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by Joel Wood





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## Overview

Canadians are concerned about the abundance and quality of our freshwater resources, yet information is widely dispersed and often difficult to obtain. This publication reviews a wide array of data and government publications to assess the state of Canada's water resources in an effort to make the information more accessible to policy-makers and the general public.

According to World Bank data, Canada has the fourth largest supply of annual renewable freshwater in the world. However, most major sources are situated far north of our population centres, southern supplies have been declining in recent decades, and we have relatively high per-capita usage (9<sup>th</sup>) compared to other countries. Nonetheless, Canadians still consume only a small fraction (1.6%) of what is annually available. Furthermore, there are proven and effective policy tools like water pricing and allocation markets that can improve management in areas that currently experience seasonal shortages.

Canada ranks 9<sup>th</sup> in the world for water quality on the basis of a small subset of water-quality parameters (dissolved oxygen, pH, conductivity, phosphorus, and nitrogen). Furthermore, calculations based on data over time from specific water monitoring stations with a larger parameter set indicate that water quality across Canada appears to have been stable at most stations since the 1990s. In addition, nutrient levels in major Canadian rivers and lakes have largely remained stable between 1990 and 2006.

To obtain a more comprehensive picture of how Canadian water quality has changed over time, *Canadian Environmental Indicators—Water* reviews numerous government reports from each province. When we examine evidence from individual provinces over the long term, it is clear that, for many forms of pollution, water quality has improved greatly since the 1970s. In Ontario, total phosphorus has generally decreased in lakes and rivers since the 1970s. There has also been a general decline in mercury, PCBs, and many other toxic substances in the waters of Ontario and Quebec. Another example of improving water quality is the return to pre-settlement levels of total phosphorus in Lake Osoyoos in British Columbia. Bacteria levels are decreasing in major Alberta rivers from improvements to sewage treatment. Due to improvements in the bleaching process used in British Columbia's pulp and

paper mills, the province's rivers have seen a significant decrease in chloride levels since the 1980s. Evidence from Ontario suggests that pesticides and pharmaceuticals in drinking water and chloride in rivers from road salt are currently not at a level to prompt concern for water quality.

There are also more localized success stories. Salmon have recently returned to the Nepisiguit River in New Brunswick. Fish and bugs have returned to the Tsolum River in British Columbia forty years after toxic releases from an abandoned mine virtually destroyed the river's ecosystem. Wheatley Harbour on Lake Erie in Ontario has recently been de-listed from the Great Lakes Areas of Concern.

Despite these improvements, there continue to be concerns about water quality that require continued vigilance or action. Though current use of polybrominated diphenyl ethers (PBDEs) has been voluntarily reduced by manufacturers and restricted by government regulations, some indicators suggest that concentrations of PBDEs have increased in the Great Lakes and the St. Lawrence River ecosystems to a level that could have an adverse effect on wildlife. Nitrogen levels in the Great Lakes, the St. Lawrence, British Columbia's lower mainland, and Prince Edward Island's rivers are high and increasing. Water in Nova Scotia's Kejimikujik National Park remains very polluted, and concentrations of mercury in fish and loons continue to increase. Improved and continued monitoring of water quality in Canada is needed, and any effort to test for the same parameters at different monitoring stations will allow more direct interprovincial comparisons.

# 1 Introduction

Are we running out of fresh water in Canada? How polluted is our freshwater? Is our freshwater becoming more polluted over time? These are questions that Canadians frequently ask but they may find it difficult to obtain answers. The purpose of this publication is to bring objective information to Canadians about the general state of Canadian water over time.

Canada has abundant supplies of freshwater, but most of these are in the north. Canada is also among the largest per-capita users of fresh water in the world. The first question this publication seeks to answer is whether we are running out of freshwater. It provides an overview of Canada's freshwater resources, how they have changed over time, how Canadians use these resources, and how these things compare to other countries.

Clean water is essential for human health, and contributes to social and economic activities. Over the past 100 years, increased population and industrialization has led to pollutants being released into Canadian lakes and rivers. Metals (e.g., mercury) and toxic substances (e.g., the pesticide DDT) can affect the quality of drinking water and can have adverse effects on aquatic life. Increases in nutrients such as phosphorus and nitrogen, which come from municipal wastewater or over-use of agricultural fertilizers, can negatively affect aquatic ecosystems and increase the frequency of nuisance algal blooms. Canadians are right to be concerned about the quality of our water for drinking, recreation, and wildlife. While this publication tries to address freshwater quality from a national perspective, more satisfactory answers are found at the local level. Therefore, it reviews detailed and more technical information for each province. Focusing on government and academic analyses at the provincial level sheds light on long-term trends in individual pollutants and helps identify how water quality has improved and which areas need additional vigilance or action.

Overall, our analysis suggests that, although annual renewable freshwater supplies in Canada are declining, we use such a small percentage of this massive resource that there should be no concern about it running out anytime soon. The quality of Canada's freshwater is mixed, with many areas enjoying excellent or good water quality, and some areas having poor water quality. In many respects, water quality in Canada has improved a great deal

since the 1970s. For example, there has been a general decline in many metals and toxic substances found in sport fish in Ontario lakes. At the same time, there are other toxic substances like polybrominated diphenyl ethers (PBDEs) that have been increasing in sport fish in Ontario lakes. Nutrient levels are relatively constant in most major Canadian water bodies; however, there are upward trends in some, and downward trends in others. Some, such as Lake Osoyoos in British Columbia, have reduced phosphorus levels to such an extent over the past 40 years that current levels are similar to those prior to major human settlement.

Section 2 provides an overview of the quantity of water in Canada and of how Canadians use water. Section 3 provides a Canada-wide overview of the water quality in Canadian rivers and lakes. Section 4 looks at nutrient levels in Canadian rivers and lakes from a Canada-wide perspective. Section 5 provides an in-depth view of water quality in each province. Section 6 discusses our general conclusions and their implications for policy.



## 2 Are we running out of water in Canada?

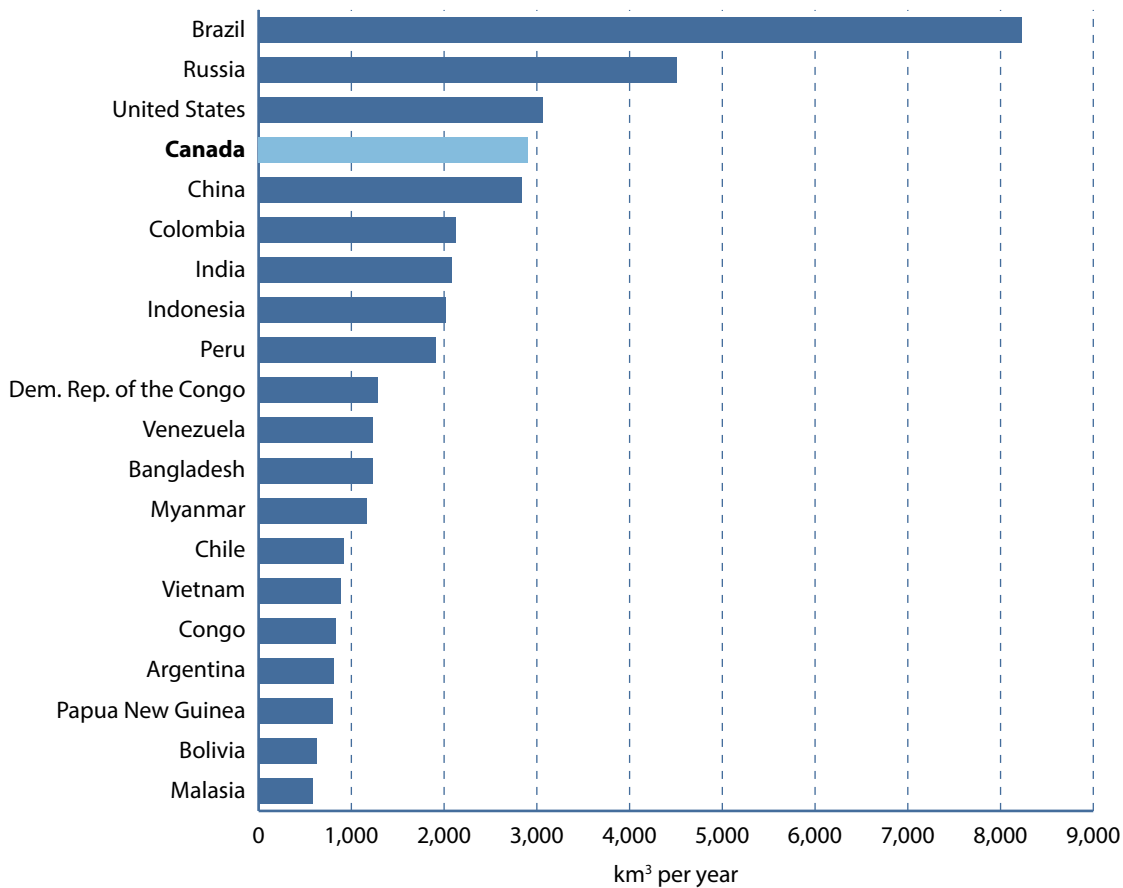
### Supply

Canadian freshwater resources can be divided into two main categories: stocks and flows. Stocks of water are supplies of water that have accumulated over time; these include glaciers, large lakes, and underground aquifers. These resources, especially lakes, do replenish themselves but it takes such a long time that they can be considered non-renewable. For example, it takes almost 200 years for the water in Lake Superior to completely renew (Dewar and Soulard, 2010). Flows of water are the annual renewable supply of water. They are replenished each year through precipitation and water inflows from the United States.

Based on water stocks, Canada has an impressive water supply. Although it is shared with the United States, approximately 18% of the world's stock of fresh surface water is found in the Great Lakes. Furthermore, Canada has a larger area covered by lakes than any other country, with as much as 20% of the global stock of freshwater on its surface (Dewar and Soulard, 2010). Long-term trends in Canada's stock of surface freshwater have not been extensively studied. However, a recent report found that the amount of water in Lake Huron is at its lowest since record keeping began in 1918, and that the other Great Lakes are reporting water levels below average (Associated Press, 2013, Feb. 6).

Canada also has an enviable supply of water flows. As of 2011, Canada trails only Brazil, Russia, and the United States in average annual volume of renewable freshwater (FAO, 2013). **Figure 2.1** shows how Canada's 2,902 km<sup>3</sup> of renewable freshwater in 2011 compares to other countries with abundant water supplies. The 2011 data for Canada is below the historical average; the supply of renewable freshwater in Canada averaged 3,472.3 km<sup>3</sup> per year between 1971 and 2004, which is roughly equivalent to the water contained in Lake Huron (Dewar and Soulard, 2010). Canada ranked 8<sup>th</sup> globally in renewable freshwater per person in 2011 (**figure 2.2**). Furthermore, amongst developed countries, only Iceland has more renewable freshwater per person than Canada (FAO, 2013; author's calculations).

**Figure 2.1: The 20 countries with the largest supplies of renewable freshwater, 2011**

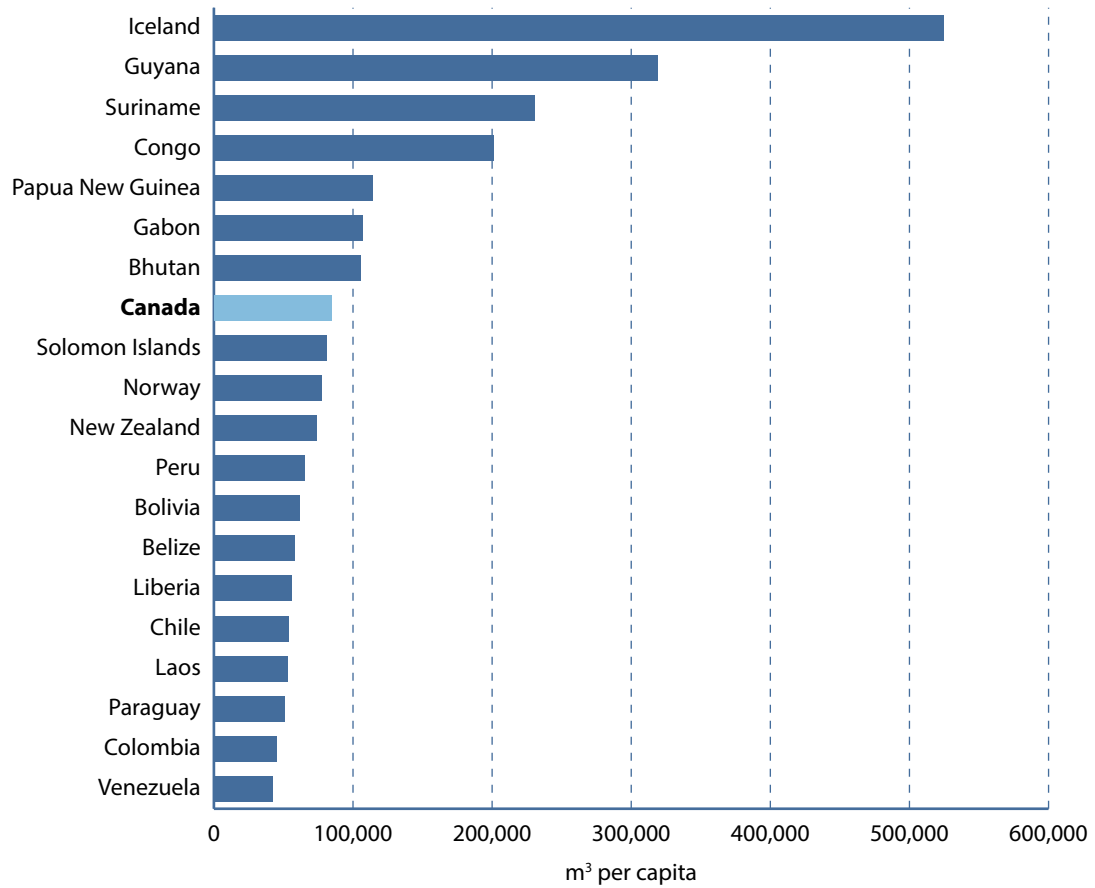


Source: Food and Agriculture Organization, 2013.

Renewable freshwater is certainly abundant in Canada; however, only 38% is located in the south where 98% of Canadians live (Dewar and Soulard, 2010).<sup>1</sup> Applying this fraction (38%) to the Canadian statistic in [figure 2.1](#) suggests that the southern, populated portion of Canada, if it were a country on its own, would still rank among the top 15 in the world for renewable freshwater (FAO, 2013; author's calculation). There are also regional differences in the supply of renewable freshwater in southern Canada. For example, the Pacific Coastal and Fraser-Lower Mainland drainage regions have relatively large supplies of renewable freshwater, whereas the Okanagan drainage region and the drainage regions in southern Alberta, Saskatchewan, and Manitoba have relatively low supplies (Dewar and Soulard, 2010).

<sup>1</sup> The North/South divide is a statistical delineation used by Dewar and Soulard (2010) based on social, biotic, economic and climatic variables. The line roughly splits the western provinces and northern Ontario in half, crosses Quebec above the St. Lawrence basin and splits Labrador from Newfoundland.

**Figure 2.2: The 20 countries with the largest supplies of renewable freshwater per capita, 2011**



Source: Food and Agriculture Organization, 2013; author's calculations.

Renewable freshwater is decreasing overall in southern Canada. Trend estimation conducted by Dewar and Soulard (2010) find that the supply of renewable freshwater decreased, on average, by 3.5 km<sup>3</sup> annually (8.5% over the entire time period). The decline differed among regions, with the largest declines occurring in the Maritimes, and the Columbia drainage region in eastern British Columbia remaining relatively constant (Dewar and Soulard, 2010).

## Demand

Water is used in Canada for a wide variety of purposes, ranging from basic personal consumption to generating electricity. In 2005, Canadians used 42.1 km<sup>3</sup> of water (Dewar and Soulard, 2010), which is less than 2% of the country's annual supply of renewable freshwater (author's calculations). Data from the World Bank provides a slightly higher estimate of water use in Canada,

45.9 km<sup>3</sup> (World Bank, 2013). **Figure 2.3** displays the amount of water used by major sectors of the Canadian economy. In 2009, thermal-electric power generation used 66% of the water withdrawn in Canada. Manufacturing accounted for 10% and 12% of the water used and residential use for 12%. Contrary to popular belief, mining, oil, and gas extraction are responsible for a only very small percentage (just above 2%) of the water used in Canada.

Data from the World Bank includes estimates of water withdrawals and supply for countries around the world. In 2011, Canada had the 48<sup>th</sup> lowest ratio (1.61%) of water withdrawn to annual supply of renewable fresh water (World Bank, 2013; author's calculations). When comparing against only other OECD member countries (that is, developed countries), Canada uses the 8<sup>th</sup> lowest percentage of its annual renewable freshwater (**figure 2.4**).

Although Canadians use only a fraction of our freshwater resources, they use a relatively large amount of freshwater per person compared to other countries. **Figure 2.5** displays the 25 countries with the highest water withdrawals per person in 2011. Canada has the 9<sup>th</sup> highest use of water on a per person basis (World Bank, 2013; author's calculations). The only developed country that uses more water per person than Canada is the United States.

### Pricing mechanisms to promote greater efficiency in water use

Although Canada uses only a very small fraction of its annual supply of renewable freshwater, regional and seasonal variability in supply and demand are problems in some areas. For example, Dewar and Soulard note that

[i]n August 2005, more than 40% of the water yield in the Okanagan-Similkameen drainage region and the Prairies was withdrawn by agriculture, industry, and households. In the Prairies, where stocks are limited, water demand must be met primarily by renewable water, and water shortages are evident when demand exceeds the renewable supply. (2010: 7)

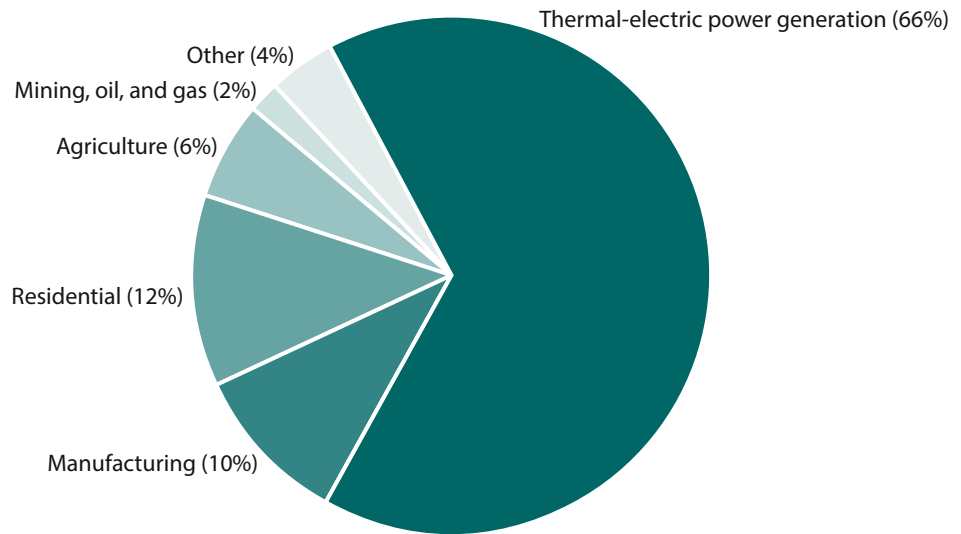
The potential for water shortages to impede economic activity is clearly present in these regions. Water in Canada is owned and managed by the government. In the areas with the largest seasonal water scarcity, the southern Prairies and the Okanagan Valley, water licenses have traditionally been allocated essentially on a first-come, first-served basis,<sup>2</sup> rather than through a market (Brandes and Nowlan, 2009). Further expansion of water markets would ensure that water is being used in its most valuable way amongst large users such as farms and industrial facilities. Water markets may also provide the appropriate financial incentives to build infrastructure to transport renewable freshwater from Canada's north to the

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2. More correctly, a "first-in-time, first-in-right" basis.



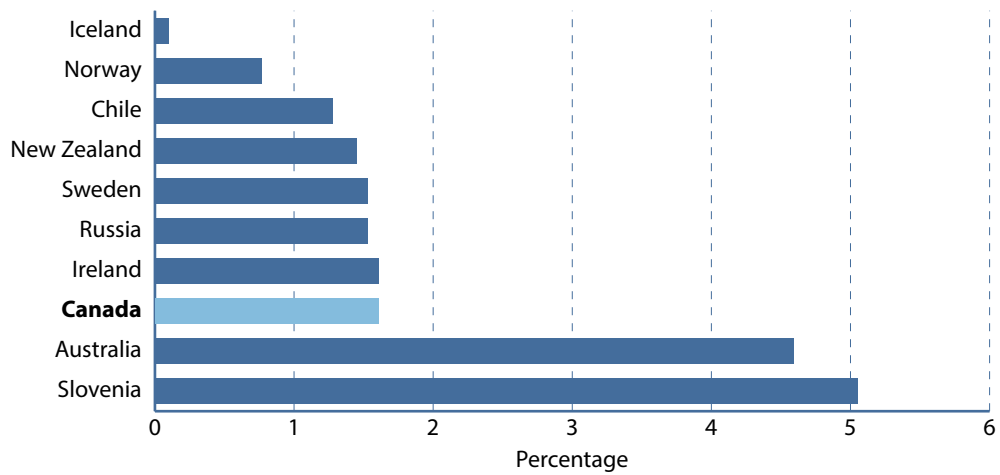
**Figure 2.3: Water use in Canada, by sector, 2009**



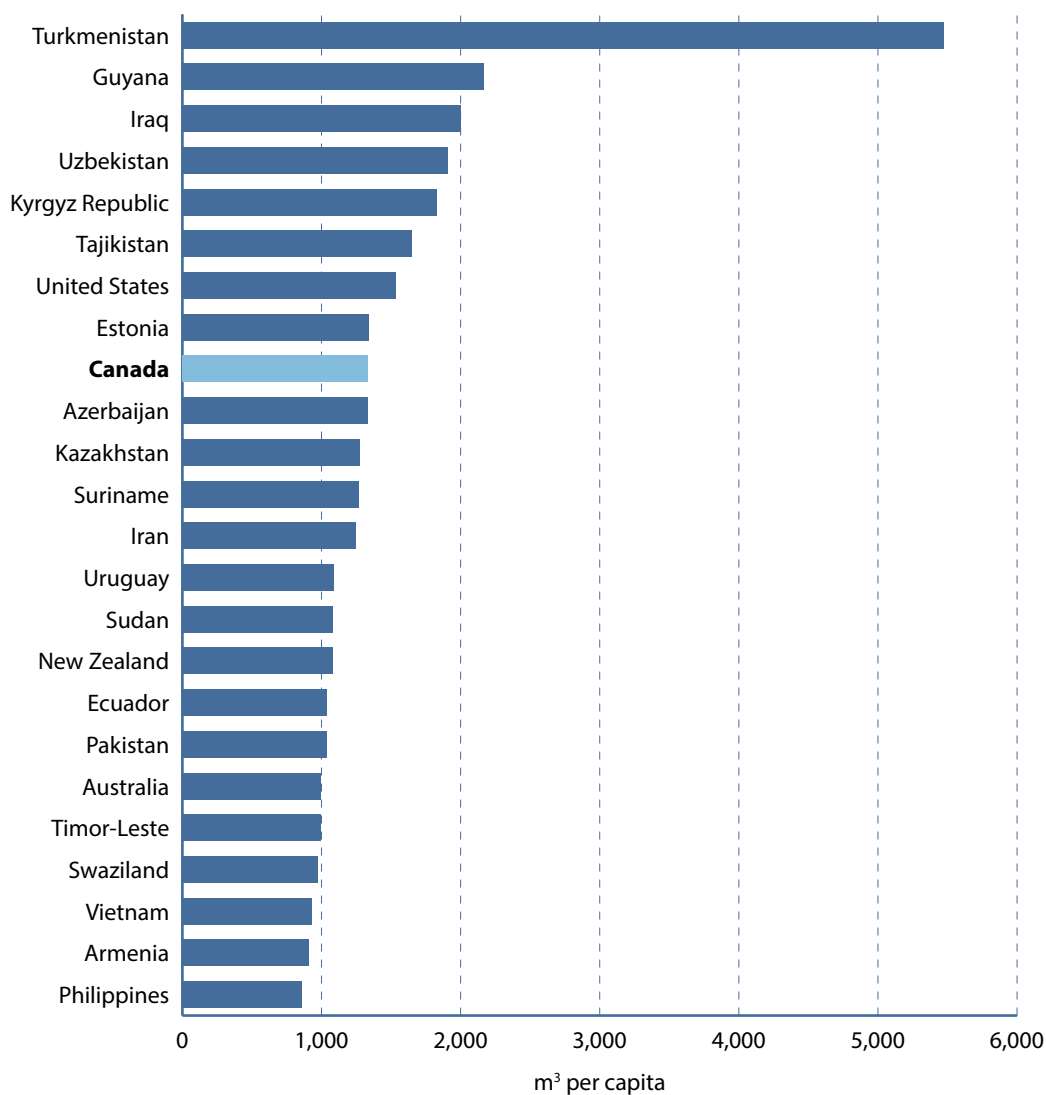
Note: In 2009, total water use by all sectors was 39,908.6 million m<sup>3</sup>.

Sources: Environment Canada, 2013b.

**Figure 2.4: Selected OECD countries ranked by withdrawals as a percentage of their supply of renewable freshwater, 2011**



Source: World Bank, 2013; author's calculations.

**Figure 2.5: Twenty-five countries ranked by withdrawals per capita, 2011**

Notes: One cubic metre (m<sup>3</sup>) is equal to 1,000 litres of water (equivalent to the contents of 500 2L soda bottles). The extremely high per-capita use in Turkmenistan is likely a result of soviet-era and post-soviet-era agricultural policies that have led to very inefficient irrigation systems in such an arid desert climate (Stanchin and Lerman, 2007). It is possible that similar policy histories and geographies may also explain the high per-capita rates in other ex-soviet central Asian countries. Source: World Bank, 2013; author's calculations.

areas that require additional supply. Indeed, Alberta has begun allowing water allocations in the South Saskatchewan River Basin to be traded and, in 2011, the total value of the transactions in this water market was estimated to be over \$4 million (Sustainable Prosperity, 2012). More effective pricing—by, for example, charging on a per-volume basis rather than a flat rate—of residential water consumption can also ensure that Canadians are using water in a more efficient manner and help fund the replacement of aging, leaking infrastructure.

## Are we running out of water?

The answer to the question, “Are we running out of water?”, is clearly “No”. Although the annual supply of renewable freshwater in southern Canada has declined between 1971 and 2004, at the current rate of decline it would take over 300 years before annual renewable freshwater ran out. This is not something to worry about; if needed, infrastructure can be built to tap into the abundant annual supplies of renewable freshwater in Canada’s sparsely populated north. Moving water over long distances by pipelines would be inherently safe.

Although some regions of Canada could experience water shortages, water markets and better pricing can ensure more efficient allocation of scarce water resources and provide financial incentive to build infrastructure to transport water from areas of abundance.

## 3 How good is water across Canada?

### What affects water quality in Canada?

Over the past 100 years, increased population and industrialization has led to pollutants being released into Canadian lakes and rivers. Metals (e.g., mercury) and toxic substances (e.g., the pesticide DDT) can affect the quality of drinking water and have adverse effects on aquatic life. Increases in nutrients from municipal wastewater or over-use of agricultural fertilizers such as phosphorus and nitrogen can have a negative effect upon aquatic ecosystems and increase the frequency of potentially toxic algal blooms.

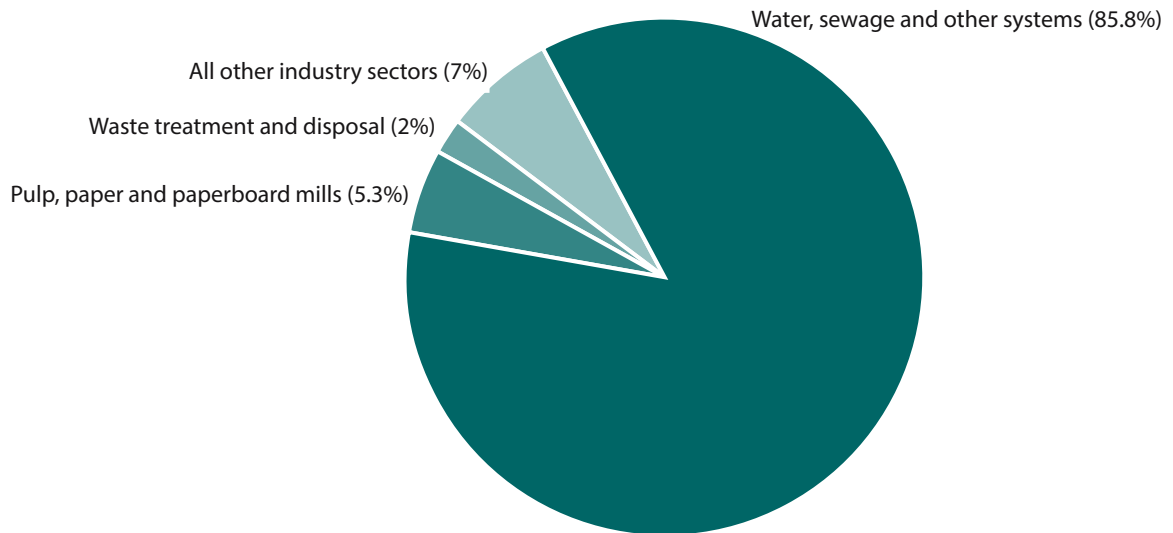
**Figure 3.1** displays pollutant releases into water by the industrial sector from the National Pollutant Release Inventory (Environment Canada, 2010b). The releases include nitrate ion, ammonia, and phosphorus, among others. The vast majority, 85.8%, of released volume is from the Water, Sewage, and Other Systems sector (e.g., municipal sewage and wastewater treatment plants). The sector, Pulp, Paper, and Paperboard Mills, is the next largest source at 5%.

The data from the National Pollutant Release Inventory (NPRI) consider only large, stationary sources of water pollution. Not included in **figure 3.1** are pollutants released into the water system from smaller and more widespread sources, such as run-off from the use of fertilizers and pesticides in agriculture or run-off from vehicle leaks.

### How clean is our freshwater?

At the national level, overall trends in water quality are difficult to discern. The question of which parameters to sample is generally decided at the local level based on local geography, geology, and human pressures. This has led to different parameters being sampled at stations in different provinces and regions. For example, a monitoring station downstream from a coal mine in British Columbia will likely sample selenium levels, whereas selenium may not be sampled at a monitoring station in New Brunswick where selenium pollution is not a concern. Evaluating an identical set of parameters at stations



**Figure 3.1: Pollutant releases into water in Canada, by source, 2008**

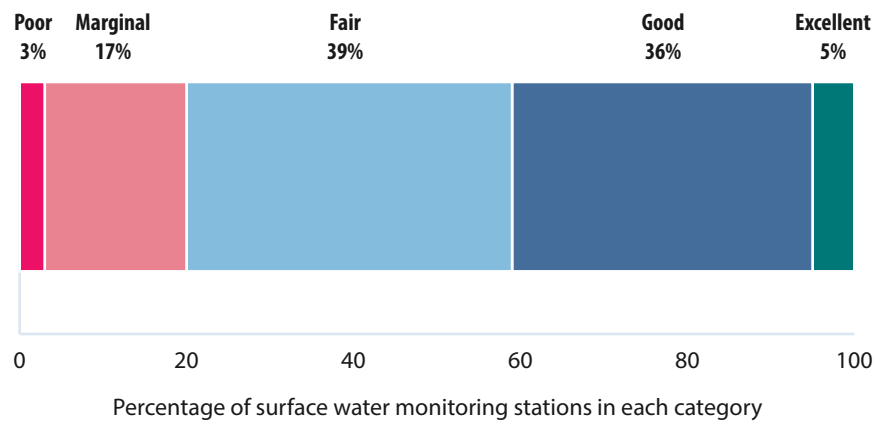
Note: The releases include nitrate ion, ammonia, phosphorus, among others; the figure provides a percentage breakdown by industrial sector. Total releases for 2008 = 122,201.

Sources: Environment Canada, 2010b.

across the country is currently not possible. Many stations and regions also have inconsistent monitoring records. A certain parameter might only be looked at in a single year, or a certain monitoring station might only be sampled in a single year.

Environment Canada (2012) uses the Water Quality Index<sup>3</sup> proposed by the Canadian Council of Ministers of the Environment (CCME) to attempt an evaluation of water quality at monitoring stations across the country. However, a set of parameters that are not identical across stations and inconsistent monitoring prevents serious comparisons among stations and regions. Out of 173 monitoring stations with data for 2007 to 2009, 5% were categorized as “Excellent”, 36% as “Good”, and 39% as “Fair”; 20% were categorized as “Marginal” (17%) and “Poor” (3%) (**figure 3.2**). This data suggests that water quality in Canada is generally fair or good, but that there are some areas of concern. Furthermore, these categorizations can probably be viewed as an underestimate of how clean Canadian water really is since they are based on an inconsistent parameter set across stations. A station in a relatively clean river is likely to have fewer parameters sampled than a station in a relatively polluted river. Even a station in a relatively polluted river may not test for all parameters since testing will focus on those that are of interest based on local human activities, thus ignoring the parameters local water quality does well on.

3. Background information on the Water Quality Index is provided in Appendix A.

**Figure 3.2: Water Quality Index, Canada, 2007–2009**

Note: This figure displays the percentage of surface water monitoring stations (173 in total) in each category based on Environment Canada's Water Quality Index calculations.

Source: Environment Canada, 2012.

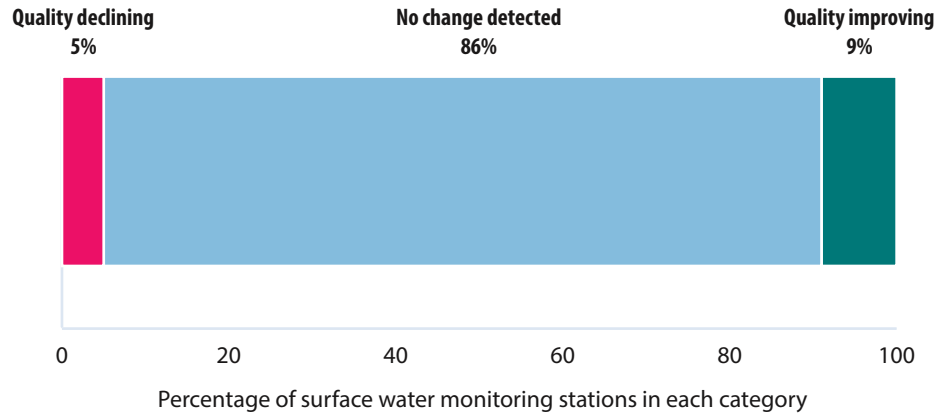
### Is Canadian water quality getting worse?

To answer this question, Environment Canada (2012) also looks at index values at individual stations over time. Looking at a consistent set of parameters at the same station over time avoids the problems discussed above. Unfortunately Environment Canada's time-series analysis is quite limited as it only starts in 2003. Between 2003 and 2009, out of a set of 80 stations, 9% of stations showed an improvement in their Water Quality Index value, and 5% (4 stations) showed deterioration. The other 86% of the stations displayed no statistically significant change over the period (**figure 3.3**). While information is limited, it appears that water quality is generally not getting worse across Canada.

### How does Canadian water quality compare internationally?

Water quality in Canada compares favourably to that of other nations although it is difficult to make comparisons across countries. The water-quality component of the Environmental Performance Index (YCELP, 2010) focuses on five key parameters that provide an overall indicator: dissolved oxygen, pH, conductivity, total nitrogen, and total phosphorus. As displayed in **figure 3.4**, Canada is among the top 20 countries (9<sup>th</sup> overall) according to the Environmental Performance Index water-quality component.

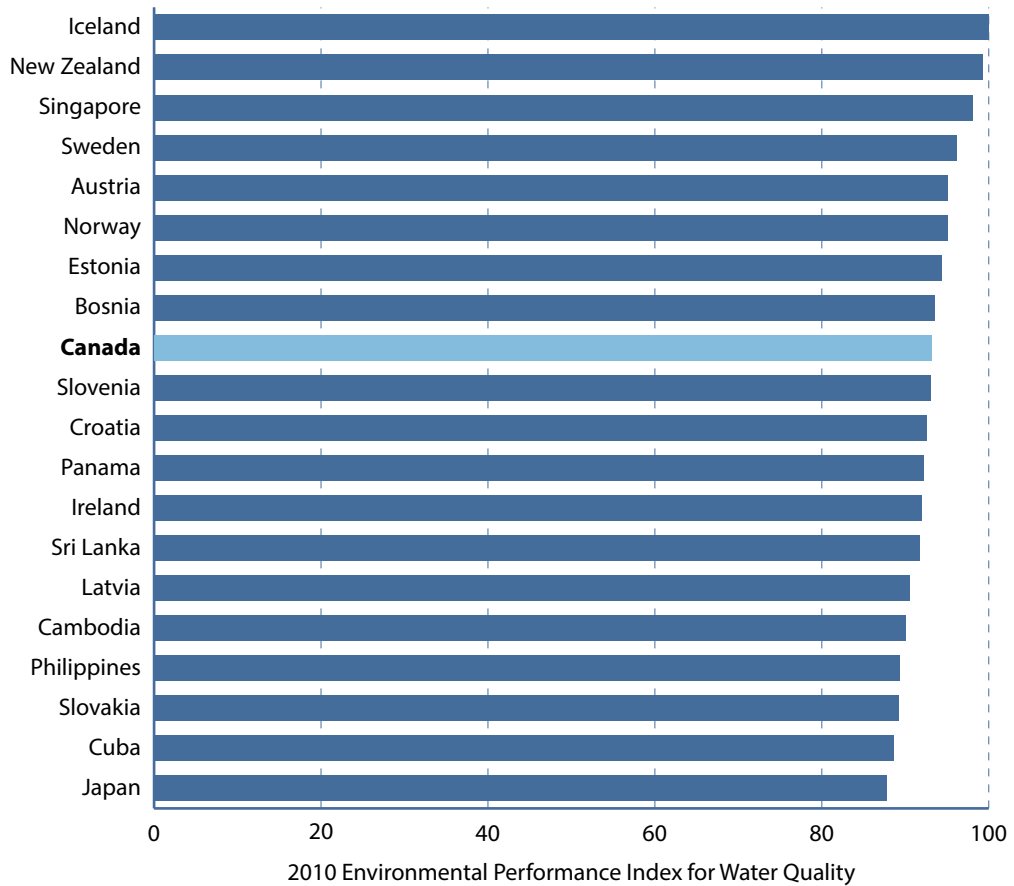
**Figure 3.3: Changes in Water Quality Index, Canada, 2003–2009**



Note: This figure displays the percentage of surface water monitoring stations (80 stations in total) that did and did not exhibit statistically significant trends in Water Quality Index values from 2003 to 2009.

Source: Environment Canada, 2012.

**Figure 3.4: The 20 countries with the highest ratings on the Water Quality Index**



Note: Ratings are based on five water-quality parameters: dissolved oxygen, pH, conductivity, total nitrogen, and total phosphorus. The index, calculated by the Yale Centre for Environmental Law and Policy, uses the latest data available for each country.

Source: Yale Centre for Environmental Law and Policy, 2010.

## **What can be concluded about Canada’s overall water quality?**

Water quality in Canadian lakes and streams is for the most part “Fair”, “Good”, or “Excellent”, though there are some problem areas. Although the time series available from monitoring stations across the country is short, water quality in Canada generally has not changed for the better or the worse in the past decade, and compares favourably to that in other countries.

The data available at the national level involves different parameters at different stations, making comparisons difficult. Water quality is not likely to change much in short periods of time so section 5 examines the provinces individually to assess trends over the longer term and to identify regionally specific problems.



## 4 Are nutrients a problem in Canadian water bodies?

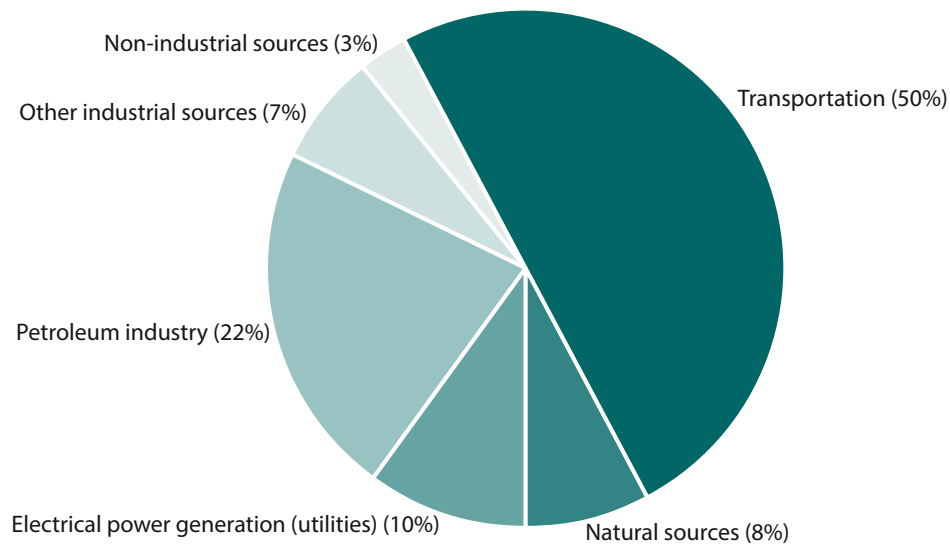
Nutrients, such as phosphorous and nitrogen, are crucial for growth of aquatic plants and the health of aquatic ecosystems but, at high levels, can cause noxious algal blooms<sup>4</sup> and other problems such as increased density of rooted aquatic plants. Nitrogen and phosphorus are naturally occurring, but concentrations in aquatic environments can be affected by human actions. Algal blooms may produce toxins that can affect the liver, the nervous system, or the skin and thereby have a negative affect upon fisheries, tourism, and recreation and blooms of cyanobacteria (also called blue-green algae) can present health risks to the liver and brains of anyone attempting to use the affected water. Similar problems in the 1970s motivated Canadian regulations limiting phosphate in laundry detergents and discharge from sewage treatment plants.

The data in figure 3.1 only includes water releases from large industrial and municipal facilities; however, nutrients also enter the water system from the agricultural sector. Excessive use of fertilizers by, for example, applying more than crops require, leads to nutrients leaching into surface water. It is unclear how great a source of increased nutrients this is, compared with industrial sources; however, evidence suggests that it is a significant source in many areas (Environment Canada, 2011b).

Nitrogen levels in rivers and lakes are also affected by atmospheric deposition. This refers to nitrogen in the air being deposited into the water system. Nitrogen oxides (NO<sub>x</sub>) are produced when burning fossil fuels, so emissions from motor vehicles and power plants can affect nitrogen levels in aquatic environments. The human sources of nitrogen dioxide (the largest component of NO<sub>x</sub>) are shown in **figure 4.1**. Natural sources, such as forest fires and biological processes, were responsible for around 8% of Canada's total NO<sub>x</sub> emissions (Environment Canada, 2010).

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4. "Harmful algal blooms (HABs) result from the proliferation of algae in environmentally stressed systems, where conditions favour opportunistic growth of one or few noxious species which displace more benign ones ... developing dense surface scums or suspensions in the water or mats on plants, stones or the bottom" (Environment Canada, 2011a).

**Figure 4.1: Nitrogen oxide emissions in Canada, by source, 2008**

Note: Emissions of nitrogen oxides (NO<sub>x</sub>) expressed as nitrogen dioxide (NO<sub>2</sub>).

Sources: Environment Canada, 2010a; calculations by author.

Regulations at the federal and provincial levels target a multitude of sources of nitrogen and phosphorus emissions. Concentrations of phosphorus in laundry detergents and household cleaning products have been regulated at the federal level since the 1970s. The *Phosphorus Concentration Regulations* have been continually amended, becoming increasingly stringent since 1989; with the most recent amendments occurring in 2009 (*Regulations Amending the Phosphorus Concentration Regulations*). There are also regulations on effluent released by industrial facilities and sewage treatment plants at both the federal and provincial levels. At the provincial level in most provinces, a large facility must obtain a permit for any effluent release. The federal government has recently implemented the country's first national standards for wastewater treatment, the *Wastewater Systems Effluent Regulations*. There is also legislation at the federal level, such as the *Fisheries Act*, that allows for fines and criminal penalties for the release of a deleterious substance that will affect fish habitat. Air emissions of nitrogen oxides from motor vehicles are regulated at the federal level, and from industrial facilities at the provincial level.

A report by Environment Canada (2011b) examines nutrient levels and trends in Canadian water bodies. The amount of phosphorus in an aquatic environment is affected by natural and human factors, so looking at concentrations over a short period is not very informative about the impact of human activity. For example, many Prairie rivers have high phosphorus levels mainly due to geology, not human pollution. However, the report also looks at phosphorus trends at 75 sites across Canada from 1990 to 2006. They find

that phosphorus levels increased at 21% of sites, decreased at 31% of sites, and experienced no change at 48% of sites (Environment Canada, 2011b). These results suggest that, for the most part, water quality with respect to phosphorus is not getting worse in Canada. Monitoring stations in Ontario, British Columbia, Alberta, and New Brunswick generally show downward trends for phosphorus. Nova Scotian rivers generally have increasing levels of phosphorus. It should be noted that the report only looked at a 16-year period, so claims that nutrient levels are as much of a concern as they were in the 1970s cannot be evaluated.

Environment Canada (2011b) also looks at levels and trends of nitrogen indicators, total nitrogen and nitrate plus nitrite (N+N). The report notes that, unlike phosphorus, nitrogen levels “reflect patterns in atmospheric deposition with added input from regional anthropogenic sources” (Environment Canada, 2011b: v). High levels of nitrogen were recorded at monitoring sites in the lower Great Lakes, Prince Edward Island, and the lower mainland of British Columbia. In regards to trends, nitrogen levels were increasing at 29% of sites, decreasing at 11% of sites, and unchanged at 61% of sites (Environment Canada, 2011b). Some regional patterns are revealed in the analysis: rivers in Nova Scotia and New Brunswick generally have decreasing levels of nitrogen whereas monitoring stations in the Great Lakes, the St. Lawrence River, and rivers in Prince Edward Island have upward trends.

An interesting result from the Environment Canada (2011b) report is that only four out of 75 sites experienced upward trends for both phosphorus and nitrogen. The locations experiencing increasing levels of phosphorus are generally not the same as those experiencing increasing levels of nitrogen.

## 5 A closer look—water quality by province

### 5.1 British Columbia

British Columbia is Canada's third largest province by population, with most people located in the lower mainland, greater Victoria, and the Okanagan valley. British Columbia's history as a resource-based economy has put pressure on water resources; however, levels of many pollutants have decreased over the past few decades due to government regulatory actions.

#### Overall water quality

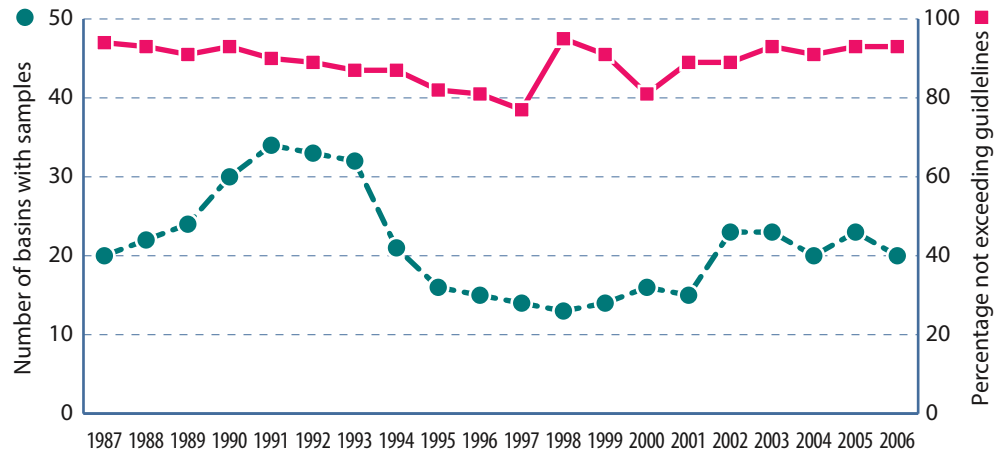
British Columbia generally has good water quality. **Figure 5.1.1** displays the annual percentage of the time that British Columbia's water-quality objectives were met between 1987 and 2006. The graph shows an initial decline, followed by a recovery back to initial levels. However, as the number of basins with samples changed between 1987 and 2006, it is unclear whether water quality has changed over time. A closer look at specific areas of the province is needed.

#### Metals and toxic substances

Sampling of metals and toxic substances is infrequent in Burrard inlet, despite concentrations in sediment of various metals, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs) exceeding guidelines (Sutherland, 2004). Monitoring was conducted between 1992 and 1994 and 2000 and 2002. The results suggest that exceedances are still common for cadmium, copper, lead, mercury, zinc, and PAHs in 2002 but that concentrations had decreased (Sutherland, 2004). However, concentrations of PCBs in sediment have either remained stable or increased since 1994 (Sutherland, 2004). The monitoring data from Coal Harbour highlight the general results for Burrard Inlet (**figure 5.1.2**). Copper, lead, mercury, zinc, and PAHs all decreased between 1993 and 2002. Concentrations of zinc and mercury exceeded guidelines in 1993, but were below guidelines in 2002. However, PCB concentrations increased 300% between 1993 and 2002 at Coal Harbour.



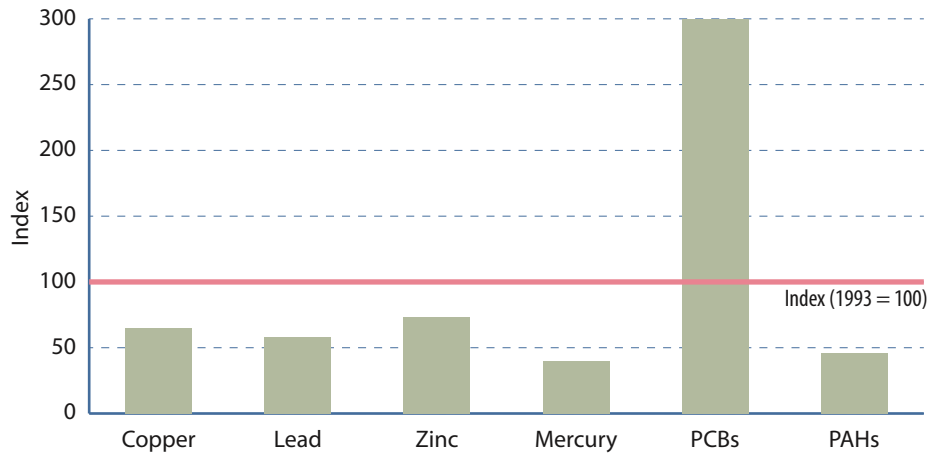
**Figure 5.1.1: Percentage of samples in British Columbia not exceeding guidelines of the Water Quality Index, 1987–2006**



Note: This right axis shows the percentage of water samples that did not exceed water quality guidelines. Care should be taken when trying to infer trends from this chart as the basins included in the annual calculation (left axis) varies from year to year.

Source: Phippen, 2008.

**Figure 5.1.2: Toxic metals in the sediment of Coal Harbour, Burrard Inlet, 2002**



Note: The figure displays concentrations of toxic metals found in sediment samples from Coal Harbour in Burrard inlet, British Columbia. The values are indexed to 1993.

Source: Sutherland, 2004.

More frequent monitoring in Burrard Inlet is needed to identify statistical trends in concentrations in the future.

British Columbia is home to numerous coal mines and more mines are planned due to growing world demand for energy resources. However, coal mines can release selenium into the water system. McDonald and Strosher (1998) find high levels of selenium downstream from coal mines in the Elk

River Basin; the levels of selenium identified were much higher than those found upstream and exceeded the guidelines of the Council of Canadian Ministers of the Environment (CCME) for the protection of aquatic life.

In-stream monitoring between 1979 and 2004 in the Fraser River at Hope shows a downward trend for most metals, but this may be due to improved detection techniques (Swain, 2007a). Metals often exceed water-quality guidelines at this site, but these occur during times of high turbidity and thus are likely not bioavailable (Swain, 2007a). Chloride concentrations decreased significantly since 1979 and 1992 and remained stable thereafter due to changes in the bleaching processes used at pulp and paper mills (Swain, 2007a). Swain (2007b) finds similar results for the Fraser River at Marguerite (downstream of five pulp and paper mills in Quesnel and Prince George).

In the Columbia River at Waneta, which is downstream of Trail, some metals exceed guidelines, but exceedances occur during seasonal high turbidity and thus are likely not bioavailable (Tri-Star Environmental Consulting, 2008). The Columbia River at Waneta exhibits downward trends for fluoride, cadmium, iron, lead, zinc, and barium between 1979 and 2005 (Tri-Star Environmental Consulting, 2008). The water quality is considered good for aquatic life and human consumption (with minor treatment), which is impressive considering it is downstream from a metal smelter, fertilizer plant, and wastewater treatment plant.

In-stream monitoring data from the Okanagan River show statistically significant downward trends for aluminum, chromium, copper, iron, lithium, manganese, potassium, and zinc (Dessouki, 2009).

The Peace River in northeastern British Columbia flows into Alberta. Monitoring between 1984 and 2002 does not show many trends, but does show arsenic, nickel and pH levels that occasionally exceed guidelines; however, the occasional nature of these exceedances suggests they are not a “cause for concern” (BWP Consulting, 2003).

## Nutrients

There were large algal blooms in the Okanagan basin in the 1950s and 1960s that led to many actions like tertiary sewage treatment and changes to irrigation practices designed to reduce phosphorus loadings in the water system (Walker and Sokal, 2009). In-stream monitoring data shows a decrease in total phosphorus concentrations in Lake Osoyoos (the last lake in the basin before<sup>5</sup> water enters the United States) since the 1990s (Walker and Sokol, 2009). Phosphorus also decreased in the Okanagan River upstream from Lake Osoyoos between 1990 and 2007 (Dessouki, 2009). Sediment core samples show that total phosphorus levels in Lake Osoyoos were highest between 1950 and 1990, and that current levels are consistent with pre-settlement

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5. Lake Osoyoos actually straddles the border between Canada and the United States.

levels (Cumming et al., 2009). Phosphorus levels in the Columbia River exhibit downward trends between 1979 and 2005 (Tri-Star Environmental Consulting, 2008).

The Sumas River in the lower mainland recorded concentrations of nitrate plus nitrite (N+N) that exceeded CCME guidelines for the protection of aquatic life (Environment Canada, 2011b). Unfortunately, the data is insufficient for trend analysis of nutrient concentrations in this river. The high nitrogen levels are likely related to the intensive agricultural operations in the area.

### Bacteria

Shell fish harvesting in Burrard Inlet is prohibited due to high levels of fecal coliforms in the shellfish (Sutherland, 2004). The recreational objective (200 coliforms/100 ml) for fecal coliform concentrations was met at all recreational sites in 2002 (Sutherland, 2004). However, Sutherland (2004) finds that five out of 8 monitoring sites in 2002 exceeded the Burrard Inlet specific objective for enterococci bacteria (a better indicator of effects on human health in marine waters).

The Okanagan River, downstream from Lakes Okanagan and Skaha and upstream from Lake Osoyoos, exhibited a statistically significant upward trend in fecal coliforms between 1990 and 2007 (Dessouki, 2009). This trend is problematic since the lakes upstream and downstream of the Okanagan River are major recreation centres in British Columbia. However, the concentrations recorded are below guidelines for recreational uses (though, above those for drinking water) (Dessouki, 2009).

BWP Consulting (2003) reports that fecal coliform levels in the Peace River near the Alberta border are occasionally high and above the guideline for partially treated drinking water.

### Conclusions

British Columbia has made significant progress in improving water quality. Chloride concentrations in the Fraser River have decreased since the 1970s and 1980s. Phosphorus levels in the Okanagan basin are back to pre-industrial levels. Metals often exceed guidelines, but these exceedances generally occur during seasonal spikes in turbidity, and thus are likely not bioavailable. However, there is a need for additional and more frequent monitoring in the waters surrounding Metro Vancouver, the largest population centre, like that provided by the buoy installed in the Fraser estuary in 2003 by the BC government in partnership with the federal government to collect in-stream monitoring data. The buoy is located downstream of much of the agriculture in the Fraser Valley and the Annacis Island sewage-treatment plant and it is hoped that the data collected will shed light on trends in this portion of the Fraser River.

## 5.2 Alberta

Alberta is Canada's fourth largest province by population, but has the fastest growing population. It is also home to the bulk of Canada's oil extraction industry, including the oil sands. Major cities, Edmonton, Calgary, Lethbridge, and Fort McMurray are all located on major rivers. Despite the increasing population and booming economy, water quality in Alberta is generally very good, and improving in many areas. However, continued and improved monitoring is needed for the Athabasca River.

### General overview of water quality

Alberta has an extensive water-monitoring network that, for many locations, dates back to the 1960s. Environment Canada's (2013a) Water Quality Index calculations based on several water-quality parameters (2,4-D, aluminum, ammonia, arsenic, cadmium, copper, lead, MCPA,<sup>6</sup> mercury, nitrogen, oxygen, phosphorus, silver, and zinc) suggest that almost half of water-quality monitoring sites exhibited "Good" or "Excellent" water quality from 2007 to 2009. **Figure 5.2.1** displays the percentage of monitoring sites in Alberta that fall into each water-quality classification.

The Alberta River Water Quality Index focuses on levels of metals, nutrients, bacteria, and pesticides found in major rivers. The Alberta index considers a larger set of water-quality parameters than that of the Environment Canada (2013a) index shown in **figure 5.2.1**. The parameters are compared to Alberta and federal water quality guidelines. The values between 1996 and 2009 of the Alberta River Water Quality Index for major Alberta rivers are displayed in **figure 5.2.2**. To account for human impacts, the values displayed are for downstream monitoring locations.

Water quality is currently rated between "Good" and "Excellent" in these rivers, and appears to be stable in some rivers and improving in others. However, the time series for the index is only available from 1996 and some water-quality concerns in Alberta are not considered in the index. A closer look is needed to get a full picture of water quality in Alberta.

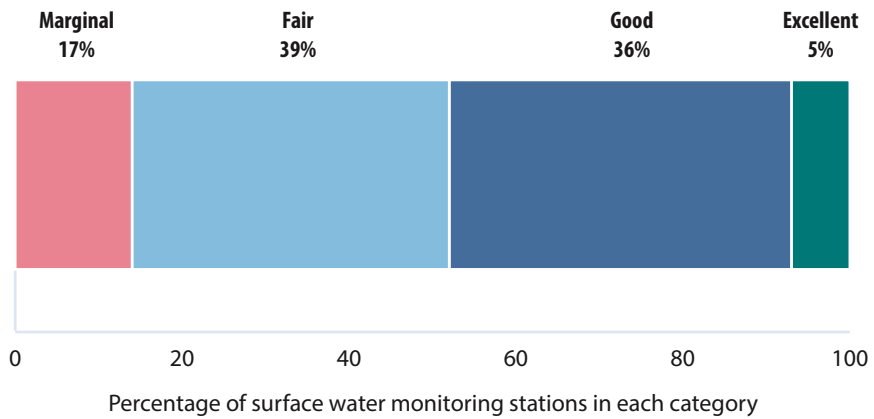
### Metals and toxic substances

Hebben (2009) examines long-term, in-stream monitoring data from the Athabasca River for trends in various water quality parameters, including metals. Focusing on the Old Fort monitoring station, which is downstream from most of the industrial and human activities (e.g., pulp and paper mills, the Fort McMurray wastewater treatment plant, oil sands operations and processing), he finds statistically significant upward trends in aluminum and arsenic. He suggests they could be due to a concurrent increase in human activities or decrease

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6. MCPA is short for 2-methyl-4-chlorophenoxyacetic acid. It is a widely used herbicide.

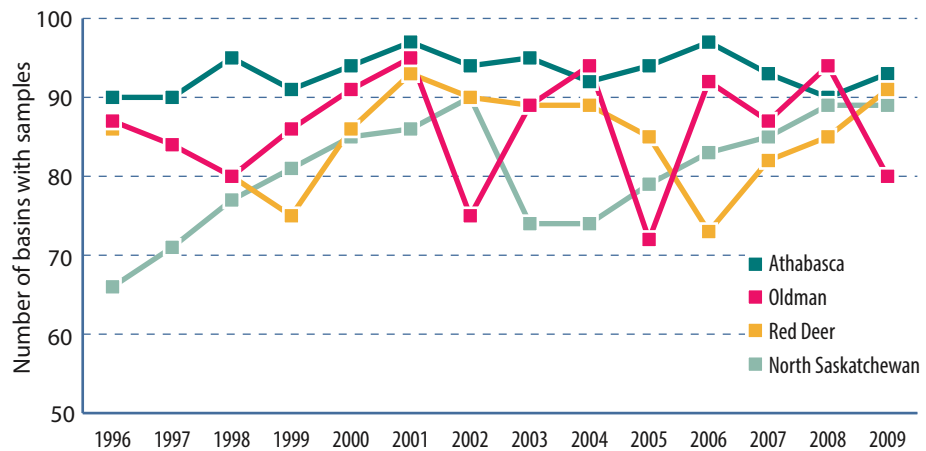
**Figure 5.2.1: Classification of water quality in Alberta’s rivers, 2007–2009**



Note: The figure displays the percentage of monitoring stations (29 stations total) in Alberta falling within each category based on the parameters: 2,4-D, aluminum, ammonia, arsenic, cadmium, copper, lead, MCPA, mercury, nitrogen, oxygen, phosphorus, silver, zinc. Monitoring stations without the data for the full parameter set were excluded.

Source: Environment Canada, 2013.

**Figure 5.2.2: Values for major rivers on Alberta Water Quality Index, 1996–2009**



Note: The figure displays annual values for the Alberta Water Quality Index (AWQI) in the following rivers: Oldman River, downstream of Lethbridge; Red Deer River, downstream of Red Deer; North Saskatchewan River, downstream of Edmonton; Athabasca River at Old Fort, downstream of Fort McMurray.

Source: Alberta Ministry of Environment and Sustainable Resource Development, 2011.

in stream flow. However, as Hebben points out, the arsenic levels measured do not exceed the CCME guideline for drinking water (10 µg/L) or the Alberta Surface Water Quality Guideline for the Protection of Aquatic Life (5 µg/L).

Hebben (2009) does not test for trends in polycyclic aromatic hydrocarbons (PAHs) since concentrations were not detected in most samples and, when detected, were low. However, Kelly et al., (2009, 2010) apply newer detection techniques to a limited number of recently collected samples and

find higher concentrations of metals and polycyclic aromatic compounds (PACs)<sup>7</sup> near oil sands operations compared to other sites in the Athabasca River system. This difference leads Dillon et al. (2011) to call for a better, more comprehensive program to monitor the Athabasca River system for the effects of oil sands operations on water quality.

Hebben (2007) examines long-term, in-stream monitoring data from the Oldman River for trends in metals and other toxic substances. Downstream of Lethbridge, the only metals that exhibit significant trends are dissolved arsenic, boron, and selenium, all of which show downward trends between 1987 and 2005. The North Saskatchewan River also displays decreasing metals (dissolved aluminum and arsenic) downstream of Edmonton between 1987 and 2002 (Hebben, 2005).

### Nutrients

For the Athabasca River downstream of Fort McMurray, Hebben (2009) finds that levels of total phosphorus are following an upward trend between 1977 and 2008 and that two nitrogen parameters are following an upward trend between 1987 and 2008. He hypothesizes that this could be due to human factors or to concurrently decreasing stream flow (Hebben, 2009).

In the Oldman River downstream of Lethbridge, Hebben (2007) finds that levels of nitrate plus nitrite follow a downward trend between 1966 and 2005. Hebben (2007) also finds that levels of total ammonia-nitrogen and total phosphorus follow downward trends after 1987.

The North Saskatchewan River downstream from Edmonton exhibits reduced nitrogen (N+N and total nitrogen) and phosphorus (total and dissolved) between 1987 and 2002 (Hebben, 2005).

Casey (2011) examines monitoring data for 39 Alberta lakes with sufficient data for trend analysis (10–30 years) for trends in nutrients (total phosphorus) and trophic status (chlorophyll-a, transparency). He finds that total phosphorus increased in 11 (26%) of the lakes, but chlorophyll-a (a proxy measure of the amount of algae in a water body) only increased in three of the lakes (Casey, 2011). He notes that this result is surprising since phosphorus and chlorophyll-a generally follow a close relationship and notes that the cause of the increased phosphorus is not currently known (Casey, 2011).

### Bacteria

For the Athabasca River downstream of Fort McMurray, Hebben (2009) finds that levels of total coliform bacteria show a downward trend between 1987 and 2008. Similarly, for the Oldman River downstream of Lethbridge, fecal coliform bacteria levels display a downward trend between 1966 and 2005

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7. PACs are the sum of parent and alkylated homologues of two-, three- and four-ring polycyclic aromatic hydrocarbons + dibenzothiophene (Kelly et al., 2009).

(Hebben, 2007). Levels of *E. coli*<sup>8</sup> downstream of Lethbridge have also been trending downwards between 1987 and 2005 (Hebben, 2007). These decreases in bacteria in the Oldman River are “likely linked to major improvements to the Lethbridge wastewater treatment plant” (Hebben, 2007: 10). The North Saskatchewan River downstream of Edmonton also experienced decreasing levels of fecal and total coliforms between 1987 and 2002 (Hebben, 2005).

Zurawell (2010) looks at sampling data from 2005 onward for the presence of cyanotoxins in Alberta lakes. Cyanobacteria, also called blue-green algae, can produce cyanotoxins that affect the liver and brain of humans. These bacteria are naturally occurring in Alberta, but can increase when nutrients from human sources rise. Zurawell (2010) finds that microcystins, which affect the liver, are found in most of the Alberta lakes sampled and that average levels often exceed draft water-quality guidelines. He also finds that the neurotoxin anatoxin-a is not frequently detected and only found in low levels when detected (Zurawell, 2010). Unfortunately, monitoring only began in 2005, so the time-series data is insufficient for trend analysis.

### Conclusions

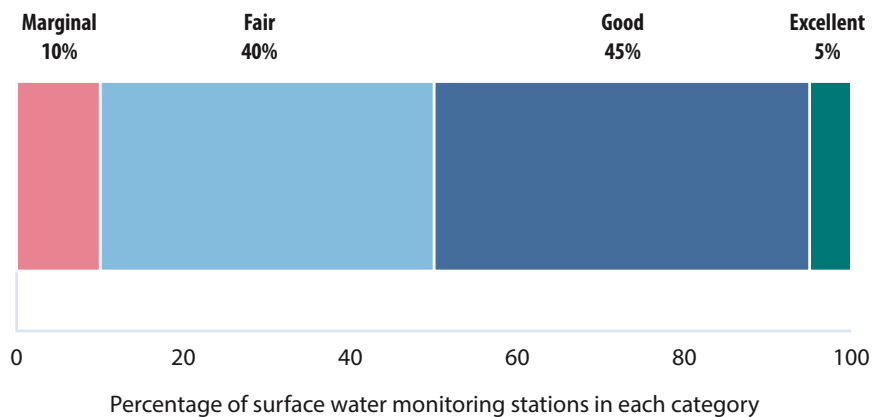
Water quality in Alberta’s major rivers is very good, and was relatively stable between 1996 and 2009. There have been major achievements in reducing nutrient loads and bacteria downstream of major population centers; these improvements are even more impressive considering the rapid population growth of the province. Continued and improved monitoring of the Athabasca River is needed because of increasing pressure from industrial development (oil sands operations and processing) and an expanding population.

## 5.3 Saskatchewan

The Water Quality Index calculated by Environment Canada (2013a) suggests that half of the monitoring sites in Saskatchewan with sufficient data are classified as “Good” (45%) or “Excellent” (5%). **Figure 5.3.1** displays the percentage of monitoring stations in Saskatchewan rivers for each classification. These classifications are for stations with data between 2007 and 2009 for the following parameters: 2,4-D, ammonia, arsenic, chloride, copper, lead, MCPA, nickel, nitrogen, oxygen, pH, phosphorus, and zinc. Only two out of 20 stations were classified as having “Marginal” water quality, and no stations had “Poor” water quality. The monitoring stations operated by the Prairie Provinces Water Board are not included, since the Water Quality Index at these stations was based on a smaller parameter set than that used by the other 20 Saskatchewan stations.

8. *Escherichia coli*, usually called *E. coli*.



**Figure 5.3.1: Classification of water quality in Saskatchewan's rivers, 2007–2009**

Note: The classifications are based on WQI calculations using the following parameters: 2,4-D, ammonia, arsenic, chloride, copper, lead, MCPA, nickel, nitrogen, oxygen, pH, phosphorus, zinc. Stations without a full parameter set were excluded.

Source: Environment Canada, 2013.

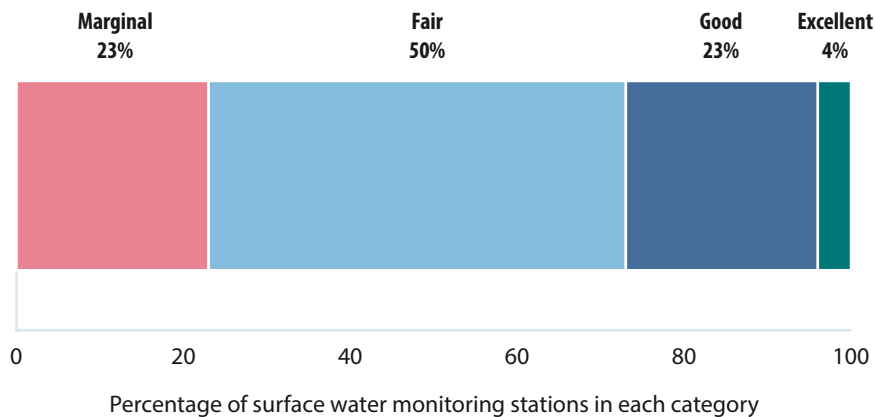
Despite having a long monitoring record for some of its rivers, trend analysis of water quality in Saskatchewan either has not been conducted or is not readily available publicly. This is unfortunate considering the rapid development currently occurring in the province. The one parameter for which trends have been analyzed is nutrients.

### Nutrients

Saskatchewan rivers generally have high levels of nutrients due to the geology of the region. However, human influences, such as municipal wastewater and agriculture, can increase these levels further. Long-term trends in nutrients in Saskatchewan rivers are mixed. Concentrations of total phosphorus, total dissolved phosphorus, total nitrogen, and N+N followed downward trends in the North Saskatchewan River near the border with Alberta between 1990 and 2006 (Environment Canada, 2011b). However, the Carrot River experienced increasing levels of total phosphorus, total dissolved phosphorus, and total nitrogen. The Red River showed upward trends in the phosphorus, but not the nitrogen, indicators. No trends were detected for the Assiniboine and Qu'appelle rivers (Environment Canada, 2011b).

## 5.4 Manitoba

Manitoba's water quality ranges between marginal and excellent based on the Water Quality Index calculated by Environment Canada (2013a). **Figure 5.4.1** displays the percentage of stations that fall into each water-quality classification for the period from 2007-2009. Out of 21 monitoring stations, almost

**Figure 5.4.1: Classification of water quality in Manitoba’s rivers, 2007–2009**

Note: The classifications are based on WQI calculations using the following parameters: 2,4-D, ammonia, arsenic, chloride, copper, lead, MCPA, nickel, nitrogen, oxygen, pH, phosphorus, zinc.

Source: Environment Canada, 2013.

half (47%) have water quality classified as “Fair” and almost a quarter of the stations are classified as “Marginal”. Despite this mediocre water-quality record and an existing database of long-term monitoring data, very little trend analysis has been undertaken or is publicly available.

### Mercury

The building of dams in northern Manitoba on the Churchill River to generate electricity had the unintended effect of increasing exposure to mercury for fish in the created reservoirs because of its presence in natural deposits (Bodaly et al., 2007). However, over time the level of mercury in fish in the reservoirs has declined (Bodaly et al., 2007).

### Nutrients

Jones and Armstrong (2001) examine in-stream monitoring data from 46 locations in Manitoban streams. They find upward trends for total nitrogen at 19 stations and for total phosphorus at 18. Eleven of those stations exhibited concurrent trends in both parameters. Downward trends were identified for total nitrogen and total phosphorus at four and seven stations, respectively, of which only two were concurrent (Jones and Armstrong, 2001).

More recent analysis by Environment Canada (2011b) on data between 1990 and 2006 finds no trends in phosphorus and nitrogen variables in the Saskatchewan River once it enters Manitoba. Environment Canada finds a statistically significant upward trend in N+N in the Red River, but no trends in total nitrogen, total phosphorus, and total dissolved phosphorus. The Pembina River, a tributary to the Red River, exhibits a downward trend in total nitrogen, but no trends in the other nutrient parameters (Environment Canada, 2011b).

## 5.5 Ontario

Ontario is Canada's most populous province, with most people living in the Windsor-to Ottawa corridor. Southern Ontario is not only densely populated; it is also home to intensive agricultural and industrial activity.

Ontario has made great strides in improving water quality since the 1970s through enacting various bans and regulatory actions. Despite this success, there are new concerns, such as low phosphorous levels, new toxic substances, and increasing algae problems. This sub-section will document some of the improvements and on-going concerns for water quality in Ontario.

### Overall water quality

Ontario's water quality ranges between poor and excellent based on the Water Quality Index (WQI) calculated by Environment Canada (2013a). **Figure 5.5.1** displays the percentage of stations that fall into each water-quality classification for the period from 2007 to 2009. Out of 24 monitoring stations, the largest portion has water quality classified as "Good" (33%) or "Fair" (33%). Four (17%) stations have water quality classified as "Marginal", and three have water quality classified as "Excellent". The Don is the only river monitored that is classified as having "Poor" water quality.

However, the Environment Canada (2013a) WQI for Ontario is not a very comprehensive indicator of the quality of Ontario's surface water. It is based on only 24 monitoring stations and a relatively small set of water quality parameters (ammonia, chloride, chromium, nickel, nitrogen, phosphorus, and zinc). It also is based on only three years of data, so it does not indicate whether Ontario's water quality has improved or not. Below is a closer look at long-term trends in the parameters considered and other parameters of concern.

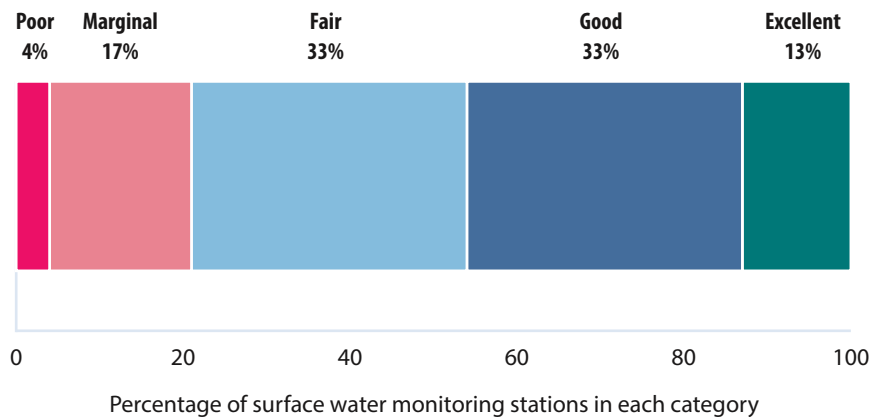
### Metals and toxic substances

Persistent, bioaccumulative, and toxic substances (PBTs) are stable chemicals that last a long time in the environment and accumulate over time in fish, animals and, humans. Some PBTs, such as pesticides, polychlorinated biphenyls (PCBs), and polybrominated diphenyl ether (PBDE), are human-made; whereas others, such as mercury and fluoride, occur naturally in the environment.<sup>9</sup> These substances are generally used because they provide some benefit; however, many can have effects on human health, such as increased risk of cancer.

Dove (2011) looks at PBT concentrations in offshore waters in the Great Lakes and finds mixed results. For example, mercury concentrations

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9. Despite its being a naturally occurring PBT substance, mercury levels in many water bodies are above natural levels due to human activities, such as the atmospheric deposition of emissions from coal-fired electricity generation.

**Figure 5.5.1: Classification of water quality in Ontario's rivers, 2007–2009**

Note: The figure displays the percentage of monitoring stations (24 stations total) in Ontario falling within each category based on the parameters: ammonia, chloride, chromium, nickel, nitrogen, phosphorus, zinc. The Don River is classified as "Poor".

Source: Environment Canada, 2013.

have declined significantly between 1986 and 2005. For example, at Niagara on the Lake, mercury concentrations declined 30% in the 20-year period. Dove also shows that concentrations of lindane, frequently used to treat head lice and previously used as an agricultural insecticide, have declined in all the Great Lakes between 1992 and 2010. On the other hand, concentrations of atrazine, a currently used pesticide, are trending upwards in all of the Great Lakes. She does note that current atrazine concentrations are well below the Canadian federal guideline of 1800 ng/L (Dove, 2011).

There has been a marked decline in the percentage of water samples with detected pesticides in surface water in Ontario: in 1986, pesticides were detected in 86% of drinking water samples; the number had dropped to 3% by 2006 (OME, 2011). A concurrent decline in occurrence in untreated surface water indicates that this decrease is not attributable to water treatment processes. Furthermore, only four samples out of over 16,000 collected from 1986 to 2006, and none since 2001, exhibited levels of pesticides that exceed the Ontario Drinking Water Quality Standards (OME, 2011). The large decrease prior to 2006 preceded Ontario's ban on the use of pesticides for cosmetic uses (e.g., lawn care, public sport fields) that took effect in 2009. Clearly, pesticides are no longer a serious issue for drinking water sources in Ontario.

It is certainly good news that concentrations of many PBTs in Ontario's water bodies are declining; however, PBTs accumulate in the ecosystem, so they may affect the environment long after they are prevalent in open water. Sediment core samples can be used to assess trends in PBTs over time. According to the Ontario Ministry of the Environment (OME, 2009), sediment cores suggest that PCB levels have declined substantially

since the 1980s, but still remain in the environment. At the same time, sediment cores suggest that concentrations of PBDEs have increased since the 1980s (OME, 2009).

Weseloh and Moore survey data from herring gull eggs and conclude that, between 1974 and 2009 in the Great Lakes areas, “virtually all significant contaminants are declining” (2011: 1). **Figure 5.5.2** contrasts the data from herring gull eggs in 1974 with 2009 for Lake Ontario. The greatest improvement is for levels of DDE, which decreased by over 94% in herring gull eggs.

The Ontario Ministry of the Environment looked at PCB and mercury found in Lake Trout in the Canadian Great Lakes and concluded that they have generally been declining since a peak in the 1980s (OME, 2009). OME (2011) reports that sport fish from the Canadian Great Lakes exhibit declining and stable levels of PCBs, mercury, dioxins, and furans. They also show evidence that sport fish in Lake Simcoe exhibit a general decline in PBTs (OME, 2011). However, a more detailed analysis by McGoldrick et al. (2011) shows that, while PCBs and PBDEs in sport fish<sup>10</sup> from the Canadian Great Lakes have declined substantially, the levels still exceed guidelines. They also conduct a more detailed trend analysis for mercury levels and find evidence that mercury in sport fish has decreased from the 1970s but has again been increasing since the mid-1990s, though they note that these mercury levels no longer exceed guidelines (McGoldrick et al., 2011).

### Acid rain

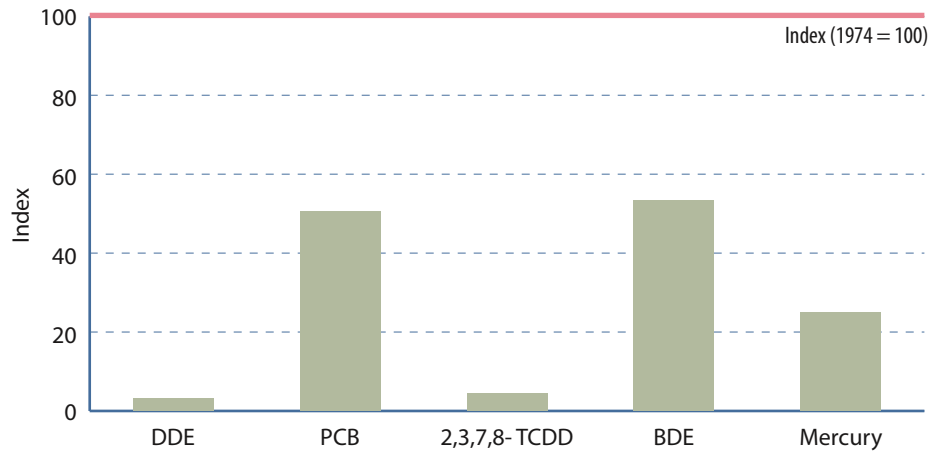
Burning fossil fuels can release sulfur dioxide and nitrogen oxides into the atmosphere. A fraction of these oxides are then converted through natural chemical processes into acids that return to the earth through precipitation (i.e., acid rain). Deposition of these acids can affect the acidity (measured as pH) of water in some geological environments and increased acidity can negatively affect the reproduction of fish, insects, plants, and bacteria. **Figure 5.5.3** displays the sources of sulfur dioxide released into the air in Canada for 2008. The majority of sulfur-dioxide emissions came from the smelting and refining sector and from coal-fired electricity generation; the largest source of nitrogen oxides in Canada was the transportation sector (Environment Canada, 2010). **Figure 4.1 (p. 16)** displays the sources of nitrogen oxides released in Canada for 2008.

Southern Ontario has large quantities of limestone in the soil, which counteracts the effects of acid rain. The Canadian Shield (in northern Ontario), however, does not have this advantage and many of its lakes have been seriously affected by acid rain in the past (OME, 2009). The emissions that caused this acidification can travel long distances and came from sources both in Canada and in the United States. However, the situation is

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10. Lake Trout and Walleye, specifically.

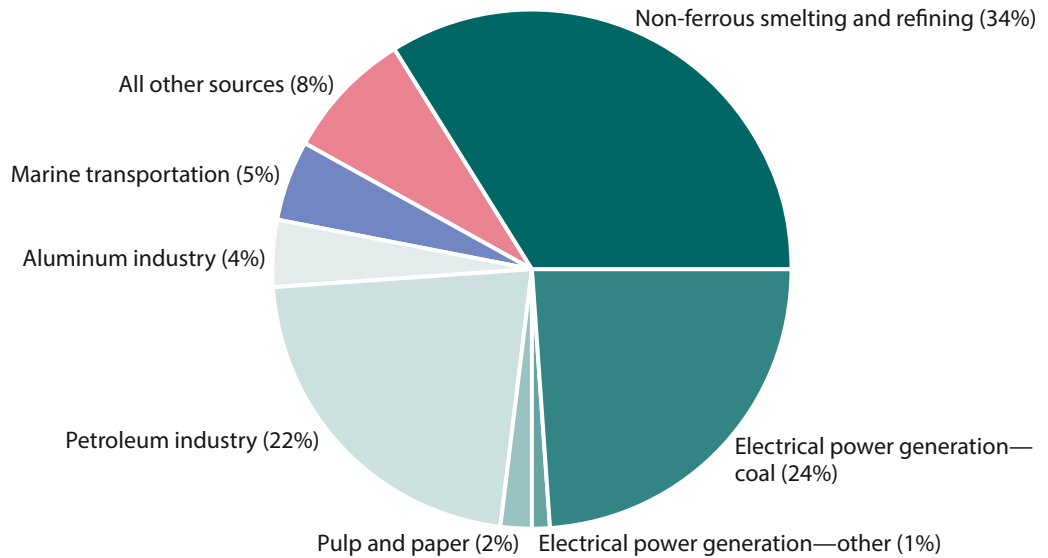
**Figure 5.5.2: Toxic substances in herring gull eggs from Lake Ontario, 2009**



Note: DDE—dichlorodiphenyldichloroethylene; PCB—polychlorinated biphenyl; TCDD—tetrachlorodibenzodioxin; BDE—brominated diphenyl ether.

Source: Weseloh and Moore, 2011.

**Figure 5.5.3: Sulfur dioxide emissions in Canada, by source, 2008**



Sources: Environment Canada, 2010a; calculations by author.

improving: 75% of Ontario’s lakes affected by acid rain are now recovering (OME, 2009). This is not surprising considering the tremendous regulatory effort to reduce sulfur-dioxide emissions in Ontario, Canada, and the United States over the past 40 years. Concentrations of sulfur dioxide and nitrogen oxides in Ontario air have decreased substantially since the 1970s (Wood, 2012). These reductions have allowed the affected lakes to begin the natural recovery process.

## Nutrients

The quality of Ontario's water is mixed with respect to nutrient levels and trends. Although progress has been made on some parameters, such as total phosphorus, other parameters are getting worse.

Since the 1970s, phosphorous concentrations have decreased in many inland lakes, rivers, and streams in Ontario (OME, 2009). Lake Simcoe is a good example of this improvement in nutrient levels. Phosphorus releases from water-treatment plants around the lake have been reduced over the past 30 years, and this reduction in phosphorus has led to decreased total abundance of phytoplankton and increased deepwater dissolved oxygen concentrations in the lake (OME, 2011). However, the deepwater oxygen concentrations generally remain below the target of 7 mg/L. The trend is moving in the right direction and the target was achieved for the first time in 2005.

There have also been decreasing phosphorus levels in most of the Canadian Great Lakes. Total phosphorus levels have declined significantly between 1970 and 2009 in Lakes Huron and Ontario (Dove and Warren, 2011). However, Dove and Warren warn that levels may have decreased too much, and recent values may be “insufficient to support a healthy off-shore biological community” (2011: 2). Dove and Warren appear puzzled by the recent low concentrations and the fact that near-shore algal biomass is not below nuisance levels in many areas of the lakes. Environment Canada (2011b) speculates that the answer may lie with invasive Zebra mussels that filter total phosphorus and make it more readily available for organisms to consume. Environment Canada finds that, although concentrations of total phosphorus are decreasing in the Great Lakes, bioavailable phosphorus (total dissolved phosphorus) is increasing. So, despite increasingly strict regulations on phosphorus releases and resulting declines in total phosphorus concentrations, algae problems are not declining.

The water-quality reports published by the Ontario government do not look at nitrogen levels in Ontario waters; however, Environment Canada finds that they are increasing. Concentrations of Nitrate + Nitrite (N+N) are increasing in all of the Great Lakes (Environment Canada, 2011b).

## Other concerns

The Ontario Ministry of the Environment examined average concentrations of chloride in Ontario streams and found they have increased from under 30 mg/L in 1975 to over 50 mg/L in 2009 (OME, 2011). This is likely due to use of road salt in the winter months to de-ice roadways. There is no Ontario or CCME guideline for chloride. OME (2011) proposes use of the British Columbia guideline (150 mg/L) in absence of an Ontario guideline. The upward trend suggests on-going monitoring is needed but that current chloride levels are not a pressing water quality concern in Ontario.



Ontario has also been actively investigating pharmaceuticals in the water system. Many people dispose of excess medications improperly by throwing them in the garbage or flushing them down the toilet. The concern is that they then enter the water system, eventually ending up in drinking water. OME (2011) examines Ontario drinking water for the presence of a multitude of pharmaceuticals. Although some pharmaceuticals are detected in drinking water (a fraction of those tested for), the levels detected are too small to affect humans. The report concludes that for the pharmaceutical with the highest detected level, “an individual would have to drink thousands of glasses of treated drinking water a day” to be negatively affected (OME, 2011: 56). Clearly, pharmaceuticals in Ontario drinking water are not at levels where they pose a concern.

## 5.6 Quebec

Quebec is Canada’s second most-populated province, with much of its population residing around the St. Lawrence River and its tributaries. The province’s major cities, Montreal and Quebec, are both located on the St. Lawrence. Other major Quebec cities are located on rivers, like the Gatineau, that feed into the St. Lawrence. The river is affected by municipal wastewater and industrial effluents. It is also a major shipping route as freighters transit through it from the Great Lakes into the Atlantic Ocean. The St. Lawrence was very polluted in the 1970s but, because of government actions, such as the St. Lawrence Action Plan, the *Programme de reduction des rejets industriels*, and improvements to municipal wastewater treatment, the situation is improving.

### Metals and toxic substances

In-stream sampling for toxic substances has been undertaken in Quebec on the Ottawa, Richelieu, and Yamaska rivers (all of which flow into the St. Lawrence). Richard (2010) examines sampling data from the Carillon monitoring station on the Ottawa River from 1995 to 2005. The results find no significant trends, and median values are well below CCME guidelines for a host of substances. He does note that there was one exceedance of the CCME guideline for nickel, but most traces of metals are on “the same order of magnitude as the levels in the earth’s crust” and much lower than in major European rivers (Richard, 2010: 6).

Laliberte (2009) examines data from the Richelieu (2001–2003) and Yamaska (1997–2003) and finds that concentrations of PCBs, polycyclic aromatic hydrocarbons (PAHs), and dioxins and furans (PCDD/Fs) are much higher than in levels found in other Quebec rivers. He also finds that concentrations

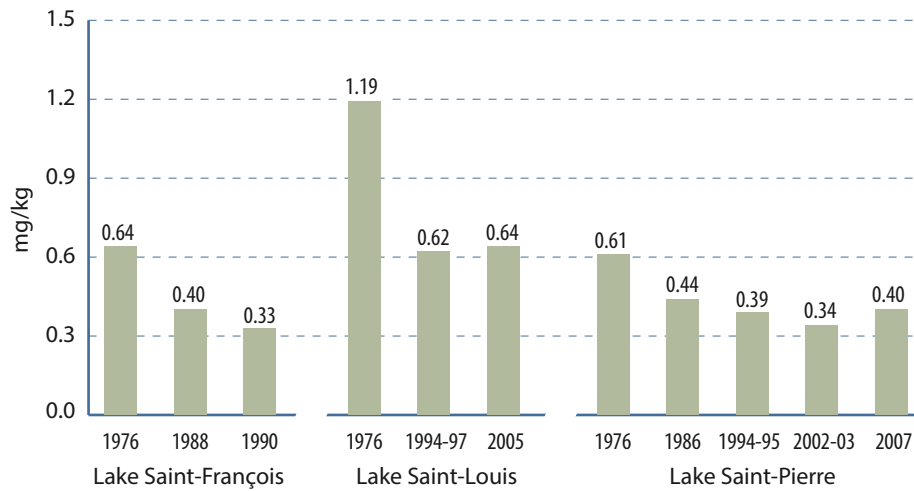
of PCBs and PCDD/Fs were much higher than the Quebec guidelines for the protection of fish-eating terrestrial wildlife. Unfortunately, a longer monitoring series was not available to compute trends in these substances, although there was a 43% drop in average PCB concentrations in the Yamaska River between the 1997–2001 and 2001–2003 monitoring periods (Laliberte, 2009).

The limited data from in-stream monitoring is supplemented by other methods of measuring toxic substances in the river. Painchaud and Laliberte (2010) present data on mercury and PCB concentrations in fish from the three major lakes along the St. Lawrence River: Lake Saint-François, Lake Saint-Louis, and Lake Saint-Pierre. **Figure 5.6.1** displays average mercury concentrations found in walleye tissue samples from 1976 to 2007. Average concentrations of mercury in walleye have decreased in all three lakes since the 1970s. Mercury in northern pike has decreased in Lakes Saint-François and Saint-Pierre since the 1970s, but has remained relatively stable in Lake Saint-Louis. The authors note that, except for northern pike in Lake Saint-Louis, current average levels are below Health Canada's guideline of (0.5 mg/kg), but above the Quebec guideline to protect fish-eating terrestrial wildlife (Painchaud and Laliberte, 2010).

Similar progress has been made in reducing PCBs in the three lakes since 1976. **Figure 5.6.2** displays average PCB concentrations in tissue from white sucker fish. Most notably, PCBs in white sucker fish from Lake Saint-François decreased by over 95% between 1976 and 2004. Recent levels are well below Health Canada guidelines for human consumption, but slightly above the Quebec guideline for fish-eating terrestrial wildlife (Painchaud and Laliberte, 2010). Despite detectable levels of mercury and PCBs, Painchaud and Laliberte point out that studies have shown there are “no dangerous levels of chemical contaminants in people who regularly eat fish caught in the St. Lawrence River” (2010: 1).

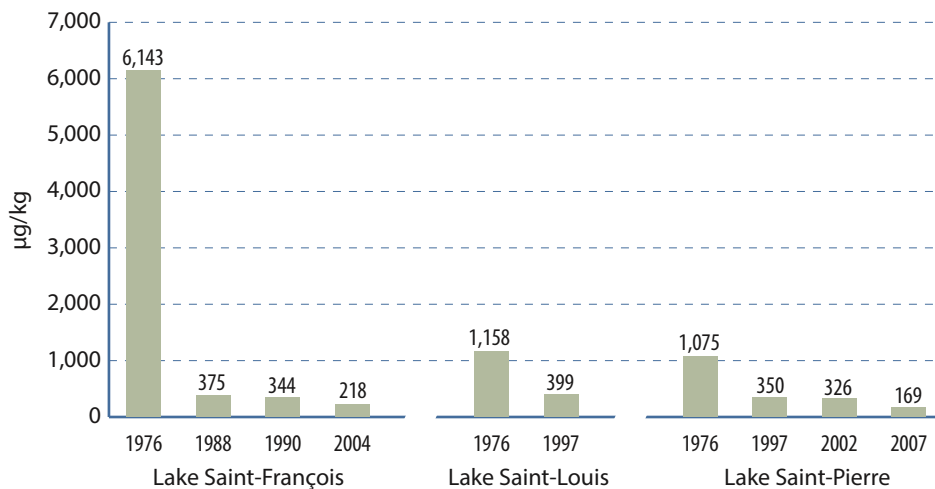
Measures et al. (2009) examine data on toxic substances found in carcasses of beluga whales found in the St. Lawrence estuary (the portion of the river between St.-Jean-Port-Joli and Rimouski). They find that average PCB levels have decreased significantly (by more than half) between 1988 and 2004. However, average levels of polybrominated diphenyl ether (PBDE) have increased exponentially (doubling every 3 to 4 years) between 1988 and 2004 (Measures et al., 2009). These concentrations merely provide an indication that PCB levels in the river system are decreasing and PBDE levels are increasing, and do not provide definitive information about their effects on the health of beluga whales. The authors clearly state that “chemical contamination has not been directly linked to pathological effects in belugas” (Measures et al., 2009: 5).

An additional way to gain a longer picture of water quality is to take sediment core samples and test them for levels of toxic substances. Pelletier (2002, 2005, 2008) examines sediment cores from the three major lakes of

**Figure 5.6.1: Mercury in walleye in Quebec's lakes, 1976–2007**

Note: The figure displays average mercury concentrations in walleye tissue samples in three Quebec lakes. Painchaud and Laliberte (2010) do not indicate why the average is reported for multiple years in some instances (1994-97, 1994-95, 2002-03). It may be that they had only a small number of samples for each of the years individually.

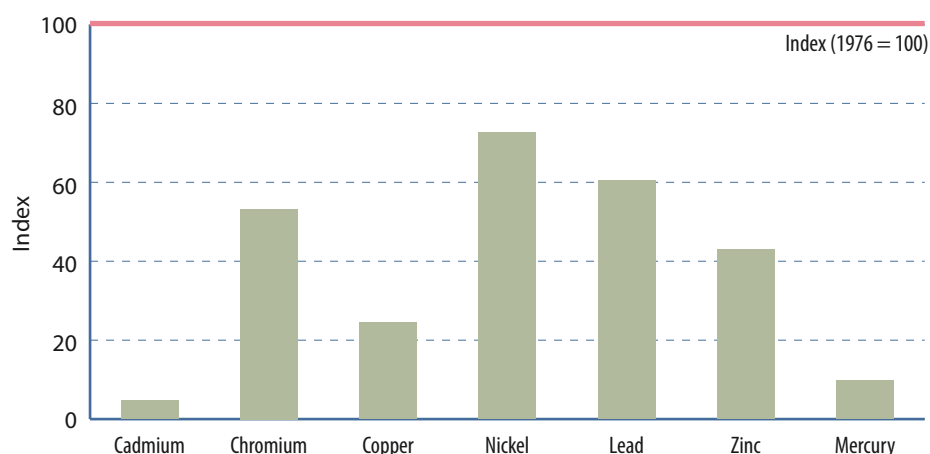
Source: Painchaud and Laliberte, 2010.

**Figure 5.6.2: PCBs in white sucker fish in Quebec's lakes, 1976–2007**

Note: The figure displays average PCB concentrations in whole white sucker fish between 1976 and 2007 for three Quebec lakes.

Source: Painchaud and Laliberte, 2010.

the St. Lawrence River. He finds that, for most substances examined, levels are much lower today than they were in the 1960s, 1970s, and 1980s. For example, mercury in Lake Saint-François peaked in the 1970s and declined by over 50% by 1990, though is still above pre-industrial levels, that is, of the early 1900s (Pelletier, 2002). **Figure 5.6.3** displays concentration for various

**Figure 5.6.3: Toxic substances in Lake Saint-Pierre, 2003**

Note: The figure displays average concentrations of selected toxic substances in sediment from the northern portion of Lake Saint-Pierre. The values are indexed to 1976 values; thus, the 2003 values are displayed as a percentage of the 1976 measurements.

Source: Pelletier, 2005.

metals from sediment in Lake Saint-Pierre for 1976 and 2003. Mercury declined 90% between 1976 and 2003, and the 2003 level is below pre-industrial levels (Pelletier, 2005). The metals listed in figure 5.6.3 all declined between 1976 and 2003, and most are now below or close to pre-industrial levels (Pelletier, 2005). Pelletier (2005) also finds that PCBs declined 61% between 1986 and 2003.

Pelletier (2008) finds downward trends for the metals (except lead and chromium) for Lake Saint-Louis; however, the levels for many of the substances (mercury, cadmium, zinc) are above the “threshold effect levels”. The concentration of lead slightly increased between 1976 and 2003, but the level is below the threshold effect level; and PCBs decreased in Lake Saint-Louis by 85% between 1986 and 2003 (Pelletier, 2008). Unfortunately, the sediment sampling has focused only on historically alarming substances, such as mercury and PCBs, and not on newer and emerging substances like PBDE, PCDD/Fs, and so on.

### Bacteria

Hebert (2006) examines in-stream water-quality data from the St. Lawrence for non-toxic pollutants. With respect to bacteria in particular, Hebert finds that in 2004–2005 bacterial contamination increased as samples were taken downriver. This increase in contamination is due to the fact that wastewater treatment plants in Montreal, Longueuil, and Repentigny do not disinfect their effluent (Hebert, 2006). When examining data between 1995 and 2005 near Quebec City, Hebert (2006) does not find any trend in fecal coliform concentrations.

## Nutrients

Environment Canada (2011b) examines trends in phosphorus and nitrogen at one in-stream monitoring station in the St. Lawrence between 1990 and 2006. Unlike its source water in the Great Lakes, no trends are detected for total phosphorus and total dissolved phosphorus. The concentrations recorded fall in the middle of the phosphorus categories provided by the CCME, but no indication is given about how these levels compare to historical norms. An upward, statistically significant trend for nitrate plus nitrite is found (Environment Canada, 2011b). However, the levels of nitrate plus nitrite are not high in comparison to those recorded at many other stations in the Great Lakes-St. Lawrence drainage area (Environment Canada, 2011b; author's calculations).

## Conclusions

The available information suggests that Quebec's water quality has improved substantially, with regards to toxic substances, since the 1970s. Although this improvement is laudable, newer water-quality problems are being discovered. The upward trends in nitrate plus nitrite and PBDEs suggest that additional monitoring and policies may be needed for further improvements.

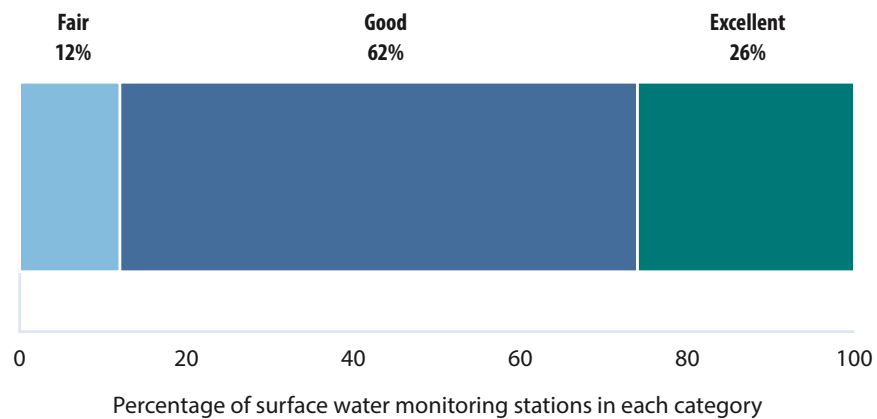
## 5.7 New Brunswick

According to the Water Quality Index calculated by Environment Canada (2013a), New Brunswick has very clean surface water, based on levels of ammonia, arsenic, chloride, copper, iron, nitrogen, oxygen, pH, phosphorus, turbidity, and zinc. **Figure 5.7.1** displays the percentage of monitoring sites that fall into each classification. Sites were overwhelmingly categorized as "Good" (35 of 57 sites) and "Excellent" (15 of 57 sites).

The basin of the Saint John River is one of the largest in eastern North America and includes parts of Maine, Quebec, and New Brunswick. Curry et al. (2011) examine water-quality data sampled from the Saint John River from as far back as the 1950s (for some parameters) up until the present. They look at data for pH, dissolved oxygen, selected metals, and bacteria. Their results suggest that water quality in the Saint John River has improved over time.

### Acidity and oxygen

Looking at pH, Curry et al. (2011) note that samples have mainly been above the lower bound of the CCME guideline range. The lowest values were found upstream (where lower pH is expected) and prior to 1980. No samples since the 1980s were outside of the CCME guideline range. For dissolved oxygen, most samples fell below the lower bound of the CCME guideline range in the 1950s. However, only one sample was below the lower bound since 1980 signalling that dissolved oxygen levels in the Saint John River have improved greatly over time.

**Figure 5.7.1: Classification of water quality in New Brunswick's rivers, 2007–2009**

Note: The classifications are based on WQI calculations using the following parameters: ammonia, arsenic, chloride, copper, iron, nitrogen, oxygen, pH, phosphorus, turbidity, zinc.

Source: Environment Canada, 2013.

### Metals

Curry et al. (2011) look at five selected metals (others were ignored because of limited data and low measurements). Depending on the decade, between 17% and 19% of samples exceeded the CCME guideline for aluminum. However, the authors attribute this to the geology of the area and not to human factors. The reported data indicate that iron exceeded the CCME guideline fewer times between 2000 and 2008 than between 1970 and 1979. The authors also note that the current “iron levels measured are normal for the geology of the region” (2011: 86) The data also indicates that levels of manganese, copper, and zinc are all now lower than in the past and are, for most samples, below guidelines for protection of aquatic life and treated drinking water.

### Nutrients

An Environment Canada (2011b) study that examines trends in nutrient levels between 1990 and 2006 for stations across Canada found that, in New Brunswick, no selected sampling sites have upward trends. Total phosphorus levels and nitrate plus nitrite (N+N) levels followed a downward trend in the St. Croix River. The Nepisiguit River experienced decreased N+N concentrations but no change in total phosphorus. The Southwest Miramichi and Peticodiac Rivers showed no change in total phosphorus or N+N. The Environment Canada report did not do trend analysis on nutrient levels in the Saint John River.

### Bacteria

Curry et al. (2011) look at bacteria levels in the Saint John River and their evidence shows that bacteria levels in the 1960s were at extremely high levels compared to those recorded between 1970 and 2008. However, despite this tremendous improvement, the evidence suggests that bacteria levels

still often exceed the guidelines for recreational use (200 coliforms/100ml). The authors identify the ongoing presence of high bacteria levels, caused by human wastewater discharges, as a risk to human health.

### Conclusions

Overall, the evidence suggests that water quality in New Brunswick is overwhelmingly good and has improved over time leading to a healthier aquatic ecosystem. Highlighting this improvement is the return of salmon to the Nepisiguit River (Environment Canada, 2011b). Despite this improvement, recurrent high levels of bacteria require continued attention.

## 5.8 Nova Scotia

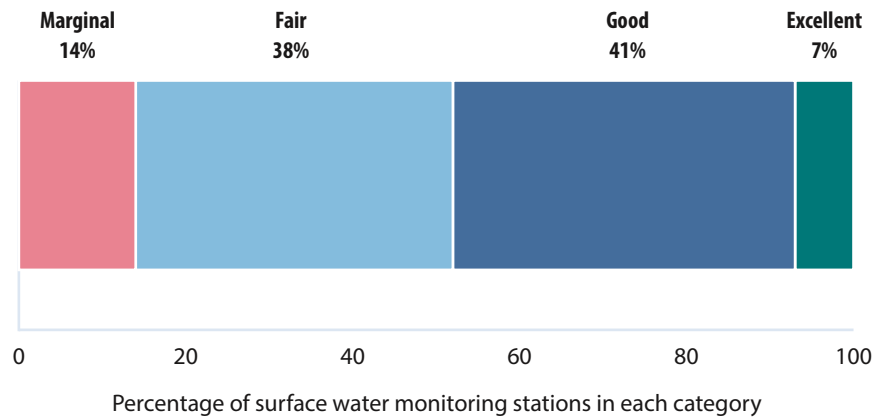
Water Quality Index calculations based on levels of chloride, copper, iron, lead, nitrogen, pH, phosphorus, zinc suggest that most rivers in Nova Scotia currently (2007–2009) have “Good” or “Fair” water quality (Environment Canada, 2013a). **Figure 5.8.1** displays the percentage of monitoring stations in Nova Scotia’s rivers for each classification. Water quality at only four out of 29 stations was classified as “Marginal”. None of the stations reported water quality classified as “Poor”, the lowest classification. These classifications only consider a small number of parameters, and do not look at long-term trends.

### Acidity and oxygen

Nova Scotia has implemented a network of continuous monitoring devices that automatically measure physical water-quality parameters, such as pH and dissolved oxygen, and transmit them to a central database electronically. The network is relatively new, so there is insufficient data for trend analysis at present. However, data from Nova Scotia Environment (NSE) indicates that dissolved oxygen levels are at very acceptable levels in the rivers and lakes monitored: all dissolved oxygen levels recorded achieve CCME guidelines (NSE, 2010). The same cannot be said for pH: values at two out of the six monitoring stations exceeded guidelines 100% of the time. Values for pH at another two of the stations exceeded guidelines 70% of the time, while another station had very few (<1%) pH exceedances (NSE, 2010). Clearly this is something worth further investigation. The authors of the report suggest that these water bodies are naturally very acidic but also subject to acid rain.

Khan et al. (2003) examine monitoring data from the Mersey River in Kejimikujik National Park between 1972 and 2000. They find that pH readings for 2,794 out of 2,806 samples did not achieve pH guidelines for drinking water or the protection of aquatic life (Khan et al., 2003).



**Figure 5.8.1: Classification of water quality in Nova Scotia's rivers, 2007–2009**

Note: The classifications are based on WQI calculations using the following parameters: ammonia, arsenic, chloride, copper, iron, nitrogen, oxygen, pH, phosphorus, turbidity, zinc.

Source: Environment Canada, 2013.

### Metals and toxic substances

Mercury is an issue in some parts of Nova Scotia. For example, mercury levels in Kejimikujik National Park, which is downwind from major urban and industrial centres of the United States, are rising despite all of the regulatory efforts to control air pollution from mercury in North America. Wyn et al. (2010) find that mercury concentrations in yellow perch increased by 29% in 10 lakes in the park between 1996 and 2007. Three lakes had downward trends and another three had no trends. The concentrations in yellow perch and common loons in the park are among the highest found anywhere in North America and negatively affect the reproduction of loons (Wyn et al., 2010).

Mercury is not the only metal that is a problem in Kejimikujik National Park. Khan et al. (2003) find that, between 1972 and 2000, all samples from the Mersey River exceeded the CCME's aluminum guideline for the protection of aquatic life. They also found that of the 193 samples that tested for lead, 191 of them reported levels exceeding the CCME guideline for the protection of aquatic life, though only one exceeded the guideline for drinking water (Khan et al., 2003). They did not detect improving trends in the water quality of the Mersey River over time.

### Nutrients

The Lahave, St. Marys, and Tusket Rivers all exhibited upward trends in total phosphorus and downward trends in total nitrogen between 1990 and 2006. The other Nova Scotian river studied, the Annapolis River, had no detectable trends in phosphorus or nitrogen (Environment Canada, 2011b). Khan et al. (2003) find that 1,745 out of 1,853 samples that tested for nitrate in the Mersey River had levels exceeding the CCME guideline for the protection of aquatic life.

## 5.9 Prince Edward Island

Prince Edward Island (PEI) is Canada's smallest province by population and land area. Agriculture is a major activity that has influenced PEI water quality. Environment Canada's (2013a) Water Quality Index calculations based on a very small parameter set (nitrogen, oxygen, pH, and total suspended solids) suggest that most (64%) of PEI's monitoring stations can be considered as having "Fair" water quality. Three out of 11 monitoring stations have "Good" water quality, and one has "Marginal" water quality ([figure 5.9.1](#)). The Water Quality Index is sensitive to the parameters included, especially when only a small number of parameters are included (GLL, 2006), and therefore readers should not compare these results to those of other provinces reported in this section.

Khan et al. (2003) examine trends in the Water Quality Index for the Dunk River between 1966 and 1998. The Dunk River is classified as having "Fair" water quality in the period from 2007 to 2009 by Environment Canada (2013a). Khan et al. (2003) do not detect any significant trend in overall water quality at the Dunk River station between 1966 and 1998.

### Metals and toxic substances

Aluminum and lead concentrations in the Dunk River regularly exceeded guidelines for the protection of aquatic life from 1966 to 1998 (Khan et al., 2003). The guidelines for drinking water were violated less often for these metals.

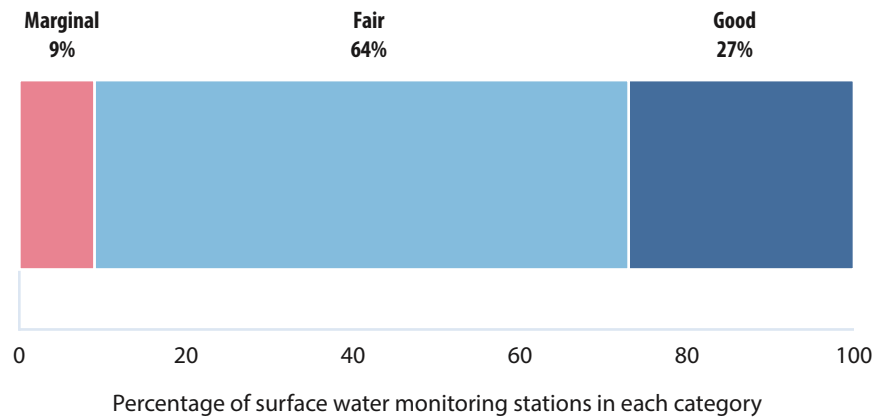
### Nutrients

Nitrogen levels are a major water quality issue in Prince Edward Island. Out of 75 monitoring stations looked at from across the country by Environment Canada (2011b), two of the three stations in PEI rivers had the highest levels of total nitrogen and N+N. The Mill and Wilmot Rivers do not only have the highest nitrogen levels in the country but also had upward trends in nitrogen (both total nitrogen and N+N) between 1990 and 2006 (Environment Canada, 2011b). These high nitrogen levels and upward trends are likely the result of agricultural operations in PEI. The Bear River also experienced upward nitrogen levels between 1990 and 2006 (Environment Canada, 2011b). Although they were not looking at trends in nutrients, Khan et al. (2003) find that nitrate concentrations exceeded guidelines for the protection of aquatic life in the Dunk River for all nitrate records between 1966 and 1998.

### Bacteria

Khan et al. (2003) examine 39 records of coliform bacteria in the Dunk River between 1966 and 1998 (when the records fall in the time period is not indicated). Out of these 39 records, 37 were in exceedance of guidelines for drinking water (Khan et al., 2003). They do not indicate how many, if any, exceed the guideline for recreational use.

**Figure 5.9.1: Classification of water quality in Prince Edward Island's rivers, 2007–2009**



Note: The figure displays the percentage of monitoring stations (11 stations total) in Prince Edward Island falling within each category based on the Water Quality Index calculated on the following parameters: nitrogen, oxygen, pH, total suspended solids.

Source: Environment Canada, 2013.

## 5.10 Newfoundland & Labrador

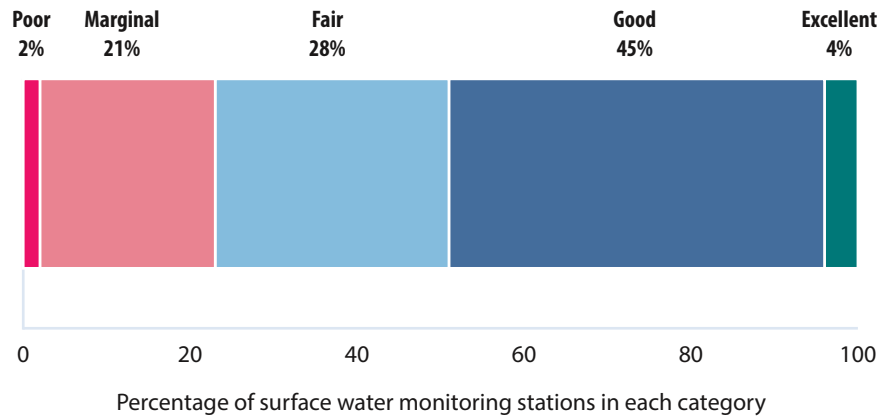
The Water Quality Index calculated by Environment Canada (2013a) suggests that almost half of the monitoring sites in the province of Newfoundland & Labrador (NL) are classified as “Good” (45%) or “Excellent” (4%). **Figure 5.10.1** displays the percentage of monitoring stations in NL rivers for each classification. These classifications are for stations with data between 2007 and 2009 for the following parameters: chloride, copper, iron, lead, nickel, nitrogen, oxygen, pH, phosphorus, and zinc. Fourteen out of 67 stations (21%) were classified as having “Marginal” water quality, and one station (on Kelly’s Brook) had “Poor” water quality.

### Metals and toxic—substances

Dawe (2006) conducted trend analysis on data for a multitude of water-quality parameters for 65 monitoring stations from 1986 to 2000 and draws conclusions about general trends in Newfoundland & Labrador’s water quality. Despite generally upward trends in colour and turbidity, concentrations of many metals, including mercury, lead, arsenic, among others, decreased across the province (Dawe, 2006).

Dawe’s (2006) results for individual rivers suggest that, though water quality in Kelly’s Brook is rated as “Poor” during the period from 2007 to 2009, it may have been even worse in the past. She finds statistically significant trends in many metals for Kelly’s Brook between 1986 and 2000, most notably some of those like copper and iron considered in the Water Quality index calculations used by Environment Canada (2013a) to classify rivers

**Figure 5.10.1: Classification of water quality in rivers in Newfoundland & Labrador, 2007–2009**



Note: The figure displays the percentage of monitoring stations (67 stations in total) in Newfoundland & Labrador falling within each category based on the Water Quality Index calculated on the following parameters: chloride, copper, iron, lead, nickel, nitrogen, oxygen, pH, phosphorus, and zinc.

Source: Environment Canada, 2013.

in Newfoundland & Labrador. Dawe also finds downward trends in cobalt, mercury, lithium, manganese, and strontium; none of which are included as parameters in the Water Quality Index calculation.

## Nutrients

The trend analysis conducted by Environment Canada (2011b) on nutrient data (1990–2006) from NL's rivers suggests that nutrient levels are generally decreasing in surface water. The major exception to this overall trend is the Waterford River, near St. John's, which exhibited an upward trend in total nitrogen. These upward nutrient levels may be related to cyanobacteria blooms in two near-by lakes (Environment Canada, 2011b).

## 6 Conclusions and policy implications

There is no shortage of freshwater in Canada as a whole as it has as much as 20% of the global stock of fresh water. Based on 2011 data, Canada ranks fourth globally for annual volume of renewable freshwater. Although Canadians are among the highest users of water on a per-capita basis in the world, this only amounts to a small fraction of our annual renewable freshwater. Although annual freshwater in southern Canada has declined for natural reasons since 1971, it is nowhere close to running out.

Despite our abundance of water, some regions face seasonal variability that can impede economic activity. Water in Canada is owned and managed by the government. In the areas with the largest seasonal scarcity of water, the southern Prairies and the Okanagan Valley, water licenses have traditionally been allocated on a first-come, first-served basis, rather than through a market. Water markets for large consumers can insure that water resources are put to their most valuable uses and provide incentive to build infrastructure to transport Canada's freshwater from areas where it is more abundant. Indeed, Alberta has moved in this direction in the South Saskatchewan River Basin by allowing water allocations to be bought and sold. More effective pricing of residential water consumption can also ensure that Canadians are using water in a more efficient manner.

It is difficult to provide a general overview of Canada's water quality, as problems with water quality differ among provinces and regions depending on natural factors and human activities. The water-quality parameters tested differ among monitoring stations and provinces. Canada does rank 9<sup>th</sup> in the world in water quality based on a small number of parameters. Also, overall water quality appears to have been relatively stable over the past decade in Canada. Overall, nutrient levels have remained stable between 1990 and 2006 in most Canadian rivers and lakes with sufficient data for trend analysis.

By looking at water quality in individual provinces, a more comprehensive picture of how Canadian water quality has changed over time can be obtained. The territories were ignored in this study since they are sparsely populated and have limited data on water quality. In many regards, water quality has improved in Canada over time. In Ontario, total phosphorus has decreased in the Great Lakes and Lake Simcoe. There has also been a general

decline in mercury, PCBs, and many other toxic substances in the waters of Ontario and Quebec. Another example of improving water quality is the return to pre-settlement levels of total phosphorus in Lake Osoyoos in British Columbia. Bacteria levels are decreasing in major Alberta rivers and because of improvements in the bleaching process used in British Columbia's pulp and paper mills, rivers in the province have seen a significant decrease in chloride levels since the 1980s. Evidence from Ontario suggests that pesticides and pharmaceuticals in drinking water and chloride in rivers from road salt are currently not issues of concern for water quality. Furthermore, large declines in water-borne pesticides occurred prior to 2006 and well before Ontario implemented a ban on the use of pesticides for cosmetic uses.

It is clear that water quality differs substantially across the country and this has implications for policies aimed at managing water pollution. For example, nitrogen is increasing at some locations, phosphorus at others. Any universal national policy is likely to be overly blunt. There may also be problems with partial regulation: it may be much easier to regulate and control industrial, municipal, and household sources than agricultural sources. In areas of intensive fertilizer use, regulating other uses may not be sufficient to make much of an impact. More research on the localities experiencing upward trends and location-specific regulations may be a more effective approach.

There are also localized success stories of greatly improved water quality. Salmon have recently returned to the Nepisiguit River in New Brunswick. Fish and bugs have returned to the Tsolum River in British Columbia 40 years after toxic releases from an abandoned mine virtually destroyed the river's ecosystem. Wheatley Harbour on Lake Erie in Ontario has recently been delisted from the Great Lakes "Areas of Concern".

Despite these improvements, there continue to be concerns about water quality that require continued vigilance or action. Nitrogen levels in the Great Lakes, the St. Lawrence river, British Columbia's Lower Mainland, and the rivers of Prince Edward Island are high and increasing. Water in Nova Scotia's Kejimikujik National Park remains very polluted, and concentrations of mercury in fish and loons continues to increase. Improved and continued monitoring of water quality in Canada is needed, especially around Metro Vancouver and the Athabasca River downstream of the oil sands.

## Appendix The CCME's Water Quality Index

This paper references results from three uses (YCELP, 2010; AMESRD, 2011; Environment Canada 2012, 2013a) of the Water Quality Index (WQI) developed by the Canadian Council of Ministers of the Environment (CCME). The three differ in results because each uses different water-quality parameters and objectives. This appendix provides readers with background on how Water Quality Index values are calculated in general.

The aim of the CCME's WQI is to provide a metric that gives a simple overview of water quality in individual locations and to provide for cross-location comparisons of water quality. The WQI assesses monitoring data of water-quality parameters with specified water-quality objectives for those parameters. The index value will differ based on which water-quality parameters are included and the stringency of the chosen water-quality objectives. The calculations of the index value assess the observed parameters with three attributes of water-quality objectives:

**scope** How many parameters do not meet their objectives?

**frequency** How often do individual measurements not meet their objectives?

**amplitude** By how much do measurements depart from their objectives?

The WQI calculations produce a WQI value for an individual monitoring station on a scale of 0 to 100. The CCME proposes five descriptive water-quality categories based on the WQI scale: Excellent, Good, Fair, Marginal, Poor. The categories are described in [table A.1](#). Unlike many other indices (for example, Gwartney, Lawson, and Hall, 2012 or Gyourko, Saiz, and Summers, 2008), the value given to an individual station is independent of the number of other stations studied.



**Table A.1: CCME Water Quality Index Categories**

Category	Value	Description
Excellent	95–100	Water quality is protected, with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within objectives virtually all of the time.
Good	80–94	Water quality is usually protected but occasionally threatened or impaired; conditions rarely depart from natural or desirable levels.
Fair	65–79	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels
Marginal	45–64	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
Poor	0–44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

Source: CCME, 2012.

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## About the author

### Joel Wood

Joel Wood is a Senior Research Economist with the Centre for Environmental Studies at the Fraser Institute. He holds a Ph.D. in economics from the University of Guelph. His work has been published in *Environmental & Resource Economics*, *Energy Economics*, *Fraser Forum*, the *Vancouver Sun*, the *National Post*, and other newspapers across Canada.

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