

Evaluating the State of Fresh Water in Canada



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2018

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Executive Summary

Canadians are concerned about the abundance and quality of our freshwater resources, yet information is widely dispersed and often difficult to obtain. This study reviews a wide range of data and government reports to examine the state of Canada's water resources.

Canada has the third-largest supply of annual renewable fresh water in the world. While abundant, Canada's freshwater resources are not evenly distributed across the country. Much of Canada's fresh water drains northward into the Arctic Ocean and Hudson Bay, limiting its availability along the country's southern border where the majority of the population resides. Nonetheless, Canadians consume only a small fraction (about 1%) of the water supply that is annually available. In addition, according to Environment Canada's analysis of water flows across the country, in 2015, most Canadian rivers (65%) had a normal water quantity and only 10% had a lower-than-normal quantity of water. In looking at areas where problems may need to be addressed, in this report we will focus on describing the current water supply and quality conditions, and we will leave policy analysis and recommendations to other publications.

In general, Canada's freshwater quality is quite good as most indicators seem to suggest stability or modest improvements over the past few years. Most of the major sources of water pollution in Canada have been recognized and progress has been made to reduce the amount of pollution that enters our waterways. Improvements were observed in the following areas: municipal wastewater treatment, households' usage of chemical fertilizers and pesticides, regulatory compliance of mining operations, and releases of metals such as lead, cadmium, and mercury into waters from pulp and paper plants and sewage treatment plants.

According to Environment Canada's recent analysis, which examined water quality in Canadian rivers for the 2014–2016 period, water quality in about 82% of the monitoring locations across the country is fair to excellent, suggesting that waterways in Canada are generally well protected. Only 2% of the stations across the country indicate poor water quality and 16% indicate marginal water quality. Regional analysis suggests that good or excellent water quality is more common in rivers draining into the Atlantic Ocean and the Arctic Ocean. Poor or marginal water quality is more common in rivers connected to the Great Lakes and the St. Lawrence River regions.

Our examination of individual monitoring stations over time indicates that, from 2002 to 2016, water quality remained stable in about 81% of locations across the country, improved in 10% of locations, and deteriorated in only 9%.

Analysis of fish tissues to discover toxic substances and their concentrations in different drainage areas suggests that, between 2013 and 2015, concentrations of polybrominated diphenyl ethers (PBDEs) in the majority of the samples across the country were

in compliance with the federal guidelines. Similarly, samples from nine drainage regions, including Pacific Coastal, Great Lakes, and St. Lawrence, taken between 2001 and 2016 yielded no exceedances of guidelines for Perfluorooctane sulfonate (PFOS) concentrations for water. The assessment of metals and toxic substances, including mercury and PBDEs, in the Great Lakes reveals that the concentrations have generally decreased over the past four decades. Another example of improving water quality is the sharp declining trend in contamination of freshwater fish in the St. Lawrence River since 1970s.

In addition, evidence from bacterial testing of waters in shellfish growing areas across the country suggest that most of the country's regions have stable water quality in shellfish growing areas, with 68% of the country's shellfish harvesting area being classified as approved or conditionally approved for harvest for human consumption.

Despite improvements in the state of Canada's water quality, there are concerns that require continued vigilance or action. Though concentrations of PBDEs have generally decreased, some indicators suggest that levels of PBDEs are still above the prescribed guidelines in the Great Lakes, Pacific Coastal, and St. Lawrence River regions. Nutrient levels in Lake Winnipeg's south basin were excessive in 2016, especially near the inflow from the Red River. Excessive concentrations of nutrients in the Great Lakes—specifically, in Lake Erie and some near shores of Lakes Ontario and Huron—have caused a resurgence of harmful algal blooms in these areas. Despite significant reductions in mercury levels in Lake Erie in Ontario since 1970s, analysis of recent mercury concentrations on fish contamination in this lake suggests that levels have stopped decreasing or started increasing. Despite reductions in nutrient levels in recent years, excessive nutrient concentrations appear to still be a problem in the St. Lawrence River and its major tributaries.

1 Introduction

Canada is richly endowed with abundant freshwater resources. Canada has the third-largest freshwater supply in the world and has more lakes than any other country but these resources are not evenly distributed across the country. Much of Canada's fresh water drains northward into the Arctic Ocean and Hudson Bay, limiting the availability of fresh water along the country's southern border where the majority of the population resides. Based on the distribution of Canada's water resources and levels of water usage, questions have been raised about Canada's ability to meet present demands for water. The first section of this publication analyzes Canada's water supply and demand to determine whether Canada is running out of water.

The second section examines the quality of Canada's fresh water in detail. Clean water is an essential public good as it is required for human health, and contributes to social and economic activities. Population growth and industrialization can lead to various stresses on lakes and rivers. Pollutants such as metals and toxic substances can affect the quality of drinking water and can have a negative impact upon aquatic life. Increases in nutrients such as phosphorus and nitrogen, which are by-products of agricultural fertilizers and municipal wastewater treatment, can have a negative impact on aquatic ecosystems and increase the frequency of nuisance algal blooms. While this publication attempts to analyze freshwater quality from a national perspective, more precise and meaningful information is found using regional data. Therefore, we use locally measured, objective, and publicly available data to review detailed and technical information for each region. Examining regional trends helps identify how water quality has changed over time and which areas require improvement.

Overall, our analysis suggests that Canada has abundant water resources and that Canadians use only a small fraction of this massive resource. In general, Canada's freshwater quality is quite good as most indicators seem to suggest stability or modest improvement over the past few years. In particular, over the period from 2014 to 2016, 82% of the monitoring stations across the country had fair to excellent water-quality status. Only 2% of the stations were found to have poor water quality while 16% had marginal water quality. Regional analysis suggests that good or excellent water quality is more common in rivers in the Atlantic Ocean and the Arctic Ocean. Poor or marginal water quality is more common in rivers in the Great Lakes and St. Lawrence River regions. Specifically, categorizing data by Canadian provinces and territories reveals that, between 2014 and 2016, all the stations with poor water-quality status were located in

only three provinces: Ontario, Quebec, and British Columbia. Evidence from individual monitoring stations suggests that, from 2002 to 2016, water quality in about 81% of locations across the country remained stable.

Section 2 provides an overview of the quantity of water in Canada and how water is used. Section 3 provides an overview of the water quality in various Canadian rivers and lakes and discusses variations across regions. The final section gives the study's general conclusions.

2 How Much Fresh Water Does Canada Have?

Canada is richly endowed with both non-renewable and renewable freshwater resources. The term “non-renewable” refers to water that is accumulated and stored in glaciers, large lakes, aquifers, and ice caps that have a negligible rate of recharge (Statistics Canada, 2017a). For instance, some fresh water in the Great Lakes is considered non-renewable as it takes a long time for these water bodies to replenish themselves. Renewable fresh water circulates in the system and replenishes each year through precipitation and water in-flows.

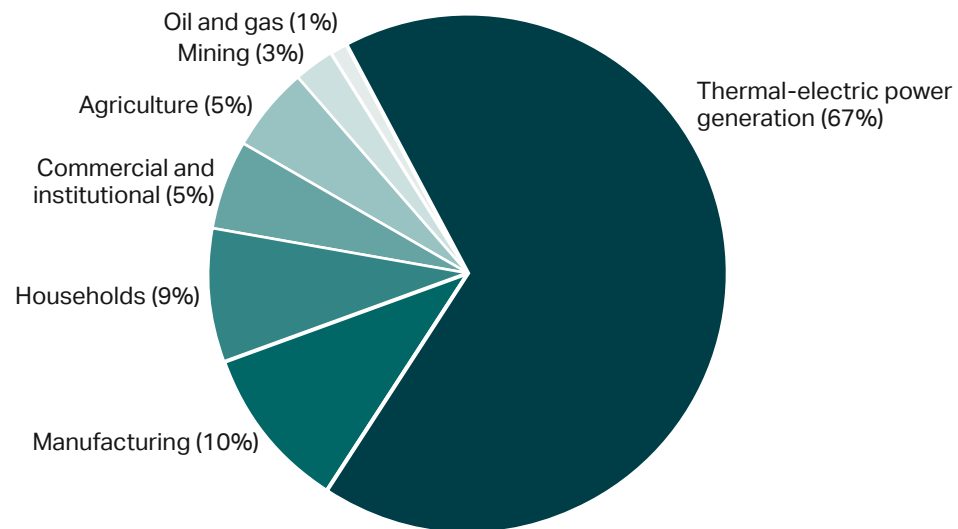
With 563 large lakes across the country, Canada has more lake areas than any other country in the world (Dewar and Soulard, 2010), giving us an impressive non-renewable water supply. The Great Lakes, which are shared between Canada and the United States, are the largest group of freshwater lakes in the world and account for 18% of the global stock of fresh surface water.

Canada has the third largest renewable freshwater supply in the world, with an average annual flow of 3,478 cubic kilometres (km^3) between 1971 and 2013. This works out to over one hundred thousand cubic meters (m^3) per person, the second largest amount among developed countries, behind only Iceland (Statistics Canada, 2017a). While abundant, renewable freshwater is not evenly distributed and the supply fluctuates over time. Specifically, only 38% of Canada’s renewable freshwater supply is located in the southern area where most Canadians live (Dewar and Soulard, 2010). Applying this fraction (38%) to Canada’s 3,478 km^3 of renewable freshwater would still rank Canada among the largest suppliers of renewable freshwater in the world (Wood, 2013). Canada’s renewable freshwater supply also shows regional differences. According to Statistics Canada’s latest analysis, the Pacific Coastal drainage in British Columbia has the highest rate of water supply per unit of area in the country whereas the Missouri, Assiniboine-Red, South Saskatchewan, and North Saskatchewan regions in the Prairies have the lowest (Statistics Canada, 2017a). Overall, as reported by Statistics Canada (2017a), the annual freshwater supply in southern Canada has been fluctuating over time, decreasing from 1971 to 1987 and then beginning a gradual recovery between 1987 and 2012.

In order to examine the potential pressure exerted on Canada’s freshwater supply one should also look at water use across the country. Sustainability requires ensuring withdrawals are kept below renewals over time. In 2013, total water withdrawals for household and economic activities in Canada totaled 37.9 km^3 , which is approximately 1% of the country’s annual supply of renewable freshwater (Statistics Canada, 2017a; calculations by authors), indicating that our use of this resource is well within sustainable limits.

Figure 2.1 shows the amount of water used by major sectors of the Canadian economy in 2013. The main user was thermal power and generation, accounting for 67% of the total withdrawals. Second was manufacturing (10%) and third, households (9%). Mining, oil, and gas extraction accounted for 4% while agriculture accounted for 5%.

Figure 2.1: Water use in Canada, by sector, 2013



Note: Totals may not add up because of rounding.
Source: Environment Canada, 2016.

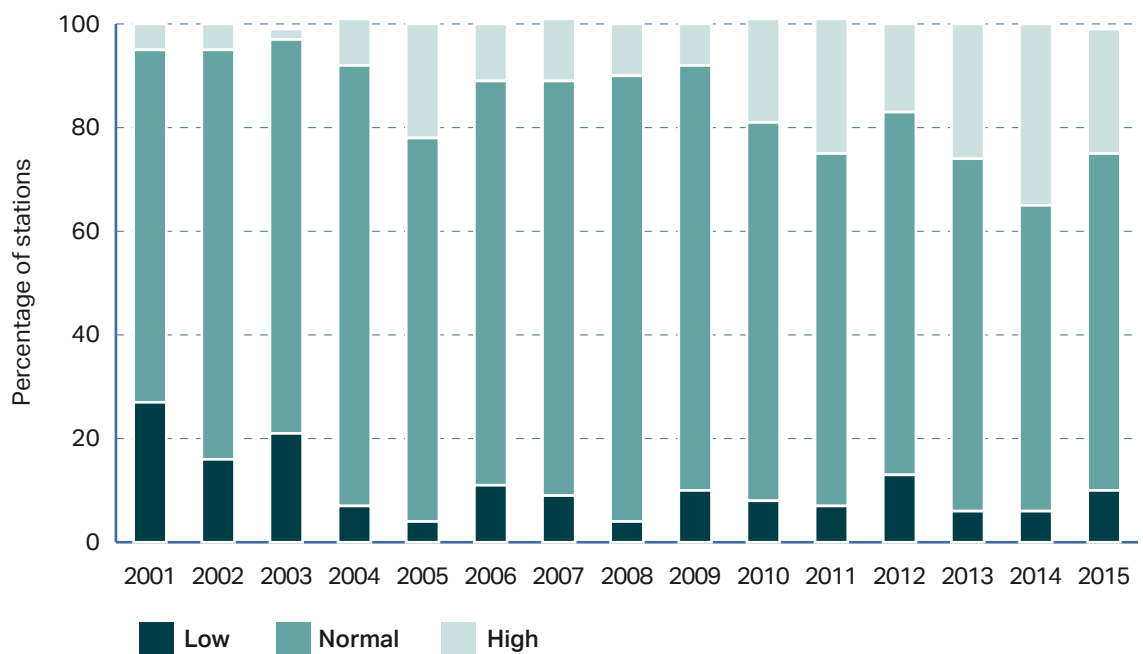
Between 2005 and 2013, water withdrawal in Canada declined by 9.2% (Environment Canada, 2016a; calculations by authors). The drop resulted in part from a 31% decline in manufacturing-sector usage in 2013 compared to 2005. Over the same period, household water use dropped by 16%, from 3.9 km³ in 2005 to 3.2 km³ in 2013. Daily, per-capita use of water, as reported by Statistics Canada, dropped from 330 litres in 2005 to 250 litres in 2013, partly due to improvements in the water efficiency of toilets and appliances (Statistics Canada, 2017b).

Although Canada has vast freshwater resources and uses only a fraction of them, uneven distribution means that challenges may still arise in balancing supply and usage in specific regions and at specific times. In order to identify regions that have a higher possibility of experiencing a water shortage, Environment and Climate Change Canada (2018a) monitors rivers across Canada over time and provides information about their water flows under the Canadian Environmental Sustainability Indicators (CESI) program. Water-monitoring stations categorize quantity into three groups: low, high, and normal. Quantity is measured as flow, namely the volume of water moving over a point over a fixed time period. The classification for a given station is based on a comparison of its most frequently observed flow condition in a year with its typical water flow

condition between 1981 and 2010. Water flow generally changes throughout a year depending on temperature, snowfall, and rainfall and is usually highest in the early spring and lowest through the summer and fall.

Figure 2.2 summarizes the distribution of water quantity categories at monitoring stations across Canada, on an annual basis, from 2001 to 2015. As shown, most Canadian rivers have exhibited normal or above-normal water quantity with a slightly declining tendency for low flow levels. In 2015, 65% of monitoring stations across Canada had a normal water quantity. As of 2015, 10% had a lower-than-normal quantity and just under 25% had a higher-than-normal water quantity.

Figure 2.2: Water quantity at monitoring stations, Canada, 2001–2015



Note: The water quantity classification for a station is based on a comparison of the most frequently observed flow condition in a given year with typical water quantity at that station between 1981 and 2010. The 2014 and 2015 data include fewer results from Quebec and British Columbia because of delays in getting data into the database. Percentages may not add up to 100 because of rounding.

Source: ECCC, 2018a.

Environment and Climate Change Canada (2017a) also examined the water quantity status of drainage regions in Canada, using data for the most downstream point in each. In areas where the watershed is shared with the United States, the water flow for Canadian portions was examined. Canada has 25 drainage regions that, based on their outflow into an ocean, can be further grouped into one of five ocean drainage areas: the Pacific Ocean, Arctic Ocean, Hudson Bay, Gulf of Mexico, and Atlantic Ocean.

In 2015, most drainage regions (15 out of 25) had normal water-quantity conditions. Although extreme weather patterns in 2015 may have affected the quantity of water,

such events are usually short lived and do not translate into changes in seasonal or long-term water quantity. Specifically, the regions with normal water quantity conditions are: Okanagan-Similkameen and Columbia (Pacific Ocean watershed); Peace Athabasca, Lower Mackenzie and Arctic Coast-Islands (Arctic Ocean watershed); Missouri (Gulf of Mexico watershed); North Saskatchewan, South Saskatchewan, Winnipeg, Churchill and Northern Ontario (Hudson Bay watershed); Great Lakes, Ottawa, Maritime Coastal, and Saint John-St. Croix (Atlantic ocean watershed).

Lower-than-normal water quantity was detected in only one drainage region: the Keewatin-South Baffin in the Hudson Bay watershed area. Higher-than-normal quantities were observed in Pacific Coastal, Fraser-Lower Mainland, and Yukon (Pacific Ocean watershed); Assiniboine-Red and Lower Saskatchewan-Nelson (Hudson Bay watershed); and Newfoundland and Labrador (Atlantic Ocean watershed). Because of a lack of sufficient data, the status of the following three drainages could not be identified: Northern Quebec in Hudson Bay area; and St. Lawrence and North Shore-Gaspé, both located in Atlantic Ocean watershed.

Environment Canada also reported local water quantity in Canadian rivers in 2015 by assessing monitoring stations across Canada (except Quebec and some areas in British Columbia that had missing data). The quantity classification for a given station in 2015 is based on a comparison of its most frequently observed flow condition in 2015 with its typical water flow condition determined based on conditions between 1981 and 2010. Most stations exhibited a normal status. Lower-than-normal status was detected more frequently at stations in central Northwest Territories, south-western Ontario, southern British Columbia and Alberta, and northern Saskatchewan. Higher-than-normal quantity was more frequently observed at stations in north-western Ontario, northern British Columbia, Yukon, south-central Saskatchewan and Manitoba. [1]

Overall, Canada does not appear to be experiencing a water shortage, as most Canadian rivers had normal water quantity levels between 2001 and 2015.

[1] With regard to these areas where problems may need to be addressed, in this report we will focus only on describing the current water supply and quality conditions, and we will leave policy analysis and recommendations to other work.

3 How Good Is Canada's Fresh Water?

3.1 Pressures on water quality

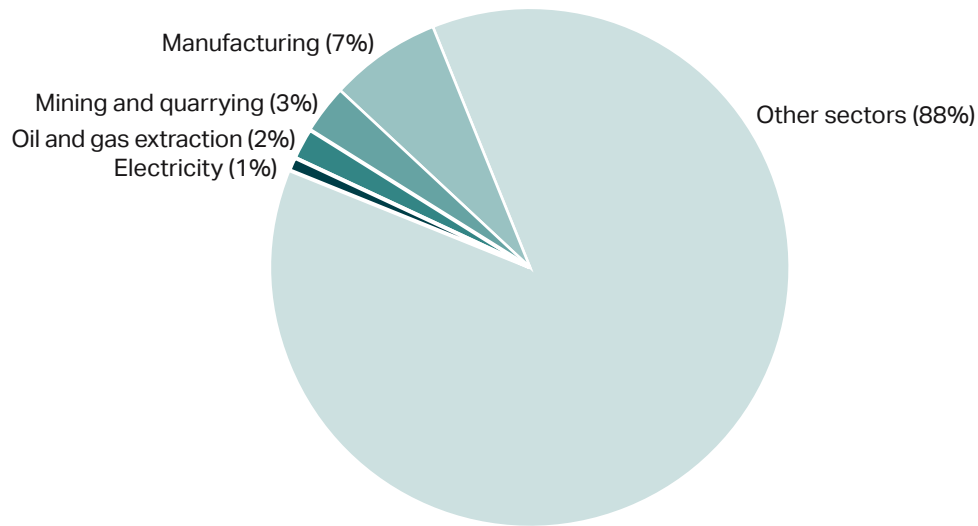
Water quality can be affected by many different processes, both anthropogenic and naturally occurring. Substances within the atmosphere (nitrogen, oxygen, carbon dioxide, dust, volcanic gases, and so on) can be dissolved and trapped in rain which, in turn, flows into lakes and rivers once it reaches the ground. Run-off from urban areas can also accumulate in lakes and rivers and increase concentrations of nutrients (phosphorus and nitrogen), sediments, animal wastes, and road salts. Industry, mining, agriculture, forestry, and other human activities can also cause the accumulation of metals and toxic chemicals, nutrients, pesticides, and suspended sediments in bodies of water (ECCC, 2015a).

Nutrients (phosphorous and nitrogen) flow into aquatic ecosystem as a result of run-off from municipal wastewater and agricultural fields. The presence of high levels of nutrients in water bodies induces excessive growth of plants and algae. This results in depletion of dissolved oxygen and causes a condition called *eutrophication*. Pesticides from agriculture and, to some extent, from urban areas also can pose a risk to aquatic life. Various toxic substances that have slow rate of degradation, including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and metals (such as mercury), are also among the threats to water bodies. PBDEs are used in flame retardants and can enter the environment during the production process of these goods, during their lifespans, or upon disposal. In 2008, regulations were passed to restrict the manufacturing and use of PBDEs in Canada (ECCC, 2016e). Substances related to pharmaceutical goods production are also being detected in the environment. They can pose significant threats by disrupting the endocrine functions of wildlife.

Figure 3.1 presents data from the National Pollutant Release Inventory breaking down water pollution release in Canada by sector (ECCC, 2017b). The releases include nitrate ion, phosphorous, and ammonia, among others. The largest category (88%) is the “other” category, which is dominated by municipal wastewater treatment plants. Manufacturing is the next largest source, accounting for 7% of the pollutants released into water.

Wastewater treatment plants

Municipal wastewater systems are the largest sources of water pollution in Canada; the treatment of wastewater, therefore, plays a significant role in protecting water quality. Wastewater treatment has different levels. Primary treatment involves pumping wastewater into a large tank where heavy solids are allowed to settle. Secondary treatment involves adding bacteria and oxygen to remove biological waste. Tertiary treatment uses

Figure 3.1: Releases of pollutants into water in Canada, by source, 2015

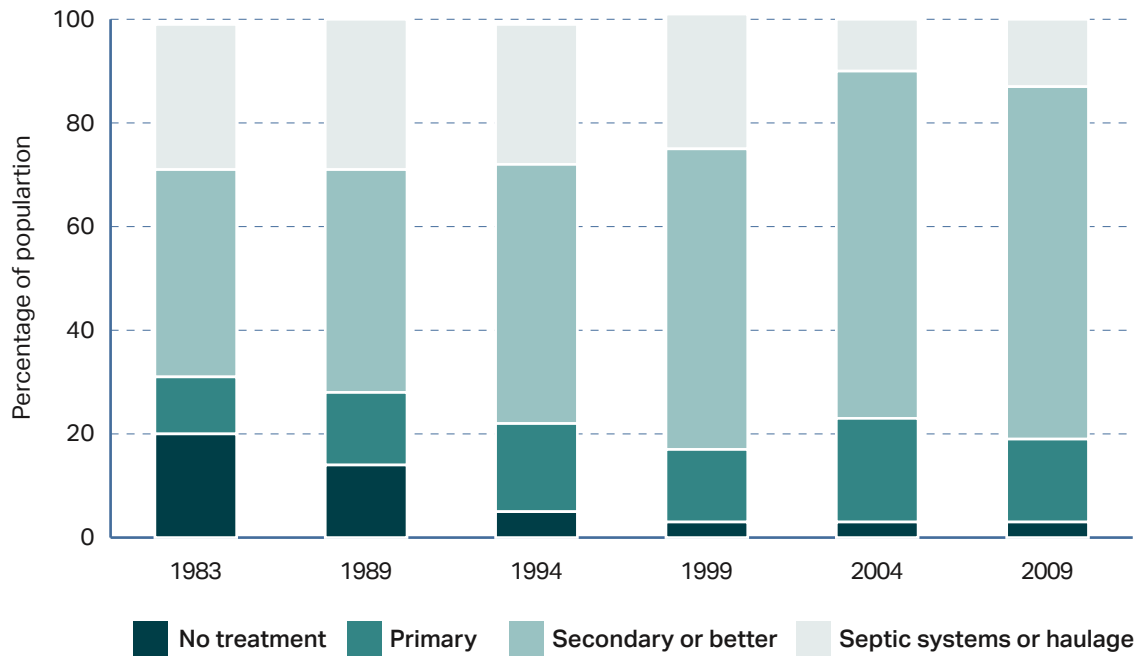
Note: Totals may not add up because of rounding.

Source: ECCC, 2017b.

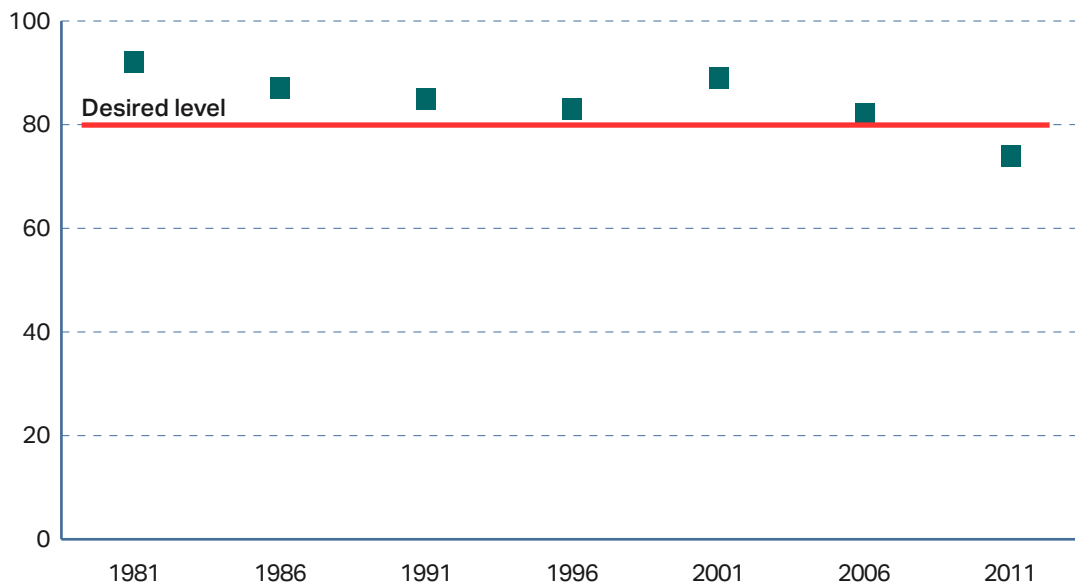
a number of physical, chemical, or biological processes to remove specific substances of concern after secondary treatment. A septic system consists of a buried tank that holds wastewater long enough to separate solid waste from liquid waste. Haulage is a system where a collection tank pumps and takes wastewater to a disposal site.

Canadian municipalities have been upgrading their wastewater treatment systems for decades. [Figure 3.2](#) presents wastewater treatment levels in Canada from 1983 to 2009. From 1983 to 2009 the percentage of Canadians on municipal systems with secondary treatment or better grew from 40% to 69%. In 2009, only 13% of Canadian households relied on septic systems or haulage (down from 28% in 1983), and only 3% lacked any system of wastewater treatment (down from 20% in 1983) (ECCC, 2017c).

Under the CESI program, Environment and Climate Change Canada examines risk to water quality from agriculture (Environment Canada, 2016b). The CESI constructed the Water Quality Agri-Environmental Performance Index that combines information about potential water contamination by phosphorus, nitrogen, bacteria, and agricultural pesticides. The index, which was calculated every five years between 1981 and 2011, aggregates the information into a single number between 0 and 100. [Figure 3.3](#) displays the Water Quality Agri-Environmental Performance Index in Canada from 1981 to 2011. Scores of 80 or higher represent the desired level while scores of 60 to 79 represent a good level. Between 1981 and 2006, Canada's score remained above the desired score of 80, but it fell to 76 in 2011. In other words, the water quality from agriculture in Canada is still good, but it has declined to below the desired level. According to the Environment and Climate Change Canada (2016b), the recent decline is likely the result of a decline

Figure 3.2: Wastewater treatment levels in Canada, 1983–2009

Source: ECCC, 2017c.

Figure 3.3: Agri-environmental performance index for water quality in Canada, 1981–2011

Source: Environment Canada, 2016b.

in livestock populations, causing a decrease in perennial crop area and an increase in annual crop area. This subsequently results in greater usage of herbicides, pesticides, and phosphorus fertilizer.

Progress

Recent reports from Environment and Climate Change Canada (ECCC, 2016g, 2017m, 2017d, 2018g) show that Canadians have made important progress in reducing the amount of pollution going into our waterways.

- 🌿 Between 1994 and 2015, the percentage of Canadian households that used chemical pesticides on their gardens and lawns declined from 31% to 19%.
- 🌿 Over the same interval, the percentage of households that use chemical fertilizers on their lawns and garden, declined from 47% to 28%.
- 🌿 These downward trends for both pesticides and fertilizers were observed in every province except Manitoba (ECCC, 2017m).
- 🌿 Between 2003 and 2015, the percentage of mining operations that met regulatory standards for total suspended solids increased from 92% to 98%. The fish toxicity test of the effect of effluent on the rainbow-trout mortality rate also showed an increase in compliance with regulations from 95% to 99.6% over the same period (ECCC, 2018g).
- 🌿 In 1985, the percentage of passed tests by pulp and paper mills in Canada was 25% for toxicity tests on fish, 68% for biochemical oxygen demand, and 60% for total suspended solids. [2] In 2014, those numbers increased to 97.5%, 99.9%, and 99.8% (ECCC, 2016g).
- 🌿 Between 2003 and 2015, releases of mercury declined by 55%, lead by 70%, and cadmium by 61% [3] (ECCC, 2017d).
- 🌿 Over 80% of the reductions were a result of increased pollution abatement in pulp and paper plants and sewage treatment plants.

[2] Biochemical oxygen demand refers to the amount of dissolved oxygen that is required to break down organic material in water. Total suspended solids refer to all particles in the water that do not pass through a filter (CESI, 2018).

[3] There was one major deviation from the trend. A mining spill in 2014 caused a 518% increase in mercury, a 499% increase in lead, and a 29% increase in cadmium releases relative to 2003. The spill occurred in August 2014 when a dam securing a tailings pond from the Mount Polley mine in British Columbia breached.

3.2 Assessments of water quality

Overall Water Quality Index

Environment Canada uses the Water Quality Index (WQI) developed by the Canadian Council of Ministers of the Environment (CCME) to assess freshwater quality at monitoring stations across Canada. The index measures a number of chemicals and physical parameters in water and compares the parameters to water quality guidelines defined by the province or the federal government. Water quality guidelines are thresholds indicating when a parameter may become harmful to animals and plants. These science-based guidelines are site specific, meaning that local water quality conditions are taken into account when establishing the threshold.

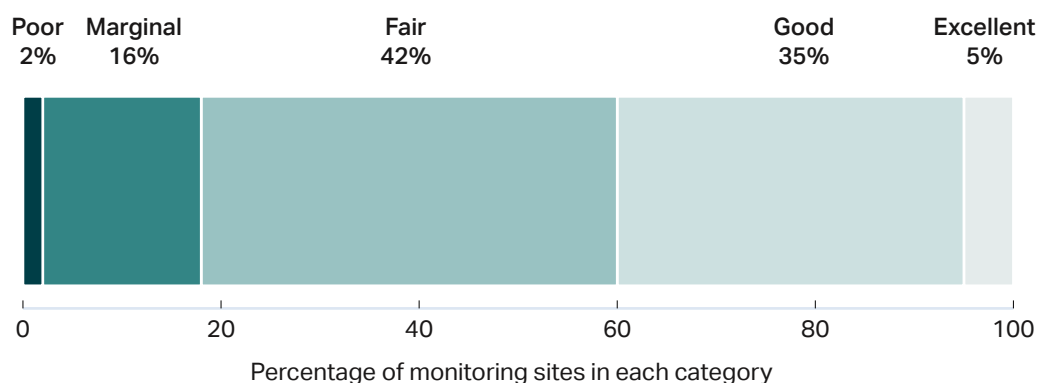
The WQI accounts for the number of parameters that do not meet guidelines, frequency of this occurrence, and by how much the parameters deviated from the guideline. Next, based on the overall suitability to support aquatic life, the index ranks water bodies as excellent, good, fair, marginal, or poor (ECCC, 2007). *Excellent* means water quality is protected, with an absence of any threat or impairment. *Good* means there are only minor threats or impairments to water quality. *Fair* means water quality is usually protected but is occasionally threatened or impaired. *Marginal* means water quality is frequently threatened or impaired. *Poor* means water quality is almost always threatened or impaired.

The selection of parameters being sampled to develop the WQI score is generally decided at the local level based on geology, geography, and human pressures. This results in different parameters being sampled at different locations and regions (Wood, 2013). Given the inconsistency of the parameters and guidelines being used at different stations, care should be taken with comparing water quality among locations. [4]

Figure 3.4 presents the CCME Water Quality Index ratings for rivers in southern Canada for the 2014–2016 period. Out of the 178 core monitoring sites examined across southern Canada, 40% are rated good (63 sites) or excellent (nine sites); 42% were rated fair (74 sites); 16% were rated marginal (28 sites); while only 2% were rated poor (four sites). The fact that water quality in 82% of the monitoring locations was found to be fair to excellent suggests that water quality in Canada is well protected.

Environment and Climate Change Canada (2018b) looked at WQI readings at individual monitoring stations over time. Many things can change water quality in rivers temporarily but over the long term it tends to change slowly. Natural factors including rainfall and snow affect water quality by washing pollution deposited on the roads and fields into the river. Altered landscapes, sewage effluents, industrial releases, and air pollution can all affect water quality over the long-term (ECCC, 2018b).

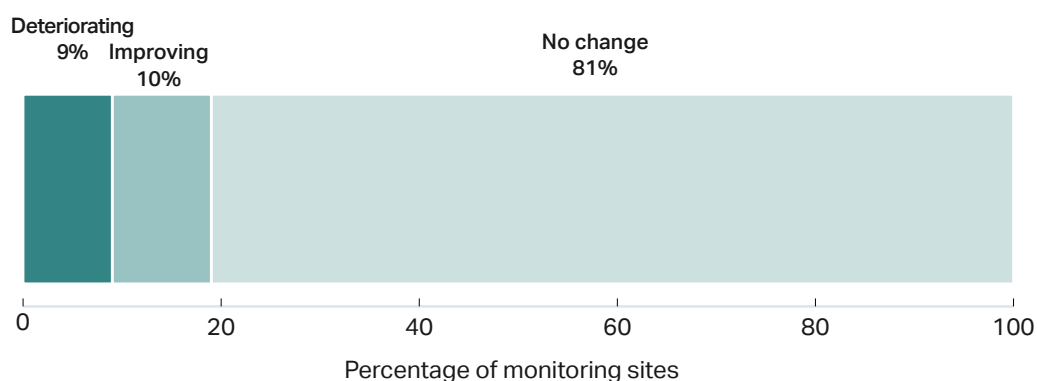
[4] Appendix A provides more details and background information on the Water Quality Index.

Figure 3.4: Water Quality Index, Canada, 2014–2016

Note: This figure displays the percentage of surface water monitoring stations (178 total) in each category based on Environment Canada's Water Quality Index calculations.

Source: Environment Canada, 2018b.

Figure 3.5 summarizes trends in water quality at 178 sites along in Canadian rivers in southern Canada from 2002 to 2016. 81% of sites showed no change while 10% exhibited statistically significant improvement and 9% showed a statistically significant decline.

Figure 3.5: Changes in the Water Quality Index, Canada, 2002–2016

Note: The trend in water quality between the first year that data were reported for each site and 2016 was calculated at 178 sites across southern Canada. A uniform set of water quality guidelines and parameters were used through time at each site for the trend analysis. A Mann-Kendall test was used to assess whether there was a statistically significant increasing or decreasing trend in the annual guideline deviation ratios at a site. Percentages may not add up to 100 because of rounding.

Source: Environment Canada, 2018b.

Toxic substances in fish and water

Environment and Climate Change Canada has also been monitoring and analyzing concentrations of particular toxic substances in fish tissue and sediment of different drainage areas across Canada. As Polybrominated diphenyl ethers (PBDEs), persistent organic pollutants used as additive flame retardants, are an area of concern for wildlife,

Environment and Climate Change Canada examines PBDE concentrations in fish and sediment against the Federal Environmental Quality Guidelines. [5] Between 2013 and 2015, Environment Canada sampled fish in 10 drainage regions and reported on the occurrence of PBDE concentrations above or below the federal guidelines in fish tissue (ECCC, 2016e, 2018f). Specifically, Environment Canada searched for the four subgroups of PBDEs for which federal guidelines have been set: triBDE, tetraBDE, pentaBDE, and hexaBDE.

No samples surpassed guidelines for triBDE or hexaBDE in any of the drainage regions. TetraBDE concentrations were below the guidelines for all sampled drainage regions but one in the Great Lakes region. Eight out of 10 regions—namely, the Columbia, Yukon, Peace-Athabasca, Assiniboine-Red, Lower-Saskatchewan-Nelson, Churchill, Great Lakes, and St. Lawrence drainage regions—were found to have pentaBDE concentrations higher than the prescribed guidelines. The Lower Mackenzie and Maritime Coastal drainage regions were all in compliance with those same guidelines. Compared to 2011/12 samples, compliance with the tetraBDE guideline in the Great Lakes drainage region and compliance with the pentaBDE guideline in the Lower-Saskatchewan-Nelson drainage region have deteriorated. However, in the case of the Lower-Saskatchewan-Nelson drainage region, the observed changes were very small and could be attributed to changes in exposure and take-up, and not necessarily increased to pentaBDE levels.

Environment Canada has also measured PBDE trends in fish in Lake Ontario. Between 1997 and 2015, the PBDE concentrations were found to be declining by 4% per year, on average. Despite this decline, the concentrations were still above the prescribed guideline in the most recent years of monitoring. [6]

Between from 2007 and 2016, Environment Canada also conducted sediment sampling in 10 drainage regions to analyze concentrations of six subgroups of PBDE. For subgroups triBDE, hexaBDE, and octaBDE all samples were in compliance with the guidelines. Only the Great Lakes region had tetraBDE concentrations above the guidelines. Six drainage areas out of 10—namely, Pacific Coastal, Okanagan-Similkameen, Lower Saskatchewan-Nelson, Great Lakes, St. Lawrence, and Maritime Coastal drainage regions—were found to have pentaBDE concentrations higher than their prescribed guidelines. Great Lakes, Pacific Coastal, and St. Lawrence also exhibited decaBDE concentrations above the guidelines.

Environment Canada has also measured PBDE trends in sediment in Lake St. Pierre, part of St. Lawrence drainage region. Sediments collected between 2003 and 2013 in this region showed a 59% decrease in pentaBDE concentrations. Despite this declining

[5] The Federal Environmental Quality Guidelines are numerical results established under Chemical Management Plan to protect aquatic life (Environment and Climate Change Canada, 2018f).

[6] Determining PBDE trends in other Canadian regions is currently impossible because there is insufficient data.

trend, which is only expected to continue as a result of domestic and international risk management for PDBEs, pentaBDE concentrations were found to be still exceeding the guidelines in recent years (ECCC, 2018f). [7]

Environment and Climate Change Canada (2016f) sampled concentrations of Perfluorooctane sulfonate (PFOS) in fish tissue in 11 drainage regions across Canada between 2011 and 2014. PFOS is of ecological concern because of its bioaccumulation, toxicity, and persistence. The analysis indicated that the PFOS concentrations in all sampled drainage regions were in compliance with the Guidelines for fish health/tissue. However, PFOS levels in some samples exceeded the Wildlife Diet Guidelines developed for the protection of mammals and birds that eat the fish. This suggests the PFOS compound could threaten predators higher in the food chain. Specifically, between 2011 and 2014, four regions showed no concentrations above the prescribed Wildlife Diet Guidelines: the Peace-Athabasca, Lower Mackenzie, Churchill, and Saint John-St. Croix drainage regions. The remaining seven—Columbia, Yukon, Assiniboine-Red, Winnipeg, Great Lakes, St. Lawrence, and Maritime Coastal drainage regions—all had at least one exceedance of Wildlife Diet Guidelines. These results are similar to those of previous sampling between 2006 and 2010.

PFOS samples were taken from fish in Lake Ontario for the period from 1979 to 2014, allowing for some analysis of multi-decadal trends. Levels increased from 1979 to 2000 but have since stabilized and shown moderate declines. While the levels in Lake Ontario were found to be consistently below the Guidelines for fish tissue in all collection years, the levels were consistently above the Guidelines for wildlife diet. Samples were also taken directly from the water in the Pacific Coastal, Okanagan-Similkameen, Assiniboine-Red, Great Lakes, St. Lawrence, St. John-St. Croix, Maritime Coastal and Newfoundland-Labrador drainage regions to analyze PFOS concentrations. Between 2011 and March 2016, none of these samples exceeded Guidelines for water quality with all samples having concentrations at least 50-fold lower than the recommended levels for PFOS concentrations.

Bacterial contamination in shellfish

Under the Canadian Shellfish Sanitation Program (CSSP), Environment Canada conducts bacterial testing of waters in shellfish growing areas in order to ensure shellfish safety for human consumption and to identify potential sources of pollution. Shellfish (oysters, clams, mussels, scallops, etc.) feed by filtering the water washing over them. This makes

[7] Overall, the use of PBDEs is declining in Canada as these chemical substances have either been subjected to prohibition or have been voluntarily phased out by manufacturers. Despite reduced use of these toxic chemicals in Canada, the PDBEs still remain in the environment as a result of their widespread use in the past and slow break down following release, long-range dispersal of PBDEs into Canada from outside the country, and PBDE's presence in certain products (ECCC, 2018f).

them vulnerable to bioaccumulation of chemicals, toxins, and bacteria entering their ecosystems. Animal and human wastes contain bacteria that enter shellfish growing areas through several pollution sources, such as poorly maintained septic systems, municipal wastewater treatment plants, and run-off from agricultural areas (ECCC, 2018h).

The CSSP currently uses the concentration of fecal coliform in the waters as a primary indicator of shellfish safety. They use five main categories of classification for shellfish harvest areas. *Approved* areas are not contaminated with fecal material, pathogenic micro-organisms and poisonous substances that would be harmful to shellfish populations. *Conditionally approved* areas meet approved classifications but depart under conditions that are easily predictable, controllable, and/or identifiable. In other words, these areas are subject to intermittent pollution as a result of discharges and releases from wastewater treatment, seasonal populations, boating activity, or nonpoint-source pollution. *Restricted* areas are contaminated with at least some of the harmful substances. *Conditionally restricted* areas meet the same criteria as restricted areas but may depart under conditions that are easily predictable, controllable, and/or identifiable. *Prohibited* areas are usually in the immediate vicinity of point-source discharges of pollutants (ECCC, 2014). The proportion of harvest area open partially indicates the quality of marine coastal water.

The latest report from Environment and Climate Change Canada on shellfish growing areas in Canada in 2017 indicates that 68% were either approved or conditionally approved (ECCC, 2018h). On the Atlantic coast, 63% of shellfish growing areas were approved or conditionally approved in 2017, compared to 69% of the Pacific coast and 74% of the Quebec coast over the same period. Overall, as reported by Environment Canada, the Quebec area open to harvest is slowly declining over time whereas areas along the Atlantic and Pacific coasts it appears to have been relatively stable since 2012.

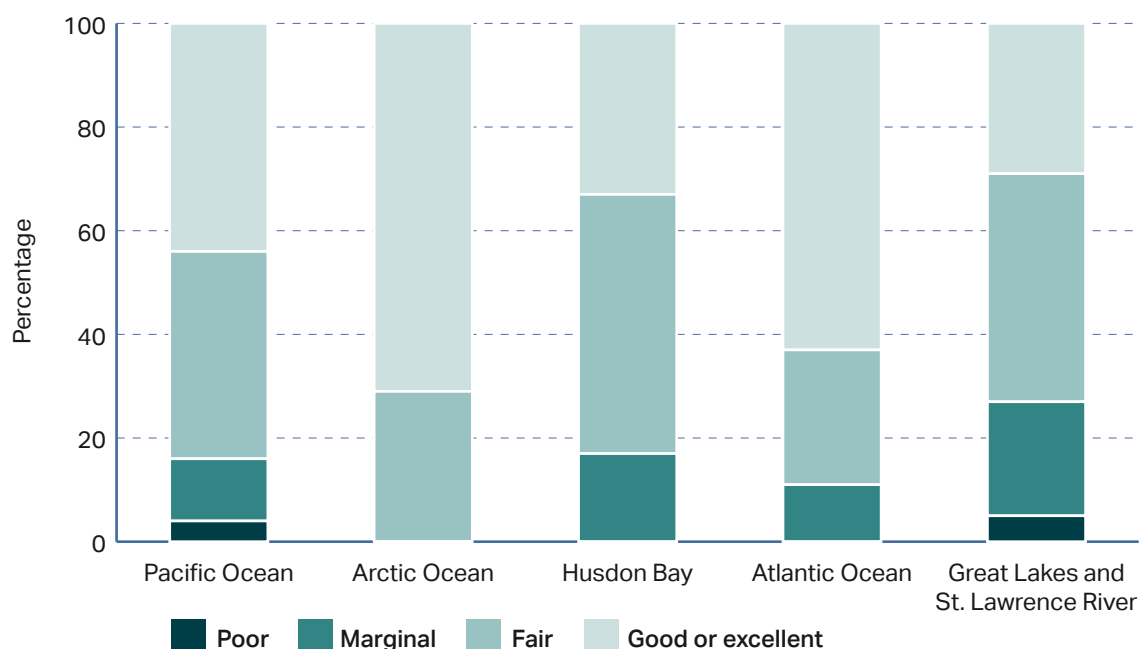
Regional water quality

Water often flows across provincial and international borders. Therefore, water quality assessments in Canada are divided by the country's major river and ocean watersheds: the Pacific Ocean, the Arctic Ocean, the Hudson Bay, the Atlantic Ocean, and the Great Lakes and St. Lawrence River (Environment Canada, 2017f). Each one covers a massive land area whose lakes, rivers, and ground water aquifers drain into a specific ocean.

Figure 3.6 shows the summary division of water quality data for these regions for the period of 2014 to 2016. As shown, water quality in the Atlantic Ocean, Hudson Bay, and Arctic Ocean are generally good. Poor and marginal water quality ratings are more frequent in the Great Lakes and St. Lawrence region than anywhere else in Canada.

Pacific Ocean watershed

The Pacific Ocean watershed is slightly larger than one million square kilometres and encompasses most of British Columbia and the Yukon along with major cities of Vancouver, Victoria, and Whitehouse. This watershed spreads from the border of the United States,

Figure 3.6: Regional water quality in Canada, 2014–2015

Source: ECCC, 2018b.

through British Columbia and Alberta, to the Yukon near the Mackenzie Delta. The largest rivers draining this region are the Fraser, Columbia, and Yukon (ECCC, 2017g). The landscape in this region varies significantly from large areas with little development to one of Canada's largest cities, Vancouver. About 16% of Canada's population lives within the vicinity of this watershed.

The CESI program assessed 25 monitoring sites in the Pacific Ocean region using the CCME Water Quality Index. Water quality in this region is generally good. From 2014 to 2016, of the 25 monitoring sites draining into the Pacific Ocean, 4% (one site) had poor water quality; 12% (three sites) had marginal water quality; 40% (10 sites) had fair water quality; and 44% had good (eight sites) or excellent (three sites) water quality. Sites with poor water quality tended to be near mining operations. Excellent or good water quality was reported more often in undeveloped rural areas (ECCC, 2018b).

Between the first year of data [8] and 2016, as reported by Environment Canada (2018b), water quality in six rivers in British Columbia—namely, the Cheakamus, Thompson, Skeena, Kootenay, Kettle, and Columbia Rivers—improved. Four stations on the Fraser River (Quinsam River, Elk River, Red Pass, and Marguerite) reported declining water quality over the same period. Water quality at the remaining 15 stations in

[8] The year in which sampling started at monitoring stations varies. Specifically, 2002 was the first year of sampling for 73 sites, 2003 for 54 sites, 2004 for 12 sites, 2005 for seven sites, 2006 for 29 sites, and 2007 for three sites (ECCC, 2018).

this region did not change. A 2009 report on water quality in the Quinsam River, using the CCME WQI, found it to range from fair to good between 2001 and 2006 (Strachan, Ryan, McDermott, and MacKinlay, 2009).

Arctic Ocean watershed

The Arctic Ocean watershed is 3.5 million square kilometres, draining most of Alberta and Northwest Territories and Nunavut, including the Arctic, part of Yukon, and northern British Columbia, and Saskatchewan (ECCC, 2017h). The major cities are Fort McMurray and Yellowknife and the longest waterways in this watershed are the Mackenzie River, Peace River, Athabasca River, and Liard River. The Peace and Athabasca Rivers—the two largest tributaries of the Mackenzie River Watershed—drain much of north-central Alberta and the Rocky Mountains in northern British Columbia. Four hundred and fifty thousand people live in the watershed with the majority living in the southern portions of the area.

The CESI program rated 21 monitoring sites around the Mackenzie River watershed using the CCME Quality Index. This is the largest river watershed in Canada, covering approximately 20% of the country, and is also one of the least developed areas of the country. The Mackenzie River region consists of significant amount of undeveloped area and its water quality is generally very good. No monitoring sites reported poor or marginal water quality. Seventy-one percent were rated good (11 sites) or excellent (four sites) while 29% were fair (six sites). Between the first year of data collection and 2016, water quality in this region did not change.

The heaviest land use in the Arctic watershed is in central Alberta where the Athabasca River, and its major tributaries, run through large deposits of bituminous oil sands. In 2012, the federal government, in collaboration with the Government of Alberta, launched an integrated water monitoring program to assess the impact of oil-sands contaminants. Water quality data from 2011 to 2015 for the lower Athabasca River, and for 17 stations in and around the Peace-Athabasca delta were collected and examined against 39 federal and provincial water-quality guidelines (ECCC, 2018c). The results show that there was no exceedance in any of the 1,300 samples for 19 of the parameters (pH, two nitrogen nutrients, five total metals, methylmercury, alkalinity, and nine organic substances). Of the remaining 20 parameters, the majority of exceedances were associated with metals. Given that these waters are known for having high concentrations of naturally occurring iron, the observed high concentrations and exceedances of metals were not surprising (ECCC, 2018c). Overall, total iron, aluminum, and copper had the highest exceedance rates in this area, meaning that their concentrations most frequently exceeded the guidelines. These high metal concentrations and the percentage of samples with exceedances were found to be consistent with historical data since the early 1990s (ECCC, 2018c).

Some exceedances for total mercury, cadmium, selenium, benzo(a) pyrene, and phenol were also observed, but they were less frequent. Specifically, the percentage of samples with exceeding values for mercury was less than 6% while the percentage of samples with exceeding values for cadmium, selenium, benzo[a] pyrene, and phenol was between 1% and 3%.

Hudson Bay Watershed

Entire watershed

The Hudson Bay watershed is the largest ocean catchment region in Canada at 3.8 million square kilometres. It extends over five provinces from Alberta to Quebec, as well as over the Northwest Territories and Nunavut. The major cities located in this region are Edmonton, Calgary, Saskatoon, Winnipeg, and Regina. The Nelson, Saskatchewan and Churchill Rivers located in Manitoba as well as Lake Winnipeg, Lake Manitoba, and Lake of the Woods are the major streams (ECCC, 2017i).

The CESI program assessed water quality for 46 monitoring sites draining into Hudson Bay for the 2014 to 2016 period using the CCME Water Quality Index. No sites were of poor quality, 17% were of marginal quality (eight sites) and 50% were of fair quality (23 sites). Water quality at 33% of the sites was rated excellent (three sites) or good (12 sites) (ECCC, 2018a). These stations with good or excellent water quality are mostly located in rivers north of Lake Winnipeg or close to the Rocky Mountains. Marginal water quality was found more frequently at stations surrounded with agriculture or mixed land use pressures (a combination of agriculture and/or mining with cities).

Over the sampling period, water quality showed improvement on the following seven rivers: North Saskatchewan, Bow, and Elbow in Alberta; South Saskatchewan and North Saskatchewan in Saskatchewan; and Cooks Creek and Pembina in Manitoba. As reported by Environment Canada (2018b), the land use in these improved monitoring sites were either agricultural alone or a mix of agriculture and mining. Water quality showed deterioration on two sites in Saskatchewan that are surrounded by agriculture: the Carrot and Assiniboine Rivers. The remaining 37 sites experienced no change in their water quality over the same period.

The Canadian prairies (comprising the provinces of Alberta, Saskatchewan, and Manitoba) are the most altered landscapes in Canada due to intensive agriculture and mining activities. In particular, almost all of the land in the prairies is covered by agriculture. Mining operations, especially the production of potash and fuels, are also another major industry in this region.

Lake Winnipeg

Lake Winnipeg is Canada's sixth-largest freshwater lake, generating hydroelectric power for all of Manitoba. As of 2016, phosphorus and nitrogen levels in Lake Winnipeg's south basin were rated poor (ECCC, 2018d). The highest levels of phosphorous and nitrogen

in the south basin occurred near the inflow from the Red River. However, the nutrient levels declined as the water moved north in the lake. In fact, in the north basin, the status of both phosphorous and nitrogen levels were good since the levels were at or below the objectives.

According to the same report, Lake Winnipeg's water quality has been deteriorating for many years. Excess phosphorus and nitrogen have been entering the lake through agricultural run-off, municipal and industrial wastewaters, air pollution, losses of wetlands, and other land developments. The excess nutrients have been contributing to algal blooms, harming the lake's ecosystem and threatening the fishery. Projects supported through the Lake Winnipeg Basin Stewardship Fund between 2010 and 2017 prevented an estimated 110,700 kilograms of phosphorous from reaching Lake Winnipeg (ECCC, 2016c).

The report also examined the status of phosphorus and nitrogen levels in the three largest tributary rivers—namely, the Winnipeg, Red, and Saskatchewan Rivers—for the period from 2014 to 2016. In the Saskatchewan River, phosphorous was rated fair because high levels were only found intermittently (between 10% and 50% of samples exceeded the objectives). However, the status of nitrogen was good as high levels were rarely detected in the river (less than 10% of the time). In the Red and Winnipeg Rivers, the status of both nitrogen and phosphorus were poor as the levels were above their respective objectives in over 50% of samples.

The report also assessed phosphorus and nitrogen levels in Lake Winnipeg's north and south basin, as well as its three tributary rivers between 1999 and 2016. It concluded that both phosphorous and nitrogen levels varied over the period but no trend was detected in any of the sites. This may be attributable to some of the Lake Winnipeg Basin Stewardship Fund projects.

Nelson River watershed

The Nelson River watershed is within the larger Hudson Bay watershed and is the second largest basin in Canada by population. This territory includes 70% of dedicated agricultural land in Canada and contains several rivers including the Carrot, Assiniboine, and Red (ECCC, 2015b). The Prairies use more pesticides than any other region because of the vast expansion of cultivated land, so pesticide contamination is more of a concern in this area. In order to examine vulnerability to pesticide contamination, the main three rivers in this watershed were analyzed for various pesticides. Of the three rivers, the Red River showed the greatest number of frequently detected pesticides.

Specifically, between 2006 and 2011, water samples from the Carrot River station were tested for 47 pesticides: 17 were found (including Clopyralid, 2, 4-D, and MCPA) but of those, none surpassed water quality guidelines. Water samples from the Assiniboine River were tested for 46 pesticides and 19 were detected. The most prevalent was 2,4-D followed by Clopyralid and MCPA. Again the pesticide concentrations were all well below

CCME (Canadian Council of Ministers of the Environment) water-quality guidelines. Between 2006 and 2011, samples from the Red River station were analyzed for 47 pesticides and 20 were detected. Of the 20 pesticides detected, 2,4-D and Clopyralid were the two most prevalent. Again, all the concentration levels were found to be far below water-quality guidelines.

Rainy Lake of the Woods

According to a 2014 report by the International Joint Commission, Rainy Lake of the Woods water quality has improved substantially over the past few decades (International Joint Commission, 2014). Since the 1970s, many water-quality indicators in this region have begun to comply with guidelines prescribed by provincial and state governments. In Rainy River, total phosphorous loads have declined since the 1960s, and have been relatively stable in recent years. Changes in climate, however, have been linked to algal blooms in this region. Mercury has been an issue in this ecosystem. The major source was chloralkali manufacture, but all of Ontario's chloralkali plants have closed, resulting in a decline in atmospheric mercury, which has had a positive impact on water quality (International Joint Commission, 2014). PCBs do not pose any immediate threat in the Rainy Lake of the Woods basin. Pesticides and herbicides in the region were also below Canada water-quality guidelines, suggesting they are not a threat to this ecosystem. Mercury is the only major contaminant at present for which data exist. Very little is known about the prevalence of contaminants associated with pharmaceuticals in waste water in this region.

Atlantic Ocean watershed

The Atlantic Ocean watershed covers an area of 1.6 million square kilometres and spreads over eastern Canada. This region includes Nova Scotia, New Brunswick, Prince Edward Island, and Newfoundland & Labrador, as well as part of Quebec and Ontario. This watershed is dominated by the Great Lakes—namely, Lakes Superior, Huron, Erie, Michigan, and Ontario—and the St. Lawrence River.

Environment Canada (2018b), under the CESI program, split the Atlantic Ocean watershed into two regions. These are the Atlantic Ocean region, consisting of part of eastern Quebec, Newfoundland & Labrador, New Brunswick, Prince Edward Island, and Nova Scotia; and the Great Lakes and St. Lawrence River region, consisting of southern Ontario and southern Quebec. About 7% of Canada's population lives in the Atlantic Ocean region, the majority in New Brunswick, Nova Scotia, and on the island of Newfoundland. Mining is one of the major industries in this region.

Atlantic Ocean region

Water quality was assessed at 46 monitoring sites draining into the Atlantic Ocean from 2014 to 2016 using the CCME Water Quality Index. None of these sites had poor water quality, 11% were of marginal quality (five sites) and 26% were fair (12 sites). Water

quality at 63% of monitoring stations was excellent (two sites) or good (27 sites). As large areas in this region of Canada are underdeveloped, particularly in Labrador, water quality tends to be good or excellent in most sites in the Atlantic Ocean region.

Between the first year of data collection and 2016, there was improvement in the water quality on three sites located in Newfoundland & Labrador: Terra Nova River, Exploits River, and Gander River; and on two sites located in Nova Scotia: Roseway River and Mersey River. None of these sites had much development around them. Saint John River in New Brunswick, the Annapolis River in Nova Scotia, and Mill River in Prince Edward Island reported deteriorated water quality over the same period. Agriculture was the main pressure in these areas. The remaining 38 monitoring sites reported no change in water quality.

Great Lakes and St. Lawrence River region

The Great Lakes and St. Lawrence River region is home to almost 60% of Canadians and contains six of the country's 10 major cities: Toronto, Ottawa, Mississauga, Montreal, Brampton, and Hamilton. This region has 59 water-quality monitoring sites in which poor and marginal water-quality ratings are more likely to be found than anywhere else in Canada. Five percent of monitored water in this region was poor (three sites), 22% was marginal (13 sites), while 44% (26 sites) was fair. Water quality was rated excellent (two sites) or good (15 sites) at 29% of monitoring sites in this region. Urbanization and the impact of increasing population density are reflected in the diminished water quality at sites in this region.

Between the first year of data collection and 2016, no monitoring station recorded improved water quality in this region. Water quality in the following six stations in Ontario and one station in Quebec deteriorated over the same period: Credit River, Ganonogue River, Nottawasaga River, the North Raisin River, the Fall River, and the Delisle River in Ontario; and the Richelieu River in Quebec. All these monitoring sites faced pressures associated with agriculture or mixed use. The remaining 52 stations in this region experienced no change in water quality. Overall, water quality ranges from fair to poor in Southwestern Ontario and along the St. Lawrence River between Quebec City and Montreal, whereas it rates good or excellent in eastern Ontario.

The Great Lakes watershed

The Great Lakes region is one of the largest sources of freshwater in the world, containing almost 20% of world's surface freshwater. This basin is Canada's most populated region. In 1972, the Government of Canada signed the Great Lakes Water Quality Agreement (GLWQA) with the United States with the objective of restoring and protecting the water quality and aquatic ecosystem health of the waters in this area (Canada-United States Collaboration for Great Lakes Water Quality, n.d.). In 2017, the two governments released a report that examined the status and trends of the Great Lakes ecosystem

since 2011 using nine core indicators. Overall, the report assessed the Great Lakes as fair and unchanging (ECCC and US-EPA, 2017). Specifically, the report assessed the status of treated drinking water from the Great Lakes in both Canada and the United States as good and unchanging since 2011. The assessment of toxic chemicals, including Polychlorinated Biphenyls (PCBs), Polybrominated Diphenylethers (PBDEs), and mercury, revealed that levels have generally decreased over the past four decades. Contaminant levels in the Great Lakes whole fish and Herring Gull eggs revealed significant reductions compared to 1970s levels. Specifically, toxic chemicals in whole fish in Lake Ontario was found to have decreased from 2011 to 2017 while they remained unchanged in Lakes Huron, Erie, and Superior over the same period. Contaminants such as mercury and PCBs in edible portions of fish tissue were also found to have declined over time. Only Lake Erie exhibited a deteriorating trend for its contaminants in edible fish. Overall, the report assessed the status of toxic chemicals in the Great Lakes as fair and a trend of unchanging to improving since last reported in 2011.

The report also examined the status of nutrients and algae in the Great Lakes and assessed the status as fair and a trend of unchanging to deteriorating from 2011 to 2017. Many offshore regions in the Great Lakes have inadequate and below-desired levels of nutrients, which resulted in insufficient growth of phytoplankton species in the food chain. Lake Superior's results were unique as offshore phosphorous concentrations were found to be acceptable. In contrast, many nearshore areas were found to have excess nutrients. [9] Despite significant efforts since the 1972 GLWQA to reduce phosphorous levels, Lake Erie, parts of Lake Ontario, Saginaw Bay of Lake Huron, and Green Bay of Lake Michigan along with other nearshore areas still suffer from elevated nutrient levels. These have resulted in a resurgence of harmful algal blooms (HABs) in the western basin of Lake Erie and some parts of Lake Ontario, which is having an adverse impact on ecosystem health, drinking water, and commercial fishing. Overall, Lake Michigan, Lake Huron, Lake Erie, and Lake Ontario all were assessed as having a deteriorating trend for nutrients from 2011 to 2017, while Lake Superior was assessed as having an unchanging trend.

A related report by CESI likewise examined phosphorous levels in the offshore waters of Lake Superior, Lake Huron, Georgian Bay, Lake Ontario, and Lake Erie. From 1972 to 2013, offshore phosphorus levels declined in the Great Lakes examined. However, recent levels vary greatly from year to year and no longer show a declining trend (ECCC, 2018e). In Lake Superior, offshore phosphorus levels have declined since 1972 and have remained consistently below the water-quality objective over the 40-year period. As of

[9] Both too-high and too-low nutrient levels can have a harmful impact on the river. Overly elevated levels result in thriving aquatic plant growth and thereby excessive blooms whereas extremely low levels result in insufficient growth of key phytoplankton species that form the base of the food chain (ECCC and US-EPA, 2017).

2013, Lake Superior's phosphorous level was good (at or near objective). In Georgian Bay and Lake Huron's offshore waters, phosphorus levels were near their objectives for about 20 years until, in the 1990s, they started to decline. Lake Ontario's offshore waters started to see declines in phosphorus in the 1980s and that trend has continued to historic low levels in 2013. The phosphorous status of these three systems has been classified as fair because their phosphorous levels are too low, with risks to open-water plankton, prey fish, and algae populations. Lake Erie's phosphorous levels were found to be too high despite declining trends over the 1973 to 2013 period, resulting in a poor status. Furthermore, recent levels no longer show a declining trend. The increase in toxic and nuisance algae in Lake Erie in recent years is likely linked to the observed high phosphorous levels in this area (ECCC, 2018e). [10]

Table 1 summarizes the findings of this report, showing the status of the offshore waters of the Canadian Great Lakes coupled with their long-term trends from 1972 to 2013. As shown, in three out of the four Canadian Great Lakes, phosphorous levels have remained an issue.

Environment and Climate Change Canada's Water Quality Monitoring and Surveillance program has assessed the presence of various toxic substances and their levels in the Great Lakes area. Based on analysis of data collected over the past 35 years on fish contamination in Lake Erie, it was observed that mercury levels in this lake were being reduced in the 1970s. However, that trend reversed in the 1990s. Most species included in the study, including White Bass, Yellow Perch, and Walleye, saw their mercury concentration begin increasing or stop decreasing (ECCC, 2017j).

Another study by American Chemical Society in 2014 analyzed the Great Lakes for its concentration of emerging compounds, such as flame retardants (Venier, Dove, Romanak, Backus, and Hites, 2014). Water samples from 18 stations across the five Great Lakes were collected in 2011 and 2012 and analyzed for PCBs, PHAs, organochlorine pesticides (OCPs), and emerging flame retardants, including organophosphate flame retardants (OPEs). PCBs were found in their highest total concentrations throughout the Great Lakes in Lake Ontario. Lake Erie also had high total concentrations of PCBs. Lake Huron had less and Lake Superior had the lowest PCB concentration. This pattern was also found for the PHAs concentration.

For organochlorine pesticides (OCPs), the results are mixed as some varieties of pesticides were more prevalent in each of the lakes. Lake Superior is particularly

[10] Environment Canada has categorized phosphorus levels as *Poor*, *Fair*, or *Good*. *Fair* means that phosphorus levels are below objective; *Poor* means that phosphorous levels are above the objective; and *Good* means that levels are at or near the objective: "Water quality in the offshore regions of a lake is considered good when it can support a healthy food web. Lakes where phosphorus levels are below objectives, and negative impacts to the offshore food web have been observed, are given a classification of fair. Where phosphorus levels are above a lake's phosphorus objectives, lakes are classified as poor" (ECCC, 2018e).

Table 1: Status and trends of phosphorous levels in the offshore waters of the Canadian Great Lakes

Lake	Status for offshore waters	Long-term trend (1972 to 2013)
Superior	Good	No trend
Huron	Fair	Decreasing
Georgian Bay	Fair	Decreasing
Ontario	Fair	Decreasing
Erie	Poor	Decreasing

Source: ECCC, 2018e.

vulnerable to OCPs because of its cold temperatures, large surface area, and long retention time. The highest concentrations of brominated flame retardants (BFRs), including PBDEs, an emergent contaminant, were found in Lake Ontario and Lake Erie. The other lakes were statistically indistinguishable from each other with regard to the presence of PBDEs. Organophosphate ester flame retardants (OPEs) were found in their highest concentrations in Lake Erie, but OPE data were not available for Lake Ontario and Lake Superior.

Overall, as measured and reported by the CESI program, water quality in Canada's Great Lakes Areas of Concern has improved since the implementation of the restoration program in 1987 (ECCC, 2017k). The CESI program classifies regions as Areas of Concern based on their use, and based on whether they are experiencing a high level of environmental damage from human activity. In 1987, 43 Areas of Concern around the Great Lakes were identified, of which 12 were entirely in Canadian waters and five areas were shared. Out of the 12 in Canada, three have been completely restored: Collingwood Harbour was fully restored in 1994, Severn Sound in 2003, and Wheatley Harbour in 2010. In addition, two of the Canadian Areas of Concern have been designated as Area of Concern in Recovery, meaning that all restoration actions have been completed in these areas and more time is required for natural recovery.

Surface waters of Ontario

A 2016 report on Ontario surface waters (Struger, Grabuski, Cagampan, Sverko, and Marvin, 2016) used sampling over the period from 2007 to 2010 to measure the occurrence of pesticides including carbaryl, matalaxyl, and pirimicarb. It found that over 50% of samples taken in 2008 contained these chemicals. Carbaryl is currently the second-most heavily used agricultural insecticide. It was detected in 64% of samples but exceeded the Canadian Water Quality Guideline for the protection of aquatic life in only 8% (23 samples). The detection rate declined in 2009 and 2010, which may have been a result of a provincial ban on the sale and use of pesticides for cosmetic purposes (Todd and Struger, 2014). Matalaxyl had a detection frequency of 75% and the frequency increased in the first three years of the study from 2007 to 2009.

Aldicarb, which was withdrawn from Canadian markets in 1996, and American markets in 2017 was not detected by this study. Carbofuran, which was scheduled for phase-out in Canada by 2012, was detected in 15% of samples (39 samples out of 272) over the course of study. However, in the last year of sampling, it was detected in only one sample. The carbofuran concentration in this study never exceeded the Canadian Water Quality Guideline.

St. Lawrence River

The St. Lawrence River connects the Great Lakes with the Atlantic Ocean and is one of Canada's most important commercial waterways. In 2016, a report by Environment Canada in collaboration with the Quebec government examined water quality in the fluvial section of the St. Lawrence River using five chemical and bacteriological parameters: total phosphorous, ammonia nitrogen, fecal coliforms, nitrates/nitrites, and chlorophyll a (Hébert, 2016). Overall, the status of the river for the period from 2012 to 2014 was rated intermediate to good, with majority of the monitoring sites (52%) showing good water quality. The report also examined changes in water quality from 2000 to 2014 and found no significant trend in the percentage of stations with good or fair water quality over time. The percentage of sites with poor water quality fell from 13% on average from 2000 to 2007 to 8% on average from 2008 to 2014.

The CESI program released a report in 2016 where it examined the status of nutrient levels in the St. Lawrence River, based on whether total concentrations exceed Quebec's water quality guidelines (ECCC, 2016d). According to the report, phosphorus and nitrogen levels were found to be above water-quality guidelines over 50% of the time at most monitoring stations for the 2012-to-2014 period. Stations close to agricultural areas along the south shore of the river between Becancour and Richelieu were found to have the highest levels of nutrients.

Trend assessment for phosphorous is possible at only two monitoring stations (Quebec City and Carillon, upstream of Montreal) because they have data going back to 2005. The data reveal a decline at Carillon and no trend at Quebec City. Available data suggests that phosphorous levels have slowly decreased at the Saint-François station but not at any other stations. None of the stations had enough nitrogen data to perform trend analysis. However, available data suggests that nitrogen levels declined at the Richelieu, Nicolet, and Yamaska stations and did not change at any of the remaining stations along the river.

Another report by Environment and Climate Change Canada concluded that eutrophication, [11] a phenomenon caused by excessive contributions of nutrients, is

[11] Some symptoms of eutrophication in aquatic system are: reduced dissolved oxygen levels, appearance of toxic aquatic flower, mass mortality of fish and shellfish, and disappearance of submergent vegetation (ECCC, 2017l).

likely to occur in Lake Saint-Pierre, as this lake's three major tributaries (the Yamaska, Saint-François, and Nicolet Rivers) drain agricultural regions (ECCC, 2017l). Out of the three, and between 2005 and 2014, the Yamaska River had the highest concentrations of phosphorous—most (67%) was estimated to come from farmland—, which resulted in hypereutrophic conditions in this river. The concentrations at the Yamaska River are still high despite the fact that the quantity of phosphorous exported to the mouth of this river has declined from 646 tonnes per year in 1994 to approximately 329 tonnes per year between 2001 and 2003 (ECCC, 2017l; Berryman, 2008). The mouths of the Saint-François and Nicolet Rivers also had high-enough phosphorus levels to result in eutrophic conditions.

Another recent report, in 2015, examined the water quality of the Richelieu and Yamaska Rivers, which are among the most significant tributaries of the St. Lawrence River (Laliberté, 2015). Between 2001 and 2013, various samples from the two rivers were collected to determine PCB and PAH concentrations in water. The concentrations were next used for an analysis of the temporal evolution of the levels of the contaminants between the periods from 2001 to 2003 and 2004 to 2013. Findings pertaining to both rivers show that average PCB concentrations (adjusted for level of turbidity) were not significantly different from one period to the next. However, during both periods, median concentrations of PCBs exceeded the water-quality guideline. The same pattern exists with respect to the total PAH concentrations in both rivers. It should be noted that PAH concentrations could not be compared against the water-quality criteria as no criterion was available.

PBDEs have been found in the St. Lawrence River, but only in small quantities. Recent analytical results show that concentrations of PBDEs in the St. Lawrence River clearly decreased between 2007 and 2016, likely as a result of the regulations imposed on these products (Rondeau, 2017).

Another recent report assessed toxic contamination—including by mercury, PCBs, and PBDEs—of freshwater fish in St. Lawrence River (Laliberté, 2016). The report found a sharp declining trend in contamination, especially for mercury and PCB levels since the 1970s. Over the period from 2010 to 2014, only one station in Lac Saint-Louis had mercury levels out of compliance with the guideline for mercury and only one station near Montreal and in Lac Saint-Pierre exceeded the guideline for PCBs.

Also of some concern in the St. Lawrence River is the presence of pharmaceutical and personal care products (PPCPs), such as shampoo and toothpaste, or hydrating creams for skin. A 2014 report investigated the presence of PPCPs, hormones such as estrogen and testosterone, and a few other emerging contaminants in the river (Berryman, 2014). As indicated, chemicals known as “endocrine disruptors” that can act as hormones and are found in various materials including personal care products, pesticides, and metals, may be the cause of fish and mussels feminizing in the St. Lawrence River downstream of Montreal. The report searched for 44 substances based on data collected from

11 sites in the St. Lawrence River and one site at the mouth of the Ottawa, Richelieu, and Saint-Maurice Rivers. Twenty-one substances were found in amounts greater than the detection limit, including four analgesics/anti-inflammatories, five antibiotics, five hormones, and cholesterol. However, the concentrations were lower than levels with a toxic effect. In general, frequency and concentrations of detected substances were higher downstream of this region, which is close to the Montreal, Quebec City, and Trois-Rivières urban areas.

With respect to analgesics and anti-inflammatories, acetaminophen (found in Tylenol®) was the most common substance followed by ibuprofen (found in Advil® and Motrin®), naxopren (found in Anaprox®) and salicylic acid (found in Aspirin®). The frequent detection of acetaminophen and salicylic acid in the St. Lawrence and its tributaries is not surprising as these two products are among the most widely-sold pharmaceutical products through prescription in Canada and also can be purchased over the counter. Out of 15 antibiotics examined, five were detected to exceed the guidelines but they were found only in a few samples. Like antibiotics, hormones were also found in only a few samples, specifically in zero percent to 8% of the samples. Cholesterol, which is a fat found in all animals, was detected at all sampling sites, with slightly larger concentrations downstream of Montreal. Caffeine, which is a component of certain medications, was present in 80% of samples. Concentrations of caffeine were higher downstream of Montreal but no concentrations surpassed guidelines. Overall, acetaminophen, cholesterol, and caffeine were detected more frequently and in higher concentrations than all other substances in this river.

Conclusion

Overall, there is no shortage of freshwater in Canada as a whole. Despite concerns about water usage and the unequal distribution of freshwater across the country, freshwater resources in Canada are abundant and Canadians consume only small fraction of the water supply. Therefore, there is no reason to believe freshwater shortages will occur in the short term.

Water quality in Canada varies from region to region depending on natural factors and human activities. It is clear that water quality differs considerably across the country and this makes it difficult to make broad conclusions about national water quality. However, most indicators used in this study seem to suggest stability or modest improvements in Canada's freshwater over the past few years. Most of the major sources of water pollution in Canada have been acknowledged and progress has been made to reduce the amount of pollution that enters Canada's waterways. In general, the results show that Canada's waterways are well-protected.

In some regards, water quality has improved in Canada over time. The assessment of toxic chemicals, including mercury and PBDEs, in the Great Lakes reveals that the concentrations have generally decreased over the past four decades. Another example of improving water quality is the sharp declining trend in contamination of freshwater fish in the St. Lawrence River since 1970s.

Despite such improvements, there continue to be concerns about water quality that require attention and action. Though concentrations of PBDEs have generally decreased, some indicators suggest that levels of PBDEs are still above the prescribed guidelines in the Great Lakes, Pacific Coastal, and St. Lawrence River regions. Nutrient levels in Lake Winnipeg's south basin were excessive in recent years, especially near the inflow from the Red River. In addition, excessive concentrations of nutrients in Lake Erie and some near shores of Lakes Ontario and Huron have caused a resurgence of harmful algal blooms in these areas. This study's analysis also reveals that mercury concentrations in fish in Lake Erie have stopped decreasing or started increasing in recent years. In addition, excessive nutrient concentrations are still problematic in the St. Lawrence River and its major tributaries. For these reasons, improved and continued monitoring of water quality in Canada is still needed despite the overall stability of the quality of fresh water in recent years.

Appendix A: The CCME's Water Quality Index

The Canadian Council of Ministers of the Environment (CCME) developed the Water Quality Index (WQI) with a goal of summarizing complex water data and facilitating its communication to the general public (CCME, 2017). The WQI assesses the data of water-quality parameters with specified guidelines for those parameters. The calculations of the index values examine the observed parameters with regard to three attributes of water-quality objectives: scope, frequency, and amplitude. *Scope* refers to the percentage of water-quality parameters that failed to comply with guidelines. *Frequency* refers to the percentage of tests that failed to comply with guidelines. *Amplitude* refers to the amount by which failed test values deviated from guidelines. The WQI calculations produce a WQI score for an individual monitoring station on a scale of 0 to 100.

There are five bins that the WQI score can fall into ([table A.1](#)). *Excellent* (95–100) scores mean water quality is protected with an absence of any threat or impairment. *Good* (80–94) scores mean there are only minor threats or impairments to water quality. *Fair* (65–79) scores mean water quality is usually protected but is occasionally threatened or impaired. *Marginal* (45–64) scores mean water quality is frequently threatened or impaired. And finally, *poor* (0–44) scores mean water quality is almost always threatened or impaired.

The specific parameters, time period, and guidelines used in developing the WQI values may vary from one location to another, depending on water-quality issues, local conditions, and purpose of the use of index (CCME, 2017). Therefore comparisons of water quality among sites should be interpreted carefully.

Table A1 : 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.

Appendix B: Classifications of the Water Quality Index by Canadian Provinces and Territories

Figure B.1 shows classification of the Water Quality Index (WQI) by Canadian provinces and territories from 2014 to 2016. As shown, the monitoring stations with poor water quality status are only located in three provinces (Quebec, British Columbia, and Ontario).

Quebec

Quebec is Canada's second most-populated province, with much of its population residing around the St. Lawrence River and its tributaries (Wood, 2013). Out of 34 stations in Quebec that were assessed and rated using the WQI, 6% of stations were rated as poor, 29% rated as marginal, 50% rated as fair, 15% rated as good, and none rated as excellent.

British Columbia

British Columbia is Canada's third largest province by population. British Columbia's water quality ranges between poor and excellent based on the WQI calculated by Environment Canada. Out of 22 stations, 5% were rated as poor, 9% rated as marginal, 41% rated as fair, 36% rated as good, and 9% rated as excellent. The Salmon River is the only river classified as having poor water quality in British Columbia.

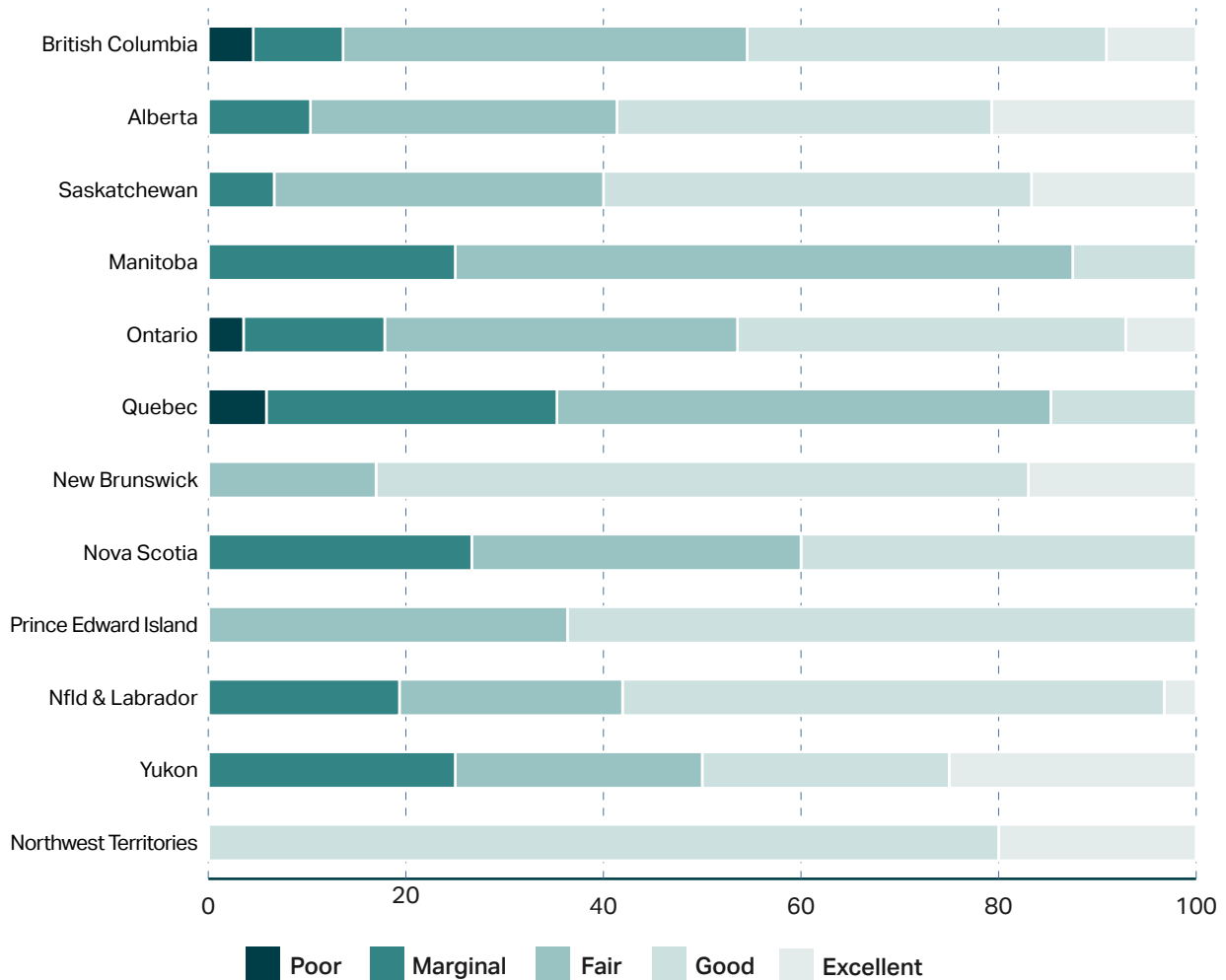
Ontario

In Ontario, which is Canada's most populous province, 28 stations were examined and rated using the WQI. Four percent of stations were found to have poor water quality, 14% had marginal, 36% had fair, 39% had good, and 7% had excellent. The Don is the only river classified as having poor water quality in Ontario.

Alberta

Alberta is Canada's fourth largest province by population. Environment Canada examined 29 stations across the province using the WQI and rated 10% as marginal, 31% as fair, 38% as good, and 21% as excellent. In other words, more than half of the stations in Alberta exhibited good or excellent water quality from 2014 to 2016.

Figure B.1: Classifications on the Water Quality Index, Canadian provinces and territories, 2014–2016



Source: Environment Canada, 2018b.

Saskatchewan

In Saskatchewan, the WQI data suggests that out of 30 stations, 7% were classified as marginal, 33% classified as fair, 43% classified as good, and 17% classified as excellent. Again, more than half of the stations across the province exhibited good or excellent water quality.

Manitoba

Manitoba's water quality ranges between marginal and good based on the WQI calculated by Environment Canada (2018b). Out of 24 stations, 25% were classified as marginal, 63% classified as fair, and 13% classified as good.

New Brunswick

According to the Water Quality Index calculated by Environment Canada (2018b), New Brunswick has clean surface water. Out of 53 stations, 17% were classified as fair, 66% as good and 17 as excellent.

Nova Scotia

The Water Quality Index calculations suggest that most rivers in Nova Scotia currently (2014–2016) have good or fair water quality. Out of 15 stations, 27% had marginal water quality, 33% had fair and 40% had good water quality. No stations were rated as excellent in this province over the same period.

Prince Edward Island

Prince Edward Island is Canada's smallest province by population and land area. Out of 11 stations, 36% were rated as fair and the remaining 64% were rated as good.

Newfoundland & Labrador

The Water Quality Index calculated by Environment Canada (2013a) suggests that, out of 62 stations, almost half of the monitoring sites in the province of Newfoundland & Labrador are classified as good (55%) or excellent (3%). Nineteen percent were rated as marginal and 23% rated as fair.

Northwest Territories

Water quality in Northwest Territories is particularly noteworthy as 80% of stations (eight out of 10) were rated as good and 20% rated as excellent.

Yukon

In Yukon, out of four stations, 25% rated as marginal, 25% rated as fair, 25% as good, and 25% as excellent.

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Acknowledgments

The authors would like to thank Mark O'Brien who helped write the initial draft of this report while he was an intern at the Fraser Institute during the summer of 2017. They would also like to acknowledge the helpful comments and insights of several anonymous reviewers. The authors, however, are alone responsible for the report itself, its conclusions, and recommendations. As the researchers have worked independently, the views and conclusions expressed in this paper do not necessarily reflect those of the Board of Directors of the Fraser Institute, the staff, or supporters.

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Date of issue

2018

ISBN

978-0-88975-526-0

Citation

Ross McKittrick, Elmira Aliakbari, and Ashley Stedman (2018). *Evaluating the State of Fresh Water in Canada*. Fraser Institute. <<http://www.fraserinstitute.org>>.

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