincial, and joint water quality monitoring programs.
Map developed by Statistics Canada, Environment Accounts and Statistics Division.

5.2 Parameter selection

The parameters used in the WQI calculations can be linked to the main stressors on water quality across Canada, including urban development, agriculture, forestry, mining, smelting, pulp and paper mills and other industrial facilities, deposition of atmospheric pollutants, and dams (Environment Canada, 2001).

Decisions regarding parameters to use for national reporting of the WQI were made by provincial, territorial, and federal water quality experts. The decisions were based on local knowledge of stressors potentially affecting water quality in the region, or at each site, using available monitoring data for 2002 to 2004. Only parameters relevant to the protection of aquatic life were included. This excludes bacterial counts, for example, which are primarily of concern for human health. For all jurisdictions except British Columbia, a common suite of parameters was applied to all sites within the jurisdiction or monitoring program. Site-specific selections of parameters were made in British Columbia, with four parameters (dissolved oxygen, phosphorus, pH, water temperature) included at each site wherever available (refer to Text table 5 for details regarding the parameters used in each jurisdiction).

5.3 Guideline selection

Nationally, guidelines are developed according to the methodology outlined by the CCME science-based protocols for guideline derivation and endorsed by the CCME (CCME, 1991). Some provinces and territories have directly adopted the CCME guidelines for their needs, while others have developed their own guidelines using similar protocols to those of the CCME. Typically, water quality guidelines are based on laboratory toxicity studies showing effects on various aquatic life (fish, invertebrates, plants) from different concentrations of a constituent in the water.

For the CESI 2006 report, calculation of the freshwater quality indicator relied largely on the use of existing water quality guidelines for the protection of aquatic life. Most of the guidelines used are based on chronic exposure. In a few instances, guidelines were applied for short-term exposure.[8] Guidelines were selected on a site-specific or jurisdictional basis by teams of regional water quality experts from the suite of generic guidelines available from various sources[9] and from existing site-specific guidelines for the parameters of local interest (Appendix 1). The principle behind guideline selection is to choose those that are most “locally relevant”, meaning appropriate to local aquatic life. Background levels of naturally occurring substances and other characteristics of water, such as hardness and temperature that can affect the toxicity of some of the substances of concern. It is recognised, however, that generic guidelines (i.e., those not derived for a specific site) are often conservative to provide a high level of protection through the use of uncertainty factors, depending on the quality and availability of toxicological information for the substance. Thus, natural concentrations of some substances may exceed these guidelines.

Site-specific guidelines based on background concentration procedure (CCME, 2003) were used in the Northwest Territories and some Nunavut sites (i.e., rivers). In these cases, the upper range of the local natural background level for selected parameters was statistically estimated and found to be greater than the recommended guideline. The CCME Canadian Water Quality Guidelines were found to be locally relevant and used at a few sites on watercourses near outlets of lakes (e.g., Great Bear Lake, Lake Hazen).

The rapid assessment approach,[10] another site-specific method for areas with high natural background levels (e.g., turbidity), was used to generate a benchmark based on long-term monitoring data (not toxicity studies). This approach was carried out for many parameters for sites in British Columbia and may be done in future in other areas (e.g., Northwest Territories).

8. In Quebec, the guideline used for turbidity is for short-term (acute) exposure.
9. Sources include Prairie Provinces Water Board (PPWB), 1992; Ontario Ministry of the Environment (OMOE), 1994; CCME, 1999; Alberta Environment, 1999; BCMOE, 2001; Le ministère du Développement durable, de l’Environnement et des Parcs (MDDEP) du Québec, 2006; Williamson, 2002; and United States Environmental Protection Agency (USEPA), 2005.
10. See Environment Canada, 2006. *Technical guidance document for Water Quality Index practitioners reporting under the Canadian Environmental Sustainability Indicators (CESI) initiative* – 2006 update. Unpublished draft. Ottawa, Ontario.

5.4 Sample numbers, timing and collection period

Annual fluctuations in meteorology 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 based on three years of data in order to dampen temporal variability and reflect a more general state of water quality. The years 2002 to 2004 were the most recent available years across all monitoring programs.

Minimum sample numbers for the three-year reporting period were established for lake, river and northern sites (Text table 3). Sites that did not meet these minima were excluded from the national reporting of the indicator in the CESI 2006 report.

Text table 3 Sample frequency requirements for WQI application in the 2006 CESI report

Water body	Minimum requirements
Lakes	6 samples for the 2002–2004 period
Rivers	12 samples for the 2002–2004 period
Northern rivers	9 samples for the 2002–2004 period

In temperate lakes, the water column can become thermally stratified, or layered by temperature, during the summer and winter. Mixed conditions are typical during early spring and late fall. Chemical contaminants can also stratify in lakes, with their concentrations being determined in part by water density, which is in turn determined by water temperature. Lakes were sampled at least twice annually, once in the spring and once in the fall. If these spring and fall samples were not available, several samples were taken at various depths during another season. The results of these samples were weighted by the volume of water at the sampled depths and then averaged. Weighting by volume, however, was not always possible. As a final option, samples were taken at the surface of the lake.

In rivers and streams, surface sampling is generally 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 better capture water quality variability. The CCME technical guidance document (CCME, 2001) recommended a minimum of four samples per year, accounting for seasonal or hydrological variability, based on the original testing of the index.

In northern and remote locations, routine water sampling can be costly and challenging, as it is sometimes dangerous and difficult to access sites, and weather conditions can be extreme. As a result, monitoring sites are often sampled less frequently. In addition, a sensitivity analysis conducted on several northern rivers revealed that having fewer samples (i.e., 9) than the required minimum (12) in a three-year period did not produce WQI scores that were significantly different (Glozier et al., pers. comm.). For these reasons, the minimum sampling frequency for rivers in the North was reduced from 12 (as used in southern Canada) to 9 for the 2002–2004 period and reported separately. These criteria apply to sites that fall north of a line delineated by McNiven and Puderer (2000).

5.5 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 site information (e.g., name and location) and water quality data were extracted from available databases, by regional and provincial data providers, and transferred to "WQI calculators" i.e., spreadsheets programmed to calculate WQI ratings. These calculators allow users to select input parameters, guidelines, and sample periods (with options allowing guidelines to be modified by hardness, pH, or temperature, when appropriate).

Suspected outliers in the datasets were identified and validated by verifying field forms and books to check for accuracy of data entry, by ensuring that reported units were correct, by consulting stream flow and meteorological records, and/or by comparing with the levels of other parameters in the dataset (e.g., turbidity, total suspended solids, major ions) that could explain the unusually high or low values of some parameters. Unless identified as likely erroneous, outliers were left in the dataset.

After validation of the dataset, calculations were verified and then peer reviewed. Environment Canada experts then transferred site information, WQI ratings and details on the application (i.e., data source, parameters, guidelines, sample numbers and dates, and contact information) onto templates for incorporation into a central database. Statistics Canada experts reviewed site data to ensure that the number of samples, timing, and locations met the methodology requirements. This information was then used to generate the freshwater quality histograms and map of monitoring site locations by staff at Statistics Canada, the National Water Quality Monitoring Office, and the Strategic Information Integration Directorate of Environment Canada.

The ratings and calculation methods (i.e., parameters included, guidelines used, site information) compiled into the national database were then verified for each site by each data provider to detect any errors introduced during the integration of this information.

6. Caveats and limitations of the indicator and data quality

6.1 Site selection

It is recognized that the current collection of monitoring networks was not designed to be representative of Canada and all its watersheds, but to respond to specific federal, provincial, or regional needs. Monitoring sites included in this analysis are almost all located in populated areas and other areas for which it is suspected that water quality is affected by surrounding land uses and other potential stressors, including acid rain deposition, dams, and industries (e.g., pulp and paper and mines). Even so, sites do not comprehensively cover all geographic areas with potential water quality issues or problems across Canada.

From a coverage standpoint, it is unknown what percentage of Canadian lakes and rivers by geographic area or stream flow, is currently represented by the existing 370 monitoring sites. Additionally, each site was weighted equally and independently regardless of location.

The only exception to this is the 62 clustered lakes in New Brunswick and Nova Scotia that were aggregated into 7 scores.

Text table 4 Number of sites in each jurisdiction in the freshwater quality indicator in 2006

Province/Territory	River sites		Lake sites	
	North	South	North	South
	number	number	number	number
British Columbia	1	30	0	0
Alberta	3	23	0	0
Saskatchewan	1	3	0	0
Manitoba	2	31	6	0
Ontario	0	90	0	7*
Quebec	0	116	0	0
New Brunswick	0	9	0	1
Nova Scotia	0	2	0	6
Prince Edward Island	0	8	0	0
Newfoundland and Labrador	5	19	0	2
Yukon	2	0	0	0
Northwest Territories	8	0	0	0
Nunavut	2	0	0	0
Total – Canada	24	331	6	16

0 true zero or a value rounded to zero
* Represents the seven basins defined for the Great Lakes bordering Canada

6.2 Parameter selection

The type and number of parameters included in the WQI calculations differed across the water quality monitoring sites and/or jurisdictions. This flexibility allowed the specific local and regional water quality concerns and objectives of the monitoring programs to be reflected in the WQI scores. However, these differences in parameter selection among jurisdictions/sites make comparability of sites for national aggregation uncertain. It was recommended that between 4 and 15 parameters be measured for the WQI calculation, and this guidance was followed (Environment Canada, 2005b). A recent sensitivity analysis, however, shows that the use of approximately 10 parameters may yield the most stable WQI results (Painter and Waltho, 2005).

In addition, not all possible stressors were sampled everywhere, for several reasons: (1) the random nature of some releases (e.g., unknown or accidental spills); (2) some substances are tracked in other media, such as sediment or fish tissue, that provide more reliable measures; and (3) the high cost of measuring on a routine basis (e.g., for organic substances).

For the Pacific and Yukon Region, metals were removed from the WQI calculation when conditions at a given site were highly turbid. The rationale behind this is the expectation that the high concentrations of metals measured during such events are due to the suspended sediments. These metals are not generally available for biological uptake, and, as such, likely do not pose the same risk to aquatic life as dissolved metals.

Text table 5 Parameters used in each jurisdiction or program for the water quality index calculation in 2006

Parameter[1]	B.C.	Alta.	Sask.[4]	Man.	Ont. (rivers)	Ont. (Great Lakes)	Que.	N.B.	N.S.	P.E.I.	N.L.	Y.T.	N.W.T.	Nvt.
Alkalinity	**B**	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum	-	**B[3]**	-	-	-	**A**	-	-	-	-	-	-	-	-
Ammonia	-	**A**	**A**	**A**	**A**	-	**A**	**B**	-	**A**	-	-	**A**	**A**
Antimony	**B**	-	-	-	-	-	-	-	-	-	-	-	-	-
Arsenic	**B**	**B**	**A**	**B**	-	**A**	-	-	-	-	**A**	-	-	-
Cadmium	**B**	**B[3]**	-	**B[3]**	-	**A**	-	-	-	-	-	**B**	-	-
Chloride	**B**	**B[4]**	**A**	**B[4]**	**A**	-	-	**A**	**A**	-	-	-	**A**	**A**
Chlorophyll	-	-	-	-	-	-	**A**	-	-	-	-	-	-	-
Chromium	**B**	-	-	-	**A**	**B**	-	-	-	-	**A**	**B**	-	-
Copper	**B**	**B**	**A**	**B**	-	**B**	-	**A**	**A**	-	**A**	**A**	**A**	**A**
Cyanide	**B**	-	-	-	-	-	-	-	-	-	-	-	-	-
Dissolved oxygen	**B**	**A**	**B**	**A**	-	-	-	**A**	-	-	-	-	**B**	-
Fluoride	**B**	-	-	-	-	-	-	-	-	-	-	-	-	-
Iron	**B**	-	-	**B[3]**	-	**B**	-	**A**	**A**	-	**A**	-	**A**	**A**
Lead	**B**	**B**	**A**	**A**	-	**B**	-	-	**A**	-	**A**	**B**	**A**	**A**
Manganese	**B**	-	-	-	-	-	-	-	-	-	-	-	-	-
Mercury	-	**B[3]**	-	-	-	**B**	-	-	-	-	-	-	-	-
Molybdenum	**B**	-	-	-	-	**B**	-	-	-	-	**A**	-	-	-
Nickel	**B**	**B[4]**	**A**	**B**	**A**	**B**	-	**B**	**A**	-	**A**	-	-	-
Nitrate[2]	**B**	-	-	**B[3]**	**A**	**B**	**A**	**A**	**A**	**A**	-	**A**	-	-
Nitrite	**B**	-	-	-	-	-	-	-	-	-	-	**A**	-	-
Nitrogen	**B**	**A**	**A**	**A[4]**	-	-	-	-	-	-	-	-	**A**	**A**
Pesticide – 2,4-D	-	**B**	**B**	**B**	-	-	-	-	-	-	-	-	-	-
Pesticide – MCPA	-	**B**	**B**	**B**	-	-	-	-	-	-	-	-	-	-
pH	**B**	**B[4]**	**A**	**A**	-	-	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**
Phosphorus	**B**	**A**	**A**	**A**	**A**	**B**	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**
Selenium	**B**	**B[3]**	-	-	-	**B**	-	-	-	-	**B**	-	-	-
Silver	**B**	-	-	-	-	**B**	-	-	-	-	-	**A**	-	-
Sodium	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulphate	**B**	-	-	-	-	-	-	-	-	-	-	**B**	-	-
Suspended solids	-	-	-	**B[3]**	-	-	-	-	-	**A**	-	-	-	-
Temperature	**A**	-	-	-	-	-	-	-	-	-	-	**A**	-	-

Text table 5 (cont.)

Parameter[1]	B.C.	Alta.	Sask.[4]	Man.	Ont. (rivers)	Ont. (Great Lakes)	Que.	N.B.	N.S.	P.E.I.	N.L.	Y.T.	N.W.T.	Nvt.
Thallium	**B**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Turbidity	**-**	**-**	**-**	**-**	**-**	**-**	**A**	**A**	**-**	**-**	**-**	**-**	**-**	**-**
Zinc	**B**	**B**	**A**	**A**	**A**	**B**	**-**	**A**	**A**		**A**	**A**	**A**	**A**
Fluoranthene	**-**	**-**	**-**	**-**	**-**	**B**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Phenanthrene	**-**	**-**	**-**	**-**	**-**	**B**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Naphthalene	**-**	**-**	**-**	**-**	**-**	**B**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Pesticide – DDD in sediment	**-**	**-**	**-**	**-**	**-**	**B**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Pesticide – DDE in sediment	**-**	**-**	**-**	**-**	**-**	**B**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
PCBs in sediment	**-**	**-**	**-**	**-**	**-**	**B**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Notes: (1) Parameters marked with an ‘A’ were tested at all sites in the province or territory; those marked with ‘B’ were only tested at selected sites. (2) Measured as nitrate+nitrite in the Great Lakes and Quebec. (3) Tested only at sites from provincial monitoring programs. (4) Tested only at sites from federal monitoring programs.
- not applicable

6.3 Guideline selection

To some extent, exceedances from all parts of Canada for naturally occurring substances (e.g., phosphorous, total suspended solids, and metals) can be due to naturally occurring phenomena, rather than human influence only (Appendix 1 provides a listing of water quality guidelines used in each jurisdiction).

In most cases, metal guidelines are based on measuring total (or extractable) rather than dissolved metals. This conservatively assumes that the full measured amount of the compound is available to be taken up by organisms. However, metals in unfiltered water may be bound to particulates or colloidal molecules and, depending on the chemical species in question, organic materials, making them less bio-available than suggested by a measure of total metals.

6.4 Sample timing and frequency

There is variation in timing and frequency of sampling among monitoring programs. Some programs are more intensive to capture the full range of variability/seasonality that is inherent to each site, while others are less intensive, more opportunistic, and/or random, due to resource constraints and the remote nature of some sites. It is not known currently if this poses a problem or creates a bias for the overall indicator. The three-year time period selected as the basis for the indicator accounts for some of this variation and helps to reduce the potential for some sites to “misrepresent” water quality on an annual basis.

A sensitivity analysis conducted on several northern rivers revealed that having fewer samples (i.e., 9) than the required minimum (12) in a three-year period did not produce WQI scores that were significantly different (Glozier et al., pers. comm.).

A sensitivity analysis for southern Ontario streams suggests that more than 12 samples over three years could be required to produce more reliable calculations (Painter and Waltho, 2005).

Table 6: Minimum and maximum number of samples for all sites by jurisdiction

Province/Territory	Samples			
	Lakes		Rivers	
	Minimum number	Maximum number	Minimum number	Maximum number
British Columbia	-	-	19	151
Alberta	-	-	22	36
Saskatchewan	-	-	25	54
Manitoba	9	9	9	39
Ontario (excluding the Great Lakes)	-	-	15	64
Quebec	-	-	19	40
New Brunswick	6	6	11	28
Nova Scotia	6	6	152	154
Prince Edward Island	-	-	19	21
Newfoundland and Labrador	-	-	9	25
Yukon	-	-	54	78
Northwest Territories	-	-	8*	16
Nunavut	-	-	6*	8
Canada	6	9	6	154

* One hybrid lotic-lentic site is located at the outflow of a large lake.
- not applicable

There were two exceptions made to the minimum 12 samples for the 2002 to 2004 period. First, three sites in Manitoba were sampled only three times per year due to limited accessibility. Local specialists were confident that the site scores were reliable because of the long monitoring history at these sites. The other exception was for three sites in New Brunswick where only one sample was missed over the three-year reporting period. The other eleven samples were well distributed through the reporting period, and local specialists agreed that the site scores were reliable and the sites should be included.

There were also two sites (one in the Northwest Territories and one Nunavut) that were located at the outflow of large lakes. These sites exhibited behaviour more similar to lakes than flowing waters, i.e., less variability in water quality throughout the year (D. Halliwell, pers. comm.). Thus, the minimum sampling frequency for lakes was adopted for these sites.

6.5 Data quality

Water quality data exist at three levels: individual samples taken at monitoring sites; the combination of individual samples to calculate a WQI value for a particular site; and the aggregated data set of all WQI values from the selected sites across the country (see 5.5).

It is inevitable that errors will sometimes occur in individual sample results. The most common are field errors (sample contamination, mislabeling), lab errors (misidentified samples, miscalculations, analytical mistakes) and data entry errors. 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 Environmental Analytical Laboratories, ensuring analytical methods are up to standard and proper quality assurance/quality control procedures are in place.

7. Future improvements

This report provides information on the status of water quality in Canada as it relates to its ability to support aquatic life. The preliminary indicator reported here will be improved in future reports.

Long-term goals for the development of the freshwater indicator include

- a consistent and comparable set of monitoring sites that is representative of key aquatic habitats (e.g., rivers, lakes, wetlands) in Canada with respect to different beneficial uses (e.g., protection of aquatic life, agriculture, source water for drinking);
- improvements in selecting parameters and guidelines used in the calculation, so that results can be aggregated regionally across the country, by drainage area and over time;
- more refined separation of the effects of natural and human-caused changes in water quality through the development of site-specific guidelines; and
- reporting on water quality for other beneficial uses, such as agriculture or raw water sources used to supply drinking water treatment plants, possibly through a series of indicators.

The following specific improvements are planned in relation to monitoring, indicator development, guideline development, and surveys:

Monitoring: Freshwater quality monitoring capacity is limited and considerably fragmented across the country, with significant spatial gaps. Over the next few years, Environment Canada, in collaboration with provincial and territorial counterparts, will expand the current water quality monitoring network to address these spatial gaps in knowledge. This, in turn, will also enhance the national representation of water bodies and aquatic habitats throughout the country. Efforts are being made collectively to identify areas of Canada that are underrepresented in the network and set priorities for increased monitoring activity. For example, key sites in southern Saskatchewan will be included in the 2007 indicator report. Another consideration in the selection of monitoring locations will be the coordination of monitoring sites and water quality parameters (where possible) to enable data collection for multiple indicators for different water uses. For example, a river monitoring site may be selected upstream from a raw[11] water intake of a water treatment plant, to enable data to be used for both the aquatic life and source water quality indicators.

The water quality indicator is currently based on measurements of physical and chemical parameters in water. Measuring biological components of a water body (e.g., benthic invertebrates) can also provide important insights into water quality and aquatic ecosystem health. Methods for incorporating biological data are being examined for future indicator reporting.

Indicator development: Work is being carried out on methods to improve the calculation and presentation of the current indicator, as there is a need to both compensate for the unbalanced geographical distribution of monitoring sites and present trends over time. The current geographical distribution of sites will be reviewed in an attempt to adopt a more systematic approach to selecting sites, and weights will be allocated to each of these sites. Also, a different way of compiling the indicator, possibly based on one-year versus three-year periods, will be adopted to report trends in water quality.

Detailed work at specific sites will be required to identify the causes of changes in water quality or to determine the reasons why water quality samples exceed guidelines. More study is also needed across Canada to link the water quality ratings at individual monitoring sites to specific human activities and natural processes.

Health Canada initiated development of the source/raw water quality indicator in October 2005 in cooperation with a federal/provincial/territorial working group. The scope of the project was broadened to include a treated water quality indicator to facilitate communication to the public on the quality of the water they drink. The overall aim of this project is to have a means of measuring, tracking, and reporting on both source (raw) and treated water quality. The new information will help to evaluate the effectiveness of source water protection initiatives, guide source water protection planning and activities, and identify the presence of gaps in the multiple barrier approach.[12] The project is scheduled to be completed by spring 2007.

The WQI will also be used to assess and report the suitability of water quality for other major uses, such as irrigation and livestock watering in the agricultural sector. This analysis will then be incorporated into the freshwater indicator.

Guideline development: How well the WQI rates water quality depends directly on the use of appropriate water quality parameters and guidelines. Parameters and guidelines used in the WQI computation should be locally relevant, meaning appropriate to the local organisms and local water characteristics. For example, water hardness and temperature can affect the toxicity of some substances; therefore, guidelines for these substances should vary according to water hardness and temperature. Environment Canada, in consultation with the provinces and territories, is assessing the ecological relevance of existing guidelines with regard to local conditions and, where necessary, will develop site-specific guidelines using

11. Water in its natural state, prior to any treatment.
12. An integrated system of procedures, processes, and tools that collectively prevent or reduce the contamination of drinking water from source to tap in order to reduce risks to public health.

nationally consistent methods and protocols. Options for a more consistent selection of parameters among jurisdictions are being evaluated as well. Investments may be needed to measure more parameters at some locations and to develop guidelines for other key substances.

Surveys: The effects of household and industrial activities on water quality as well as the needs of households and industry for high-quality water are being documented through several new national surveys. Results from the Households and the Environment Survey will provide information on household activities that can impact water quality and changes in household behaviour in response to water quality concerns. In addition, the Industrial Water Use Survey will collect information on water use and management from manufacturers, thermal power generators, and mines. A survey of municipal water treatment plants is planned, which will support the Source Water Quality Indicator. A survey of agricultural water use is also under development.

9. References

Alberta Environment. 1999. *Surface Water Quality Guidelines for Use in Alberta*. Science and Standards Branch, Alberta Environment, Edmonton, Alberta (www3.gov.ab.ca/env/water/Legislation/Guidelines/index.cfm).

Alberta Environment. 2002. *Alberta Environment's Performance Measures and Indicators — Levels 1 & 2: Environmental Indicators and Behavioural Indicators*. Alberta Environment, Edmonton, Alberta.

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

BCMOE. 1996. *British Columbia Water Quality Status Report.* April 1996. Environmental Protection Division, British Columbia Ministry of Environment, Victoria, British Columbia (www.env.gov.bc.ca/wat/wq/public/bcwqsr/bcwqsr1.html).

BCMOE. 2001. *British Columbia Approved Water Quality Guidelines (criteria) 1998 Edition*. Environmental Protection Division, British Columbia Ministry of Environment, Victoria, British Columbia. Updated August 24, 2001 (www.env.gov.bc.ca/wat/wq/BCguidelines/approv_wq_guide/approved.html).

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.

CCME. 1991. "Appendix IX — A protocol for the derivation of water quality guidelines for the protection of aquatic life" (April 1991). In: *Canadian Water Quality Guidelines*. Canadian Council of Resource and Environment Ministers, 1987. Prepared by the Task Force on Water Quality Guidelines (www.ccme.ca/assets/pdf/wqg_aql_protocol.pdf). [Updated and reprinted with minor revisions and editorial changes in *Canadian Environmental Quality Guidelines*, Chapter 4, Canadian Council of Ministers of the Environment, 1999, Winnipeg, Manitoba.]

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

CCME. 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 (www.ccme.ca/assets/pdf/wqi_usermanualfctsht_e.pdf).

CCME. 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. 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 (www.ec.gc.ca/soer-ree/English/resource_network/status_report_e.cfm).

CCME. 2005b. *Canadian Environmental Quality Guidelines. Update 5.0.* Canadian Council of Ministers of the Environment, Winnipeg, Manitoba (www.ccme.ca/publications/ceqg_rcqe.html).

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. (NWRI Scientific Assessment Report Series No. 1).

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 [now the Canadian Environmental Sustainability Indicators or CESI] 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. June 23, 2005.

Fidler, L.E., and G.G. Oliver. 2001. *Towards a Water Quality Guideline for Temperature in the Province of British Columbia*. Water Quality Section, Water Management Branch, British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia.

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.

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

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.

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.

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.

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
www.gov.mb.ca/waterstewardship/water_quality/quality/website_notice_mwqsog_2002.html.

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.

McNiven, C., and H. Puderer. 2000. *Delineation of Canada's North: An Examination of the North-South Relationship in Canada.* Geography Working Paper No. 2000-3, Catalogue no. 92F0138MIE. Statistics Canada, Ottawa, Ontario.

MDDEP. 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 (http://www.mddep.gouv.qc.ca/eau/criteres_eau/fondements.htm).

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.

Nagpal, N.K. 1987. *Water Quality Criteria for Lead: Technical Appendix*. Water Management Branch, British Columbia Ministry of Environment and Parks, Victoria, British Columbia.

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

Nordin, R.N., and L.W. Pommen. 1986. *Water Quality Criteria for Nitrogen (Nitrate, Nitrite, and Ammonia)*. Water Quality Unit, Resource Quality Section, Water Management Branch, British Columbia Ministry of Environment and Parks, Victoria, British Columbia.

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

Ontario Ministry of the Environment (OMOE). 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. (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.

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

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.

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

Singleton, H.J. 1987. *Water Quality Criteria for Copper: Technical Appendix*. Water Management Branch, British Columbia Ministry of Environment and Parks, Victoria, British Columbia.

Singleton, H.J. 2000. *Ambient Water Quality Guidelines for Sulphate*. Water Quality Section, Water Management Branch, British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia.

USEPA. 2005. *Current National Recommended Water Quality Criteria*. United States Environmental Protection Agency (http://www.epa.gov/waterscience/criteria/wqcriteria.html).

Warrington, P.D. 1995. *Ambient Water Quality Criteria for Fluoride*. Resource Quality Section, Water Management Branch, British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia.

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.

Further reading

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

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.

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.

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

Obedkof, W. 1981. *Water Quality Assessment and Objectives for the Fraser River from Moose Lake to Hope.* British Columbia Ministry of Environment, Lands and Parks, 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.

Acronyms

BCMOE – British Columbia Ministry of Environment

CCME – Canadian Council of Ministers of the Environment

CESI – Canadian Environmental Sustainability Indicators

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

OECD – Organisation for Economic Co-operation and Development

PPWB – Prairie Provinces Water Board

USEPA – United States Environmental Protection Agency

WQI – Water Quality Index

Appendix 1: The water quality guidelines used in each jurisdiction

Parameter	Form	Guideline description[1]	Unit	Source
Alberta				
Aluminum[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	USEPA, 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
British Columbia[4]				
Alkalinity		20	mg/L ($CaCO_3$)	BCMOE, 2001
Antimony	Total	20	µg/L	BCMOE, 2001
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 $CaCO_3$	µg/L	BCMOE, 2001; CCME, 2005b; Environment Canada, 2005c
Cadmium	extractable	SSG	µg/L	BCMOE, 2001; CCME, 2005b; Environment Canada, 2005c

Parameter	Form	Guideline description[1]	Unit	Source
Chloride	Dissolved	150	mg/L	Levy et al., 1981
Chromium	Total or dissolved	SSG	µg/L	BCMOE, 2001; Environment Canada, 2005c
Copper	Total or dissolved	SSG	µg/L	Singleton, 1987
Cyanide	Total	SSG	µg/L	Singleton, 1986
Cyanide	Weak acid dissociable	5	µg/L	Singleton, 1986
Dissolved oxygen		SSG	mg/L	BCMELP, 1997
Fluoride	Dissolved	0.38	mg/L	Warrington, 1995
Fluoride	Total	0.30	mg/L	Warrington, 1995
Iron	Total	300	µg/L	CCME, 2005b
Lead	Total or extractable	SSG	µg/L	Nagpal, 1987
Manganese	Total	SSG	µg/L	Reimer, 1999
Molybdenum	Total	SSG	µg/L	CCME, 2005b
Nickel	Total	e^(0.76*ln[hardness]+1.06)	µg/L	CCME, 2005b; Environment Canada, 2005c
Nitrate	Total as N	2.93	mg/L	CCME, 2005b; Environment Canada, 2005c
Nitrite	Not available	0.02	mg/L	Nordin and Pommen, 1986
Nitrogen	Total and total dissolved	SSG	mg/L	BCMOE, 2001; Environment Canada, 2005c
Ph		SSG	n/a	McKean and Nagpal, 1991; BCMOE, 2001
Phosphorus	Total or total dissolved	SSG	mg/L	Nordin, 2001
Selenium	Total	2	µg/L	Howell and Nagpal, 2001
Silver	Total	SSG	µg/L	Warrington, 1995; Environment Canada, 2005c
Sulphate	Dissolved	SSG	mg/L	Singleton, 2000
Temperature		SSG	°C	Fidler and Oliver, 2001
Thallium	Extractable	0.8	µg/L	BCMOE, 2001; CCME, 2005b; Environment Canada, 2005c
Zinc	Total or total dissolved	SSG	µg/L	Nagpal, 1981

Parameter	Form	Guideline description[1]	Unit	Source
Manitoba				
Ammonia[2]	Total as nitrogen	Calculation based on pH and temperature	mg/L	USEPA, 2005
Ammonia[3]	Un-ionized	0.019	mg/L	CCME, 2005b
Arsenic[2]	Total or extractable	0.15	mg/L	USEPA, 2005
Arsenic[3]	Total	150	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	USEPA, 2005
Chloride[3]	Dissolved	150	µg/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	USEPA, 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; USEPA, 2005
Dissolved oxygen[2]		5	mg/L	USEPA, 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	USEPA, 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	USEPA, 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				
Arsenic[5]	Total	5	µg/L	CCME, 2005b
Chromium[5]	Total	1	µg/L	CCME, 2005b
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[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
Molybdenum[5]	Total	73	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
pH		6.5–9.0	n/a	CCME, 2005b
Phosphorus	Total	0.03 (rivers)	mg/L	Dodds et al., 1998
Selenium[5]	Total	1	µg/L	CCME, 2005b
Zinc[5]	Total	30	µg/L	CCME, 2005b

Parameter	Form	Guideline description[1]	Unit	Source
Northwest Territories and Nunavut				
Ammonia	Dissolved	SSG (lotic sites) and 0.019 (lentic-lotic sites)	mg/L	CCME, 2005b
Chloride	Dissolved	SSG (lotic sites) and 150 (lentic-lotic sites)	mg/L	CCME, 2005b
Copper	Total	SSG (lotic sites) 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 (lotic sites) and 300 (lentic-lotic sites)	µg/L	CCME, 2005b
Lead	Total	SSG (lotic sites) 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-nitrate	Dissolved	SSG (lotic sites) and 2.93 (lentic-lotic sites)	mg/L	CCME, 2005b
Oxygen	Dissolved	5	mg/L	CCME, 2005b
pH		SSG (lotic sites) and 6.5–9.0 (lentic-lotic sites)	pH units	CCME, 2005b
Phosphorus	Total	SSG (lotic sites) and 0.03 (lentic-lotic sites)	mg/L	Dodds et al., 1998
Zinc	Total	SSG (lotic sites) and 30 (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	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; Environment Canada, 2005c
Iron	Dissolved	300	µg/L	CCME, 2005b; Environment Canada, 2005c
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
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
Ontario (rivers)				
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
Ontario (Great Lakes)				
Ammonia	Un-ionized	0.019	mg/L	CCME, 2005b; Environment Canada, 2005c
Cadmium	Total	≤10^0.86[log(hardness)]−3.2, when >50mg/L $CaCO_3$; ≤0.019, when <50 mg/L $CaCO_3$	µg/L	BCMOE, 2001; CCME, 2005b; 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; Environment Canada, 2005c

Parameter	Form	Guideline description[1]	Unit	Source
Chromium	Total	2	µg/L	CCME, 2005b; Environment Canada, 2005c
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
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
Nitrate	Total	2.93	µg/L	CCME, 2005b; Environment Canada, 2005c
Phosphorus	Total	0.01	mg/L	CCME, 2005b; Environment Canada, 2005c
Arsenic	Total	5	µg/L	CCME, 2005b; Environment Canada, 2005c
Iron	Total	300	µg/L	CCME, 2005b; Environment Canada, 2005c
Molybdenum	Total	73	µg/L	CCME, 2005b; Environment Canada, 2005c
Aluminum	Total	100	µg/L	CCME, 2005b; Environment Canada, 2005c
Silver	Total	0.1	µg/L	CCME, 2005b; Environment Canada, 2005c
Selenium	Total	1	µg/L	CCME, 2005b; Environment Canada, 2005c
Fluorene	Dissolved	3	µg/L	CCME, 2005b; Environment Canada, 2005c
Naphthalene	Dissolved	1.1	µg/L	CCME, 2005b; Environment Canada, 2005c
Phenanthrene	Dissolved	0.4	µg/L	CCME, 2005b; Environment Canada, 2005c
DDD	sediment	3.54	µg/kg	CCME Interim Sediment Quality Guideline
DDE	sediment	1.42	µg/kg	CCME Interim Sediment Quality Guideline
PCBs	sediment	34.1	µg/kg	CCME Interim Sediment Quality Guideline

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
Quebec				
Ammonia	Total (as N)	0.05, at pH 8.2 and 20ºC	mg/L	MDDEP, 2006
Chlorophyll a		8	mg/m^3	OECD, 1982
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
Turbidity		10	NTU	MDDEP, 2006
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
Yukon[4]				
Arsenic	Total	5	µg/L	CCME, 2005b

Parameter	Form	Guideline description[1]	Unit	Source
Cadmium	Total	0.026	µg/L	BCMOE, 2001; CCME, 2005b; Environment Canada, 2005c
Chromium	Total	SSG	µg/L	BCMOE, 2001; Environment Canada, 2005c
Copper	Total	SSG	µg/L	Singleton, 1987
Lead	Total	e(1.273[ln*(hardness)]−4.705)	µg/L	CCME, 2005b; Environment Canada, 2005c
Nitrate	Total as N	2.93	mg/L	CCME, 2005b; Environment Canada, 2005c
Nitrite	Not available	0.02	mg/L	Nordin and Pommen, 1986
pH		SSG		CCME, 2005b
Phosphorus	Total	0.03	mg/L	Dodds et al., 1998
Silver	Total	SSG	µg/L	Warrington, 1995; Environment Canada, 2005c
Sulphate	Dissolved	50	mg/L	
Temperature		SSG	˚C	Fidler and Oliver, 2001
Zinc	Total	SSG	µg/L	BCMOE, 2001; Environment Canada, 2005c

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 sites monitored by provincial monitoring programs. (3) Applies to sites 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.