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Canadian Environmental Sustainability Indicators 2006

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Canadian Environmental Sustainability Indicators 2006

Environment Canada
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Health Canada

Executive summary

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

The following are the three main components of the Canadian Environmental Sustainability Indicators (CESI):

Air quality: The national air quality indicators in this report focus on human exposure to ground-level ozone and fine particulate matter ($PM_{2.5}$), both key components of smog. Human exposure to ground-level ozone and $PM_{2.5}$ is of concern because there are no established thresholds below which these pollutants are safe and do not pose a risk to human health.

At the national level, from 1990 to 2004, the ozone indicator showed year-to-year variability, with an average increase of 0.9% per year. Stations in southern Ontario reported the highest levels in the country in 2004 and the most rapid increase since 1990. From 2000 to 2004, the highest levels of $PM_{2.5}$ were also reported in southern Ontario, with areas in southern Quebec/eastern Ontario also showing high levels. There was no discernible upward or downward trend in $PM_{2.5}$ levels at the national level for the 2000 to 2004 period.

Human activities contributing to air pollution include the use of motor vehicles, fossil fuel combustion for residential and industrial purposes, thermal-electric power generation and wood burning for residential home heating. Air quality is also influenced by the atmospheric transport of pollutants from other regions and by weather conditions.

Health Canada is researching the feasibility of developing and reporting an integrated environment and health indicator (Air Health Indicator) that would be based on the combined health risks of exposure to several air pollutants, including particulate matter and ozone.

Greenhouse gas emissions: The greenhouse gas emissions indicator focuses on total national emissions of greenhouse gases. Emissions rose 27% from 1990 to 2004. In 2004, emissions were 35% above the target to which Canada committed in December 2002 when it ratified the Kyoto Protocol to the United Nations Framework Convention on Climate Change - 6% below the 1990 baseline by the period 2008 to 2012. Thermal-electric power generation, road vehicle use and oil and gas production were the principal sources of the increase in emissions. While total emissions rose, emissions per unit of Gross Domestic Product fell 14% from 1990 to 2004. The expansion of the Canadian economy, however, more than offset gains in fuel and emissions efficiency, resulting in a net increase in total emissions. Over the same period, greenhouse gas emissions also grew faster than the Canadian population, resulting in a 10% rise in emissions per person.

Freshwater quality: Good-quality fresh water is fundamental to ecosystems, human health and economic performance. Freshwater quality in Canada is under pressure from a range of sources, including agriculture, industrial activity and human settlements.

The freshwater quality indicator presented in this report covers the period from 2002 to 2004 and focuses only on the ability of Canada's surface waters to support aquatic life. For the 340 sites selected across southern Canada, water quality was rated as "good" or "excellent" at 44% of sites, "fair" at 34% and "marginal" or "poor" at 22%.

Because of issues of consistency in water quality monitoring programs across Canada, a national trend is not yet available for this indicator. The indicator results do not reflect the quality of all fresh water in Canada. They apply to selected monitoring sites in southern Canada, northern Canada and the Great Lakes that met the CESI data quality criteria. Improvements planned to the monitoring networks, the water quality guidelines and the analysis will enable a better assessment of surface water quality in the future.

In summary, the three indicators reported here individually provide important information—about Canada's environmental sustainability, the health and well-being of citizens, as well as the consequences of our economic growth and lifestyle choices. The air quality, greenhouse gas emissions and freshwater quality indicators are also connected in fundamental ways.

- Some of the same forces are driving the phenomena measured by the indicators.
- Some of the same substances are involved.
- The same regions of the country show the greatest stress.

Reporting these indicator results as a set, integrated with other information on the environment, measures of economic performance and indices of social progress, is challenging. The "Connecting the indicators" chapter of this report represents a first step in this direction. The long-term goal is to enable decision-making that fully accounts for environmental sustainability.

Improvements in the report

This is the second of an annual set of reports on the CESI. Key improvements in this year's report are as follows:

Air quality
- Inclusion of the $PM_{2.5}$ indicator
- More refined statistical analysis of indicator trends

Greenhouse gas emissions
- Better estimation methods and more data on key variables used in the calculations
- Inclusion of final demand category data and analysis from Statistics Canada's Greenhouse Gas Emissions Account

Freshwater quality
- Calculation of the indicator for selected monitoring sites in northern Canada that met data quality standards established to reflect northern conditions
- Further information on the main threats to surface freshwater quality in Canada

Connecting the indicators
- Analysis of the socio-economic context and an initial attempt to identify the economic forces influencing the three indicators

The individual indicators continue to be developed, with increasingly robust analyses to track changes. Improvements are being implemented to make the indicators more understandable, relevant and useful to decision-makers and the public. They will benefit in the future from better environmental monitoring, new scientific knowledge and guidelines, improved data management and better analytical methods. New surveys of business and household actions affecting the environment will provide information to assist in interpreting the indicator trends. Online tools are being developed that will enable users to examine regional and sectoral details and conduct their own analyses.

The Government of Canada website (www.environmentandresources.ca) and the Statistics Canada website (www.statcan.ca) provide electronic versions of this report and access to additional information related to the indicators.

List of acronyms

CCME	Canadian Council of Ministers of the Environment
CESI	Canadian Environmental Sustainability Indicators
FPT	federal/provincial/territorial
GDP	Gross Domestic Product
HFC	hydrofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
NAPS	National Air Pollution Surveillance
NO_x	nitrogen oxides
NPRI	National Pollutant Release Inventory
PCB	polychlorinated biphenyl
PFC	perfluorocarbon
$PM_{2.5}$	fine particulate matter (particulate matter less than or equal to 2.5 micrometres in diameter)
ppb	parts per billion
SO_x	sulphur oxides
SUV	sport utility vehicle
UNFCCC	United Nations Framework Convention on Climate Change
VOC	volatile organic compound
WQI	Water Quality Index

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1 Introduction

The health of Canadians and the country's social and economic progress are highly dependent on the quality of the environment. Recognizing this, efforts are being directed towards providing more accessible and integrated information on society, the economy and the environment to help guide the actions of Canadians and their governments.

As part of this, Canadians need clearly defined indicators that will help them measure progress and foster greater accountability on the part of the federal government and its partners to provide cleaner air, lower greenhouse gas emissions and cleaner water. The Canadian Environmental Sustainability Indicators (CESI) were developed for this purpose. They respond to the recommendations of the National Round Table on the Environment and the Economy in May 2003 that the federal government establish a core set of easily understood environmental and sustainable development indicators to track factors of importance to Canadians (NRTEE 2003). Environment Canada, Statistics Canada and Health Canada are collaborating, on behalf of the Government of Canada, to develop and communicate these indicators to policy-makers and Canadians.

The indicators in this annual report are described below.

The **air quality indicators** reflect the potential for long-term exposure of Canadians to ground-level ozone and fine particulate matter ($PM_{2.5}$), key components of smog and two of the most common and harmful air pollutants to which people are exposed. Both the ozone and $PM_{2.5}$ indicators are population-weighted estimates of average warm-season concentrations of these pollutants observed at monitoring stations across Canada.

The **greenhouse gas emissions indicator** tracks the annual releases of the six greenhouse gases that are the major contributors to climate change. The indicator comes directly from the greenhouse gas inventory report prepared by Environment Canada for the United Nations Framework Convention on Climate Change (UNFCCC).

The **freshwater quality indicator** reports the status of surface freshwater quality at selected monitoring sites across the country, including the Great Lakes and, for the first time, northern Canada. The indicator uses the Water Quality Index (WQI), endorsed by the Canadian Council of Ministers of the Environment (CCME)[1], to summarize the extent to which water quality guidelines for the protection of aquatic life (plants, invertebrates and fish) are exceeded in Canadian rivers and lakes.

These indicators are designed to supplement traditional social and economic measures, such as Gross Domestic Product (GDP), so that Canadians can better understand the relationships that exist among the economy, the environment and human health and well-being. They are intended to assist those in government who are responsible for developing policy and measuring performance, as well as offering all Canadians information about environmental sustainability in Canada. This report is not intended as a summary or evaluation of policies and management activities to address the issues measured by the indicators.

The indicators are in different stages of development. This is the second time a national water quality indicator has been assembled from the different federal, provincial, territorial and joint monitoring programs

1. The CCME brings together the Ministers of the Environment from the federal government and all provincial and territorial governments.

across the country. The air quality indicators draw on a well-established national network of monitoring sites, but differ from existing indicators by presenting a health-based perspective, population-weighting the results to estimate human exposure. The greenhouse gas emissions indicator is the most developed: it comes directly from the inventory created by Environment Canada to meet international climate change-related monitoring requirements. Under the CESI program, these core environmental indicators have been brought together in a single report.

This report and the indicator results will be further developed in the years ahead: improvements will be made to increase their accuracy, relevance and usefulness to decision-makers and the public. Research will be carried out on the linkages between air quality and human health; new surveys will be conducted on businesses and households regarding their environmental actions; and more integrated and representative national monitoring networks will be put in place. The indicators will also provide the basis for a publicly accessible information system where the underlying environmental data can be used and linked to social and economic information.

For each indicator, this report presents the latest national status, trends over time (where possible), an interpretation of what the indicator trends mean and plans for future improvements. The report concludes with a discussion of how the indicators are linked, primarily by analysing the socio-economic factors influencing the indicator trends.

The Government of Canada website on Sustaining the Environment and Resources for Canadians (www.environmentandresources.ca) and the Statistics Canada website (www.statcan.ca) provide searchable electronic versions of this CESI report, as well as access to additional information related to the indicators.


2 Air quality

- Ground-level ozone and fine particulate matter ($PM_{2.5}$) are two key components of smog that have been linked to health impacts ranging from minor respiratory problems to hospitalizations and premature death. There are no established thresholds below which these pollutants are safe and do not pose a risk to human health.
- At the national level, from 1990 to 2004, the ground-level ozone indicator showed year-to-year variability, with an average increase of 0.9% per year.
- In 2004, ground-level ozone values were the highest at monitoring stations in southern Ontario, followed by southern Quebec/eastern Ontario. Southern Ontario exhibited increasing trends since 1990; other regions showed no noticeable increase or decrease.
- The highest $PM_{2.5}$ levels for 2004 were in southern Ontario, while some areas in eastern Quebec also showed high levels. There was no discernible national trend in $PM_{2.5}$ levels for the period 2000 to 2004.

2.1 Context

Air quality influences our lives in many ways. Air pollution has significant negative effects on human health, on the natural environment and, consequently, on economic performance. Important air pollutants include, among others, sulphur oxides (SO_x), carbon monoxide, nitrogen oxides (NO_x), heavy metals, volatile organic compounds (VOC), gaseous ammonia, ground-level ozone and particulate matter. These latter two pollutants are the main components of smog and the focus of the air quality indicators in this report.

Ozone is not emitted directly as a pollutant. It is a colourless gas formed by chemical reactions involving the precursors NO_x and VOC in the presence of sunlight (Warneck 1988). These ozone precursors may be emitted locally or transported by the movement of air from other regions or countries. Ozone concentrations may vary from location to location and from hour to hour, depending on sunlight intensity, weather conditions and the movement of air over various distances. Ozone occurs naturally in the air we breathe and is found throughout the atmosphere (see Box 1). Human activities contribute to the formation of ground-level ozone, however, by increasing the concentrations of NO_x and VOC.

BOX 1

Stratospheric ozone versus ground-level ozone

While ozone in the stratosphere is the same gas found at ground level, it has very different effects. High in the atmosphere, it forms the "ozone layer," which protects life on Earth by preventing some of the sun's ultraviolet rays from reaching the Earth's surface, thereby reducing negative effects such as skin damage (CCME 2004). Stratospheric ozone does have a role in the natural cycling of ozone through the atmosphere, but it has little direct effect on the occurrence of elevated levels of ground-level ozone.

Most NO_x emissions come from human activities, such as burning gasoline in motor vehicles and burning fossil fuels in homes, industries and power plants (Environment Canada n.d.a). Canadians contribute to VOC in the air primarily by producing oil and gas, by driving off-road vehicles as well as light-duty motor vehicles and trucks and by burning wood in fireplaces, furnaces and stoves in their homes. Evaporation of gasoline and other liquid fuels and solvents also adds VOC to the air (Environment Canada n.d.a). Paints, cosmetics and spray cans further contribute to VOC emissions in Canada. Forests, grasslands and swamps produce VOC naturally; the relative importance of these natural sources varies from region to region (Conway 2003).

Fine particulate matter ($PM_{2.5}$) consists of airborne particles less than or equal to 2.5 micrometres (μm) in diameter (about 5% of the width of an average human hair). These small particles pose a great threat to human health because they can travel deep into the lungs (Liu 2004). Although the burden of population exposure to ozone and smog is generally higher during the warm season, "winter smog" caused by particulate matter is also a significant concern (Environment Canada n.d.b).

The formation of $PM_{2.5}$ is complex, and its sources are varied. NO_x, sulphur dioxide, ammonia and VOC emissions all contribute to the formation of $PM_{2.5}$, and their interaction is affected by meteorological conditions. $PM_{2.5}$ is also emitted directly as a pollutant. Transportation and industrial emissions are the main contributors, while wood burning for home heating is also a significant anthropogenic source of $PM_{2.5}$ (Environment Canada, Ministère de l'Environnement du Québec and City of Montréal 2004). Dust from wind erosion and ash from forest fires are natural sources of $PM_{2.5}$.

Human exposure to ground-level ozone and $PM_{2.5}$ is of particular concern because there are no established threshold concentrations below which these pollutants are safe and do not pose a risk to human health. Ground-level ozone can increase respiration and heart rates. Other observed health effects of these pollutants include aggravated asthma attacks, more severe problems with bronchitis and emphysema and pain during inhalation. In general, health impacts worsen and the probability of health problems rises as concentrations increase. These effects are linked to more emergency room visits, hospitalizations and absenteeism, lower labour force participation and higher health care costs, as well as premature death (Willey et al. 2004).

Children are especially sensitive to air pollution and are more severely affected than adults. Children grow rapidly, their bodies are developing, they breathe in more air in proportion to their body size and they are more likely to be active outdoors (CIHI et al. 2001).

Studies have also shown that air pollution may contribute to problems during pregnancy, such as early fetal loss, preterm delivery and low birth weight (Schwartz 2004). Ozone has likewise been shown to be more toxic to the elderly and to those with pre-existing health conditions (CCME 2004).

In summary, the risk to an individual's health from air pollution is a complex function of a number of factors including the quality of the air (level of pollutant), their level of exposure and their particular situation (e.g., health, age). Determining an individual's exposure to these pollutants requires consideration of factors such as the amount of time the individual spends doing outside activities, particularly during the warm season.

BOX 2
The air quality indicators

Two air quality indicators are presented in this report: one for ground-level ozone and one for $PM_{2.5}$, as these are two key components of smog. The ground-level ozone indicator is based on the highest eight-hour daily average concentrations recorded at monitoring stations across Canada. The ozone indicator is presented for the period 1990 to 2004.

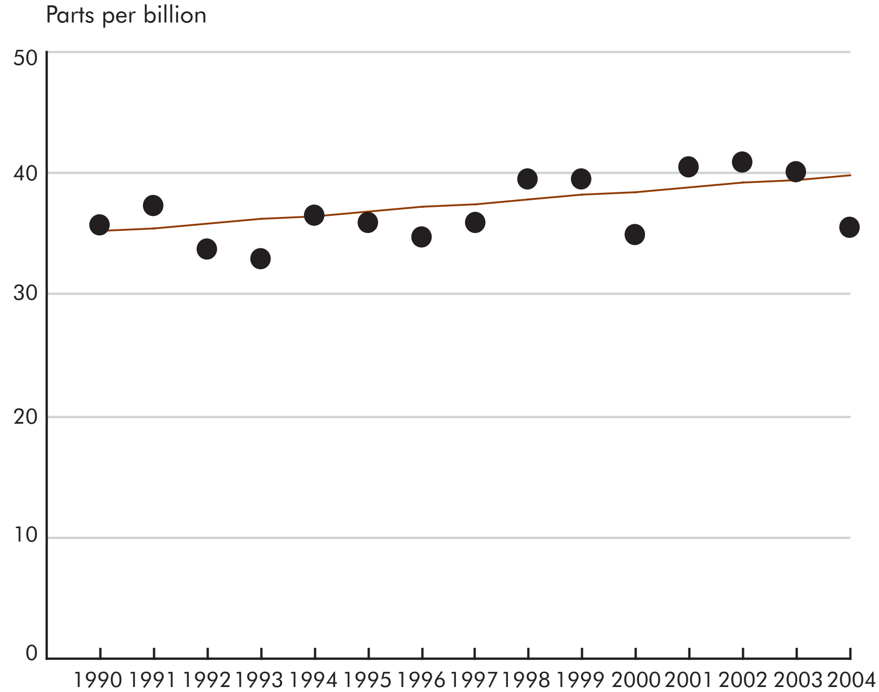
The $PM_{2.5}$ indicator is based on the 24-hour average daily concentrations recorded at monitoring stations across Canada. As the $PM_{2.5}$ network has expanded sufficiently since 2000, the national $PM_{2.5}$ indicator is presented for the period 2000 to 2004.

Both indicators are based on yearly warm-season averages (April 1 to September 30). Ground-level ozone concentrations are normally highest during these months, at the same time as Canadians are most active outdoors (Leech et al. 2002). While winter $PM_{2.5}$ is a concern, current monitoring methods present challenges with instrument variability in cold weather.

Monitoring data from the National Air Pollution Surveillance (NAPS) network was used in determining the CESI air quality indicators. For both ozone and $PM_{2.5}$, warm-season average concentrations for each station are population-weighted to estimate potential human exposure to the pollutants. Each monitoring station included in the analysis is assigned a weight based on the population estimated to be within a 40-kilometre radius. As a result, more weight is given to the air pollution measurements observed in the more highly populated areas so that the indicators are more representative of the exposure of the population to the air pollutants.

For maps of the monitoring locations used and additional details on the indicators, see Appendix 1.

Figure 1 Ground-level ozone indicator, Canada, 1990 to 2004



Notes: The indicator is a population-weighted estimate based on data from 76 monitoring stations. The trend line represents the average rate of change based on the Sen method. The average rate of change is 0.9% per year, with a 90% confidence interval between 0.1% and 1.6% per year. See Appendix 1 (Map A.1) for monitoring station locations and for information on trends and their statistical significance.

Sources: Environment Canada, National Air Pollution Surveillance Network Database; Statistics Canada, Environment Accounts and Statistics Division.

The CESI air quality indicators (Box 2) represent an intermediate step towards a more complex Air Health Indicator, which accounts for changes in both exposure and health risk.

A number of different measures are used to assess and report on ground level ozone and particulate matter in Canada[2]. These measures are calculated in different ways, depending on the purpose of the indicator. The CESI air quality indicators are designed to capture the longer-term trends in, ozone and $PM_{2.5}$ at national and regional levels, while informing about the potential risk to the population of exposure to these pollutants.

2.2 Status and trends—Ground-level ozone

2.2.1 National status and trends

At the national level, from 1990 to 2004, the ozone indicator showed year-to-year variability, with an average increase of 0.9% per year (Figure 1).[3]

Ozone levels are partly determined by local emissions of its precursors (nitric oxide[4] and VOC). However, during the last decade, the levels of these precursors declined in urban areas (Environment Canada 2004a), likely due to improvements in fuel quality and emission control technologies on road vehicles (Environment Canada n.d.a).

At first glance, this inverse relationship between the decline in local emissions of precursors and the rise in the ground-level ozone indicator appears counter-intuitive. However, the relationship between ozone and nitric oxide is complex. While nitric oxide is an ozone precursor, it also removes ozone from the air through a process known as ozone scavenging. A decrease in nitric oxide emitted locally may lead to less ozone being removed from the air, thus increasing ambient local ozone levels. However, further downwind, ground-level ozone may be reduced.

2. For example, air quality indices are used to forecast and report on the hourly and daily air quality in communities across the country (see: http://www.msc-smc.ec.gc.ca/aq_smog/index_e.cfm). Information on the Canada-wide Standards for Particulate Matter (PM) and Ozone can be accessed on the Canadian Council of Ministers of the Environment web site at: http://www.ccme.ca/ourwork/air.html?category_id=99.

3. This 0.9% average increase per year has a 90% confidence interval between 0.1% and 1.6% per year. Refer to Appendix 1 for more information on the trends observed and their statistical significance.

4. Nitric oxide is a component of NO_x.

Meteorological factors, long-range transport of air pollution from sources outside Canada and natural sources of ozone precursors are also contributing to the ozone levels.

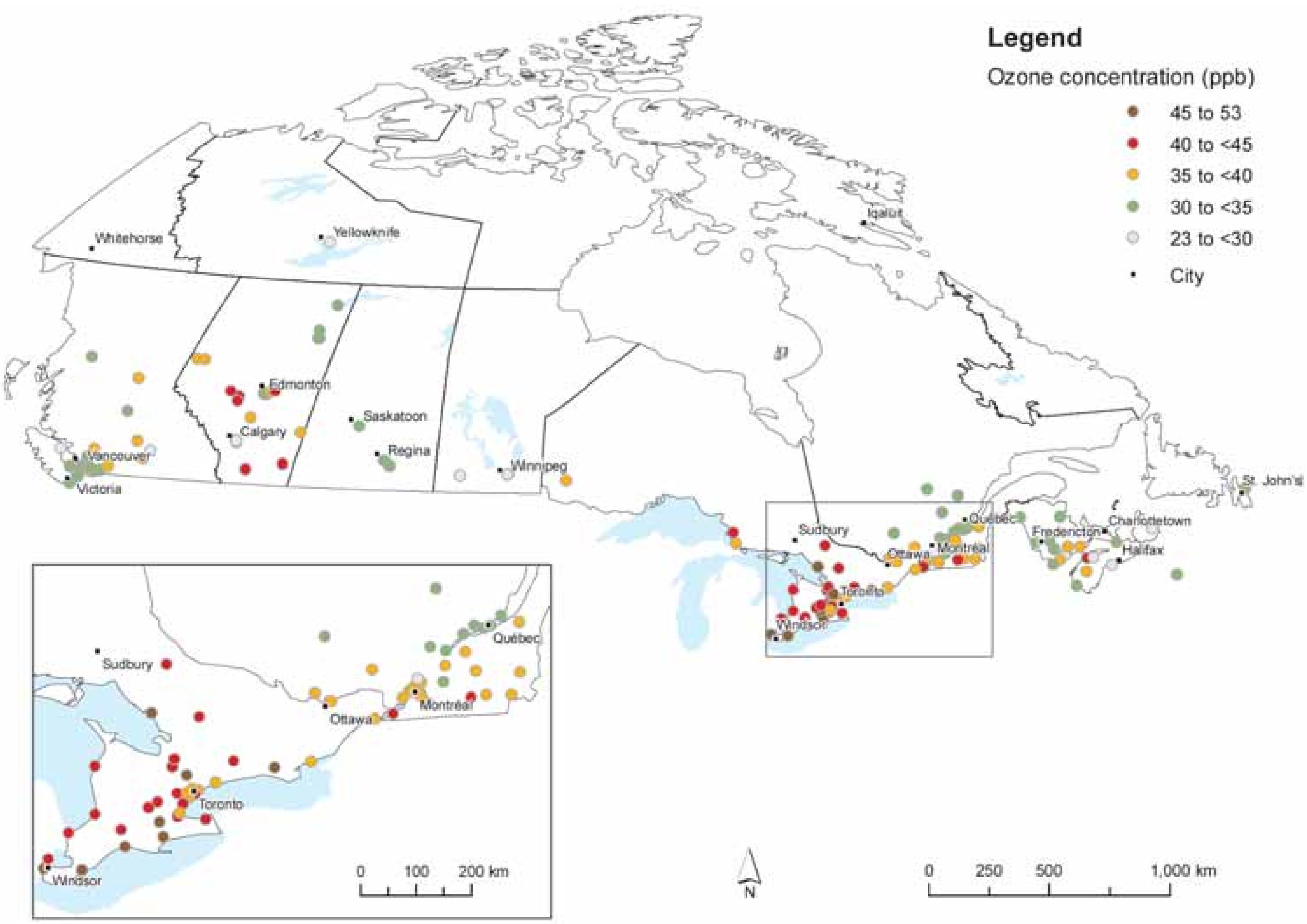
Levels of air pollution are not determined only by local emissions. Daily weather patterns can greatly influence the amount of pollutants brought in by the wind, how quickly pollutants accumulate or are dispersed into the atmosphere and the chemical formation of secondary pollutants, such as ozone and $PM_{2.5}$. Local pollution episodes often correspond to characteristic weather patterns. Summer smog events are often linked to heat waves, when light winds allow pollution to accumulate, and the sunshine and high temperatures contribute to smog formation. This means that higher local pollution levels occur in years with higher summer temperatures, even without any increase in emissions. Assessment of air quality trends is complicated by such meteorological variations, especially when factoring in the effects of winds flowing north from the United States, a main source of transboundary air pollution affecting Canada.

2.2.2 Regional status and trends

Ground-level ozone concentrations vary substantially across the country (Map 1). The stations with the highest average ozone concentrations for 2004 (greater than 45 parts per billion, or ppb) were located mainly in southern Ontario.

Data from 1990 to 2004 show an increasing trend in the ozone indicator levels in southern Ontario (Figure 2). Southern Ontario, home to approximately 30% of Canadians (Statistics Canada 2002), had the highest concentrations and fastest rise of all regions monitored.

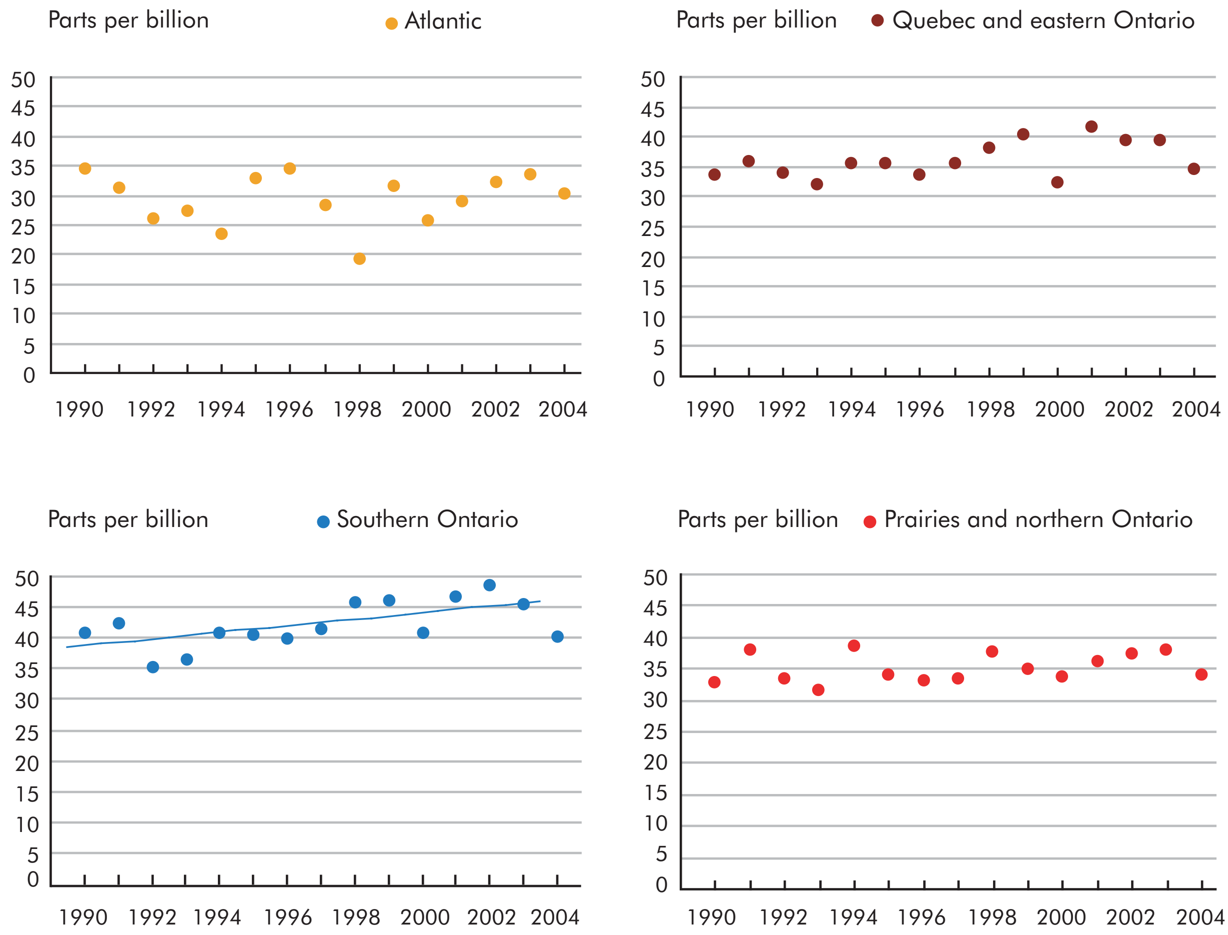
Map 1 Ground-level ozone concentrations at monitoring stations, Canada, 2004

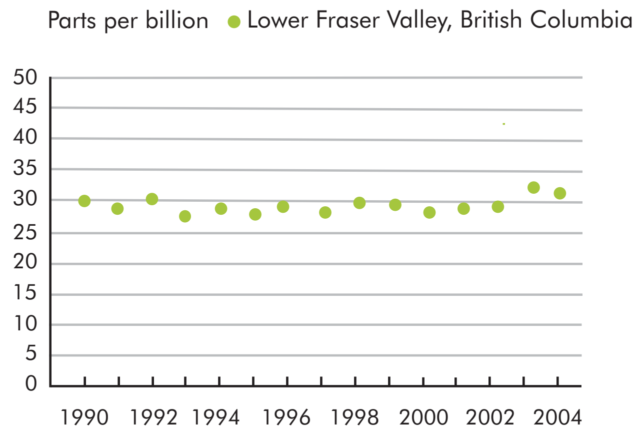


Notes: Number of monitoring stations is 159. Concentrations are the seasonal mean of daily maximum 8-hour ozone observations. These are not weighted by population.

Sources: Environment Canada, National Air Pollution Surveillance Network Database; Statistics Canada, Environment Accounts and Statistics Division.

Figure 2 Ground-level ozone indicator by region, 1990 to 2004

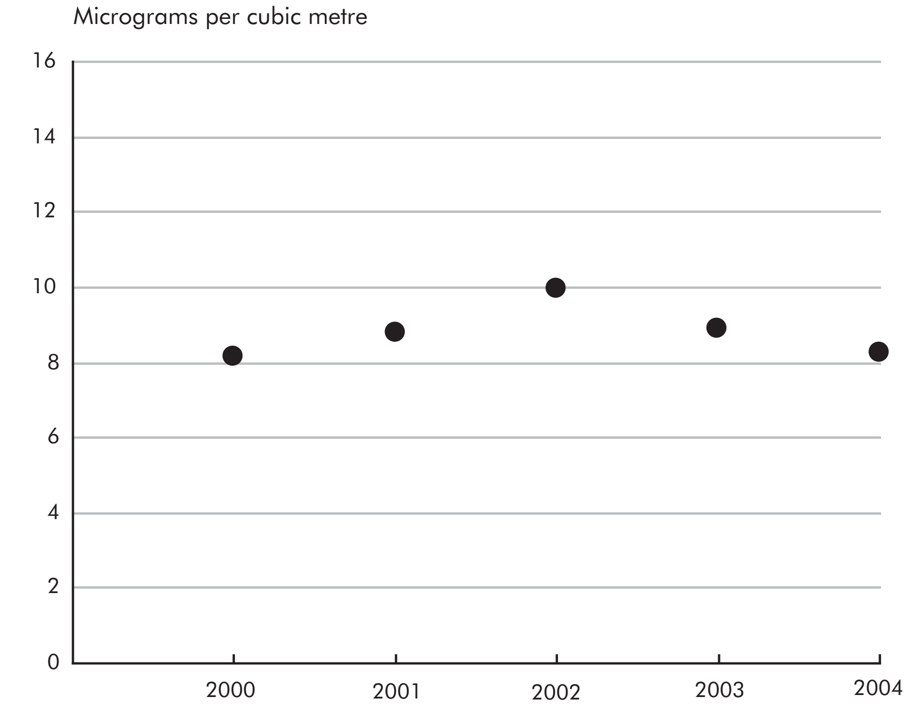




Notes: The indicator is a population weighted estimate. A trendline represents the average rate of change based on the Sen method. It is shown only for the region with a statistically significant trend. See Appendix 1 (Map A1) for monitoring station locations and for information on trends and their statistical significance.

Sources: Environment Canada, National Air Pollution Surveillance Network Database; Statistics Canada, Environment Accounts and Statistics Division.

Figure 3 Fine particulates ($PM_{2.5}$) indicator, Canada, 2000 to 2004



Notes: The indicator is a population-weighted estimate, based on data from 63 monitoring stations across Canada. The limited number of years that contributed to this indicator (2000 to 2004) does not permit trend analyses. See Appendix 1 (Map A.1) for station locations and for information on trends and statistical significance.

Sources: Environment Canada, National Air Pollution Surveillance Network Database; Statistics Canada, Environment Accounts and Statistics Division.

The southern Ontario region had an average increase of 1.3% per year. Ozone levels in the Atlantic region, the Quebec and eastern Ontario region, and the Prairies and northern Ontario region showed year-to-year variability but no apparent trend. Ozone levels in the Lower Fraser Valley in British Columbia were relatively stable.

Because of dominant warm-season wind patterns and the proximity of southern Ontario and Quebec/eastern Ontario to U.S. emission sources, these two regions are subject to greater influence from long-range transport of ozone and its precursors. High ozone levels rarely occur in these areas without similar levels occurring in the adjacent U.S. states. However, data show that ozone precursor emissions in the United States have dropped over the period considered (U.S. EPA 2004). More analysis is required to determine the factors responsible for the trends observed.

2.3 Status and trends—Fine particulates ($PM_{2.5}$)

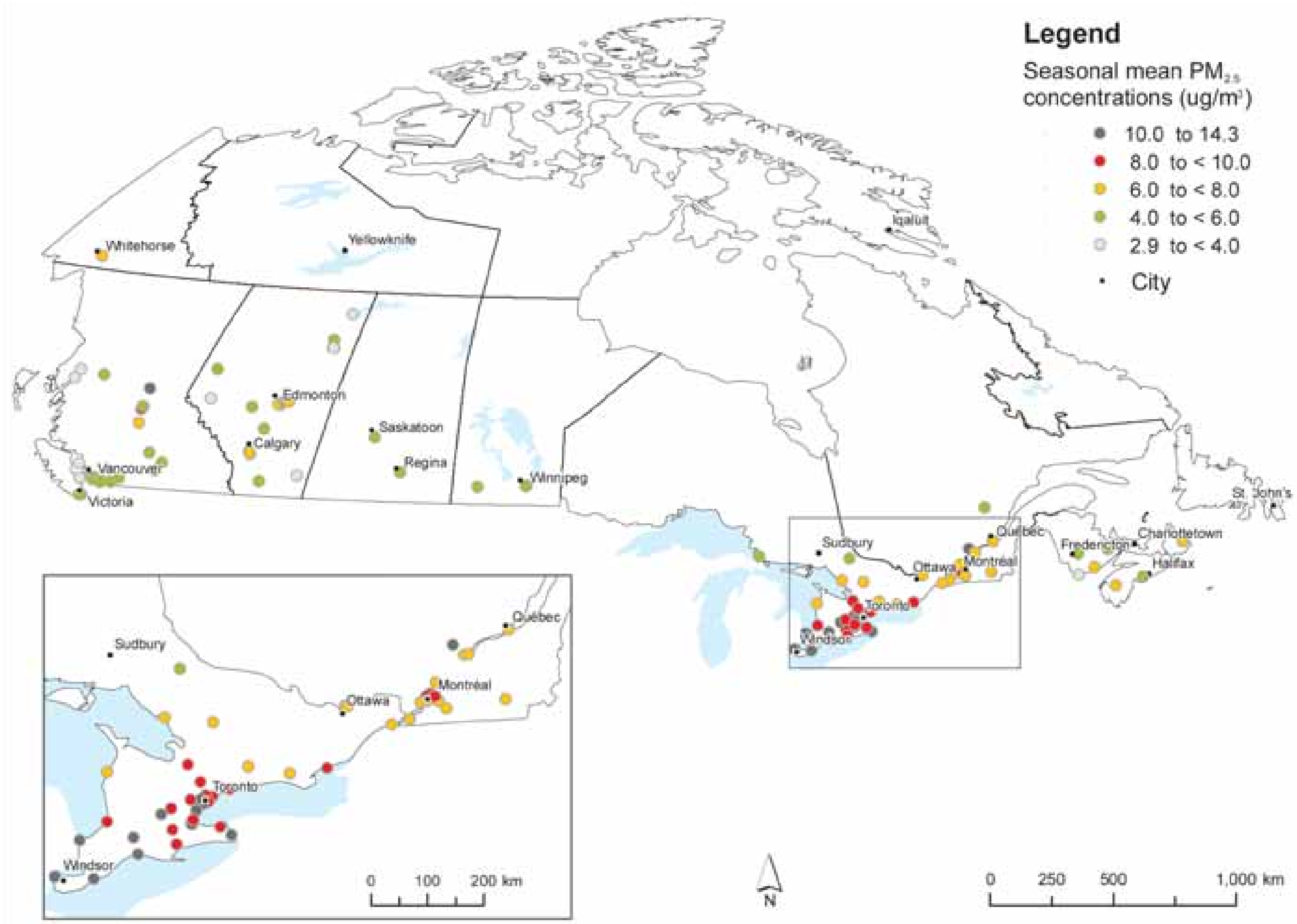
2.3.1 National status and trends

Figure 3 shows the $PM_{2.5}$ indicator results from 2000 to 2004. No significant upward or downward trend is apparent over this period. These results are not yet fully understood, as the formation of $PM_{2.5}$ is complex and its sources are varied.

In the early stages of fine particulate monitoring (1984 to 1999), $PM_{2.5}$ concentrations were measured in only 10 Canadian cities and were collected using manual filter-based samplers. The network and capability for monitoring $PM_{2.5}$ were improved greatly in 2000 to increase coverage on a national basis. The data presented in this report cover the 2000 to 2004 period, based on a much larger network of monitoring stations using continuous and more representative sampling methods than were available in the past.[5]

5. See Appendix 1 for additional details about changes in monitoring of $PM_{2.5}$.

Map 2 Fine particulate ($PM_{2.5}$) concentrations at monitoring stations, Canada, 2004



Note: Number of monitoring stations is 117. Concentrations are the warm-season mean of the 24-hour average daily observations. These are not weighted by population.

Sources: Environment Canada, National Air Pollution Surveillance Network Database; Statistics Canada, Environment Accounts and Statistics Division.

$PM_{2.5}$ levels vary substantially across the country (Map 2) due to differences in direct emissions of $PM_{2.5}$ and in formation of $PM_{2.5}$ from precursors. The stations with the highest average $PM_{2.5}$ levels for 2004 were primarily located in southern Ontario. Southern Quebec/eastern Ontario also had high values, but to a lesser extent. Western Canada and Atlantic Canada generally had lower concentrations, except for a few locations. A regional trend analysis for the $PM_{2.5}$ indicator was not performed at this time owing to the limited data available.

2.4 What's next?

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

Indicator development: The air quality indicators presented in this report are being used on an interim basis. The current indicators represent separate estimates of average population exposure to both ozone and $PM_{2.5}$. This pair of indicators represents a midway point on the continuum from ambient air quality data towards an indicator that uses pollution exposure estimates to derive an indicator based on risk to human health.

Health Canada is examining the feasibility of a broader indicator based on the health risk caused by exposure to a combination of several air pollutants (an Air Health Indicator). This should provide a more comprehensive picture than examining pollutants individually (Burnett et al. 2005). This indicator would be based on linking deaths and hospitalizations due to heart and lung problems with air pollutants present at particular locations and times. The indicator would incorporate ground-level ozone, $PM_{2.5}$, nitrogen dioxide and sulphur dioxide. By focusing on the association between exposure and consequences—deaths or hospitalizations—the new indicator would reflect changes over time in both exposure and health risks, the latter potentially attributable to changes in population susceptibility (e.g. due to aging) or the nature of the air pollution mix.

Monitoring: Environment Canada will continue to invest in new instruments to fill gaps in pollutant coverage at existing monitoring facilities and to establish new stations. A priority will be placed on upgrading existing continuous $PM_{2.5}$ monitoring instruments and improving the sampling and consistency for monitoring of $PM_{2.5}$ during cold seasons. Improved monitoring in remote locations will enhance understanding of background levels and inform interpretations of the trends. For the purposes of this indicator, the monitoring network should ideally provide balanced coverage of the Canadian population to best estimate the potential exposure to air pollutants.

Analysis: Currently, calculation of the indicator does not make full use of the existing National Air Pollution Surveillance (NAPS) Network and population data due to geographic and temporal gaps in the monitoring data available. Work is progressing to provide means of fully exploiting the available data to obtain better estimates of national and regional trends in air quality through the use of interpolation and modelling.

Another important area of research is determining the relative importance of the various factors that affect observed levels of air pollution. For instance, long-range transport of pollutants, sunlight, temperature and pollutant emissions all contribute to observed levels of ozone and $PM_{2.5}$, but the extent of their contributions remains unknown. The linkages between ozone and particulate matter formation during smog episodes will also be explored. Future work will examine ways to measure the relative importance of these influences on ambient ozone and $PM_{2.5}$ levels at both the national and regional levels.

Surveys: In early 2006, Statistics Canada surveyed Canadian households regarding selected environmental practices, such as commuting practices and ownership of household gasoline-powered equipment, to provide additional context for the air quality indicators. Initial results of this survey will be available in late 2006, and full results will come out in 2007. The Households and the Environment Survey will be repeated in 2007 and every second year thereafter.

3 Greenhouse gas emissions

- In 2004, Canada's total greenhouse gas emissions reached an estimated 758 megatonnes of carbon dioxide equivalent, up 27% from 1990.
- Canada's 2004 emissions were 35% above the target to be achieved in the period 2008 to 2012 under the Kyoto Protocol.
- Emissions per person rose 10% from 1990 to 2004; emissions per unit of GDP fell 14%.
- The production and consumption of energy (including road transportation, oil and gas industries and fossil fuel-fired electricity generation) accounted for 82% of total Canadian emissions in 2004 and 91% of the growth in emissions from 1990 to 2004.
- Alberta and Ontario had the highest emissions of all provinces in 2004.

3.1 Context

Naturally occurring greenhouse gases, mainly carbon dioxide, nitrous oxide, methane and water vapour, help regulate the Earth's climate by trapping heat in the atmosphere and reflecting it back to the surface. Over the past 200 years, increased atmospheric concentrations of greenhouse gases resulting from human activities such as burning fossil fuels (oil, coal and natural gas) and deforestation have amplified this natural process, and scientists predict that this trend will continue (Environment Canada 2006a).

Global atmospheric concentrations of carbon dioxide are now about 31% greater than in pre-industrial times, and global average temperature has increased by 0.8°C since the start of the industrial revolution. Canada has seen a rise in average temperature of about 1°C since 1950, with six of the warmest years on record in Canada occurring during the last decade (Mehdi 2006).

Emissions of greenhouse gases have been estimated by scientists and governments for more than a decade. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations Environment Programme and the World Meteorological Organization to investigate climate change. The panel concluded that a doubling of greenhouse gas concentrations in the atmosphere would lead to serious consequences for the world's social, economic and natural systems (Houghton et al. 1990). It estimated that a doubling of carbon dioxide levels would lead to an average global temperature increase of 1.4°C to 5.8°C by 2100 (IPCC 2001).

A warming of this speed and magnitude could significantly alter the Earth's climate, causing severe storm patterns, more heat waves, changes in precipitation and wind patterns, a rise in sea level and regional droughts and flooding. A general warming trend could also affect forest distribution around the world and the length of the growing season for crops. Although an extended growing season might yield some economic benefits in northern countries like Canada, indigenous species would have little time to adapt to a warmer climate and would likely have to cope with more extreme events, such as forest fires, and with increased stress from invasive, exotic species and diseases. In Canada's north, permafrost can be expected to melt, with implications for infrastructure such as buildings and highways, and the extent of Arctic sea ice can be expected to decline, which will affect northern travel and traditional hunting practices. Loss of sea ice will also amplify the warming effect, because seawater reflects less solar radiation than ice. On a national basis, agriculture, forestry, tourism and recreation could be affected, as could related supporting industries and towns.

Climate change is also projected to impact human health by leading to an increase in cases of heat stress, respiratory illnesses (e.g. asthma) and transmission of insect and waterborne diseases (e.g. malaria), thereby placing additional stresses on health infrastructure and social support systems.

The greenhouse gas emissions indicator focuses on total national emissions of the six main greenhouse gases (Box 3).

3.2 Status and trends

3.2.1 National status and trends

Canada's greenhouse gas emissions were an estimated 758 megatonnes of carbon dioxide equivalent in 2004, up 27% from 1990, when they were estimated to be 599 megatonnes. To put this in perspective, a typical mid-sized car driven 20 000 kilometres per year produces about 5 tonnes of carbon dioxide (Environment Canada n.d.c). The trend in estimated emissions and the target to which Canada committed in December 2002 when it ratified the Kyoto Protocol—6% below the 1990 baseline by the period 2008 to 2012—are shown in Figure 4. In 2004, Canada was 35% above the Kyoto target.

In terms of individual greenhouse gases, 78% of the 2004 emissions were attributed to carbon dioxide, 15% to methane and 6% to nitrous oxide. Sulphur hexafluoride, PFCs and HFCs accounted for the remaining 1%. These shares of total emissions were about the same as in 1990 (Environment Canada 2006a).

The 27% increase in total greenhouse gas emissions between 1990 and 2004 outpaced the increase in population (15%). This means that emissions per capita rose 10% from 1990 to reach 24 tonnes per person in 2004, making Canada one of the highest per capita emitters in the world (Figure 5). Although Canadians make up only 0.5% of the global population, Canada's share of global greenhouse gas emissions is approximately 2% (Environment Canada 2006a). The growth in Canada's economy has been in resource-based energy-intensive industries such as oil and gas, mining, steelmaking, pulp and paper and petrochemicals largely destined for export. Canada's large size, low population density and northern climate are also contributing factors. Together, these factors lead to high energy usage for the transportation of goods and people and for space heating (Government of Canada 2001).

BOX 3

The greenhouse gas emissions indicator

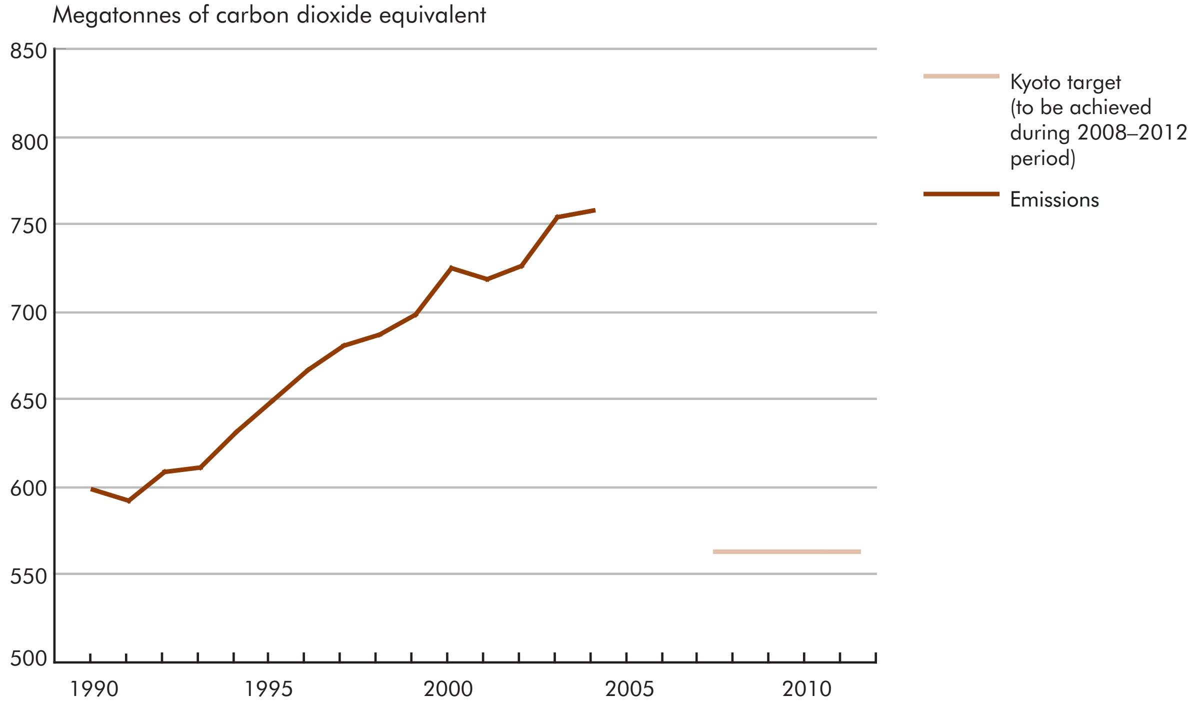
The national greenhouse gas emissions indicator comes directly from the National Inventory Report: Greenhouse Gas Sources and Sinks in Canada (Environment Canada 2006a), which contains emissions estimates for sources categorized by economic sector as identified by the IPCC. It includes estimates for six greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs). The land use, land-use change and forestry sector is excluded from the greenhouse gas totals constituting the indicator.

The emissions estimates and sector definitions used for reporting are based on methodological guidance provided by the IPCC and reporting guidelines under the United Nations Framework Convention on Climate Change (UNFCCC). The estimates for each sector are generally calculated by multiplying a measure of the amount of greenhouse gas-producing activity by the quantity of greenhouse gases emitted per unit of activity (e.g. carbon dioxide released per litre of gasoline combusted). Emissions estimates for different gases are converted to their equivalent in carbon dioxide, based on their impact on global warming compared with carbon dioxide.

All greenhouse gas emissions are expressed as megatonnes (million tonnes) of carbon dioxide equivalent (Mt CO_2 eq), unless otherwise noted.

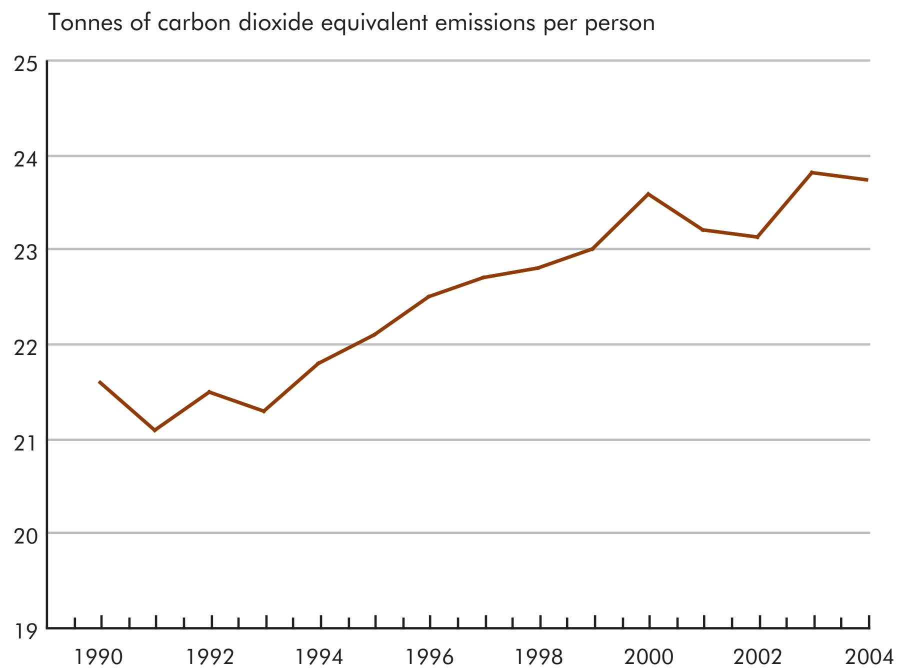
A more detailed description of the indicator and how it is calculated is provided in Appendix 2. The complete National Inventory Report: Greenhouse Gas Sources and Sinks in Canada (Environment Canada, 2006a), is available at (www.ec.gc.ca/ghg).

Figure 4 Greenhouse gas emissions, Canada, 1990 to 2004



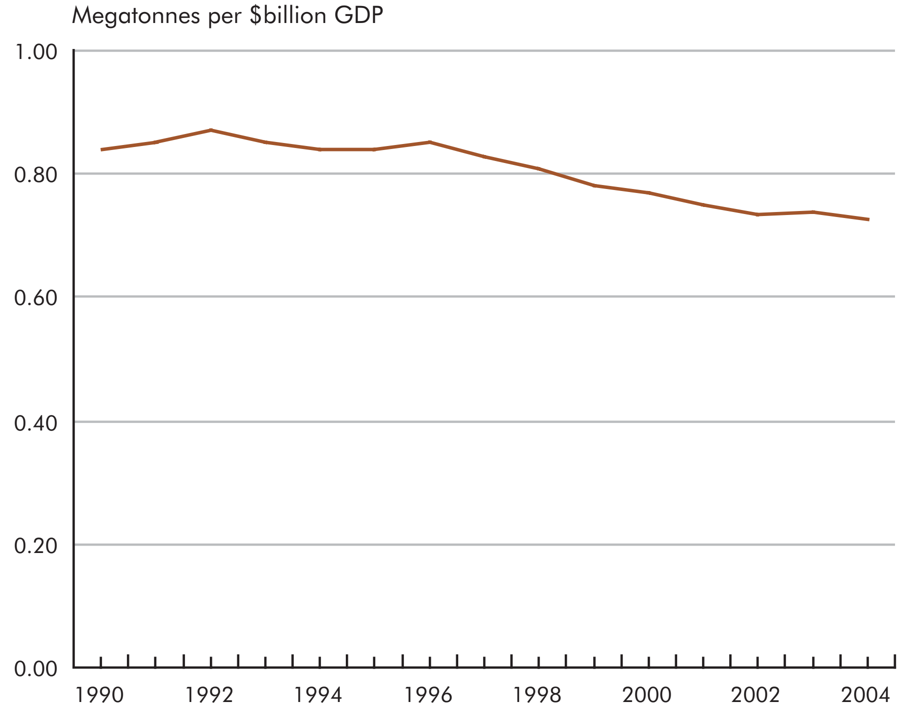
Source: Environment Canada. 2006a. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario.

Figure 5 Greenhouse gas emissions per person, Canada, 1990 to 2004



Source: Environment Canada. 2006a. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario.

Figure 6 Greenhouse gas emissions per unit of Gross Domestic Product, Canada, 1990 to 2004



Source: Environment Canada. 2006a. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario.

Canada's total greenhouse gas emissions per unit of GDP decreased 14% from 1990 to 2004 (Figure 6), which means that more goods were manufactured and more commercial activity occurred for each tonne of greenhouse gases emitted. Efficiency improvements in the energy sector partly explain this decrease. Without improvements in energy efficiency, it is estimated that total emissions would have been 52 megatonnes, or 7%, higher for the year 2003 (Natural Resources Canada 2005b). Despite these gains, rapid growth in the economy has resulted in higher total emissions.

Figure 7 illustrates the breakdown of industrial greenhouse gas emissions by final demand category.[6] From a demand perspective, almost half of Canadian industrial greenhouse gas emissions in 2002 can be attributed to satisfying exports (46%), with personal expenditure the next largest emissions source, at 37% (Figure 7). In 1990, exports accounted for 36% of industrial greenhouse gas emissions from a demand perspective, while personal expenditure accounted for 40%.

3.2.2 Sectoral status and trends

Estimates of greenhouse gas emissions are reported for the following major sectors defined by the IPCC: energy, industrial processes, solvent and other product use, agriculture and waste. Emissions and removals from managed lands (forests, croplands, wetlands) and deforestation are not included in the total national emission estimates.

The energy sector

The production and consumption of energy accounted for most (82%) of the total greenhouse gas emissions in 2004 (Figure 8). This broad category of emissions includes sources such as transportation, electricity generation, space heating, fossil fuel production and consumption, mining and manufacturing. From 1990 to 2004, emissions from these sources rose 30%,

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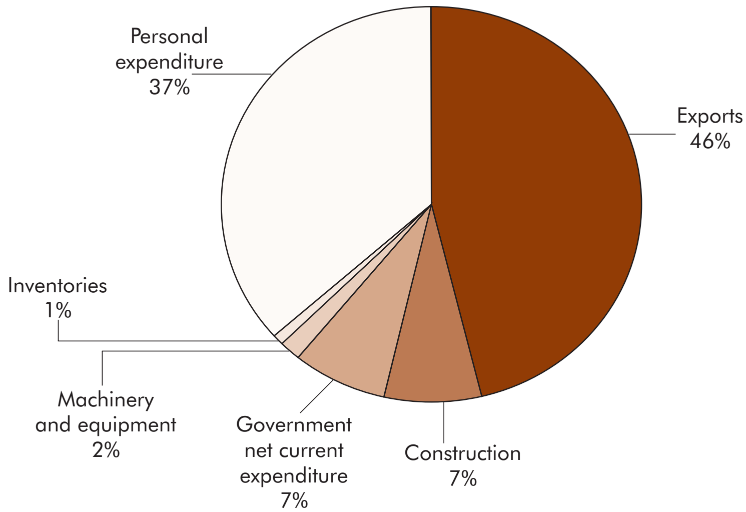
6. These are the emissions associated with the production activity required to produce final demand. They do not represent the emissions associated with the final consumption of commodities once they have been purchased. Please see Appendix 2 (Box A.1) for a description of the data sources and methods associated with Figure 7.

Figure 7 Industrial greenhouse gas emissions by final demand category, 2002



Source: Statistics Canada's Greenhouse Gas Emissions Account.

accounting for 91% of the growth in total emissions in Canada. The increase in total emissions was driven mainly by the oil, gas and coal industries (32% of the overall increase), road transportation (24%) and thermal electricity and heat production (22%) (Environment Canada 2006a).

Oil, gas and coal industries: Overall, the greenhouse gas emissions from the oil, gas and coal industries increased 49% from 1990 to 2004. By 2004, greenhouse gas emissions (including fugitive emissions[7] from oil, gas and coal production and transport) accounted for 20% of total emissions. This category includes emissions related to the production and processing of oil, natural gas and coal, petroleum refining and tranportation by pipelines. Much of the increase in this category is attributable to the rapid growth in the production and export of crude oil and natural gas. In addition, Canadian crude oil requires much more energy for extraction than in the past, as a larger share of production comes from oil sands as conventional reserves become harder to exploit.

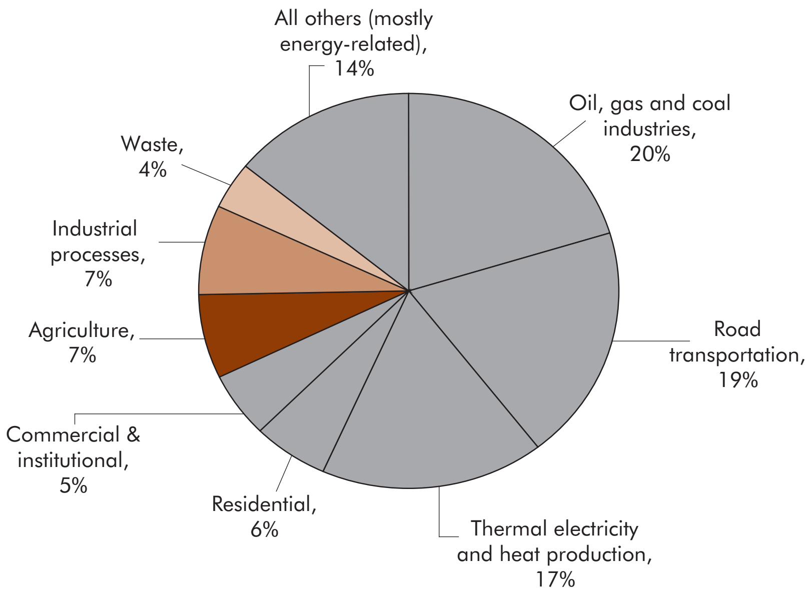
Road transportation: Greenhouse gas emissions from road transportation rose 36% from 1990 to 2004. By 2004, moving people and goods by road accounted for 19% of total greenhouse gas emissions. Changes in both passenger and freight transportation explain this growth. From 1990 to 2004, the number of vehicle-kilometres increased for passenger transportation. There was also a shift in the types of personal vehicles from automobiles to minivans, sport utility vehicles (SUVs) and small pickup trucks. These heavier vehicles with lower fuel efficiency emit on average 40% more greenhouse gases per kilometre than automobiles. As a result, whereas total greenhouse gas emissions from cars fell about 8% from 1990 to 2004, emissions from light-duty gasoline trucks rose 101% (Environment Canada 2006a).

Freight transportation, for its part, saw a doubling in the number of heavy-duty diesel vehicles from 1990 to 2004. Greenhouse gas emissions from this class of vehicles jumped 83% over the period. This is partly due to the advent of "just-in-time" delivery systems, which eliminate the need for the manufacturing and commercial sectors to keep large inventories in stock. Other modes of transportation (domestic aviation and marine, railways, off-road vehicles) accounted for a lesser share (6%) of the 2004 greenhouse gas emissions total from road transportation.

Thermal electricity and heat production: Greenhouse gas emissions from thermal electricity and heat production rose 37% from 1990 to 2004. By 2004, electric utilities

7. Fugitive emissions are intentional or unintentional releases of gases from industrial activities. In particular, they may arise from the production, processing, transmission, storage and use of fuels and include emissions from combustion only when it does not support a primary activity (e.g. flaring of natural gases at oil and gas production facilities).

Figure 8 Greenhouse gas emissions by sector, Canada, 2004



Note: The grey portion of the chart represents greenhouse gas emissions from the energy sector.
Source: Environment Canada. 2006a. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario.

and other industries that generate electricity and steam accounted for 17% of Canada's total greenhouse gas emissions. The growth in emissions was driven by a rising demand for electricity—total annual electricity production increased by 23% between 1990 and 2004—and by the increase in the use of fossil fuels for electricity generation relative to other non-emitting sources, such as nuclear and hydro. Hydroelectricity's share of national generation fell from 63% to 59%, while coal, oil and natural gas together rose from 21% to 25% of the mix during this period (Environment Canada 2006a).

Factors that influenced growth in demand for electricity at the residential level included population growth, increased numbers of electrical appliances in use (such as secondary refrigerators) and a slight increase in the average home size, resulting in greater heating and cooling needs (Natural Resources Canada 2005b).

Other sectors

The emissions from industrial processes include emissions such as carbon dioxide from limestone calcination in cement production and carbon dioxide from the use of natural gas as feedstock in the manufacture of fertilizers. The overall emissions from this sector remained relatively stable between 1990 and 2004 (2% increase) and accounted for 7% of the 2004 total. However, the individual sources within this sector showed different trends—for example, carbon dioxide emissions from cement production grew by 31% due to the increase in clinker[8] production capacity over the years, whereas PFC emissions from aluminum smelting decreased by 54% due to application of emission control technologies to the process.

The agricultural sector also accounted for 7% of the 2004 emissions total; however, emissions from this sector increased by 23% from 1990 levels, mainly as a result of expansion in the beef cattle, swine and poultry industries, along with increased applications of fertilizers in the Prairies (Environment Canada 2006a).

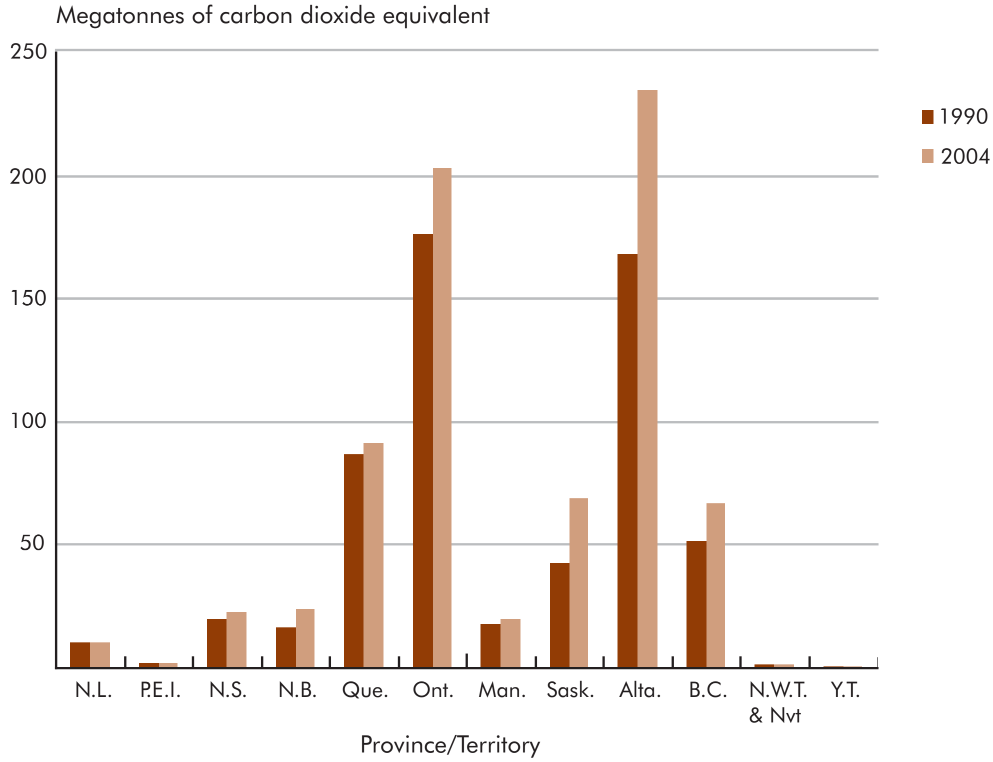
For its part, the waste sector, representing 4% of the 2004 total, increased its emissions by 16% from 1990, slightly more than the 15% growth in population. This increase would have been larger if landfill gas recovery projects, composting and recycling programs had not been implemented in Canada.

3.2.3 Regional status and trends

Greenhouse gas emissions vary from region to region. Between 1990 and 2004, total emissions rose in all

8. An intermediate product from which cement is made. Gypsum is added to clinker to produce portland cement.

Figure 9 Greenhouse gas emissions, provinces and territories, 1990 and 2004



Source: Environment Canada. 2006a. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario.

provinces and territories except for the Yukon, where they dropped slightly (Figure 9) (Environment Canada 2006a). In 2004, Alberta and Ontario reported the highest emissions, accounting for 31% and 27% of Canada's emissions, respectively. The geographic distribution of emissions is linked to the location of natural resources, population and heavy industry.

3.3 What's next?

Environment Canada is continuously planning and implementing refinements to the national greenhouse gas emissions inventory that will improve the accuracy of emission estimates and the quality of the indicator reported here. These refinements take into account the results of annual quality assurance and quality control procedures and reviews and verifications of the inventory, including an annual external examination of the inventory by an international expert review team (Environment Canada 2006a).

The following specific improvements are planned in relation to analysis and surveys:

Analysis: Priorities for the future development of the indicator include better estimation methods and more data on key variables used in the emissions calculations. For example, refinements to the estimation methods and emission values for the Canadian bitumen industry within the energy sector are currently under way.

Over the longer term, improvements to transportation-related emissions estimates are also planned. These will mainly focus on obtaining and employing improved activity data, in particular more detailed profiles of vehicle types and numbers, better estimates of vehicle-kilometres traveled, improved information on fuel consumption patterns for individual classes of vehicles and marine activity data for a better distinction between domestic and international emissions.

Refinements to the industrial processing sector, in particular ammonia production estimates, are under way, and efforts to update nitric acid emission factors[9] are planned. Further research is under way in the agriculture sector to assess changes in methane

9. Based on samples of measurement data, emission factors are representative rates of emissions for a given activity level under a given set of operating conditions. They are the estimated average emission rate of a given pollutant for a given source, relative to units of activity.

emissions from the digestion of feed by beef and dairy cattle and the effects of irrigation and soil texture on nitrous oxide emissions from agricultural soils.

Within the waste sector, a multiyear initiative supported by Environment Canada and the University of Manitoba has been undertaken to develop an inventory of landfills in Canada. Additional studies are also being considered to improve municipal and industrial wastewater emissions data and to collect new municipal, clinical and hazardous waste incineration data.

Mandatory greenhouse gas emissions reporting was established in 2005, the result of a collaboration among federal, provincial and territorial governments to develop a harmonized system of greenhouse gas reporting. Launched on March 15, 2005, the system is being implemented in phases. The first phase required facilities generating 100 kilotonnes or more of carbon dioxide equivalent emissions to report their 2004 emissions by June 1, 2005. These facility data will be used by Environment Canada as an additional input for improving future emissions estimates.

Surveys: In early 2006, Statistics Canada surveyed Canadian households regarding selected environmental practices, such as commuting practices and ownership of household gasoline-powered equipment. This information can provide additional context for the greenhouse gas emissions indicator. Initial results of this survey will be available in late 2006, and full results will come out in 2007. The Households and the Environment Survey will be repeated in 2007 and every second year thereafter.

4 Freshwater quality

- This indicator assesses surface freshwater quality with respect to protecting aquatic life (e.g. fish, invertebrates and plants), but not for human consumption. It is based on information gathered from 2002 to 2004 from 340 selected monitoring sites across southern Canada.
- Freshwater quality in southern Canada was rated as “good” or “excellent” at 44% of the sites, “fair” at 34% and “marginal” or “poor” at 22%.
- New information has been included for monitoring sites in northern Canada. At these 30 sites, freshwater quality was rated as “good” or “excellent” at 67% of the sites, “fair” at 20% and “marginal” or “poor” at 13%.
- Freshwater quality for the Great Lakes—Lake Superior, Lake Huron, Georgian Bay, Lake Erie (west, central and eastern basins) and Lake Ontario—was rated as “good” or “excellent” in four basins, “fair” in one and “marginal” in two.

4.1 Context

Good-quality water in adequate quantities is fundamental to ecosystems, human health and economic performance. In Canada, water is mostly used by households and in industries such as electricity generation, agriculture, manufacturing, petroleum extraction and mining. Tens of billions of cubic metres of water are withdrawn from surface water and groundwater sources every year (Statistics Canada 2003a). In some cases, intensive and competing water uses can lead to local shortages and can compromise water quality (Environment Canada 2004b).

Water quality can also be compromised by toxic and other harmful substances. Every day, primary manufacturing and service industries, institutions and households discharge hundreds of different substances, directly or indirectly, into rivers and lakes. At least 110 000 tonnes of pollutants were directly discharged to Canada’s surface waters (both freshwater and coastal) in 2004 (Environment Canada 2006b). Nitrate ion and ammonia were the pollutants released to water in the largest quantities in 2004; other, more highly toxic substances, such as mercury, are released in much smaller, but nevertheless significant, amounts (UNEP 2002; Environment Canada 2006b).

Many more pollutants make their way into water bodies indirectly after being released into the air or onto the land. Aquatic ecosystems receive airborne pollutants transported over long distances, such as sulphur dioxide and NO_x, which cause acidification, as well as heavy metals (e.g. lead and mercury) and organic compounds (e.g. polychlorinated biphenyls [PCBs] and pesticides). Untreated runoff from agricultural lands and urban areas also degrades water quality (Coote and Gregorich 2000; Environment Canada 2001a).

Degradation of water quality can affect both aquatic life and human uses of water. For example, high concentrations of nutrients (e.g. nitrogen and phosphorus) may result in excessive plant growth and subsequently reduce the amount of dissolved oxygen available for fish and other aquatic animals. Degraded water quality can affect economic activities such as freshwater fisheries, tourism and agriculture.

It is important to note that the indicator presented in this report focuses on water quality for the protection of aquatic life. It does not assess the quality of water for human consumption. Freshwater aquatic life can be sensitive to slight changes in their environment. Thus, monitoring the environment in relation to the basic requirements of aquatic life is an effective method of assessing the health of freshwater ecosystems.

Water quality is difficult to define and assess on a national basis. For example, the chemistry is complex and depends on many physical and chemical properties that vary naturally over space and time. These properties can affect the suitability of water for aquatic organisms, which themselves vary from place to place, have a wide range of habitat requirements and have different sensitivities to different substances. Evaluating whether water quality is degraded by human activity is further complicated by natural processes such as heavy rain, melting ice and snow, soil erosion and weathering of bedrock, which also influence levels of certain substances in water (e.g. nutrients, major ions and trace metals). These natural phenomena are essential to the maintenance of the habitat for a wide range of indigenous species, as well as the conditions underlying other ecosystem processes. These processes vary considerably across the country, making for a diverse mix of aquatic ecosystems.

To report on water quality, experts measure specific substances in water and compare the observed concentrations against scientifically established thresholds for potential adverse effects. This is the basis of the Water Quality Index endorsed by the CCME in 2001 and used in this report to produce the water quality indicator (see Box 4). This index has been calculated using the results of ongoing water quality monitoring programs managed by federal, provincial and territorial governments.

BOX 4
The Water Quality Index (WQI)

The CCME WQI is a tool that allows experts to translate large numbers of complex water quality data into a simple overall rating for a given site and time period. It provides a flexible method for assessing surface water quality that can be applied across Canada.

The WQI is based on a water quality index developed by British Columbia in 1995. This version was then modified through research, testing and consultation by a CCME task group.

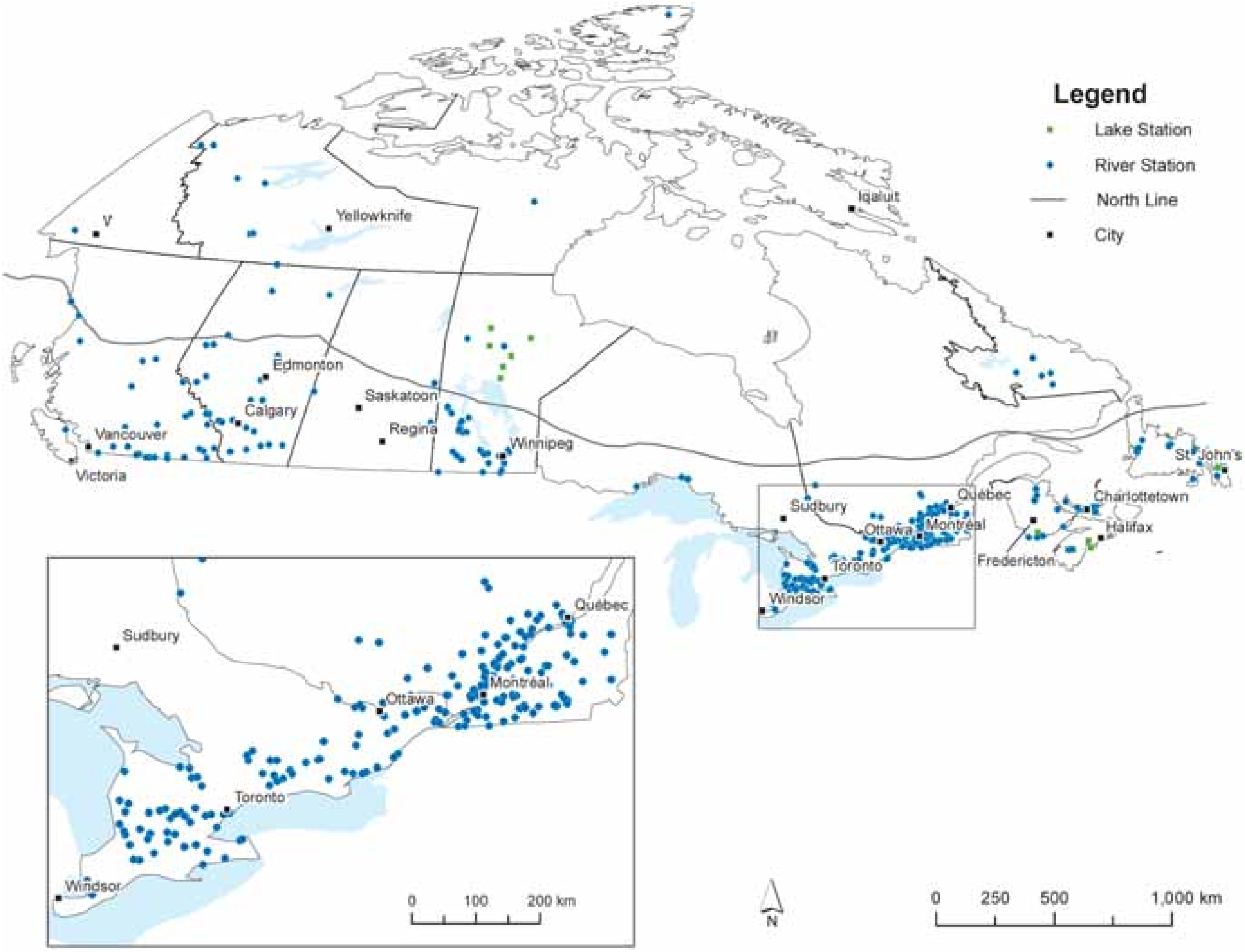
The index combines three different aspects of water quality: the "scope," which is the percentage of water quality variables with observations exceeding guidelines; the "frequency," which is the percentage of total observations exceeding guidelines; and the "amplitude," which is the amount by which observations exceed the guidelines. The results are then converted into the following qualitative scale that is used to rate sites:

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

Water quality guidelines are numerical values for physical, chemical, radiological or biological characteristics of water that, when exceeded, show a potential for adverse effects. Guidelines are often based on toxicity studies using a standard set of test organisms found in aquatic ecosystems in Canada. Water quality guidelines can be adjusted to reflect site-specific conditions, such as a different species composition or background levels of naturally occurring substances such as phosphorus. Guidelines are also specific to how the water is used, be it for supporting aquatic life, drinking, recreation, irrigation or livestock watering. In this report, the WQI is used to assess the suitability of surface water bodies (rivers and lakes) for the protection of aquatic life (CCME 2001).

For a more detailed description of the indicator, and how it is calculated see Appendix 3.

Map 3 Water quality indicator stations, Canada, 2002 to 2004



Notes: The "North Line" is based on a statistical area classification of the north by Statistics Canada reflecting a combination of 16 social, biotic, economic and climatic characteristics that delineate north from south in Canada. (McNiven and Puderer 2000).

Sources: Statistics Canada, Environment Accounts and Statistics Division. Monitoring station information assembled by Environment Canada from federal, provincial and joint water quality monitoring programs.

4.2 Status[10]

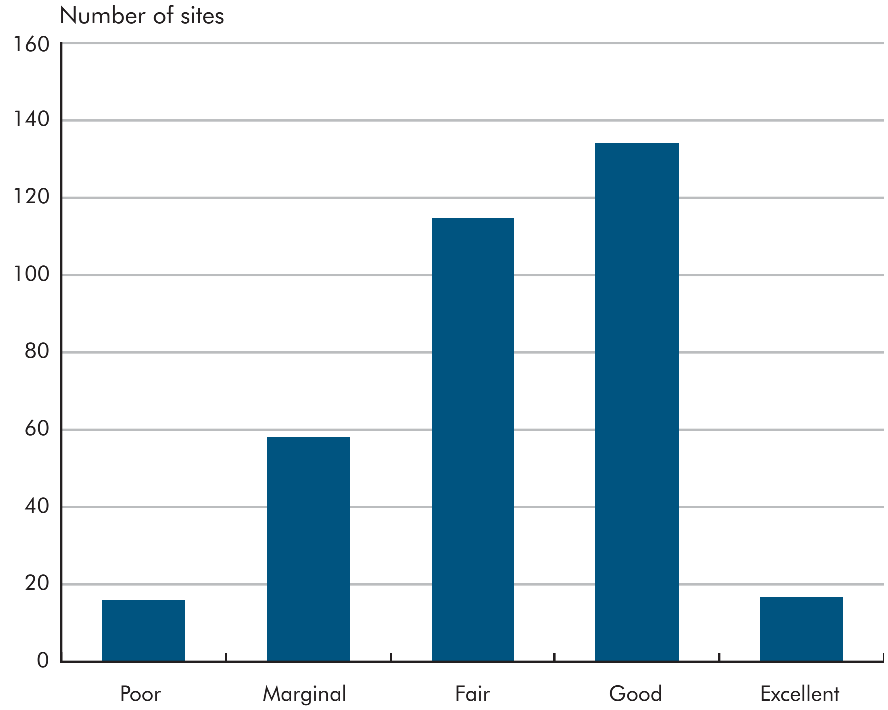
Water quality data from a mix of federal, provincial, territorial and joint monitoring programs were assessed by regional experts and assembled into a national data set to calculate this indicator. Summaries were prepared for monitoring sites located in southern Canada, northern Canada (Box 5) and the Great Lakes (Box 6). In total, data from 370 sites (Map 3) were compiled for the 2002 to 2004 period: 30 for northern Canada and 340 for southern Canada. In addition, water quality was assessed for seven basins of the Great Lakes from surveys conducted in April 2004 and 2005.

Northern areas were not included in the national indicator but reported separately because these sites were usually sampled less frequently and were less representative of the overall territory. Freshwater quality in the Great Lakes was also reported separately because a different sampling approach is used.

In southern Canada, water quality measured using the WQI for 2002 to 2004 was rated as excellent at 17 sites (5%), good at 134 sites (39%), fair at 115 sites (34%), marginal at 58 sites (17%) and poor at 16 sites (5%) for their suitability to protect aquatic life. Nine lakes and 331 rivers were included in the analysis (Figure 10).

10. With only two reporting periods to date, it is not possible to determine whether or not there is a significant trend in water quality across the sites selected for status reporting. As a result, water quality trend information is not reported.

Figure 10 Status of freshwater quality at sites in southern Canada, 2002 to 2004



Notes: The results are for surface freshwater quality with respect to protecting aquatic life. They do not assess the quality of water for human consumption. Number of sites is 340. Observations for the Great Lakes are not included, but appear in Box 6. Sites in the North are not included, but are presented separately in Box 5. See Map 3 for site locations.

Source: Data assembled by Environment Canada from federal, provincial, territorial and joint water quality monitoring programs.

The indicator results should not be interpreted as representing the state of all fresh water in Canada: they apply to water quality at the selected sites. All sites, whether small rivers or large lakes, are weighted equally in this summary of results.

In last year's report, the water quality indicator (2001 to 2003) was based on 345 monitoring stations and showed good or excellent for 44% of the sites, fair at 31% of the sites, and marginal or poor at 25% of the sites. In this 2006 report, the water quality indicator for southern Canada (2002 to 2004) was based on 340 sites, some of which were in different locations from the previous year. In addition, the indicator in the 2005 report was based on a slightly different formula for one province. The WQI formula used in the current report is consistent for all provinces. Due to the changes in data and improvements in the indicator, comparison with results from the previous year should not be made.

Different water quality variables were measured at different locations across the country, depending, in part, on the priorities of the various monitoring programs, the kind of human influences in the area and the characteristics of the aquatic ecosystems. Overall, the variables included most often in calculations across Canada were phosphorus (334 sites), ammonia (276), nitrates (260), pH (230) and zinc (211). Of those sites, phosphorus measurements exceeded guidelines at least once at 81% of sites, ammonia at 18% of sites, nitrates at 28%, pH at 25% and zinc at 27%. Moreover, 38% of sites that included phosphorus had phosphorus measurements above guidelines in more than 50% of collected samples.

Natural phenomena contributed to water quality variables exceeding guidelines as well. For example, glacial melt, snowmelt and heavy rainfall can lead to high levels of suspended sediments that are rich in nutrients and metals, and the naturally acidic water of bogs and other wetlands can result in lower pH and higher concentrations of certain metals at downstream sites. The year-to-year variations of these factors justify the use of three years of monitoring results (2002 to 2004). They also justify the development and implementation of site-specific water quality guidelines that consider the levels of naturally occurring substances and conditions at individual sites.

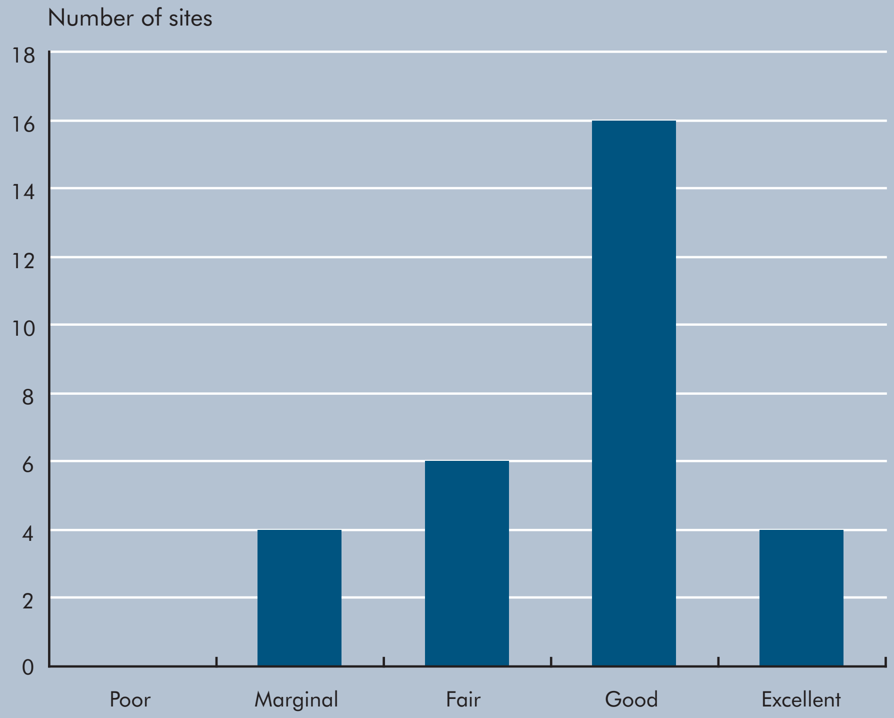
BOX 5

Freshwater quality in northern areas

Northern areas[1] are less populated than those in southern Canada. As a result, they are not exposed to the same pressures of human settlements, industry and agriculture. However, water quality in northern watersheds is at risk from the long-range transport of pollutants and from primary resource industries, such as forestry and pulp and paper mills, mining and exploration, oil and gas development and hydro power development. Moreover, northern freshwater ecosystems may also be particularly vulnerable to the added stresses posed by recent changes in temperature and precipitation and increased ultraviolet radiation (Schindler and Smol 2006).

Water quality was rated as excellent at 4 sites (13%), good at 16 sites (53%), fair at 6 sites (20%) and marginal at 4 sites (13%). No "poor" sites were reported (Figure 11). Six lakes and 24 rivers were included in the analysis. Further work is being conducted to assess the degree to which exceedances in the fair and marginal sites can be attributed to human activities or natural processes, such as flows rich in suspended sediments.

Figure 11 Status of freshwater quality at sites in northern Canada, 2002 to 2004



The Canadian North is vast, making the sampling of remote sites costly and access difficult. As a result, water quality monitoring sites in the North are sampled less frequently. For this reason, the minimum sampling frequency for the inclusion of northern monitoring sites in the calculation of the freshwater quality indicator for the North was reduced from 12 (as used in southern Canada) to 9 for the 2002 to 2004 period.

The WQI was calculated over the period 2002 to 2004 for 30 monitoring sites from the Yukon, British Columbia, the Northwest Territories, Nunavut, the northern Prairies and Labrador. No water quality monitoring sites from northern Ontario or northern Quebec could be included. Although the calculations were usually based on fewer observations than in southern Canada, the observations captured seasonal variation in water quality.

1. The North is delineated on Map 3.

BOX 6

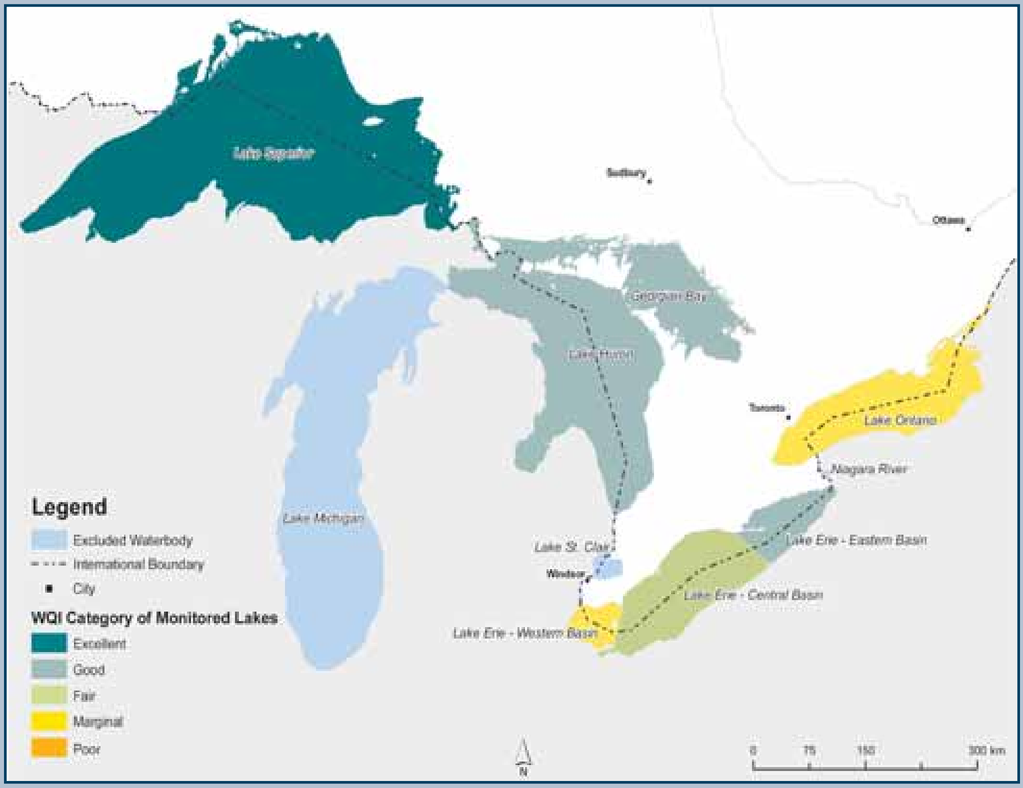
Freshwater quality in the Great Lakes

The Great Lakes watershed is heavily farmed and industrialized. It is home to more than 10 million Canadians (Statistics Canada 2002), which puts significant pressure on water quality. Historically, the Great Lakes have been degraded by excess nutrients and the accumulation of toxic contaminants in the water and sediments. Some aspects of water quality (e.g. phosphorus concentrations) have been substantially improved in parts of the Great Lakes through human intervention (Environment Canada and U.S. EPA 2003).

Because of the large area of the lakes (about 92 200 square kilometres in Canadian territory) and the nature of the surface water and bottom sediment monitoring program (each lake is sampled at multiple sites once every two years, rather than by multiple samples at the same site every year), water quality in the Great Lakes region was assessed differently from other sites for the purposes of the freshwater quality indicator (see Appendix 3 for additional details).

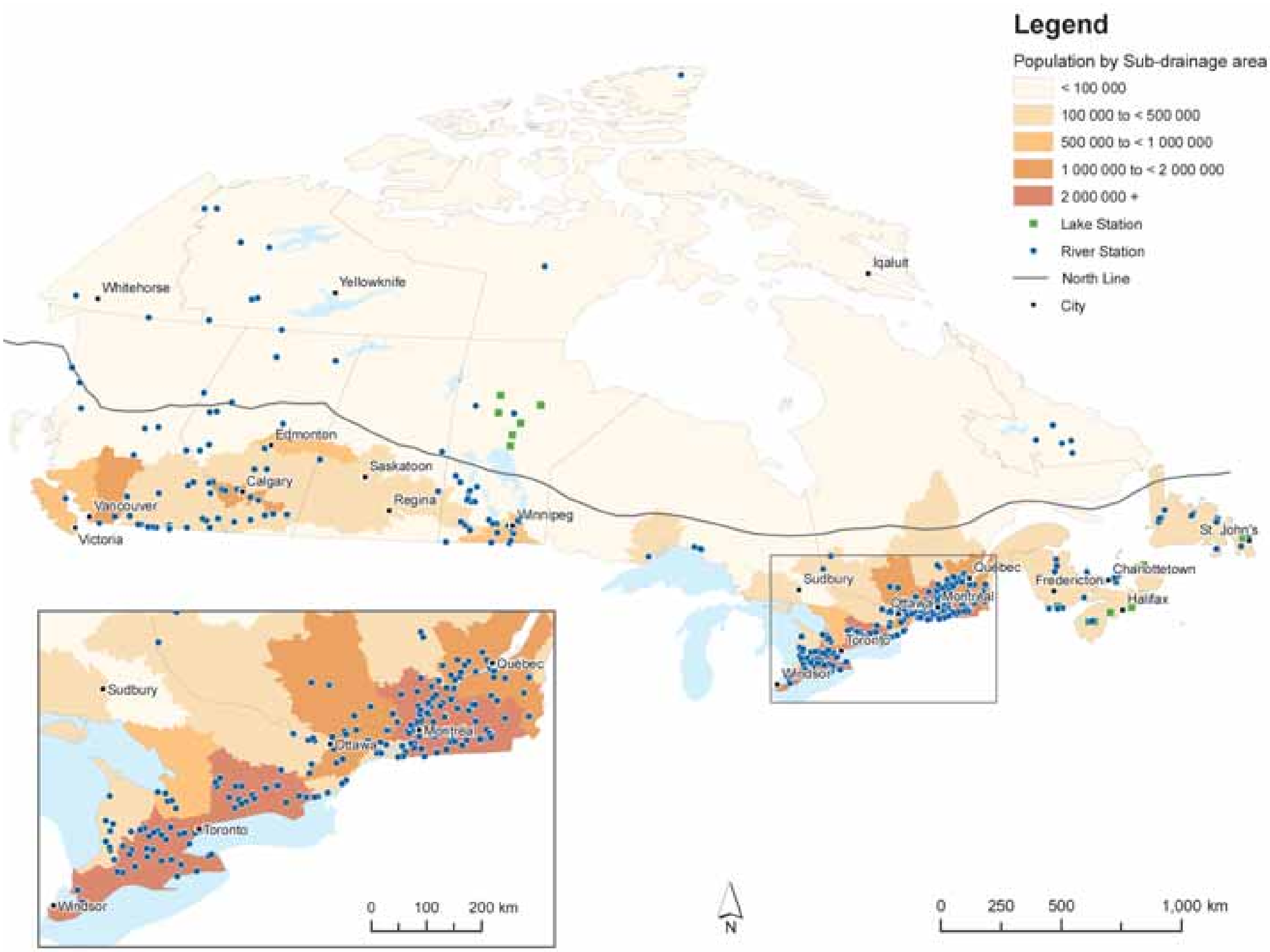
The WQI was calculated using the most current year (2004 or 2005) for seven basins: Lake Superior, Lake Huron, Georgian Bay, Lake Erie (the western, central and eastern basins) and Lake Ontario. Water quality was rated as excellent in one basin, good in three, fair in one and marginal in two (Map 4). The differences in water quality across the Great Lakes partly reflects the variation in the level of population, urbanization, agriculture and industry along the shores and in the watersheds of the lakes, as well as differences in the size and depth of the lakes. In contrast to measurements of surface water, significant levels of contamination continue to be found in the sediments. These observations reflect the historical accumulation of pollutants.

Map 4 Status of freshwater quality, Great Lakes basins, 2004/2005



In order to more adequately evaluate the effect of some persistent, bioaccumulative and toxic chemicals on water quality, the data from lake bottom sediments were included in the calculation for two chemicals. Dichlorodiphenyltrichloroethane (DDT), a legacy pesticide, and PCBs, an industrial class of chemicals, which were both banned in the 1970s, still persist in the environment (Environment Canada and U.S. EPA 2003). The primary repository of these compounds in the environment is in the sediment, which represents a significant route of exposure to aquatic life.

Map 5 Population in relation to water quality monitoring sites, Canada, 2001



Note: Population numbers are shown by Canada's sub-drainage basins.

Sources: Statistics Canada, Environment Accounts and Statistics Division. Monitoring station information assembled by Environment Canada from federal, provincial and joint water quality monitoring programs.

4.2.1 Human impacts on freshwater quality

Almost all sites located in southern Canada are in areas potentially affected by human activities such as those occurring in settlements, on farms, at industrial facilities and at mining operations, as well as by dams and acid precipitation. The extent of these activities and the range of their potential impacts on water quality are highlighted below.

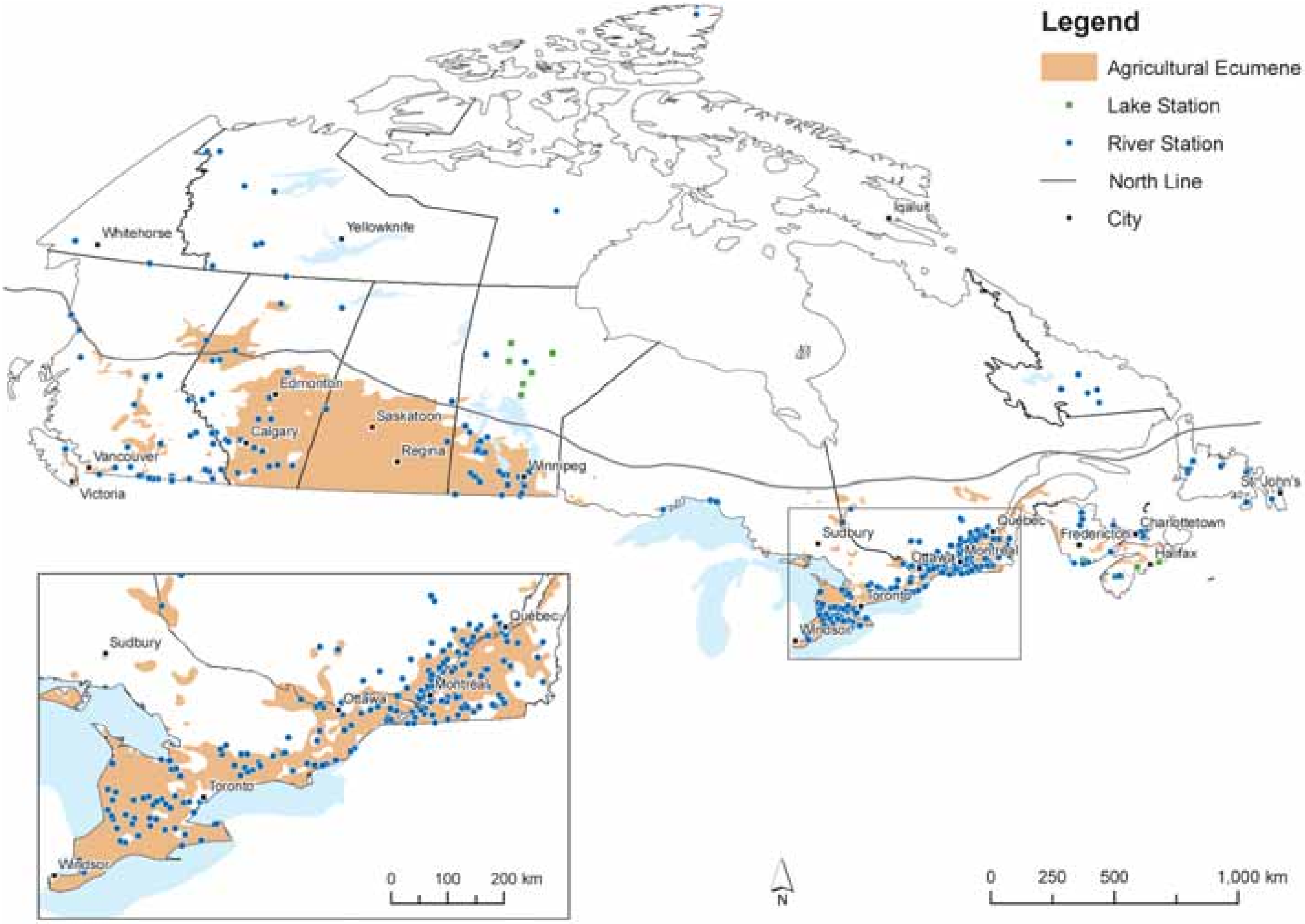
Human settlements

In 2001, nearly four-fifths of Canadians lived in urban areas with a population of 10 000 people or more. Moreover, two-thirds of the Canadian population lived in only 10 of the 164 sub-drainage areas (Statistics Canada 2006a). Impacts on water quality include contaminated runoff water from storm sewers and impervious surfaces and discharges of sewage. In 1999, 83% of urban Canadians living in inland communities were serviced by secondary or tertiary wastewater treatment (Environment Canada 2001b).

The impact of human settlements on water quality are often associated with exceedances of water quality guidelines for nutrients, turbidity or suspended solids, chloride and metals such as copper, iron, lead and zinc. However, it is known that hundreds of other substances can be released in wastewater effluents, including industrial chemicals, pesticides, oil and grease and pharmaceuticals.

Nearly all of the water quality monitoring sites included in this indicator for southern Canada fall within moderately to heavily populated sub-drainage basins, while all of the northern sites are located in sparsely populated sub-drainage basins (Map 5).

Map 6 Areas of agricultural activity in relation to water quality monitoring sites, Canada, 2001



Notes: Based on the national agricultural ecumene, which includes all areas with "significant" agricultural activity. Uses agricultural indicators, such as the ratio of agricultural land on census farms relative to total land area, and total economic value of agricultural production (Statistics Canada 2003b).

Sources: Statistics Canada, Environment Accounts and Statistics Division. Monitoring station information assembled by Environment Canada from federal, provincial and joint water quality monitoring programs.

Agriculture

Over the past several decades, Canadian crop and livestock outputs have grown considerably. Large-scale operations, new technologies and increased inputs involving mechanization, genetics, nutrient science and irrigation have helped foster these agricultural increases. For example, expenditures on manufactured fertilizers rose more than 29% from 1991 to 2001, while expenditures on agricultural chemicals per square kilometre increased 67% during the same period (Statistics Canada 2006a). Similarly, manure production increased 13.9% from 1981 to 2001, with the largest amounts produced in southern Alberta, Ontario and Quebec (Statistics Canada 2006b).

These highly productive technologies and large-scale agricultural operations, however, involve environmental risks that may increase the threat to water quality.

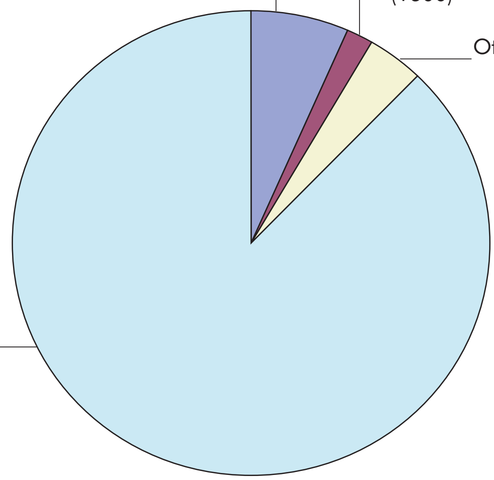
Agricultural operations can cause water quality guidelines to be exceeded for phosphorus and nitrogen, turbidity, suspended solids, pesticides and metals. For example, impacts on water quality can result from the production of manure and the application of nutrients in the form of mineral fertilizer, manure, compost and sewage sludge to increase crop productivity. However, if sound management practices are followed, the environmental risks to water quality can be minimized.

Two-thirds of water quality monitoring sites in southern Canada fall within the areas subject to agricultural activity, while only one-tenth of northern monitoring sites are located within agricultural areas (Map 6).

Industrial and commercial facilities

In 2004, 88% of the 112 000 tonnes of pollutants released to either coastal or freshwater bodies by

Figure 12 Total pollutant releases to either coastal or freshwater bodies from large industrial and commercial facilities reporting to the NPRI, 2004 (tonnes)



Source: National Pollutant Release Inventory, Environment Canada.

large industrial and commercial facilities reporting to the National Pollutant Release Inventory (NPRI) were from municipal water and wastewater services. About 7600 tonnes of effluent were from pulp and paper mills, 1600 tonnes from metal ore mining and 4500 tonnes from all other sectors combined (Figure 12). A total of 513 facilities across Canada reported releases of 102 different substances to either coastal or freshwater bodies, with the largest releases being nitrate (53 000 tonnes), ammonia (49 000 tonnes) and phosphorus (6000 tonnes) (Environment Canada 2006b).

Pulp and paper mills are found throughout Canada and produce large volumes of waste effluent. The main effects of pulp mill effluent include chronic toxicity to aquatic organisms and eutrophication (Environment Canada 2001a). Recent improvements in pollution prevention and control have reduced overall amounts of pollutants released, especially methanol, ammonia and nitrate (Environment Canada 2006c).

The effects of mining on water and aquatic ecosystems can be long-lasting. Concerns related to active and abandoned mines are the long-term effects on the environment from chronic exposure to low levels of metals, including bioaccumulation, sediment contamination, endocrine disruption and long-term changes to characteristics of surface waters receiving mining discharges (Environment Canada 2001a).

Dams and diversions

Dams are used for many different purposes, including power generation, creating reserves of water for agriculture, controlling floods and treating mine tailings. Dams alter the natural flow and shape of rivers. As such, they can affect downstream water temperatures, metal concentrations and oxygen levels, prevent the downstream transport of sediments containing nutrients and, for certain spillways, release gas bubbles in concentrations dangerous for fish downstream (Fidler and Miller 1997; Environment Canada 2001a).

Although human activities are linked to the degradation of water quality in many areas of Canada, management practices can control or reduce impacts on water quality. Furthermore, important improvements have occurred in several industrial sectors, including pulp and paper mills and metal mines, as a result of strong regulations and cooperation between government and industry.

4.3 What's next?

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

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

- a consistent and comparable set of monitoring sites that is representative of key aquatic habitats (e.g. rivers, lakes, wetlands) in Canada with respect to different beneficial uses (e.g., protection of aquatic life, agriculture, source water for drinking);
- improvements in selecting variables and guidelines used in the calculation, so that results can be

aggregated regionally across the country, by drainage area and over time;
- more refined separation of the effects of natural and human-caused changes in water quality through the development of site-specific guidelines; and
- reporting on water quality for other beneficial uses, such as agriculture or raw water sources[11] used to supply drinking water treatment plants, possibly through a series of indicators.

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

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

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

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

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

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

Once developed, this tool is intended to provide a mechanism to evaluate source water and treated water quality, track changes and identify deteriorating or improving water quality conditions; to evaluate the effectiveness of source water protection initiatives and help guide source water protection planning and activities; to identify the presence of gaps in the multiple barrier approach; and to report on source water and treated water quality. Project outcomes continue to be refined as the work progresses.

The first phase of the project, completed in March 2006, focused on developing the process and timeline, clearly identifying the goals of the project and addressing challenges identified by the working group. In the second year of this project, the working group will concentrate its efforts on:

- reviewing related international initiatives;
- developing the methodology for the indicators;
- sharing information with interested stakeholders; and
- pilot-testing the methodology and resulting indicators and making appropriate final adjustments.

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

The indicators will be submitted for review and approval to the appropriate federal departments and FPT committees. The project is scheduled to be completed by the end of March 2007.

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

Guideline development: How well the WQI rates water quality depends directly on the use of appropriate water quality variables and guidelines. Variables and guidelines used in the WQI computation should be locally relevant, meaning appropriate to the local organisms and local water characteristics. For example, water hardness and temperature can affect the toxicity of some substances; therefore, guidelines for these substances should vary according to water hardness and temperature. Environment Canada, in consultation with the provinces and territories, is assessing the ecological relevance of existing guidelines with regards to local conditions and, where necessary, will develop site-specific guidelines using nationally consistent methods and protocols. Options for a more consistent selection of variables among jurisdictions are being evaluated as well. Investments may be needed to measure more variables at some locations and to develop guidelines for other key substances.

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

5 Connecting the indicators

This chapter uses socio-economic data from Statistics Canada as contextual information to help explain the indicators.

Each of the three indicators focuses on separate issues and reflects different temporal and geographic scales. The air quality indicator has links to human health, while the freshwater quality indicator focuses on the protection of aquatic life. Local water and air quality may change from year to year due to episodic events, while atmospheric concentrations of greenhouse gases evolve globally and cumulatively over decades.

The indicators are also connected in fundamental ways:

- Some of the same social and economic forces drive the changes in the indicators.
- Some of the same substances impact all three indicators.
- The indicators reflect stresses in some of the same regions of the country.

The following sections examine some of the relationships between society, the economy and the air quality, greenhouse gas emissions and freshwater quality indicators.

5.1 Societal pressures

5.1.1 Population

Population size, distribution and density partly determine the impacts that human activities have on the environment. Between 1990 and 2004, Canada's population grew by 15%, from 27.7 million people to 32.0 million.

Although Canada's overall population density is low, people are increasingly living in densely populated urban centres, most of which are located in a relatively narrow strip along the Canada–U.S. border. From 1991 to 2001, the urban population increased 14% while the rural population decreased by 5% (Figure 13). These changes have consequences for environmental quality. Drainage areas where the population is dense may experience increased stress on water quality from wastewater discharges and other uses. Pressure from urban areas, sewage treatment plants, industry and agriculture, for instance, all impact the quality of water in the Great Lakes. In 2001, 62% of Canadians lived in the St. Lawrence major drainage area.

5.1.2 Behaviours

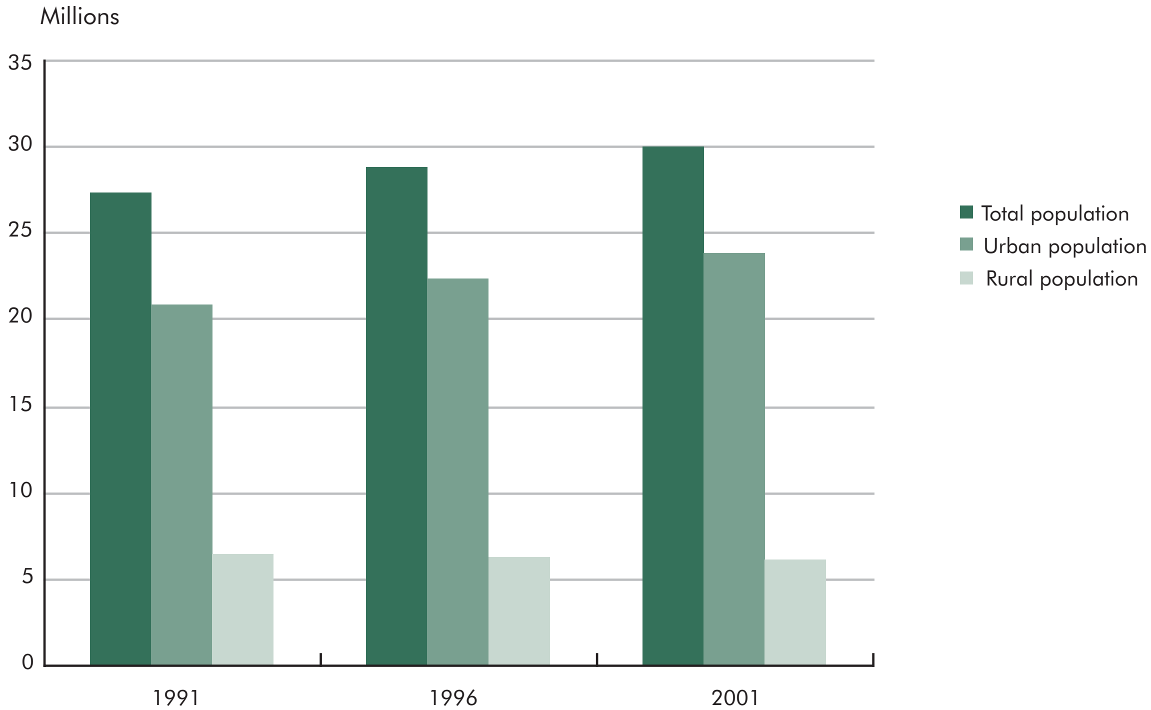
A variety of factors influence Canadians' consumption behaviours. Income and prices are key drivers, while climate, geography, trends in housing size and density and the adoption of technology can also affect how much energy or water we consume.

Household energy consumption

The pollutants that combine to form ground-level ozone (NO_x and VOC) are emitted from transportation and energy production and consumption—activities that are also major sources of greenhouse gas emissions. In turn, NO_x and SO_x, both by-products of the combustion of fossil fuels, combine with water and fall as acid precipitation. This affects water in sensitive lakes and rivers, notably in parts of eastern Canada (Environment Canada 2005).

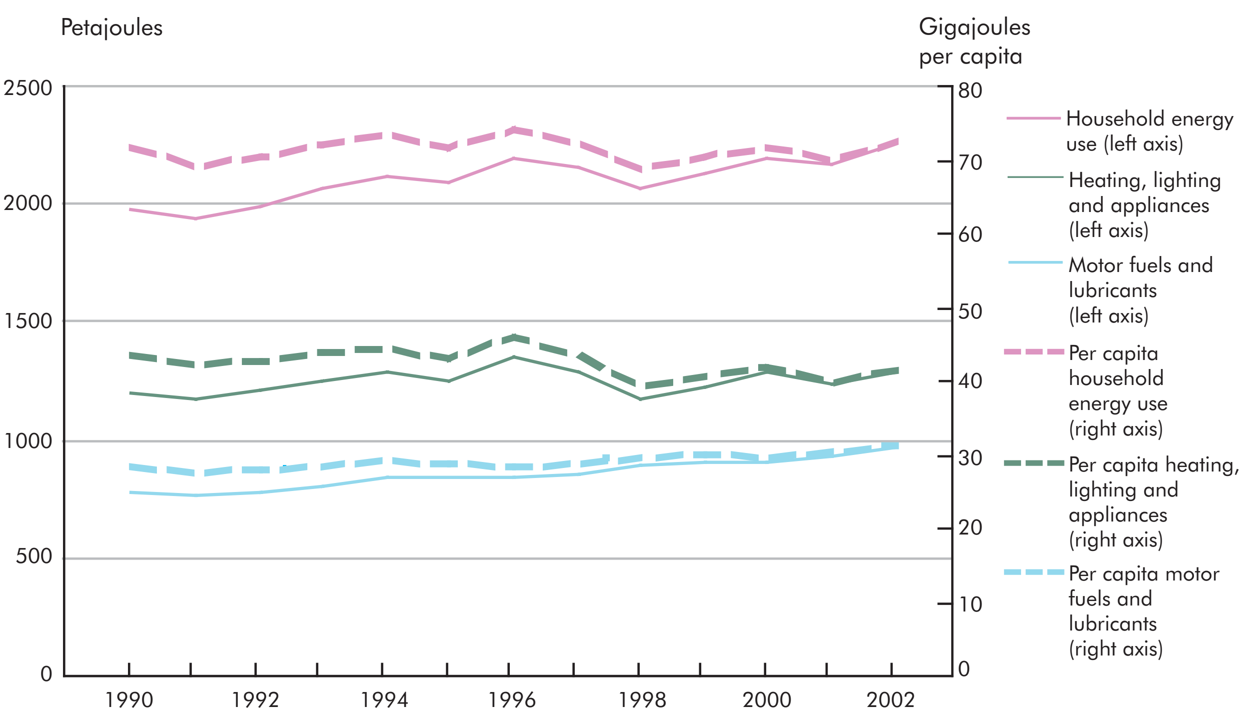
From 1990 to 2002, total household energy consumption increased 14.6% to a high of 2264

Figure 13 Total, urban and rural population, Canada, 1991 to 2001



Source: Statistics Canada. 2006a. Selected population characteristics. In: *Canadian Environmental Sustainability Indicators: Socio-economic Information.* Catalogue No. 16-253-XWE. Ottawa, Ontario.

Figure 14 Energy use, household sector, Canada, 1990 to 2002



Note: The joule is the standard unit for energy in the SI (Système International) system of units. A petajoule is equivalent to 10^{15} multiplied by the number of joules, while a gigajoule is equivalent to 10^{9} multiplied by the number of joules.

Source: Statistics Canada. 2006a. Energy use by sector 1990 to 2002. In: *Canadian Environmental Sustainability Indicators: Socio-economic Information*. Catalogue No. 16-253-XWE. Ottawa, Ontario.

petajoules (Figure 14). With more people choosing to live alone or in smaller households, the number of private dwellings has increased faster than the population (Statistics Canada 2006a). The average size of homes has also increased, and appliances and electrical devices are more common (CMHC 2004; Natural Resources Canada 2006).

At the same time, furnaces and appliances have become more energy-efficient, and improved insulation and other building envelope improvements have increased the energy efficiency of houses (Natural Resources Canada 2005a).

Personal transportation

Per capita private vehicle fuel usage increased by 10% from 1990 to 2002 (Figure 14), and, despite record high fuel prices, Canadians continued to increase their use of gasoline. By 2004, retail pump sales of gasoline had increased 24% over 1990, reaching 36.6 billion litres, the highest level ever recorded (Statistics Canada 2006a).

In general, cars are more fuel-efficient than larger SUVs, trucks and vans. From 1990 to 2004, greenhouse gas emissions from light-duty gasoline automobiles decreased 7.4%, while emissions from gasoline-powered light-duty trucks doubled (Environment Canada 2006d). In 2004, cars accounted for more than half of the total number of kilometres driven by light vehicles, followed by pickups (20%), vans (17%) and SUVs (9%) (Statistics Canada 2006a).

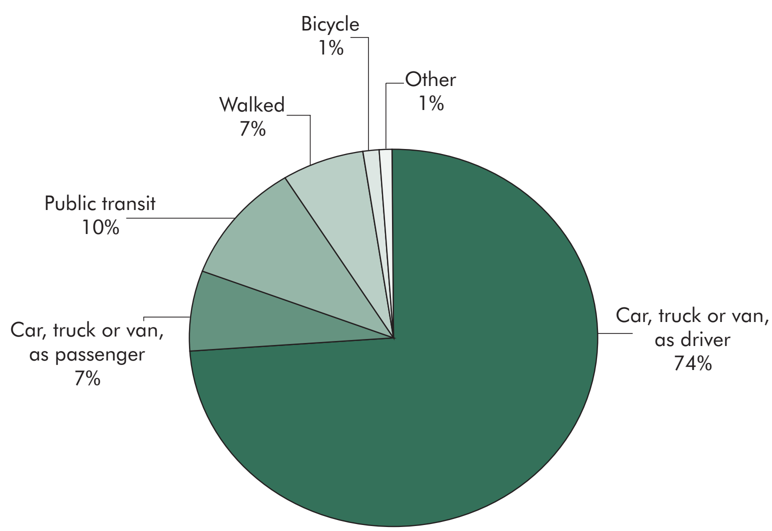
Driving remains the preferred means of personal transport. In 2001, 81% of commuters travelled to work as a driver or passenger of a car, truck or van (Figure 15). By contrast, only 10% of Canadians commuted using public transit, although the proportion reached 15% in metropolitan areas. A further 8% commuted by walking or cycling.

5.2 Economic pressures

Changes in the three environmental indicators can also be viewed against the backdrop of economic activities. Real GDP, which measures the total value of goods and services produced in Canada corrected for inflation, increased by 47% from 1990 to 2004. Over the same period, total primary energy consumption increased 26% (Figure 16). Primary energy consumption per unit of economic activity dropped 14% from 1990 to 2004.

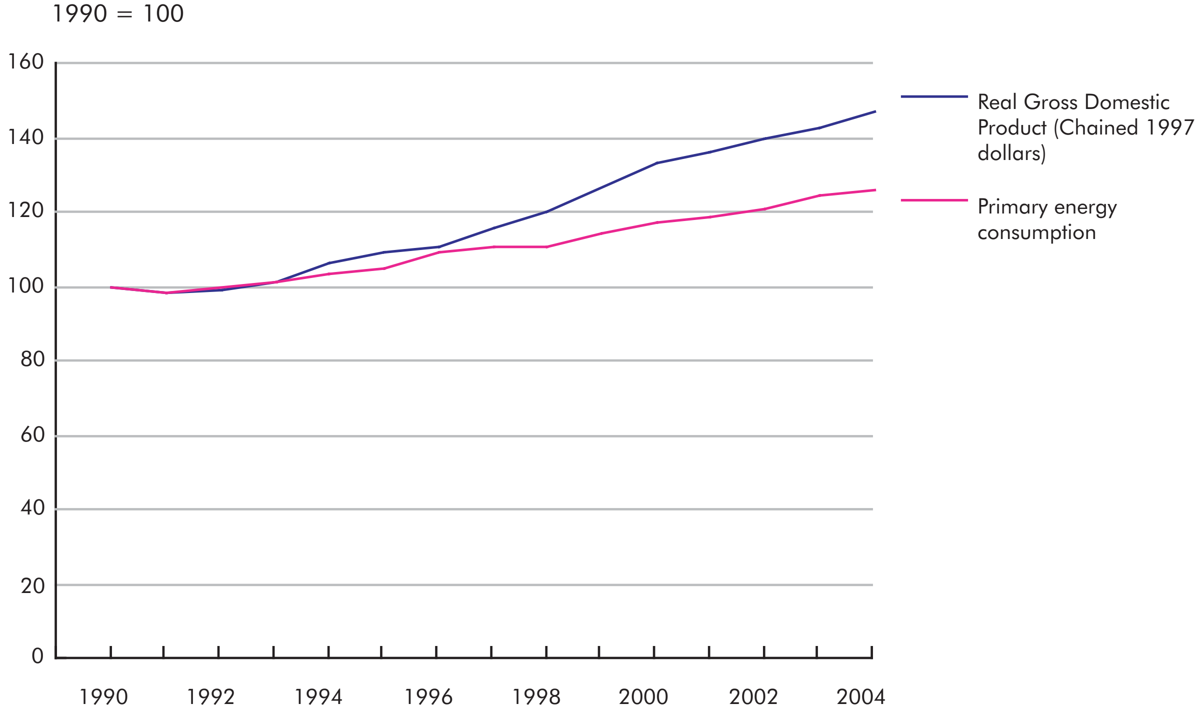
The structure of the economy and distribution of activities across the country help to explain trends in the indicators both nationally and regionally. Each industry has different impacts in terms of water usage, emission of pollutants and greenhouse gases. Service industries (trade, transportation, travel and communications) make up 68% of Canada's GDP, while goods-producing industries (manufacturing, construction and resource industries) account for the remainder (Statistics Canada 2006a). The following sections look in detail at several industries whose activities significantly influence the air

Figure 15 Mode of transportation to work, Canada, 2001



Source: Statistics Canada. 2003c. Where Canadians work and how they get there. In: *2001 Census of Population* (www12.statcan.ca/english/census01/Products/Analytic/companion/pow/contents.cfm; accessed June 15, 2006).

Figure 16 Gross Domestic Product and energy consumption, Canada, 1990 to 2004



Source: Statistics Canada. 2006a. Primary energy consumption indicators. In: *Canadian Environmental Sustainability Indicators: Socio-economic Information*. Catalogue No. 16-253-XWE. Ottawa, Ontario.

quality, greenhouse gas emissions and freshwater quality indicators.

5.2.1 Transportation industries

While freight transport has increased across all modes since 1990, the trucking industry, in particular, has seen a dramatic rise, caused in part by the advent of just-in-time delivery (Figure 17). Between 1990 and 2003, freight carried by the for-hire trucking industry increased 75% from 174 million tonnes to 305 million tonnes. Greenhouse gas emissions from heavy-duty diesel vehicles rose 83% from 1990 to 2004 (Environment Canada 2006d).

Vehicles and fuels are becoming cleaner. New regulations limiting the sulphur content of diesel fuel to 15 parts per million and technologies to eliminate particulate matter and NO_x from truck engine emissions will help to improve air quality.

5.2.2 Energy production

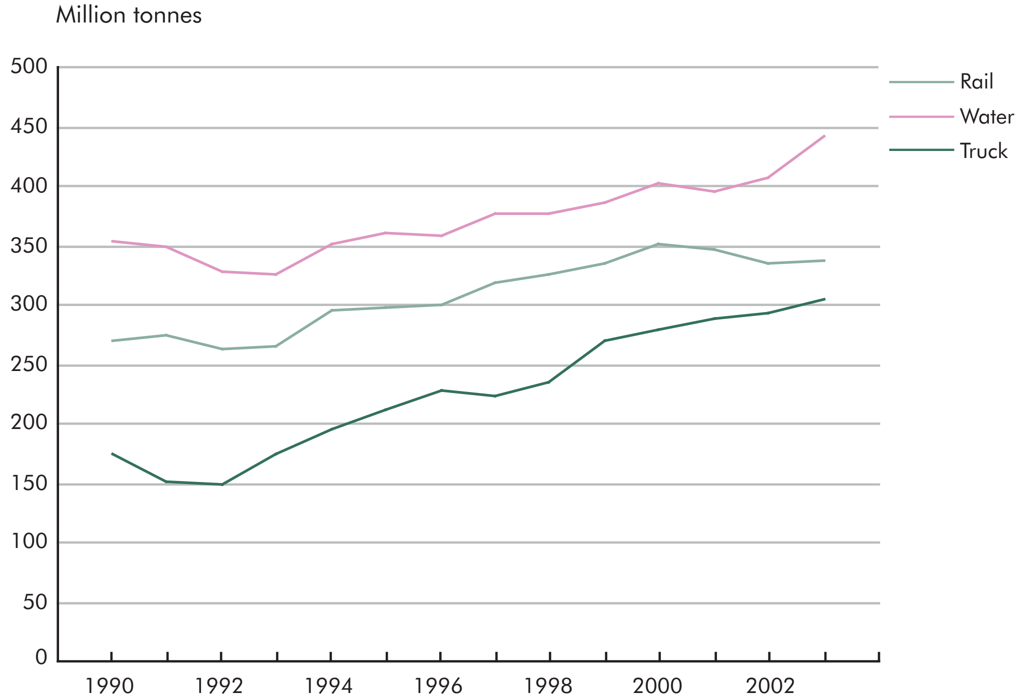
Oil and gas production emits air pollutants and greenhouse gases and is a major user of water. Since 1990, primary energy production rose 44%, largely as a result of increases in the production of natural gas and crude oil (Statistics Canada 2006a). Canada's oil sands are becoming an increasingly important source of crude oil production. In 2004, the oil sands accounted for over 38% of total crude oil and equivalent production (Statistics Canada 2005a). With current technology, Canada's oil sands deposits are second only to Saudi Arabia's oil reserves (Canadian Association of Petroleum Producers n.d.); however, extracting oil from oil sands is more energy intensive than conventional oil recovery.

Lakes and rivers are affected by damming for hydro-electric power generation. In 2004, 59% of electric power was generated from hydro power and 15% from nuclear sources, while the remainder was produced using fossil fuels through conventional steam and combustion generation (Figure 18). In comparison, 63% of electricity was generated from hydro power in 1990, while generation from nuclear sources was unchanged at 15%.

5.2.3 Agriculture

Over the last several decades, farming has undergone many changes, such as the rapid adoption of new

Figure 17 Freight shipped, by mode, Canada, 1990 to 2003



Sources: Statistics Canada. n.d.a. *Shipping in Canada*. Various issues. Catalogue No. 54-205-XIE. Ottawa, Ontario.
Statistics Canada. n.d.b. *Rail in Canada*. Various issues. Catalogue No. 52-216-XIE. Ottawa, Ontario.
Statistics Canada. n.d.c. *Trucking in Canada*. Various issues. Catalogue No. 53-222-XIB. Ottawa, Ontario.

technologies and increasing productivity. Between 1981 and 2001, the number of farms decreased 22%, while cropland areas increased 18%.

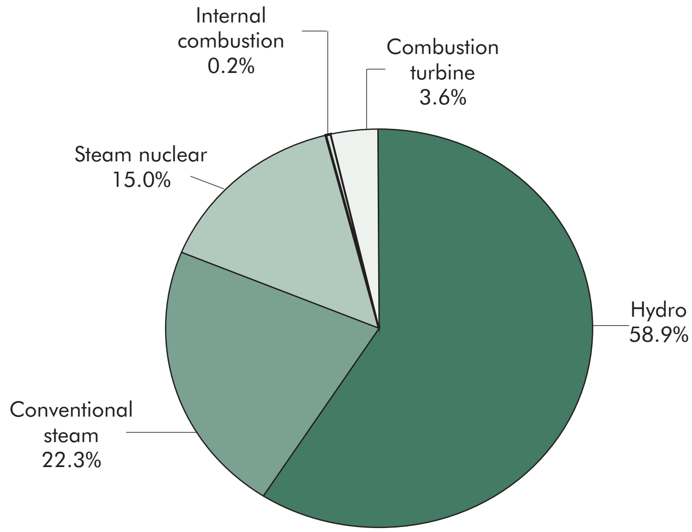
Agricultural fertilizer application and poor manure management have been linked to high concentrations of nutrients such as nitrogen and phosphorus in some water bodies (Environment Canada 2001a). From 1981 to 2001, fertilized areas increased 29.8% to 240 000 square kilometres (Statistics Canada 2005a). For the whole of Canada, manure production increased 13.9% from 1981 to 2001, with the largest amounts produced in southern Alberta, Ontario and Quebec . Counter to the overall trend, manure production in the St. Lawrence major drainage area, which feeds into the Great Lakes, decreased 18.0% (Statistics Canada 2006b).

Pesticides, used to control weeds, insects and other pests, can potentially harm non-target organisms. Effects vary depending on the chemical used along with the level and duration of exposure (U.S. Geological Survey 1999). Pesticides can contaminate water through runoff and infiltration into groundwater. From 1981 to 2001, real farm business expenditures on chemical products such as herbicides, insecticides and fungicides increased 132% (Statistics Canada 2006a). Agricultural activities are the most important source of ammonia in the air, and also contribute to emissions of methane and nitrous oxide, both potent greenhouse gases (Agriculture and Agri-Food Canada 2003, Environment Canada 2006d).

5.2.4 Other industries

Effluent discharges from pulp and paper manufacturing, mining and other industries can influence water quality. Effects range from toxicity to aquatic organisms to nutrient enrichment (Environment Canada 2001a). Industrial processes are also responsible for emissions of air pollutants and greenhouse gases. According to Environment Canada (2006d, 2006e), industrial releases of NO_x totalled 868 kilotonnes in 2004, up 104% from 426 kilotonnes in 1990 while 895 kilotonnes of VOC were released from industrial facilities, an increase of 3% since 1990. In contrast, releases of particulate matter by industry declined 8% from 1990 to a level of 635 kilotonnes in 2004. From 1990 to 2004, greenhouse gas emissions from manufacturing industries decreased 7.2%, while emissions in the industrial processes sector increased 1.9% (Environment Canada 2006f).

Figure 18 Electric power generation, by source, Canada, 2004



Source: Statistics Canada. 2006a. Electric power generation, by source. In: *Canadian Environmental Sustainability Indicators: Socio-economic Information.* Catalogue No. 16-253-XWE. Ottawa, Ontario.

5.3 The social and economic costs

The Intergovernmental Panel on Climate Change (2001) has concluded that North America, among other regions, will face environmental, economic and social costs if global efforts fail to reduce greenhouse gas emissions. Effects on water resources could include reduced water supply and diminished water quality, although these would vary among regions. If extreme weather events became more frequent and intense, damage to settlements and agricultural crops could occur. Forest productivity and wildlife could also be harmed. Continually increasing emissions could lead to pollution-related health problems, heat-related morbidity and mortality, and higher incidence of waterborne and vector-borne diseases.

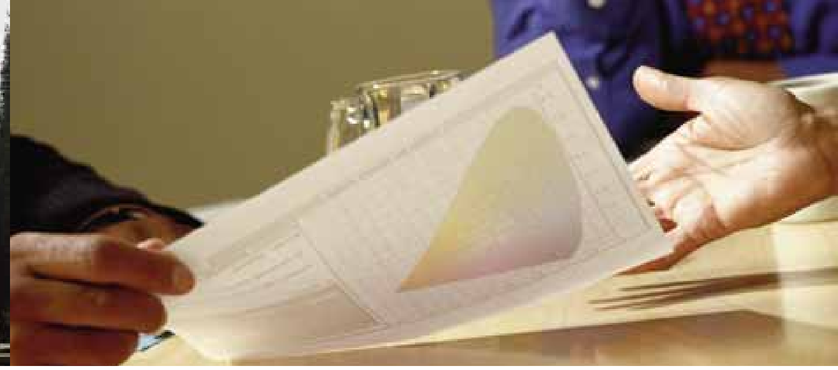
Another consideration is the socio-economic cost of the pollution itself. For example, Health Canada has estimated, based on data from eight cities (Québec, Montréal, Ottawa, Toronto, Hamilton, Windsor, Calgary and Vancouver), that 5900 premature deaths each year in these cities are attributable to air pollution (Judek et al. 2004). Economists have also tried to estimate the social costs of poor health due to air pollution. A monetary estimate of all the health impacts—health care costs, lost productivity, and pain and suffering—runs to the billions of dollars per year in Canada (Chestnut et al. 1999).

5.3.1 Expenditures to protect the environment

Part of the economic dimension of the indicators is the cost associated with reducing greenhouse gas emissions and water and air pollution. Canadian companies have substantially increased their spending to protect the environment. Spending by primary and manufacturing industries reached $6.8 billion in 2002, a 24% increase over expenditures in 2000. Much of the increase resulted from responses to new environmental regulations and industry's effort to reduce air emissions such as greenhouse gases.

Canadian businesses spent $1.106 billion to reduce greenhouse gas emissions in 2002. The oil and gas extraction industry spent almost $245 million, followed by the pulp, paper and paperboard mills industry at $242 million (Statistics Canada 2004). In 2004, over a quarter of businesses surveyed introduced new or significantly improved equipment to reduce greenhouse gas emissions (Statistics Canada 2006c).

Businesses invested $428 million in 2002 to prevent and control water pollution. Significantly more was invested that year on protecting air quality: about $1.531 billion, three-quarters of which was paid by the oil and gas, electric power and petroleum and coal products industries (Statistics Canada 2004).

6 Conclusion

CESI reports are to be produced annually to track changes in air quality, greenhouse gas emissions and water quality in Canada. The long-term goal is to enable better decision-making that fully accounts for environmental sustainability. To assist with this, future reports will be supported with an online information system that will allow users to examine regional and sectoral details and conduct their own analyses.

The 2006 indicator results provide evidence of increased pressures on Canada's environmental sustainability, the health and well-being of Canadians and potential consequences for our long-term economic performance. The trends for air quality and greenhouse gas emissions are pointing to greater threats to human health and the planet's climate, while the water quality results show that guidelines are being exceeded, at least occasionally, at many of the selected monitoring sites across the country.

The greenhouse gas emissions indicator is currently the best developed of the three. It clearly shows a rise in Canada's emissions between 1990 and 2004 and helps to pinpoint the major sources of the increase—oil, gas and coal production and consumption. Further development and improvements are under way for this indicator, as noted in the "What's next?" section of the chapter.

The air quality indicators are based on an established national monitoring network. However, the task of linking policy measures to air quality and then to human health effects is formidable: ozone levels and fine particulate matter are influenced by complex factors, including weather and the atmospheric transport of pollutants. The approach taken in this report—analysing the observed concentrations in relation to where people live—is just a start. In the future, the indicators will be further developed through systematic measurements of other air pollutants and analyses of their cumulative effects, which will then be integrated into a comprehensive air health indicator.

The assembly of information for the freshwater quality indicator from across the country, including the Great Lakes and the North, demonstrates that jurisdictions can cooperate to sketch a national picture of water quality. Revisions and improvements to this indicator for future reports will require a better understanding of how well particular monitoring sites represent the quality of the water bodies or watersheds in which they are located and how accurately the monitoring network reflects the water quality of all Canadian rivers and lakes. The development of a more accurate national indicator will also rely on choosing variables and developing water quality guidelines that better match the ecological diversity of Canada's water bodies.

New surveys, enhanced monitoring capabilities, new scientific knowledge and guidelines and improved data management and analytical methods will benefit future reports. This report has set the three indicators in a socio-economic context. However, more work is needed to complete the transition from reporting these indicator results separately to reporting them as a set that is integrated with other information on the environment, measures of economic performance and indices of social progress.

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Appendix 1
Description of the air quality indicator

The air quality indicators are designed to track the longer term trend in human exposure to ozone and $PM_{2.5}$ levels from both a national and regional perspective.

Air Monitoring

Canada has a coordinated air monitoring network that includes stations from across the country. A national database of concentrations of air pollutants contains information provided by the National Air Pollution Surveillance (NAPS) network, a federal–provincial–territorial cooperative network focused on urban air quality (Environment Canada 2003). This network is, in turn, complemented by information from the Canadian Air and Precipitation Monitoring Network, a federal network that measures rural and remote background levels of air pollutants.

Ground-level ozone

From 1990 to 2004, 255 monitoring stations across the country reported hourly concentrations of ground-level ozone. Data sets from 76 of these stations were sufficiently complete for the period 1990 to 2004 to be used for the national trend analysis (Figure 1). Data sets from these same stations, less three stations that did not fit into the five geographic clusters considered, were used for the regional trend analysis between 1990 and 2004 (Figure 2). Data sets from 159 of the monitoring stations were sufficiently complete for the 2004 warm season to be used for reporting on the 2004 status of ground-level ozone concentrations (Map 1). (See Map A.1 for locations of ozone monitoring stations.)

The measurement error for ozone concentrations at individual sampling stations is estimated to be $\pm$10% (Dann and Conway 2005). Selected sampling stations are subject to federal audits. Agencies contributing data to the NAPS database may perform additional audits and strive to adhere to established quality assurance and quality control standards to maintain national consistency.

The ground-level ozone indicator was calculated on a yearly basis as follows. For each given station, hourly concentrations of ground-level ozone were first averaged per period of eight hours (using 24 overlapping periods of eight hours per day, each period starting one hour after the start of the previous period and including the previous seven hours). The maximum of these averages was then taken on a 24-hour basis. These daily maxima were then averaged over the entire warm season (April 1 to September 30). Finally, these seasonal averages per station were averaged and population-weighted to provide a yearly indicator estimate.

Fine particulate matter ($PM_{2.5}$)

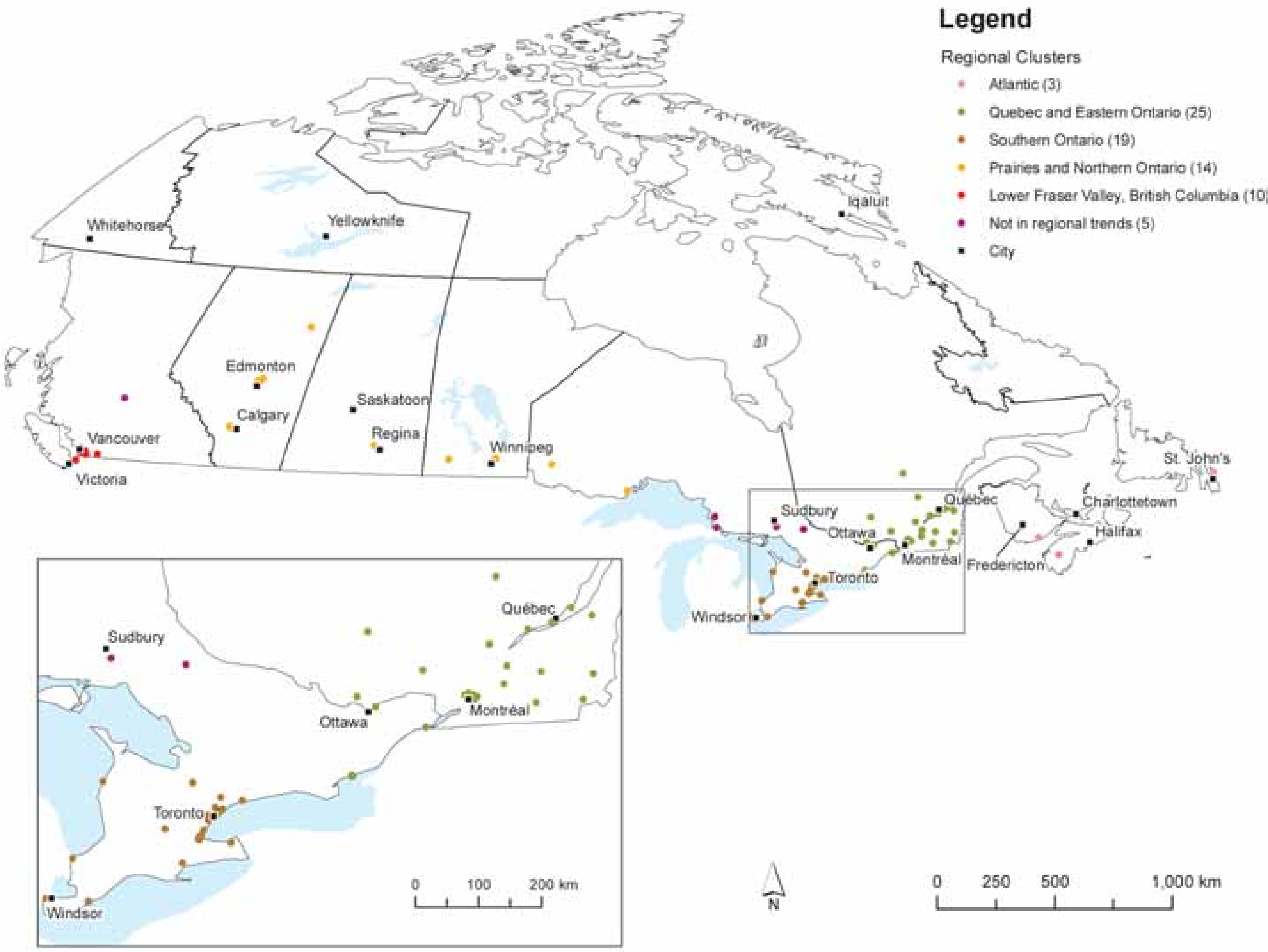
In 1984, the first year of monitoring $PM_{2.5}$, concentrations were measured in only a few Canadian cities. Gravimetric analysis was used to collect $PM_{2.5}$ samples by passing air through a size-selective filtering medium and weighing it. The use of this filter sampling is labour- and resource-intensive. It entails collecting and sending each sample to a certified laboratory for manual weighing. Other methods that continuously monitor and provide in situ, real-time, hourly $PM_{2.5}$ data became available in the mid-1990s and are being gradually deployed at different sites across Canada. These new automated methods are replacing and/or supplementing filter sampling. The two new $PM_{2.5}$ monitoring methods that have been deployed since 2000 are the tapered element oscillating microbalance (TEOM)[13] method and the beta attenuation monitor (BAM)[14] method. The filter sampling program still continues and provides the historical record required for trend analysis.

A comparative analysis between manual weighing and TEOM instruments shows good agreement during summertime. Sampling stations are subject to federal audits, and agencies contributing data to the NAPS database may perform additional audits.

From 2000 to 2004, 136 monitoring stations reported hourly observations for $PM_{2.5}$ concentration across the country. In this report, 63 monitoring sites had sufficient data to calculate the warm-season average $PM_{2.5}$ levels for 2000 to 2004, and 117 monitoring sites had sufficient data for reporting in 2004 (Map 2). The 24-hour averaging period was based on health aspects, representing the commonly used unit for assessing exposure to $PM_{2.5}$. There were insufficient data to

13. The most widely used method in Canada; 125 total in 2004.
14. Increasingly being deployed in Atlantic Canada; 26 total in 2004.

Map A.1 Locations of monitoring stations contributing to the ozone indicator



Note: Number of monitoring stations is 76. Regional clusters were defined by Environment Canada.
Sources: Environment Canada, National Air Pollution Surveillance Network Database; Statistics Canada, Environment Accounts and Statistics Division.

conduct an analysis for $PM_{2.5}$ on a regional scale. (See Map A.2 for locations of $PM_{2.5}$ monitoring stations.)

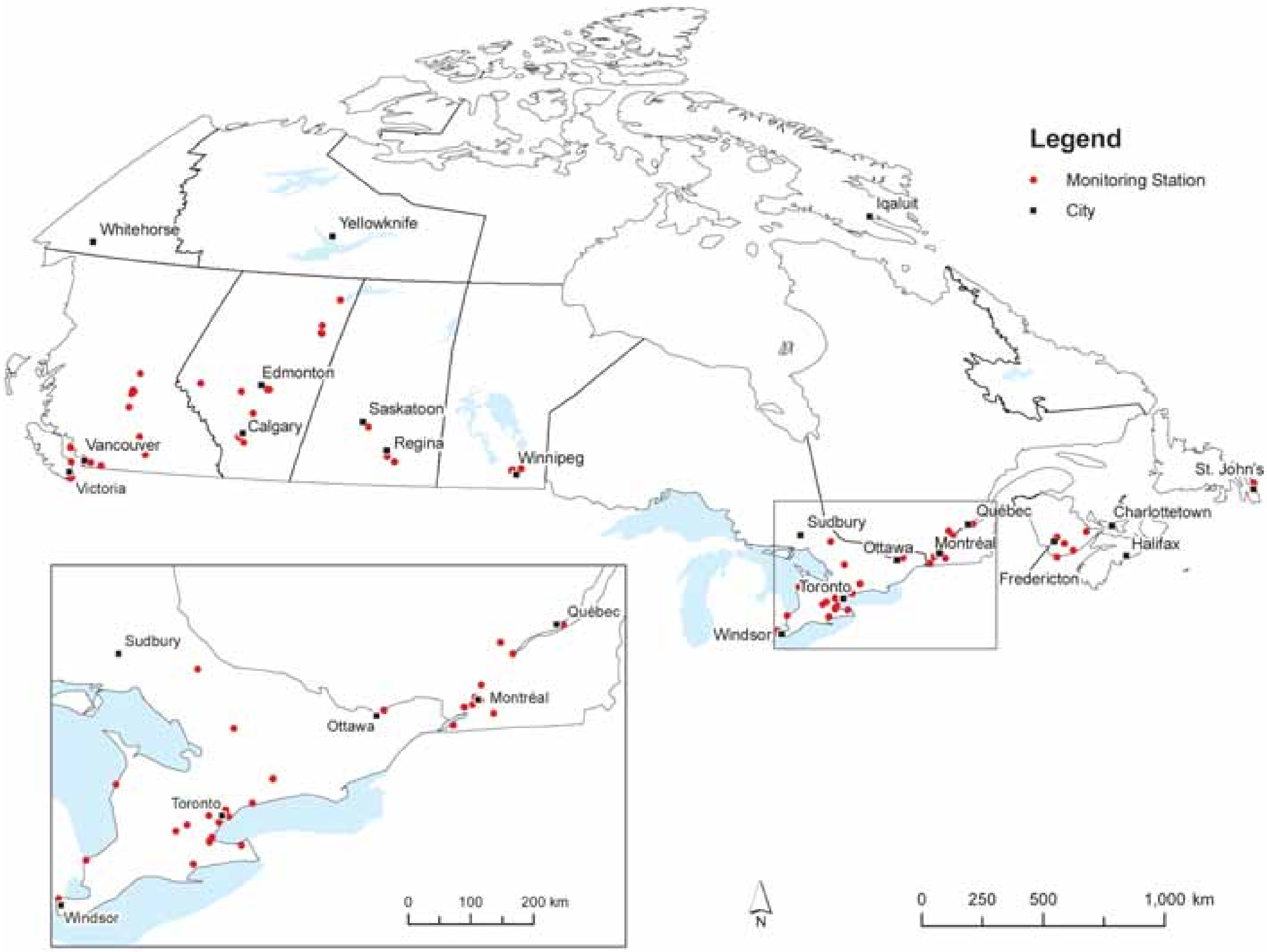
The $PM_{2.5}$ indicator was calculated on a yearly basis as follows. For each given station, hourly concentrations of $PM_{2.5}$ were first averaged on a daily basis. These daily averages were then averaged over the entire warm season (April 1 to September 30). Finally, these seasonal averages per station were averaged and population-weighted to provide the yearly indicator estimate.

Population-weighted concentration

Monitoring stations in the NAPS network tend to be located in more populated areas, but they are not in direct proportion to the total population in each area. As a result, the warm-season average concentrations of ozone and $PM_{2.5}$ are population-weighted in this report to proportionally adjust for population exposure. Census data were used to estimate the number of Canadians living within a 40-kilometre radius of each monitoring site. The population-weighted concentration was calculated by summing the products of the population count and the warm-season average concentration of the pollutant at each monitoring site and then dividing by the total population, the sum of population counts of all the monitoring sites.

This population adjustment gives more weight to air pollution measurements observed in more highly populated areas so that the indicators are more

Map A.2 Locations of monitoring stations used in $PM_{2.5}$ air quality indicator trends



Note: Number of monitoring stations is 63.
Sources: Environment Canada, National Air Pollution Surveillance Network Database; Statistics Canada, Environment Accounts and Statistics Division.

representative of the exposure of the population to air pollutants. It should be noted that the indicators currently track the population observed by the NAPS network and not the entire population of the country.

Interpretation of the trend and statistical significance of the air quality indicators

Interpretation of trends in air quality indicators should give careful consideration to the slope of the trend lines. The magnitude of statistically significant trend slopes may not always be environmentally important when compared with detection limits, background levels and air quality standards.

Nevertheless, in the case of the air quality indicators, there are no established thresholds below which these two population exposure indicators, ground-level ozone and $PM_{2.5}$, are safe and do not pose a risk to human health. As a result, an increase in trend slopes of these indicators, regardless of their magnitudes, may signal the potential for increased health risk.

Non-parametric statistical tests were conducted to examine the direction and the magnitude of the annual rate of change in the air quality indicators. The standard Mann-Kendall trend test was used to determine the direction of the yearly changes, and the Sen trend slope estimator was used to assess the magnitude of the observed rates. The Sen method is a non-parametric linear slope estimator that is commonly used in environmental statistics with time series data.

Trends were calculated and tested only for time series that extended over 15 years. Confounding factors and possible autocorrelation will be investigated in the future.

In the case of the ozone indicator (Figure 1), the reported increase was 0.9% per year, with a 90% confidence interval between 0.1% and 1.6% per year.

For the regional ozone indicators (Figure 2), the reported increase in southern Ontario was 1.3% per year, with a 90% confidence interval between 0.1% and 2.6% per year. There were no statistically significant increases or decreases in the other four regions; hence, no trends were reported for these regions.

Further details on the indicator are provided on the Government of Canada website (www.environmentandresources.ca) and the Statistics Canada website (www.statcan.ca)

Appendix 2
Description of the greenhouse gas emissions indicator

The greenhouse gas emissions indicator, related data and trends information come directly from Canada's National Inventory Report, 1990–2004, an annual report submitted by Environment Canada as required under the United Nations Framework Convention on Climate Change (UNFCCC) (Environment Canada 2006a). Greenhouse gas emissions are estimated according to the procedures and guidelines prescribed by the Intergovernmental Panel on Climate Change (IPCC) and are reviewed annually by a United Nations Expert Review Team. The indicator estimates Canada's total annual anthropogenic (human-induced) emissions into the atmosphere of six main greenhouse gases:

Carbon dioxide (CO_2) is emitted partly by human activities such as fossil fuel combustion, deforestation and industrial processes.

Methane (CH_4) emissions result from sources such as livestock, incomplete combustion of biomass, leakage from natural gas transportation and delivery systems, coal mining and decay of organic waste in landfills.

Nitrous oxide (N_2O) is released by cultivating soil, applying nitrogen-based fertilizers, producing nylon and burning fossil fuels and wood.

The electric power industry emits sulphur hexafluoride (SF_6) when installing, servicing and disposing of equipment such as circuit breakers, gas-insulated substations and switchgears. Sulphur hexafluoride is also used during primary magnesium production.

Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are used, for example, in refrigeration equipment, fire extinguishers and air conditioners. Emissions of these gases occur when this equipment is used and when it is discarded.

Carbon dioxide, methane and nitrous oxide are produced by both natural and human sources. Sulphur hexafluoride, HFCs and PFCs come only from human sources.

The total emissions estimate is calculated by adding the individual estimates for each of the six gases. The individual estimates are all converted to an equivalent amount of carbon dioxide by multiplying the estimated emissions for each gas by a weighting factor called "global warming potential" that is specific to the gas. This potential represents the amount of warming over 100 years that results from adding one unit of each gas to the atmosphere, compared with the effect of adding one unit of carbon dioxide. Each unit of methane, for example, is multiplied by 21, and each unit of nitrous oxide is multiplied by 310, to determine their carbon dioxide equivalents.

The emissions for each greenhouse gas are estimated by summing the individual estimates for different activities. In general, measurements of the amount of activity (e.g. kilometres driven or amount of a given product manufactured) are multiplied by the emissions per unit for that activity. Estimates of emissions per unit of activity, also known as emission factors, are based on measurements of representative rates of emission for a given activity level under a given set of operating conditions (U.S. EPA 1996). Some emission factors can be calculated for individual industrial facilities; most are more general and are derived from national or international averages.

The indicator does not include emissions from naturally occurring sources (e.g. organic matter decay, plant and animal respiration, and volcanic and thermal venting) or the absorption of emissions by natural sinks, such as forests and oceans. Emissions and removals from some types of land, such as forests and wetlands, and changes in land use are excluded from the indicator as well.

Environment Canada's Greenhouse Gas Division developed and compiled these data from several sources, including Statistics Canada (statistics on energy, transport, livestock, crop production and land), Natural Resources Canada (statistics on mineral production and forestry) and Agriculture and Agri-Food Canada (some agricultural parameters), as well as other sections of Environment Canada (data on landfill gas capture, HFC use and PFC use, ozone and aerosol precursors). Environment Canada engineers and scientists estimate emissions using methods developed by IPCC as well as

BOX A.1

Statistic Canada's Greenhouse Gas Emissions Account

Statistics Canada's Greenhouse Gas Emissions Account forms the basis for Figure 7. Produced following the concepts of the System of National Accounts,[1] it uses many of the same basic data as the greenhouse gas inventory compiled by Environment Canada; however, the information is recast into the commodity and industry framework of the System of National Accounts so that the emissions data can be used for economic modelling. In particular, this linkage permits use of Statistics Canada's national input–output accounts to analyse the interplay between production and consumption of goods and services and the greenhouse gas emissions that result from those activities. Emissions from the production of goods and services are attributed via the input–output model to the final purchaser.

Statistics Canada's Greenhouse Gas Emissions Account provides emissions estimates for 119 industries and two categories of household expenditure. In addition to the detailed emissions data produced by sector, several environment–economy "intensity" indicators are derived from Statistics Canada's Greenhouse Gas Emissions Account, including the greenhouse gas intensity of gross industrial output, the greenhouse gas intensity of household consumption and the greenhouse gas intensity of net exports.

Emissions factors from Environment Canada are applied to Statistics Canada's energy use account data (which are also based on the System of National Accounts industry and commodity frameworks). The energy use data come mainly from Statistics Canada's Industrial Consumption of Energy Survey, transportation surveys, the Report on Energy Supply–Demand in Canada and Natural Resources Canada's Census of Mines. Additional estimates of emissions that are not linked to fossil fuel consumption are taken directly from the Environment Canada greenhouse gas inventory and are applied to the appropriate industries in the System of National Accounts.

The final demand categories outlined in Figure 7 can be defined as follows:

Exports: receipts from other provinces and territories or from abroad for sales of merchandise or services. The barter, grant and giving of goods and services as gifts would also constitute exports.

Gross fixed capital formation (subdivided into "Construction" and "Machinery and equipment"): the value of a producer's acquisitions, less disposals, of fixed assets during the accounting period plus certain additions to the value of non-produced assets (such as subsoil assets or major improvements in the quantity, quality or productivity of land) realized by the productive activity of institutional units.

Government net current expenditure: economic activities of the federal government (including defence), the provincial and territorial governments, local (municipal) governments, universities, colleges, vocational and trade schools, publicly funded hospitals and residential care facilities, and publicly funded schools and school boards.

Inventories: consist of stocks of outputs that are still held by the units that produced them prior to their being further processed, sold or delivered to other units or used in other ways, and stocks of products acquired from other units that are intended to be used for intermediate consumption or for resale without further processing.

Personal expenditure: represents the purchases of commodities, commodity taxes, wages and salaries and supplementary labour income of persons employed by the personal sector. Includes individuals, families and private non-profit organizations.

1. Readers interested in more information on Statistics Canada's System of National Accounts are invited to refer to www.statcan.ca/english/ nea-cen/pub/guide/sna.htm

methods and models developed in-house specifically for estimating Canadian emissions (Environment Canada 2006a).

The draft inventory is reviewed by an interdepartmental working group that includes representatives of provincial, territorial and federal government departments working in air pollution measurement and estimation. Emissions estimates for the various sectors are also reviewed by experts from the organizations that provided the source data, such as Statistics Canada, Natural Resources Canada and Agriculture and Agri-Food Canada. Finally, the information submitted by Canada each year to the UNFCCC Secretariat is subject to external review by a team of experts, and a report of their findings is published by the UNFCCC. The inventory underwent an in-depth review in Canada in 2003 and a “desk” review in 2004 and 2005.

Sources of uncertainty in the estimated emissions include the definitions of the activities that are incorporated in the estimates, methods for calculating emissions, data on the underlying economic activity and the scientific understanding. Uncertainty information is used to set priorities to improve the accuracy of future inventories and to guide decisions about improvement of the estimation methods. The uncertainty about estimates for individual gases, individual sectors or specific provinces will be higher than for the overall national estimate (Environment Canada 2006a).

Quality assurance, quality control and verification procedures are part of preparation of the inventory. They take the form of internal checks and external reviews and audits, following international standards. Activities based on these reviews are intended to further improve the transparency, completeness, accuracy, consistency and comparability of the national inventory. The detailed documentation, uncertainty estimates, international reporting guidelines, domestic and international scrutiny and reliance on Statistics Canada energy survey results all contribute to the quality of the greenhouse gas estimates.

Further details on the indicator are provided on the Government of Canada website (www.environmentandresources.ca) and the Statistics Canada website (www.statcan.ca).

Appendix 3
Description of the freshwater quality indicator

The national freshwater quality indicator is based on the Water Quality Index (WQI), which is endorsed by the Canadian Council of Ministers of the Environment (CCME 2001). The WQI is described further on the CCME's website (www.ccme.ca).

In this report, the WQI was calculated for 340 locations in southern Canada, 30 locations in northern Canada and 7 basins in the Great Lakes. In the 2005 CESI report, the WQI was reported for 345 locations nation-wide, virtually all in Southern Canada, as well as 7 basins and 2 harbours in the Great Lakes. There was no reporting for northern Canada in the 2005 CESI report.

The set of monitoring sites was assembled from existing federal, provincial, territorial and joint water quality monitoring programs (Map 3). These monitoring sites were established for many different reasons, including regulatory requirements, compliance with interprovincial or international agreements and the need to manage local water quality issues. For example, some small lakes in the Maritimes are being monitored because they are located in acid-sensitive areas.

The monitoring sites included in the calculation met minimum requirements for the timing of the sample collection (from 2002 to 2004) and the number of samples taken (12 for rivers and 6 for lakes over the three-year period). Most of the sites were located in southern Canada and were potentially affected by human settlements, farms, industrial facilities and dams, as well as acid precipitation. Consequently, the monitoring sites are not statistically representative of Canada as a whole. Most were originally chosen for monitoring because they are in areas where there is concern about the effects of human activities on water quality. Saskatchewan, northern Ontario and northern Quebec are large areas that now have little or no representation in the water quality indicator. The minimum sample requirement was reduced for sites in northern locations to reflect the reality of water quality sampling in northern Canada and to allow more sites to be included in the indicator for this reference period. Analysis showed that the reduction of sample requirements in this case did not impact the results significantly.

Running waters included in this analysis range from small streams, such as Prince Edward Island's Bear River, which has an average flow of 0.3 cubic metres per second and drains an area of about 15 square kilometres (Environment Canada n.d.d), to powerful rivers such as the Mackenzie, which discharges 9910 cubic metres per second and drains an area of about 1.8 million square kilometres (Mackenzie River Basin Board 2004). The lakes also vary considerably in size—from Glasgow Lake (0.24 square kilometres) in Nova Scotia's Cape Breton Highlands to Sipiwesk Lake in Manitoba (454 square kilometres) (Natural Resources Canada n.d.).

The range of water quality variables incorporated into the WQI calculations includes:

- nutrients (e.g. phosphorus and nitrogen);
- metals (e.g. arsenic, cadmium, copper, chromium, lead, mercury, nickel, selenium, silver and zinc);
- physical characteristics (e.g. pH, dissolved oxygen, turbidity and total suspended solids);
- major ions (e.g. chloride and sulphate); and
- some organic compounds (e.g. pesticides).

Different subsets of these variables were selected and applied either uniformly throughout different jurisdictions and regions or, in the case of British Columbia, at individual sites. Generally, Environment Canada and its provincial and territorial counterparts chose which variables to use in the calculation based on which variables had been measured, the human activities of concern and the availability of suitable water quality guidelines. The choices were made by drawing on local knowledge and advice provided by provincial, territorial and federal water quality experts. The variables used in the WQI calculations reflect some of the main stressors on water quality across Canada noted above. Water quality guidelines were selected from national, provincial and site-specific sources.

For the Great Lakes case study, the WQI was calculated using data collected by Environment Canada's Great Lakes Surveillance Program. Conducted on a two-year rotation, this program took measurements for Lake Erie, Lake Huron and Georgian Bay in April 2004 and for

Lakes Ontario and Superior in April 2005. Fifteen variables were included in the calculation of the WQI, but not all of them were available for all lakes.

Additional work will be required on several aspects of the freshwater quality indicator, such as the representation and distribution of sites across the country, the consistency with which variables are used in the calculations and the implementation of locally relevant guidelines. How different variables are combined to produce the index values will also be reviewed and refined.

Further details on the indicator are provided on the Government of Canada website (www.environmentandresources.ca) and the Statistics Canada website (www.statcan.ca).

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This publication, a highlights report, the related websites and web-based information system were prepared by Environment Canada (EC) and Statistics Canada (STC) with input from Health Canada (HC). The summary of socio-economic information was prepared by Statistics Canada. The reports and web products reflect the efforts of many people. These range from scientific research and nationwide monitoring of environmental changes to assembling the data and refining, analysing and calculating the indicators, and from writing, reviewing and revising the reports and web products to planning the next steps for the overall initiative.

These reports would not have been possible without the input and co-operation of numerous program staff throughout Environment Canada and Statistics Canada as well as Health Canada and the provincial and territorial governments. In particular, the water quality indicator would not have been possible without the provision of data, co-operation and expert water quality advice from the provinces and territories. The air quality indicator relies on the National Air Pollution Surveillance Network Database, made possible through federal–provincial–territorial collaboration. We thank all of those who provided data and analysis, advice and comments, as well as production and co-ordination expertise for these reports and websites. Finally, we also wish to recognize the many other people who have worked on various aspects of the development of this initiative over the past three years.

Some individuals served on several committees or teams, but each person is only listed once.

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