Canadian Environmental Sustainability Indicators

2007

Government of Canada Gouvernement du Canada

Canada

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Canadian Environmental Sustainability Indicators 2007

Environment Canada
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Executive summary

The health of Canadians and their social and economic well-being are highly dependent on the quality of their environment. One way to assess environmental quality is to use indicators that convey complex information in a simple form. The Canadian Environmental Sustainability Indicators (CESI) provide an indication of the health of our environment in much the same way as the gross domestic product (GDP) and other signals provide a sense of the health of the economy. Over the long term, the intent of the CESI initiative is to supplement traditional social and economic measures with information that will allow Canadians to better understand the relationships that exist among the economy, the environment and human health and well-being.

This is the third annual publication of the *Canadian Environmental Sustainability Indicators* report. It is the result of an ongoing collaboration between Environment Canada, Statistics Canada and Health Canada. It has also greatly benefited from the cooperation and input of all the provinces and territories, which share responsibility for environmental management in Canada. While there are policies and programs designed to address the issues tracked by the indicators, CESI reporting is not intended to provide a summary or evaluation of these policies and programs.

The report has the following three main components, which have been updated with 2005 data:

Air quality: The air quality indicators track measures of exposure of Canadians to ground-level ozone and fine particulate matter ($PM_{2.5}$). These are key components of smog and two of the most pervasive and widely spread air pollutants. Exposure to these pollutants can be harmful. Both the ozone and $PM_{2.5}$ exposure indicators are population-weighted average concentrations observed at monitoring stations across Canada during the warm season (April 1 to September 30) when ozone concentrations are normally highest and Canadians are most active outdoors.

Nationally, the ozone exposure indicator increased an average of 0.8% per year from 1990 to 2005. This resulted in an overall increase of 12% for this time period.[1] In 2005, ozone concentrations were highest at stations in southern Ontario; southern Quebec and Alberta also had many stations with high concentrations. Between 1990 and 2005, the ozone exposure indicator increased in two regions—in southern Ontario by 17%[2] and in southern Quebec by 15%.[3] In other regions, the ozone exposure indicator showed no statistically significant increasing or decreasing trends.

The $PM_{2.5}$ exposure indicator showed no statistically significant increasing or decreasing trends, either nationally or regionally between 2000 and 2005. The highest $PM_{2.5}$ concentrations were measured at stations in southern Ontario and southern Quebec in 2005.

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 affected by the atmospheric transport of pollutants from other regions and countries and by weather conditions such as temperature and wind direction.

Greenhouse gas emissions: The greenhouse gas (GHG) emissions indicator tracks annual Canadian releases of the six greenhouse gases (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, perfluorocarbons and hydrofluorocarbons) that are the major contributors to climate change. The indicator comes directly from the *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada*, prepared annually by Environment Canada for the United Nations Framework Convention on Climate Change (Environment Canada 2007a).

In 2005, Canada's total GHG emissions were estimated to be 747 megatonnes (Mt) of carbon dioxide equivalent, up 25% from 1990. This was 33% above the Kyoto

1. Plus or minus 10 percentage points, resulting in an increase ranging from 2% to 22% at a 90% confidence level.
2. Plus or minus 13 percentage points, resulting in an increase ranging from 4% to 30% at a 90% confidence level.
3. Plus or minus 12 percentage points, resulting in an increase ranging from 3% to 27% at a 90% confidence level.

Protocol target of 563 megatonnes, which is 6% below the 1990 baseline level. Overall, energy production and consumption contributed about 82% of Canada's total GHG emissions in 2005. From 1990 to 2005, these emissions rose by 29%, accounting for 90% of the growth in Canada's total GHG emissions over the 16-year period.

Recently (2003 to 2005), the growth in GHG emissions has slowed, due primarily to a significant reduction in emissions from electricity production (reduced coal and increased hydro and nuclear generation), coupled with a reduced rate of increase in fossil fuel production and a reduced demand for heating fuels due to warm winters.

The amount of GHGs emitted per unit of economic activity was 17.8% lower in 2005 than in 1990. Increases in overall economic activity, however, resulted in increases in total energy use and GHG emissions.

Alberta and Ontario had the highest emissions of all provinces and territories in 2005 at an estimated 233 and 201 megatonnes respectively.

Freshwater quality: Water quality in Canada is under pressure from a range of sources, including human settlement, agriculture and industrial activities, and household behaviour. Degraded water quality can affect both aquatic life and human uses of water for industry, recreation, agriculture and as a source of drinking water.

This indicator, as a water quality index based on many chemical parameters, assesses surface freshwater quality with respect to protecting aquatic life (e.g., fish, invertebrates and plants). It provides a sensitive measure of the overall health of aquatic ecosystems. The indicator does not assess the quality of water for human consumption and use. The national indicator is based on information gathered from 2003 to 2005 for southern Canada only. Northern sites are reported separately.

Freshwater quality for 359 monitoring sites in southern Canada was rated as "good" or "excellent" at 44% of the sites, "fair" at 33% and "marginal" or "poor" at 23%. Freshwater quality measured at 36 monitoring sites in northern Canada was rated as "good" or "excellent" at 56% of the sites, "fair" at 31% and "marginal" or "poor" at 14%. Freshwater quality was also presented by major drainage areas, as a step toward characterizing regional water management challenges.

Phosphorus, a nutrient mainly derived from human activities and a key driver of the Water Quality Index (WQI), is a major concern for surface freshwater quality in Canada. Phosphorus levels in southern Canada exceeded limits set under the water quality guidelines for aquatic life over half the time at 127 of 344 monitoring sites.

Because of differences in water quality monitoring programs across Canada, a national trend is not yet available for this indicator. In addition, the indicator results do not reflect the quality of all fresh water in Canada as the monitoring sites are currently highly concentrated in certain parts of the country. Rather, they reflect the selected monitoring sites in southern and northern Canada that meet the CESI data quality criteria. Planned improvements to the monitoring networks, water quality guidelines and data analysis will permit a better assessment of surface water quality in the future. Work is under way to use available data to track significant national trends in freshwater quality. Other water quality indicators, information and analysis for drinking water sources, agricultural use and recreational use are also being developed as part of the freshwater quality indicator series.

Linking the indicators to society and the economy: An important goal of the CESI initiative is to examine the linkages between these environmental indicators and the socio-economic factors that influence indicator trends.

Population size, distribution and density play a major role in determining the impacts that human activities have on the environment. Between 1990 and 2005, Canada's population grew by 17%, from 27.7 to 32.3 million people. With growing numbers of people living in and around urban areas, the potential for impacts on local and regional air and surface water quality is multiplied. From 1991 to 2006, urban populations increased by 21%, while rural populations decreased by 2%.

Growth in economic activity brings benefits in the form of increased income, but can also lead to greater pressure on the environment. For instance, economic growth has led to greater energy use by industries, which in turn has resulted in increased GHGs and air pollutants. Nevertheless, some large energy-consuming industries are becoming more energy-efficient, thereby offsetting some of the growth in emissions. For instance, the manufacturing industry reduced its energy requirements to produce a unit of goods and services by 33% between 1990 and 2002.[4] However, total growth in sales of manufactured goods and services outpaced energy-efficiency improvements, resulting in an overall 4% increase in total manufacturing energy use.

4. Uses real gross output (the value of an industry's sales corrected for inflation) to calculate energy intensity.

Consumption behaviours also have an effect on the environment. For example, close to one fifth (17%) of the energy consumed in Canada is used directly by households to heat and power their homes, a fact that impacts both air quality and GHG emissions.

The 2006 *Households and the Environment Survey*, conducted under the CESI initiative, shows that, since 1994, Canadians' environmental priorities and concerns have led to some changes in household behaviours.

- Over 55% of Canadian households now use compact fluorescent bulbs. Between 1994 and 2006, the proportion using at least one compact fluorescent light bulb almost tripled.
- Forty percent of households now have a programmable thermostat, more than double the number in 1994. Of those households who owned this type of thermostat and who programmed it, two out of three turned down the heat at night. On the other hand, 17% of the households equipped with programmable thermostats had not, in fact, programmed them.
- Use of water-saving devices, such as water-saving showerheads and low-flow toilets, is increasing. For example, 54% of Canadian households reported having a water-saving showerhead as opposed to 42% in 1994.

However, other behaviours observed through the survey indicate that environmental values are still competing with the practical realities of personal time use, comfort and convenience.

- The use of chemical pesticides, which can affect water quality, was down only slightly in 2006 from 1994 levels. Also, over 39% of households flushed down the drain or put in the garbage their leftover pharmaceutical products.
- During the warmer months in 2006, 73% of Canadians working outside the home travelled to work by motor vehicle, 14% walked or cycled, and 10% used public transit. In colder months, the proportion of commuters who travelled by car increased to 81%. In both seasons, well over half of all commuters travelled alone to work in a motor vehicle. This has implications for both air quality and GHG emissions.

Improvements in this year's report

This is the third annual *Canadian Environmental Sustainability Indicators* report. Key improvements in this year's report are as follows:

Air quality

- A regional break-down of the $PM_{2.5}$ indicator
- More interpretation of influencing factors

Greenhouse gas emissions

- Improved estimation methods and more data on key variables used in the calculations

Freshwater quality

- A breakdown of freshwater quality by Canada's major drainage areas
- A focus on phosphorus, a key freshwater pollutant that drives the freshwater quality indicator in many areas of Canada
- An increased number of water-quality monitoring sites included in the indicator. In southern Canada, sites increased from 340 to 359, while in northern Canada, sites increased from 30 to 36 for 2007.

Linking the indicators to society and the economy

- Incorporation of 2006 data from Statistics Canada's *Households and the Environment Survey*, which describes some of the household behaviours that can affect the three indicators
- Incorporation of 2005 data from Statistics Canada's *Industrial Water Survey*, which describes water usage by the primary, manufacturing and thermal-electric industries

Improving the integration of environmental and socio-economic information

The long-term goal of CESI is to examine and highlight the linkages between this report's three indicators and socio-economic issues to enable decision making that better takes into account environmental sustainability. To this end, complementary information tools have been developed and further improvements to the indicators are planned.

Work is continuing to further develop the individual indicators, with more robust analyses to track changes, and with improvements to make the indicators more understandable, relevant and useful to decision makers and the public. All of the indicators will benefit from recent and planned improvements to environmental monitoring systems driven by the CESI initiative. In particular, the freshwater indicator will benefit from new and updated scientific water quality guidelines currently under development, and the scope of the indicator will be broadened to include other beneficial water uses. Improved data management and better analytical methods are also being developed.

To provide important contextual information that can assist in interpreting the indicators, Statistics Canada is developing and delivering new surveys of business and household actions affecting the environment. This year's CESI report includes data from the first two such surveys to be completed: the 2006 *Households and the*

Environment Survey and the 2005 *Industrial Water Survey*. Other surveys under CESI will include an agricultural water use survey and a municipal water survey.

Online tools are already enabling users to examine regional and sectoral details and to conduct their own analyses. To further support independent research and analysis, Environment Canada has developed an interactive website that allows users to examine the indicator data in more detail. In addition, Statistics Canada has developed a report on socio-economic information that contains supporting information for CESI. The report provides a wide range of contextual information on the human activities that can influence the indicators.

The Government of Canada website (www.environmentandresources.ca/indicators) and the Statistics Canada website (www.statcan.ca/bsolc/english/bsolc?catno=16-251-X) both provide electronic versions of this report and access to additional information and online analytical tools related to the indicators.

List of abbreviations

CAPMoN	Canadian Air and Precipitation Monitoring Network
CCME	Canadian Council of Ministers of the Environment
CESI	Canadian Environmental Sustainability Indicators
CFC	chlorofluorocarbon
CH_4	methane
CO_2	carbon dioxide
DFO	Fisheries and Oceans Canada
FPT	federal/provincial/territorial
GDP	gross domestic product
GHG	greenhouse gas
GWP	global warming potential
HFC	hydrofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
μg	micrograms
$\mu g/m^3$	micrograms per cubic metre
μm	micrometre; the average diameter of a human hair is approximately 80 micrometres
Mt	megatonnes; million tonnes
Mt CO_2 eq	megatonnes (million tonnes) of carbon dioxide equivalent
NAPS	National Air Pollution Surveillance
n.d.	no date
NO_X	nitrogen oxides; includes nitric oxide (NO) and nitrogen dioxide (NO_2)
N_2O	nitrous oxide
NPRI	National Pollutant Release Inventory
NRTEE	National Round Table on the Environment and the Economy
O_3	stratospheric ozone
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
SF_6	sulphur hexafluoride
SO_X	sulphur oxides
SUV	sport utility vehicle
UNFCCC	United Nations Framework Convention on Climate Change
VOC	volatile organic compounds
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 made to provide more accessible and integrated information on society, the economy and the environment to help guide the actions of Canadians and their governments.

A key component of this is the tracking of clearly defined environmental indicators that convey complex information in a simple form. These indicators can help measure progress and can be used to foster greater accountability on the part of the federal government and its partners as Canadians work together to achieve cleaner air and water and to limit greenhouse gas (GHG) emissions. The Canadian Environmental Sustainability Indicators (CESI) were developed for this purpose. They respond to the May 2003 recommendations of the National Round Table on the Environment and the Economy (NRTEE) 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 have been collaborating, on behalf of the Government of Canada, to develop and communicate these indicators to policy makers and the Canadian public.

This report presents the latest national status for each indicator, trends over time (except for fresh water), an interpretation of the indicator results, a short description of influences that may have affected them and plans for future improvements to the indicators. Where trend information is available, as in the case of the air quality and GHG emissions indicators, the main focus is on long-term trends, not annual fluctuations. The report concludes with a discussion of how the indicators are linked, primarily focusing on the socio-economic factors influencing the status and trends associated with the indicators.

The indicators in this annual report are described below.

The **air quality indicators** track measures of long-term exposure of Canadians to ground-level ozone and to fine particulate matter ($PM_{2.5}$). These are key components of smog and two of the most pervasive and widely spread air pollutants to which people are exposed. Both the ozone and $PM_{2.5}$ exposure indicators are population-weighted average concentrations of these pollutants observed at monitoring stations across Canada during the warm season (April 1 to September 30).

The **greenhouse gas emissions indicator** tracks annual releases of the six GHGs that are the major contributors to climate change. The indicator for this report comes directly from the *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada, 1990–2005* prepared by Environment Canada for the United Nations Framework Convention on Climate Change (UNFCCC) for 1990 to 2005 emissions estimates (Environment Canada 2007a).

The **freshwater quality indicator** reports the status of surface freshwater quality at selected monitoring sites across the country. The indicator uses the Water Quality Index (WQI) endorsed by the Canadian Council of Ministers of the Environment (CCME)[5] to summarize the extent to which water quality guidelines for the protection of aquatic life (plants, invertebrates and fish) are not met in Canadian rivers and lakes.

These three indicators are designed to supplement traditional social and economic measures such as the

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

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. The indicators are intended to assist those in government who are responsible for developing policy and measuring performance, as well as to offer all Canadians information about environmental status and trends, and about the implications of the choices they make for the sustainability of the environment. This report is not intended to be a summary or evaluation of policies and management activities designed to address the issues tracked by the indicators.

The CESI indicators are currently in different stages of development. While the quality and regional detail of the national freshwater quality indicator is improving, work is still needed to fill regional gaps in the monitoring network, to improve consistency in monitoring among sites and to report on trends and on other uses, such as drinking water sources. The air quality indicators draw on a well-established national network of monitoring sites, but differ from other existing indicators in presenting a health-based perspective with population-weighted results to estimate human exposure. The GHG 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 initiative, these core environmental indicators and related socio-economic information have been brought together in a single report.

The suite of reporting products and the indicator results will be further developed in the years ahead, with improvements made to increase their accuracy, relevance and usefulness to decision makers and the public. These efforts are being supported by research on the linkages between air quality and human health, by new surveys being conducted on the environmental actions of businesses and households, and by more integrated and representative national monitoring networks now being established. The indicators already form the basis for a publicly accessible information system providing underlying environmental data that can be used and linked to social and economic information. This system will be refined as the CESI initiative evolves.

The Government of Canada website on Sustaining the Environment and Resources for Canadians (www.environmentandresources.ca/indicators) and the Statistics Canada website (www.statcan.ca/bsolc/english/bsolc?catno=16-251-X) provide searchable electronic versions of this report, as well as additional information and online analytical tools related to the indicators.

2 Air quality

The air quality indicators track measures of long term exposure of Canadians during the warm season (April 1 to September 30) to ground-level ozone and to fine particulate matter ($PM_{2.5}$), two key components of smog that have been linked to health impacts ranging from minor respiratory problems to hospitalizations and even premature death. Studies indicate that adverse health effects can occur even with low concentrations of these pollutants in the air.

- Nationally, the ozone exposure indicator increased an average of 0.8% per year from 1990 to 2005. For the full time period, this resulted in an overall increase of 12% (plus or minus 10 percentage points, resulting in an increase ranging from 2% to 22% at a 90% confidence level). In 2005, ozone concentrations were highest at stations in southern Ontario; southern Quebec and Alberta also had many stations with high concentrations.
- Between 1990 and 2005, the ozone exposure indicator increased in two regions—in southern Ontario by 17% (plus or minus 13 percentage points, ranging from 4% to 30% at a 90% confidence level) and in southern Quebec by 15% (plus or minus 12 percentage points, ranging from 3% to 27% at a 90% confidence level). In other regions, the ozone exposure indicator showed no statistically significant increasing or decreasing trends.
- The $PM_{2.5}$ exposure indicator showed no statistically significant increasing or decreasing trends, either nationally or regionally between 2000 and 2005. The highest $PM_{2.5}$ concentrations in 2005 were detected at stations in southern Ontario and southern Quebec.

2.1 Context

Smog is one of the most recognizable air quality problems. It refers to a noxious mixture of air pollutants that often gives the air a hazy appearance. The major components of smog in Canada are ground-level ozone (referred to in this report simply as "ozone" unless otherwise noted) and fine particulate matter ($PM_{2.5}$). Ozone and the precursor pollutants that lead to its formation can be transported by winds over long distances and affect areas hundreds or even thousands of kilometres from the sources of the pollutants (Environment Canada 2007b).

The air quality indicators in this report focus on ozone and $PM_{2.5}$ because studies indicate that adverse health effects can occur even with low concentrations of these pollutants in the air (e.g., WHO 2005).

Box 1

Stratospheric ozone versus ground-level ozone

While ozone in the stratosphere is the same gas as the one found at ground level, it causes very different effects. High in the atmosphere, it forms the "ozone layer" that 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 2004a). Under certain meteorological conditions, stratospheric ozone (O_3) can, at times, be transported downward to the earth's surface and can contribute to ground-level ozone.

Nature of ozone

Ozone is found throughout the atmosphere (Box 1) but is not emitted directly to the air. Instead, it is formed

through a series of complex chemical reactions involving two precursor pollutants, nitrogen oxides (NO_X)[6] and volatile organic compounds (VOC).

In many parts of Canada, the short-term peak (1- to 8-hr average) ozone levels produced from chemical reactions involving NO_X and VOC are typically highest in the summer because ozone formation is favoured by strong sunlight and high air temperatures. Ozone concentrations vary considerably on an hourly, daily and monthly basis, depending on precursor emission levels and prevailing meteorological conditions such as temperature and wind direction (Environment Canada 2007b).

Nature of fine particulate matter

Particulate matter (PM) refers to very tiny liquid and solid particles of various sizes that are suspended in the air. PM is emitted as a primary pollutant or is formed in the air as a secondary pollutant from precursor gases such as sulphur dioxide, NO_X, VOC, ammonia (NH_3) and numerous carbon-containing substances (Environment Canada 2007b). Of particular interest is fine particulate matter ($PM_{2.5}$), particles with a diameter of no more than 2.5 micrometres.[7] From a health perspective, $PM_{2.5}$ particles are of greatest concern because they are sufficiently small to reach the finer structures of the human lung (Liu 2004).

Elevated ambient levels of $PM_{2.5}$ can occur year-round and are affected by location, time of year and prevailing meteorological conditions. Levels in urban areas are typically highest in the mornings and evenings, largely reflecting local emission sources such as transportation (Environment Canada 2007b).

Sources of ozone and fine particulate matter

Human activities are the major sources of $PM_{2.5}$, and ozone and $PM_{2.5}$ precursors such as NO_X and VOC. Principal sources include

- the transportation sector (e.g., cars, trucks, marine vessels, trains, tractors, recreational vehicles and airplanes);
- industrial sectors (e.g., oil and gas exploration, drilling and extraction; base metal smelting; wood product mills, pulp and paper processing; and petroleum refining);
- thermal-electric power generation (i.e., electricity generation from power plants fuelled by coal, oil, natural gas or wood);
- agricultural activities; and
- consumer and commercial products (e.g., woodstoves, fireplaces, industrial and residential cleaners, cosmetics and paints).

Natural sources also emit precursor pollutants that contribute to the formation of ozone and $PM_{2.5}$. For example, trees and vegetation emit very substantial quantities of VOC during the growing season, and these emissions contribute to both ozone and $PM_{2.5}$ formation. Forest fires emit large quantities of primary $PM_{2.5}$ as well as precursors of both ozone and secondary $PM_{2.5}$. Volcanoes (none active in Canada) release massive quantities of particulate matter; and high winds can lift soil particles into the air, causing dust storms in extreme cases.

Health and environmental effects

Observed health effects of human exposure to ozone and particulate matter include respiratory symptoms such as coughing, triggering of asthma attacks and episodes of chronic bronchitis, emphysema, angina and other heart conditions. In general, as concentrations of these pollutants increase, so does the risk of health impacts. These effects may, in turn, result in a range of activity restrictions, increased emergency room visits, hospitalizations and premature death. Socio-economic consequences include lost productivity and higher health care costs (De Civita et al. 2002).

Children are especially sensitive to air pollution because they 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 (U.S. EPA 2006). The elderly and individuals with pre-existing health conditions are also at greater risk of being affected than healthy adults (WHO 2005).

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 pollutants), the individual's level of exposure (e.g., activity outdoors) and their particular situation (e.g., health, age).

In addition to causing health risks, ozone and $PM_{2.5}$ are also associated with ecosystem impacts. Deposition of the acidic compounds contained within $PM_{2.5}$ contributes to

6. In this document, "nitrogen oxides" (NO_X) refers to nitric oxide (NO) and nitrogen dioxide (NO_2).
7. By comparison, the average diameter of a human hair is approximately 80 micrometres.

ecosystem acidification, harming terrestrial and aquatic ecosystems. Elevated concentrations of ozone reduce plant growth and yield, decreasing productivity in agriculture and forestry. Elevated concentrations of particulate matter reduce visibility by decreasing how far and how clearly we can see. Both ozone and $PM_{2.5}$ are also known to cause damage to various types of materials through fading, cracking, erosion or corrosion.

The ozone and $PM_{2.5}$ exposure indicators

The air quality indicators track measures of Canadians' long-term exposure during the warm season (April 1 to September 30) to ozone and to fine particulate matter ($PM_{2.5}$), two of the most pervasive and widely spread air pollutants to which Canadians are exposed (Box 2).

Box 2

The air quality indicators

Two air quality indicators are presented in this report: one for ozone and one for $PM_{2.5}$.

The ozone exposure indicator is based on the highest 8-hr daily average concentrations recorded at monitoring stations across Canada. The ozone exposure indicator is presented for the period 1990 to 2005. Data were collected through the National Air Pollution Surveillance (NAPS) Network, a joint federal, provincial, territorial and municipal program, and through the Canadian Air and Precipitation Monitoring Network (CAPMoN) operated by Environment Canada.

The $PM_{2.5}$ exposure indicator is based on the 24-hr daily average concentrations recorded at monitoring stations across Canada. As the $PM_{2.5}$ network has expanded sufficiently since 2000, the national $PM_{2.5}$ exposure indicator is presented for the period 2000 to 2005. Data were collected through the National Air Pollution Surveillance (NAPS) Network.

Both indicators are based on yearly warm-season averages (April 1 to September 30). Ozone concentrations are normally highest during these months and Canadians are typically most active outdoors (Leech et al. 2002). While winter $PM_{2.5}$ is a concern, current monitoring methods may underestimate levels due to instrument variability in cold weather.

When calculating national and regional annual averages during the warm season for both ozone and $PM_{2.5}$, 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-km radius. The population data are from Statistics Canada's *Census of Population*. As a result, more weight is given in the annual average 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.

These annual population-weighted values vary from year to year, primarily as a result of changing conditions such as weather patterns. To detect whether there was a trend in the exposure indicators, a statistical test was applied to the national and regional exposure indicators. For this report, only statistically significant trends are reported as a percentage change per year, obtained by dividing the slope of the trend line by the median of all the annual exposure indicator values. The percentage change over the entire time period was also calculated by summing over years and the 90% confidence interval reported to more fully describe the trend.

See Appendix 1, Map A.1 for the locations of the monitoring stations and regions used in trend analyses and for additional details on the methods. It is important to note that the definition of regions has changed since the last report to improve geographical representivity. Stations in eastern Ontario are now grouped with stations in southern Ontario, rather than with the Quebec ones, as in previous reports.

2.2 Status and trends

2.2.1 Ozone exposure indicator

National status and trends

Nationally, the ozone exposure indicator increased an average of 0.8% per year from 1990 to 2005 (Figure 1). Over the full time period, this represented an overall increase of 12% (plus or minus 10 percentage points, resulting in a possible increase ranging from 2% to 22% at a 90% confidence level).

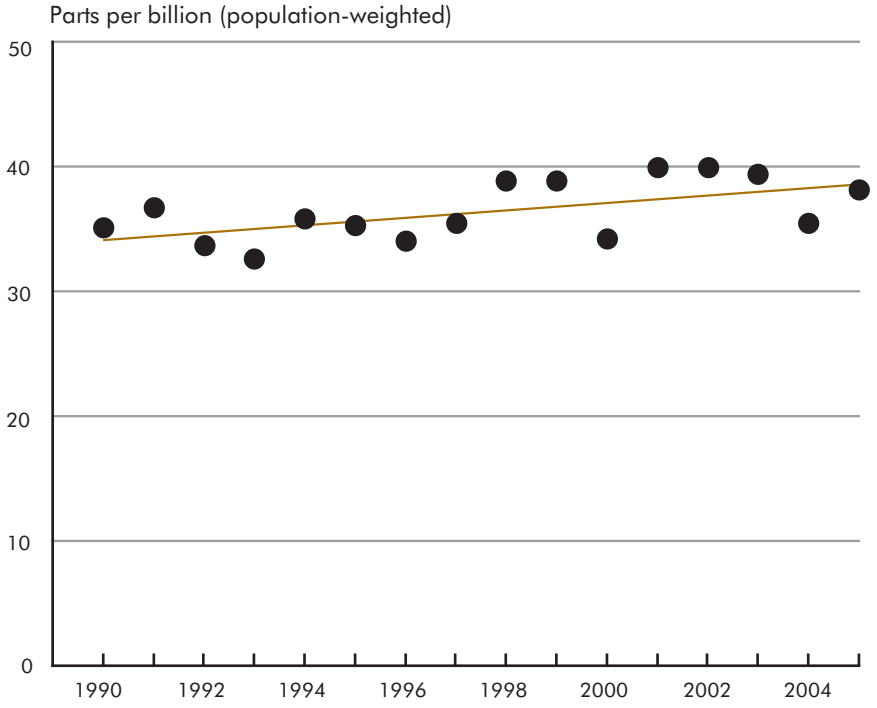
This increasing trend would suggest that the Canadian population represented in this analysis experienced an increasing health risk from exposure to ozone over this period.

Because of the greater population and number of monitoring stations in southern Ontario and southern Quebec, the national ozone exposure indicator is primarily driven by the ozone concentrations and populations in these two regions. In 2005, stations in southern Ontario had the highest ground-level ozone concentrations; southern Quebec and Alberta also had many stations reporting high concentrations (Map 1).

Regional status and trends

From 1990 to 2005, the ozone exposure indicator showed an increasing trend in southern Ontario and southern Quebec; no statistically significant increasing or decreasing trends were detected in other regions (Figure 2). During this period, the ozone exposure

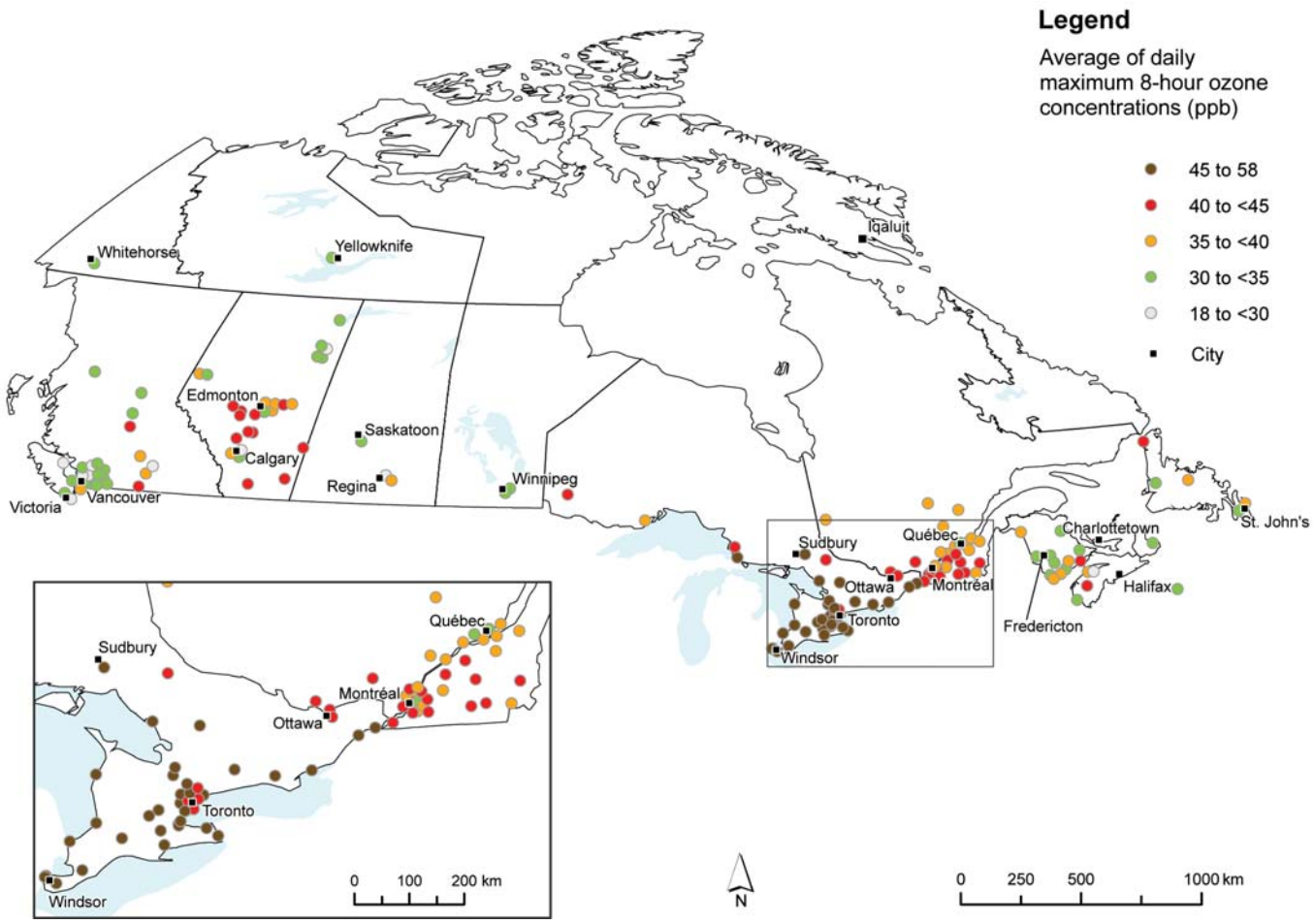
Figure 1 Ground-level ozone exposure indicator, Canada, 1990 to 2005



Note: The trend line represents an average rate of change of 0.8% per year. From 1990 to 2005, the indicator shows a statistically significant increase of 12% (plus or minus 10 percentage points, resulting in a possible increase ranging from 2% to 22% at a 90% confidence level). Ambient data collected from 76 monitoring stations.

Sources: National Air Pollution Surveillance (NAPS) Network and the Canadian Air and Precipitation Monitoring Network (CAPMoN); Statistics Canada *Census of Population*.

Map 1 Ground-level ozone concentrations at monitoring stations, Canada, 2005

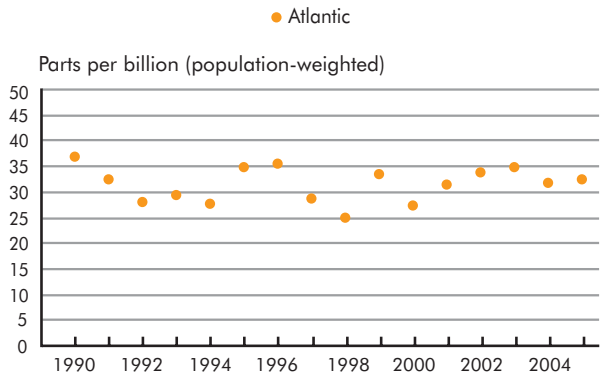


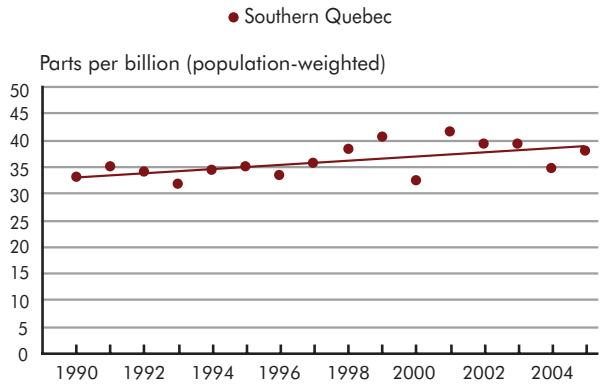
Note: Ambient data collected from 175 monitoring stations. Concentrations are not weighted by population.
Sources: National Air Pollution Surveillance (NAPS) Network and the Canadian Air and Precipitation Monitoring Network (CAPMoN).

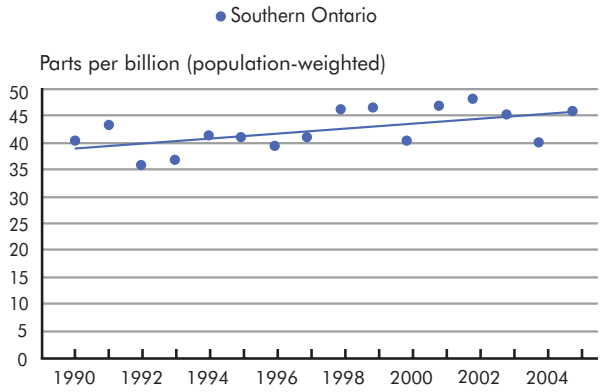
indicator in southern Ontario increased an average of 1.1% per year, resulting in an overall increase of 17% (plus or minus 13 percentage points, ranging from 4% to 30% at a 90% confidence level). Southern Ontario is home to approximately 30% of Canadians (Statistics Canada 2002). In southern Quebec, where most Quebecers live, the ozone exposure indicator increased an average of 1.0% per year, resulting in an overall increase of 15% (plus or minus 12 percentage points, ranging from 3% to 27% at a 90% confidence level).

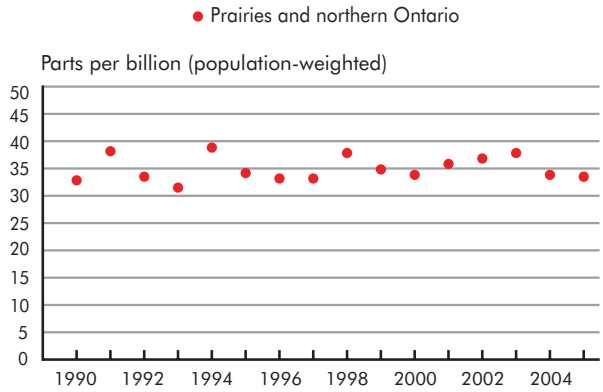
These increasing trends suggest that the population health risk associated with ozone exposure increased in these regions between 1990 and 2005.

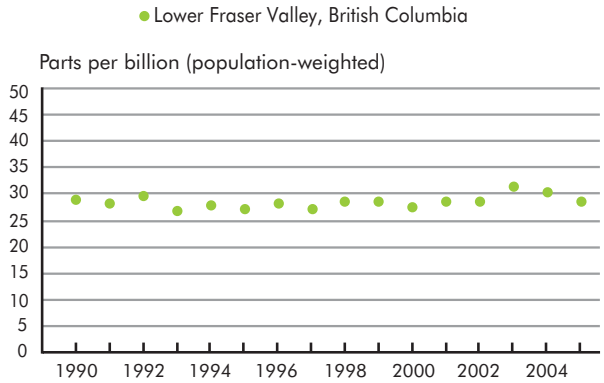
Figure 2 Ground-level ozone exposure indicator by region, 1990 to 2005











Notes: A trend line is shown only for the regions with a statistically significant trend at the 90% confidence level. The rate of change in southern Ontario was 17% (plus or minus 13 percentage points, ranging from 4% to 30% at a 90% confidence level). The rate of change in southern Quebec was 15% (plus or minus 12 percentage points, ranging from 3% to 27% at a 90% confidence level).

Number of monitoring stations: Atlantic, 6; southern Quebec, 22; Ontario, 24; Prairies and northern Ontario, 13; Lower Fraser Valley, B.C., 11. Regional groupings have changed for southern Ontario and southern Quebec; thus results are not comparable with previous reports.

See Appendix 1, Map A.1 for monitoring station locations, definition of regions and information on monitoring networks, trends, and statistical significance.

Sources: National Air Pollution Surveillance (NAPS) Network and the Canadian Air and Precipitation Network (CAPMoN); Statistics Canada *Census of Population*.

2.2.2 Fine particulate matter exposure indicator

National status and trends

Between 2000 and 2005, the national $PM_{2.5}$ exposure indicator showed no significant increasing or decreasing trends (Figure 3). This suggests that the Canadian population represented in this analysis did not experience any change in health risk from exposure to fine particulate matter over this period.

Because of the greater population and number of monitoring stations in southern Ontario and southern Quebec, the national $PM_{2.5}$ exposure indicator is primarily driven by the $PM_{2.5}$ concentrations and populations in these two regions. The highest $PM_{2.5}$ concentrations in 2005 were detected at stations in southern Ontario and southern Quebec (Map 2).

Regional status and trends

No statistically significant increasing or decreasing trends from 2000 to 2005 were detected for the $PM_{2.5}$ exposure indicator for any region (Figure 4). This suggests that the population health risk associated with exposure to $PM_{2.5}$ did not change over this period in any region.

2.3 Influencing factors

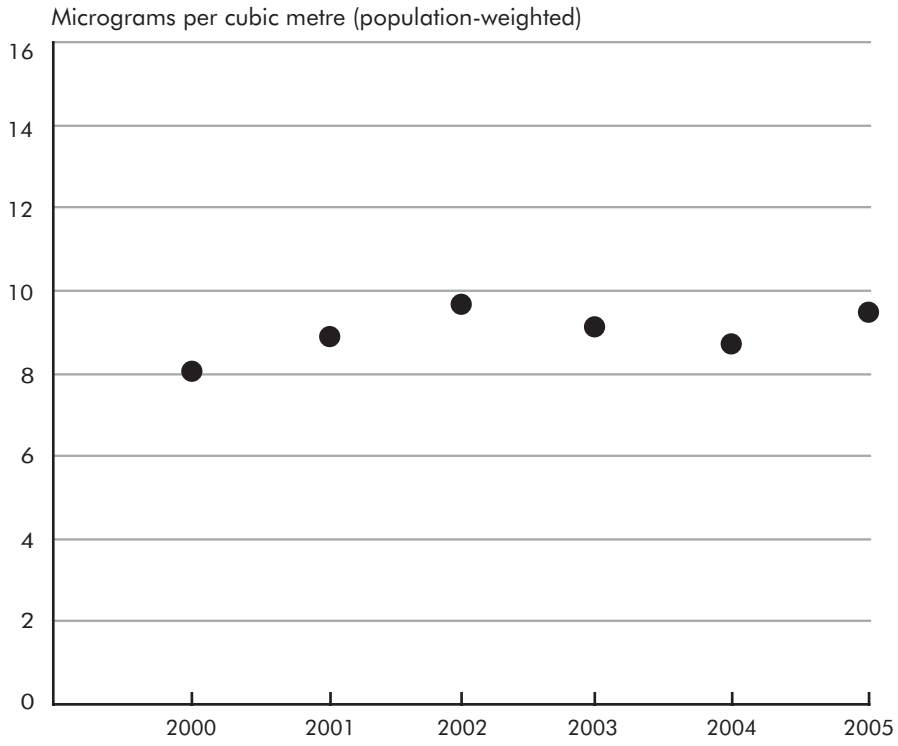
Local ambient levels of a pollutant in a given community are influenced by local emissions, weather conditions and the long-range transport of pollutants from other communities, provinces, countries and even, in some cases, other continents. All of these factors may explain the increasing trends of ozone exposure in southern Ontario and southern Quebec.

Local emissions

Location is a factor influencing individual exposure to certain air pollutants, with those who are in close proximity to pollutant sources most often experiencing higher ambient levels than those farther away. For example, air pollutant levels (e.g., NO_X) are generally higher close to a busy road than they are in low-traffic areas.

In general, reducing emissions of air pollutants will result in a comparable decrease in ambient levels of the pollutants. For example, from 1991 to 2000, emissions of the ozone precursors NO_X and VOC from on-road vehicles decreased by 23% and 35%, respectively.

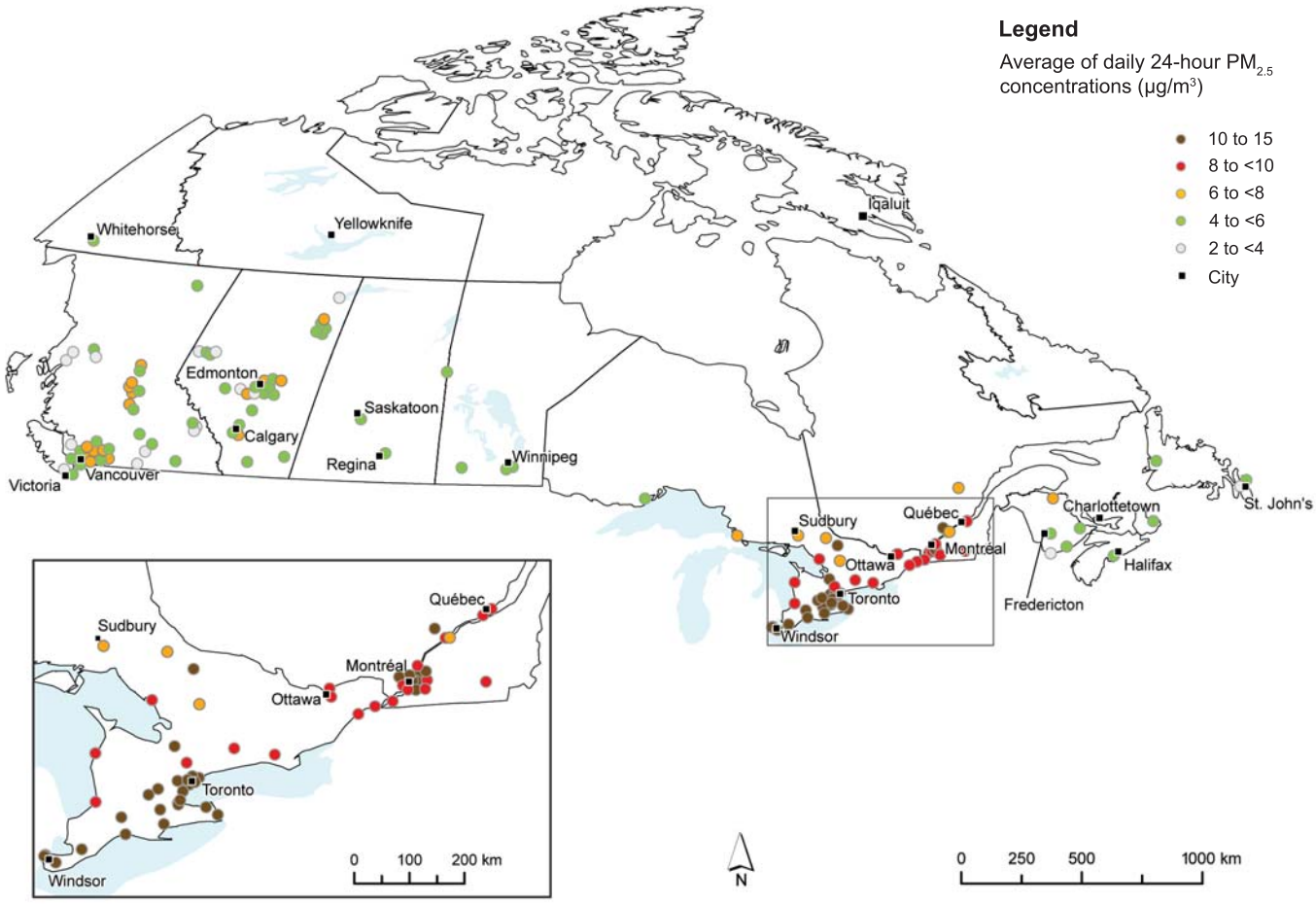
Figure 3 Fine particulate matter ($PM_{2.5}$) exposure indicator, Canada, 2000 to 2005



Note: No trend line is presented because there has been no statistically significant increase or decrease from 2000 to 2005 at a 90% confidence level. Ambient data collected from 65 monitoring stations.

Sources: National Air Pollution Surveillance (NAPS) Network and Statistics Canada *Census of Population*.

Map 2 Fine particulate matter ($PM_{2.5}$) concentrations at monitoring stations, Canada, 2005



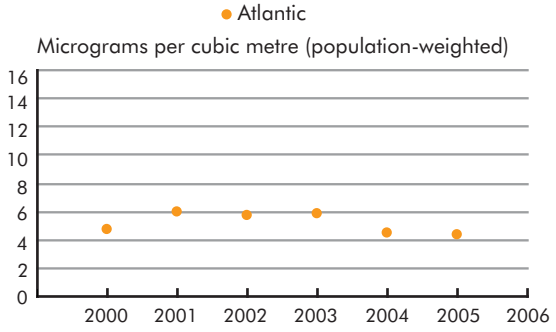
Note: Ambient data collected from 144 monitoring stations. Concentrations are not weighted by population.
Source: National Air Pollution Surveillance (NAPS) Network.

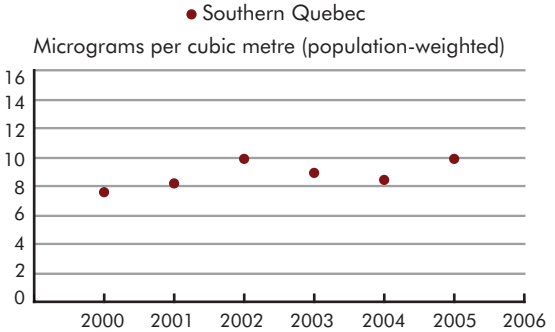
Similarly, NO_X and VOC concentrations in the air decreased by 13% and 33% in urban areas (greater than 100 000 population) over the same period (Environment Canada 2007b).

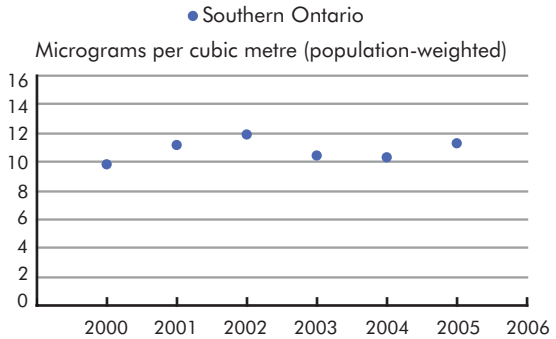
However, emissions and ambient pollutant concentrations vary among locations, and these geographical variations influence the chemical processes in the air that form and remove secondary pollutants (i.e., ozone and PM). For example, ozone is a secondary pollutant that is formed in the air through a series of chemical reactions involving NO_X (NO and NO_2) and VOC. However, when there are high local NO_X emissions (e.g., from motor vehicles), the excess amount of NO removes ozone from the air, keeping the local ozone concentrations lower than expected through a process known as "NO (i.e., nitric oxide) scavenging of ozone." A consequence of this process is that the lowering of local emissions of NO could cause an increase in local ozone concentrations because a comparatively smaller amount of ozone is then being removed from the air. Nevertheless, the lower local NO emissions can still result in lower ozone concentrations downwind because less ozone is then formed from these emissions.

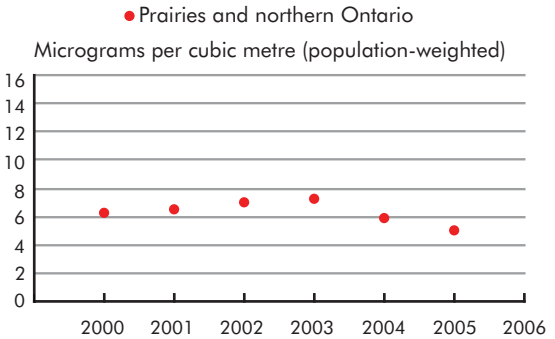
In rural areas, ozone concentrations may actually be higher than in nearby urban areas due to the absence of NO_X emissions and, therefore, lack of NO (nitric oxide)

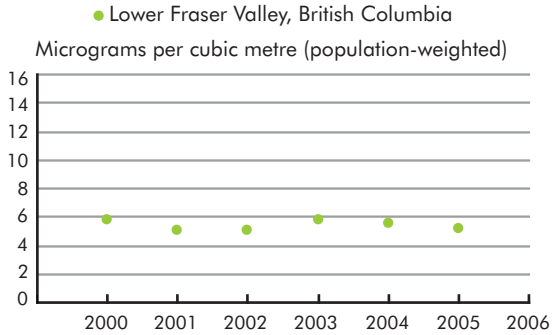
Figure 4 Fine particulate matter ($PM_{2.5}$) exposure indicator by region, 2000 to 2005











Notes: No trend lines are presented because there were no statistically significant increases or decreases from 2000 to 2005 at a 90% confidence level.

Number of monitoring stations: Atlantic, 5; southern Quebec, 11; southern Ontario, 20; Prairies and northern Ontario, 14; Lower Fraser Valley, B.C., 15.

See Appendix 1, Map A.1 for monitoring station locations, definition of regions and information on monitoring networks, trends, and statistical significance.

Sources: National Air Pollution Surveillance (NAPS) Network; Statistics Canada *Census of Population*.

scavenging of ozone. These ozone concentrations in rural areas can be further increased by the long-range transport of pollutants.

Weather conditions

Variability in ambient air pollutant levels is detected daily, seasonally and annually. This variability can be attributed to meteorological conditions: factors such as wind speed and direction, air temperature, atmospheric stability,[8] temperature inversions,[9] relative humidity, cloud cover and precipitation amounts can affect both the dispersion of emitted pollutants and the chemical reactions that the pollutants undergo. Both local conditions and the conditions through which the pollutants pass before arriving in a community influence these levels.

For example, stagnant air (i.e., high atmospheric stability, calm winds) leads to higher ambient pollutant levels than

8. Atmospheric stability describes the resistance of the atmosphere to vertical mixing. Reduced vertical mixing traps emitted pollutants closer to the surface.

9. Air temperatures usually decrease with height from the earth's surface; however, with temperature inversions, they increase. This inversion produces a stable atmosphere that allows the build-up of emitted pollutants near the ground.

windier conditions because locally emitted pollutants accumulate rather than being carried away. Conversely, some meteorological conditions improve air quality: a very unstable atmosphere allows for efficient dispersion of pollutants; rain increases the deposition and removal of $PM_{2.5}$ from the air; and days with rain, clouds and cool temperatures do not favour ozone formation. In addition, meteorology can affect the quantity of emissions; for instance, warmer summers lead to increased use of air conditioning and, as a result, higher emissions from thermal-electric power generation.

Long-range transport of pollutants

Air pollutants do not necessarily remain in the area where they are emitted. The wind (i.e., airflows) can transport them tens or even thousands of kilometres away from their sources, a process known as long-range or transboundary transport. As such, air quality (ambient pollutant levels) in a particular area can be affected by pollutants emitted in another community, province or country or even, in some cases, another continent. For example, large quantities of pollutant emissions from the eastern United States are often transported to parts of southern Ontario, southern Quebec and the Atlantic provinces, raising ambient pollutant levels in those regions. In Windsor, ozone concentrations are about 40% higher under southerly airflows than they are under northerly ones (Johnson et al. 2007). Another factor is that higher temperatures generally accompanying southerly airflows are more conducive to ozone formation.

2.4 What's next?

The following specific improvements are planned in relation to air quality exposure indicator development, monitoring, analysis and surveys.

Indicator development: Research is ongoing to determine the cumulative effect of air pollution and to integrate associated risk factors into a comprehensive air quality and health indicator. The intent is that an air quality and human health indicator will provide a means of tracking changes in health risks related to air pollution and, consequently, the effectiveness of air pollution reduction measures. As part of the development of such an indicator, Health Canada is examining the association between mortality and the combined effects of multiple pollutants related to mortality. Factors influencing the risk of mortality, such as the chemical composition of pollutants, weather and social conditions are also being explored.

Monitoring: Currently, there are no monitoring stations in some parts of Canada. However, Environment Canada will continue to invest in new instruments to increase coverage at existing monitoring facilities and to establish new stations. 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.

Surveys: The 2007 *Households and the Environment Survey* will include more detailed questions about home heating and air conditioning, the use of gasoline-powered recreational and small household engines, as well as more information on the types of motor vehicles owned by Canadians. As in 2006, respondents will be asked whether they are aware of air quality advisories and whether they have changed their normal behaviours in light of this awareness; this year, however, the survey will expand the question to ask which specific behaviours were changed.

Analysis: Calculations of the indicator do not currently make full use of the existing National Air Pollution Surveillance Network and population data because of geographical and temporal gaps in the monitoring data available. To allow for use of more existing data in the calculation of the exposure indicator, the application of broader trend analysis is being examined for inclusion in future CESI reports, as well as the differences in concentrations between stations with overlapping population area boundaries.

Research is also being conducted to help determine how the indicator responds to temporal and meteorological factors (e.g., day of the week, temperature), compared with changes in emissions, sources of pollutants and related precursors.

3 Greenhouse gas emissions

- In 2005, Canada's total greenhouse gas (GHG) emissions were estimated to be 747 megatonnes of carbon dioxide equivalent, up 25% from 1990.
- Canada's 2005 emissions were 33% above the Kyoto Protocol target of 563 megatonnes, which is 6% below the 1990 baseline level.
- Recently (2003 to 2005), the growth in emissions has been slowed due primarily to a significant reduction in emissions from electricity production (reduced coal and increased hydro and nuclear generation), coupled with reduced demand for heating fuels due to warm winters and a reduced rate of increase in fossil fuel production.
- Overall, energy production and consumption contributed about 82% of Canada's total GHG emissions in 2005. From 1990 to 2005, these emissions rose by 29%, accounting for 90% of the growth in Canada's total GHG emissions over the 16 year period.
- The amount of GHGs emitted per unit of economic activity was 17.8% lower in 2005 than in 1990. Increases in overall economic activity, however, resulted in increases in total energy use and GHG emissions.

3.1 Context

Naturally occurring GHGs, 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, however, human activities such as burning fossil fuels (oil, coal and natural gas) and deforestation have led to an increase in atmospheric concentrations of GHGs. Scientists predict that this trend will continue.

The consensus of the Intergovernmental Panel on Climate Change (IPCC) (IPCC 2007a), as reflected in the *Fourth Assessment Report* is that incremental GHG emissions caused by human activity are having a discernible impact on the climate by upsetting the delicate balance of GHGs in the atmosphere. The result is the continued warming of the atmosphere.

Global atmospheric concentrations of carbon dioxide are now about 35% greater than in pre-industrial times, and the global average temperature has increased by 0.55° C from the 1970s to the present. In fact, an increasing rate of warming has taken place over the past 25 years, and 11 of the 12 warmest years on record have occurred in the past 12 years (1995 to 2006) (IPCC 2007b).

Warming of this speed and magnitude is significantly altering the earth's climate. These changes are expected to cause 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 increased stress from invasive species and diseases.

Climate change impacts will be particularly pronounced in Canada's North, and some changes are already being observed. For example, the permafrost is melting, with implications for infrastructures such as buildings and

highways (IPCC 2007c). Melting of the permafrost may also have broader consequences for the climate system because of the potentially higher releases of GHG emissions (IPCC 2007c). The size of sea ice cover can be expected to decline, which will affect transportation, wildlife distributions and traditional hunting practices in the North. 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 supporting industries and towns (IPCC 2007a).

The rate of climate change projected by the *Fourth Assessment Report* (IPCC 2007a) can be expected to affect humans through increased deaths, disease and injury due to heat waves, floods, storms, fires and droughts, increased frequency of cardio-respiratory diseases, and changes in the geographic distribution of infectious diseases. This will place additional stresses on health and social support systems if significant adaptation measures are not put in place.

The GHG emissions indicator focuses on total national emissions of the six major GHGs (Box 3).

3.2 Status and trends

3.2.1 National status and trends

Canada's GHG emissions were estimated at 747 megatonnes (Mt) of carbon dioxide equivalent in 2005, up 25% from 1990 when they were estimated to be 596 Mt. To put this into perspective, a typical mid-sized car driven 20 000 kilometres produces about five tonnes of carbon dioxide (Environment Canada 2007a.) The trend in estimated GHG emissions from 1990 to 2005 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 5. In 2005, Canada's emissions were 33% above the Kyoto target.

Emissions in 2005 increased 0.3% from 2003 but did not increase from 2004. The growth in emissions has been slowed, due primarily to a significant reduction in emissions from electricity production (reduced coal and increased hydro and nuclear generation), coupled with reduced demand for heating fuels due to warm winters and a reduced rate of increase in fossil fuel production.

In terms of individual GHGs, 78% of the 2005 emissions were attributed to carbon dioxide, 15% to methane and 6% to nitrous oxide. Sulphur hexafluoride, PFCs and HFCs accounted for the remaining 1%. The individual contributions of each GHG to total emissions were about the same as in 1990.

The 25% increase in GHG emissions between 1990 and 2005 outpaced increases in population, which totalled 17%, and approximately equalled the increase in energy use, which was 23%.

Box 3

The greenhouse gas emissions indicator

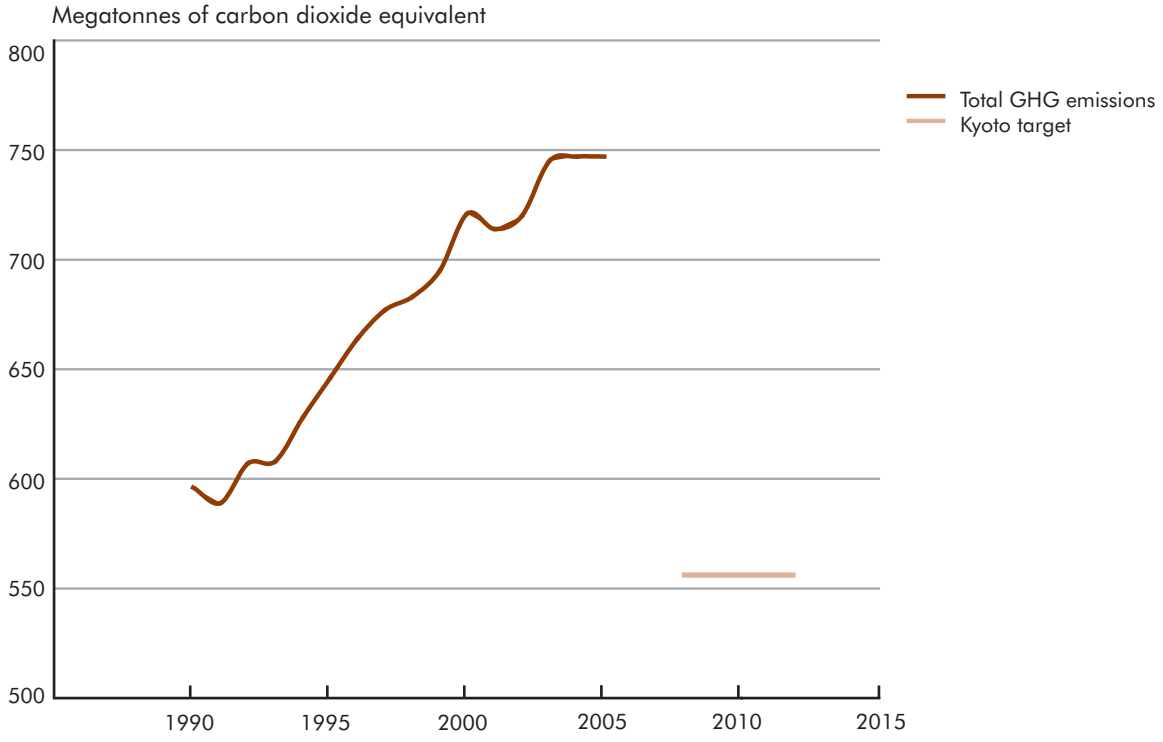
The national GHG emissions indicator data come directly from the *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada, 1990–2005* (Environment Canada 2007a), which contains emissions estimates for sources, categorized by economic sector as defined by the IPCC (energy, industrial processes, solvents and other product use, agriculture, land use, land-use change and forestry, and waste). It includes estimates for six GHGs: 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 GHG 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 GHG-producing activity by the quantity of GHGs 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 GHG emissions are expressed as megatonnes (million tonnes) of carbon dioxide equivalent (Mt CO_2 eq), unless otherwise noted.

A more detailed description of the GHG emissions indicator and how it is calculated is provided in Appendix 2.

This chapter is based on the *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada, 1990–2005* (Environment Canada 2007a). The complete report is available on the Greenhouse Gas Division website (http://www.ec.gc.ca/pdb/ghg/inventory_e.cfm).

Figure 5 Greenhouse gas emissions, Canada, 1990 to 2005



Source: Environment Canada, 2007a. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada, 1990–2005*. Greenhouse Gas Division, Ottawa, Ontario.

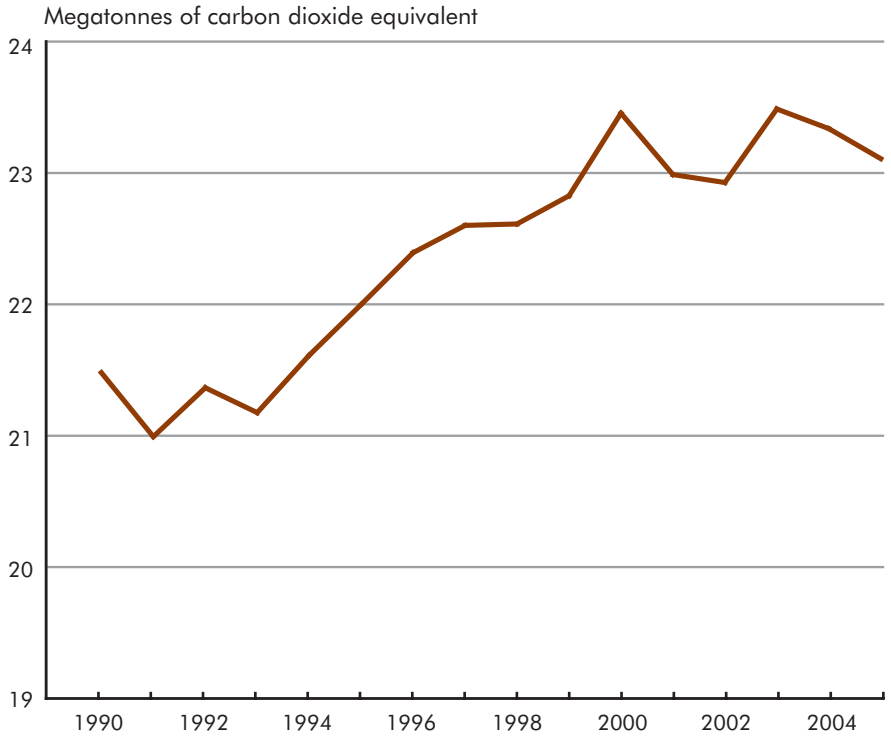
Although Canadians make up only about 0.5% of the world population, Canada's share of global GHG emissions is approximately 2%. Emissions per capita in 2005 were approximately 23 tonnes of carbon dioxide equivalent per person, an increase of nearly 10% over 1990 levels (Figure 6). Alberta had the highest per capita emissions at 72 tonnes of GHGs per person per year, while Quebec had the lowest at 12 tonnes per capita per year.

"GHG emissions intensity" is the ratio of emissions (as expressed in CO_2 equivalent) to economic activity as measured by the real (inflation-adjusted) gross domestic product (GDP). By this measure, GHG intensity decreased by 17.8% between 1990 and 2005, an average of 1.2% per year, which means more economic activity took place for each tonne of GHGs emitted in 2005 than in 1990 (Figure 7). However, Canada's GHG intensity remains high compared with that of most other countries. In fact, it is the highest among G7 countries (Environment Canada 2006a).

To date, emissions have been categorized according to the sector that produced them. However, it is also possible to categorize emissions based on their final user by looking at who creates the demand for GHG emissions. For example, the emissions associated with the production of an automobile would be credited to the final purchaser of this vehicle. Figure 8 illustrates the breakdown of industrial GHG emissions by final demand category.[10] From a demand perspective, almost half of Canadian industrial GHG emissions in 2002 could be attributed to satisfying exports (46%). Household/personal expenditure was the next largest category at 37%. These two categories have switched positions in terms of priority since 1990, when personal expenditure was the largest source of emissions from a demand perspective at 41% and exports were second at 36%.

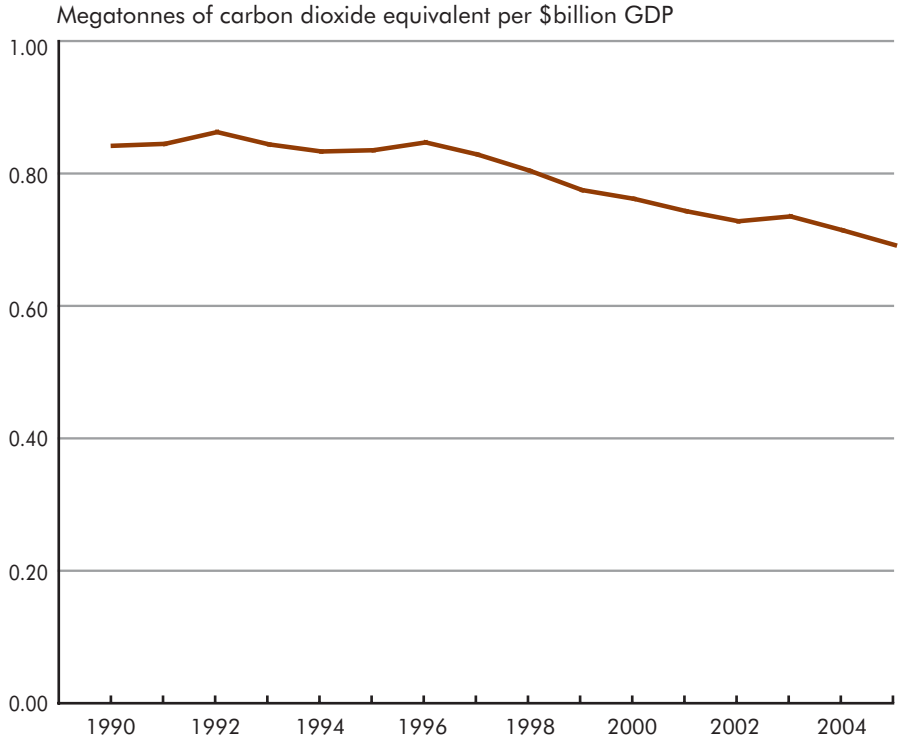
10. These are the emissions associated with the production activity required to meet final demand. They do not represent the emissions associated with the final consumption of commodities once they have been purchased. A description of the data sources and methods associated with Figure 8 is provided in Appendix 2 (Box A.1).

Figure 6 Greenhouse gas emissions per person, Canada, 1990 to 2005



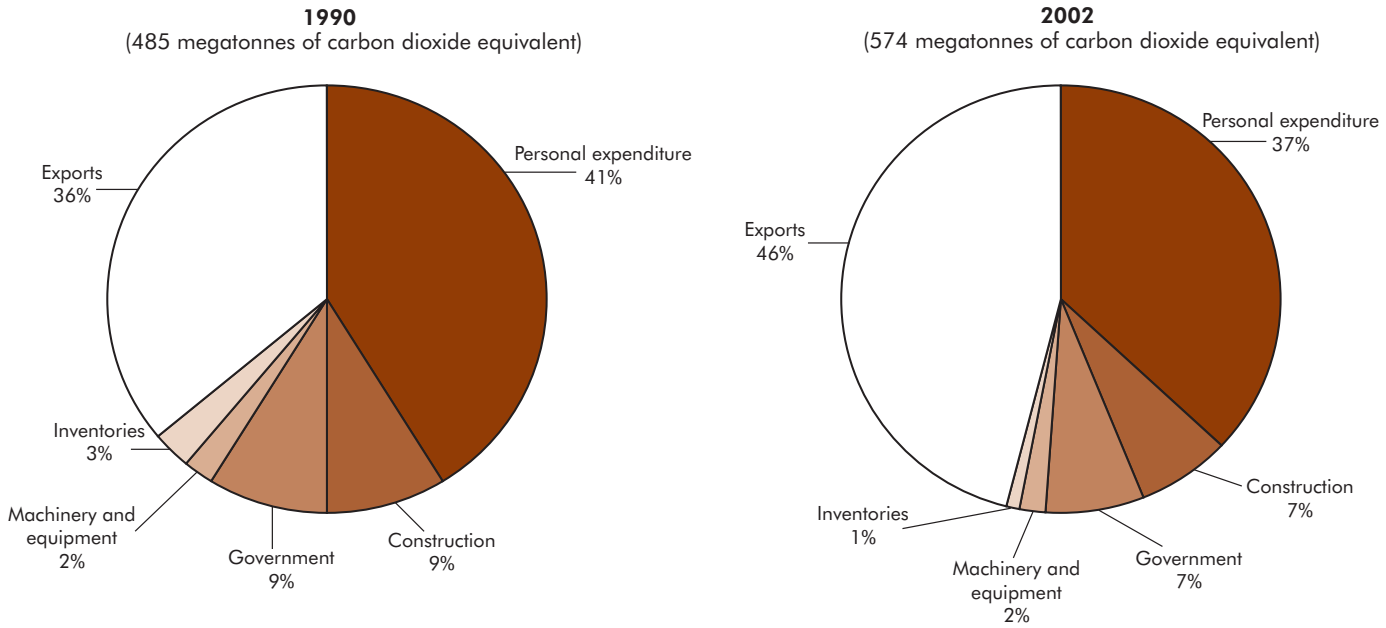
Source: Environment Canada, 2007a. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada, 1990–2005*. Greenhouse Gas Division, Ottawa, Ontario.

Figure 7 Greenhouse gas emissions per unit of gross domestic product, Canada, 1990 to 2005



Note: GDP in 1997 constant dollars.
Source: Environment Canada, 2007a. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada, 1990–2005*. Greenhouse Gas Division, Ottawa, Ontario.

Figure 8 Industrial greenhouse gas emissions by final demand category, 1990 and 2002



Note: Figures for 2002 are preliminary.
Source: St. Lawrence, Joe, 2007, "A demand perspective on greenhouse gas emissions," *EnviroStats*, Statistics Canada Catalogue no. 16-002, vol. 1, no. 2.

3.2.2 Regional status and trends

Canada's GHG emissions vary considerably from region to region. In 2005, Alberta and Ontario reported the highest emissions, accounting for 32% (233 Mt) and 27% (201 Mt) of national emissions, respectively. Between 1990 and 2005, total emissions rose in all provinces and territories except for the Yukon, where they dropped slightly (Figure 9).

The geographic distribution of emissions is linked to the location of natural resources, population and heavy industry, which tend to be concentrated in particular geographic areas. Because of this, as well as varying levels of dependence on fossil fuels for energy production, certain regions or provinces in Canada tend to produce more GHG emissions.

3.3 Influencing factors

There are a number of significant factors and circumstances that can influence national GHG emissions, including geography, climate, demography and the contribution of various sectors of Canada's economy.[11] Figure 10 shows the contribution of various sectors to national GHG emissions.

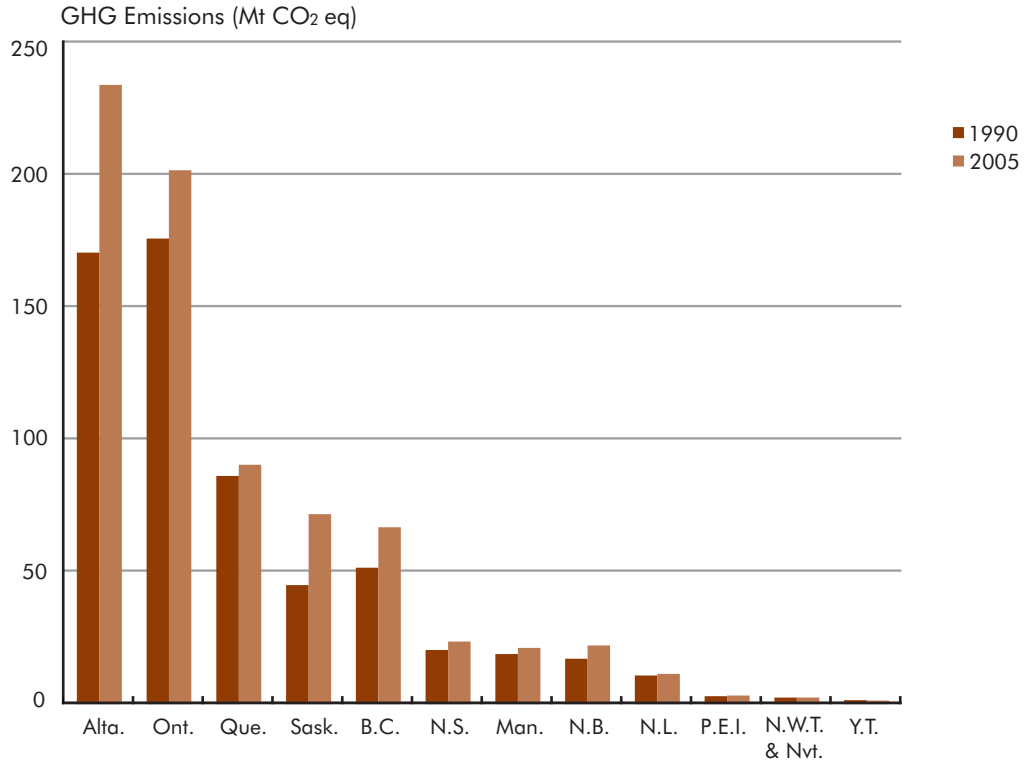
3.3.1 Energy production and consumption

The production and consumption of energy includes activities such as transportation, electricity generation, fossil fuel production and consumption, mining and manufacturing, and residential consumption. Overall, energy production and consumption contributed about 82% (or 609 Mt CO_2 eq) of Canada's total GHG emissions in 2005. From 1990 to 2005, these emissions rose by 29%, accounting for 90% of the growth in Canada's total GHG emissions.

Consistent with the finding that almost half of Canadian industrial GHG emissions in 2002 were related to satisfying export demand, total emissions associated with energy exports in 2005 were 73 Mt, representing a 162% increase over the 1990 level of 28 Mt. Moreover, 40% of Canada's exports are energy-intensive, resource-based commodities,[12] a fact that also influences overall emissions.

11. A detailed discussion of national circumstances influencing greenhouse gas emissions can be found in *Canada's Fourth National Report on Climate Change: Actions to Meet Commitments Under the United Nations Framework Convention on Climate Change* (Environment Canada 2006a), Chapter 2.
12. Energy-intensive commodities include items such as alumina and aluminium, copper, gypsum, iron ore, nickel, wood pulp, news print and potash fertilizer.

Figure 9 Greenhouse gas emissions by province/territory, 1990 and 2005



Source: Environment Canada, 2007a. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada, 1990–2005*. Greenhouse Gas Division, Ottawa, Ontario.

The three largest energy-related sources of GHG emissions are the oil and gas industries, transportation, and electricity and heat generation.

Oil, gas and coal industries: GHG emissions from the oil, gas and coal industries accounted for 18% of total emissions in 2005, increasing by 48% from 1990 to 2005. This includes emissions related to the production and processing of oil, natural gas and coal, petroleum refining, transportation by pipelines and related fugitive emissions.[13]

Transportation: Emissions from transportation accounted for 198 Mt or 26% of total national GHG emissions in 2005, rising by about 33% from 1990 to 2005. Of particular note was an increase of over 111% in the emissions from light-duty gasoline trucks, reflecting the growing popularity of sport utility vehicles, vans and light trucks. These vehicles, which emit, on average, 40% more GHG emissions per kilometre than gasoline automobiles, increased emissions by 23.2 Mt between 1990 and 2005.

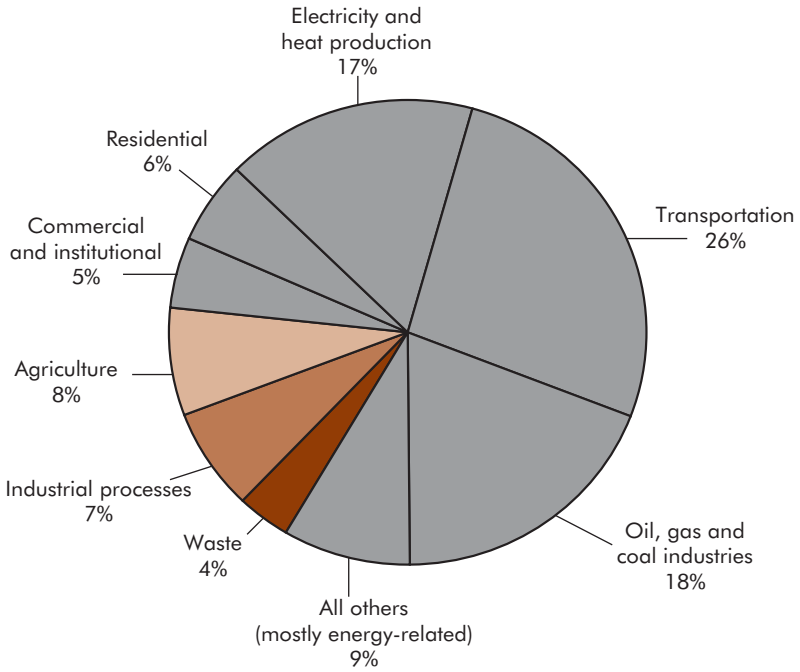
Emissions from heavy-duty diesel vehicles also increased over the period by approximately 84%, which is indicative of greater heavy-truck transport. This increase in the use of heavy-duty diesel vehicles led to an increase of 17.8 Mt between 1990 and 2005.

Reductions in GHG emissions attributed to gasoline cars, as well as propane and natural gas cars offset a small portion of the increases described above, representing a reduction of 6 Mt and 1.5 Mt, respectively, from 1990 to 2005.

Electricity and heat production: Greenhouse gas emissions from electricity and heat production accounted for 129 Mt or 17% of total national GHG emissions in 2005, rising by almost 37% between 1990 and 2005. The increase was driven by a rising demand for electricity (electricity production increased by 29% between 1990 and 2005) and by an increase in the use of fossil fuels, such as coal for electricity generation relative to other non-emitting sources, including nuclear and hydro.

13. 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. They include emissions from combustion only when the combustion does not support a primary activity (e.g., flaring of natural gases at oil and gas production facilities).

Figure 10 Greenhouse gas emissions by activity sector, Canada, 2005



Note: The grey portion of the chart represents GHG emissions from the energy sector. The activity sectors reflect the UNFCCC methodology.
Source: Environment Canada, 2007a. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada, 1990–2005*. Greenhouse Gas Division, Ottawa, Ontario.

3.3.2 Non-energy-related sources

There are three main non-energy sources of GHG emissions in Canada: industrial processes, agriculture and waste.

The emissions from industrial processes include, for example, carbon dioxide from limestone calcination in cement production and carbon dioxide from the manufacture of chemicals. The overall emissions from this sector slightly decreased between 1990 and 2005 and accounted for 7% (53.3 Mt) of the 2005 total.

However, the individual sources within this sector showed different trends. Some categories within this sector showed significant increases. For example, the substitution of HFCs for ozone-depleting substances in refrigeration and air conditioning systems, caused GHG emissions associated with this increased use of HFCs to rise by almost 235% between 1995 and 2005. There were also some significant reductions in other sources. For example, emissions of N_2O from Canada's only adipic-acid manufacturing plant decreased by 8 Mt (75%) between 1990 and 2005 due to the installation of N_2O abatement technology. Process emissions from the aluminium industry decreased by 1.4 Mt (15%) from 1990 to 2005 due to improved PFC-emission control technologies, despite increases in the production of aluminium during the same period.

The agricultural sector also accounted for 8% of the 2005 emissions total; however, emissions from this sector increased by 24% 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.

The waste sector, representing 4% (28 Mt) of the 2005 total, increased its emissions by 21% from 1990 to 2005, surpassing the 17% growth in population. This appears to be largely due to growing amounts of landfilled waste. This increase would have been larger if landfill gas recovery projects, composting and recycling programs had not been implemented in Canada.

3.4 What's next?

Environment Canada is continuously planning and implementing refinements to the national GHG 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 by an international expert review team.

4 Freshwater quality

This indicator, as a water quality index based on many chemical parameters, assesses surface freshwater quality with respect to protecting aquatic life (e.g. fish, invertebrates and plants), but does not assess the quality of water for human consumption or use. The data available are not sufficient to report national trends for the indicator at this time. It is based on information gathered from 2003 to 2005.

- Freshwater quality for 359 monitoring sites in southern Canada was rated as "good" or "excellent" at 44% of the sites, "fair" at 33% and "marginal" or "poor" at 23%.
- Freshwater quality measured at 36 monitoring sites in northern Canada was rated as "good" or "excellent" at 56% of the sites, "fair" at 31% and "marginal" or "poor" at 14%.
- Phosphorus, a nutrient mainly derived from human activities and a key driver of the water quality index, is a major concern for surface freshwater quality in Canada. Phosphorus levels exceeded limits set under the water quality guidelines for aquatic life over half the time at 127 of 344 monitoring sites in southern Canada.

4.1 Context

Water of sufficient quality and in adequate quantities is fundamental to ecosystems, human health and economic performance. The indicator presented in this report focuses on water quality for the protection of aquatic life, a use which is relevant to all water bodies and a broad reflection of ecosystem health. Freshwater aquatic life can be sensitive to slight changes in their environment. As a result, monitoring the environment in relation to the basic requirements of aquatic life is an effective method of assessing the overall health of freshwater ecosystems. However, water that is assessed to be suitable for aquatic life may not be so for other uses, such as drinking or livestock watering, due to the presence of, for example, pathogens or algal toxins. Thus, this indicator does not assess the quality of water for human consumption or use.

In Canada, water is mostly used by households and in industries such as electricity generation, agriculture, manufacturing, petroleum extraction and mining. In 2005, over 40 billion cubic metres of water were withdrawn from surface water and groundwater sources for industrial purposes alone (Statistics Canada 2007b). 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, manufacturing and service industries, institutions and households discharge hundreds of different substances, directly or indirectly, into rivers and lakes. At least 115 000 tonnes of pollutants were directly discharged to Canada's surface waters (both freshwater and coastal) in 2005 (Environment Canada 2007c). Nitrate and ammonia were the pollutants released to water in the largest quantities in 2005 from industrial and commercial facilities; other, more highly toxic substances, such as mercury, were released in much smaller, but nevertheless significant, amounts (Environment Canada 2007c).

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 nitrogen oxides that cause acidification, as well as

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. A high rating (excellent or good) indicates a low number of exceedances, while a low rating (marginal or poor) indicates a high number of exceedances.

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.

metals (e.g., lead and mercury) and organic compounds (e.g., polychlorinated biphenyls [PCBs] and pesticides). Runoff from agricultural lands and urban areas also degrades water quality (Coote and Gregorich 2000, Environment Canada 2001a). Degraded water quality can affect economic activities such as freshwater fisheries, tourism and agriculture, or recreational uses of water such as swimming.

Water quality is difficult to define and assess on a national basis. Firstly, water bodies are spread across a large geographic and geological setting. Secondly, water chemistry is complex and depends on many physical and chemical properties that vary naturally across seasons and years. 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 large quantities of 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. These thresholds can be

national or provincial in nature (referred to as national or provincial guidelines) or can be refined on a case-by-case basis to account for the presence of natural substances that may influence the toxicity of another substance (referred to as site-specific guidelines). This is the basis of the Water Quality Index (WQI) endorsed by the Canadian Council of Ministers of the Environment (CCME) in 2001 and used in this report to produce the water quality indicator (Box 4). This indicator has been calculated using the results of ongoing water quality monitoring programs managed by federal, provincial and territorial governments.

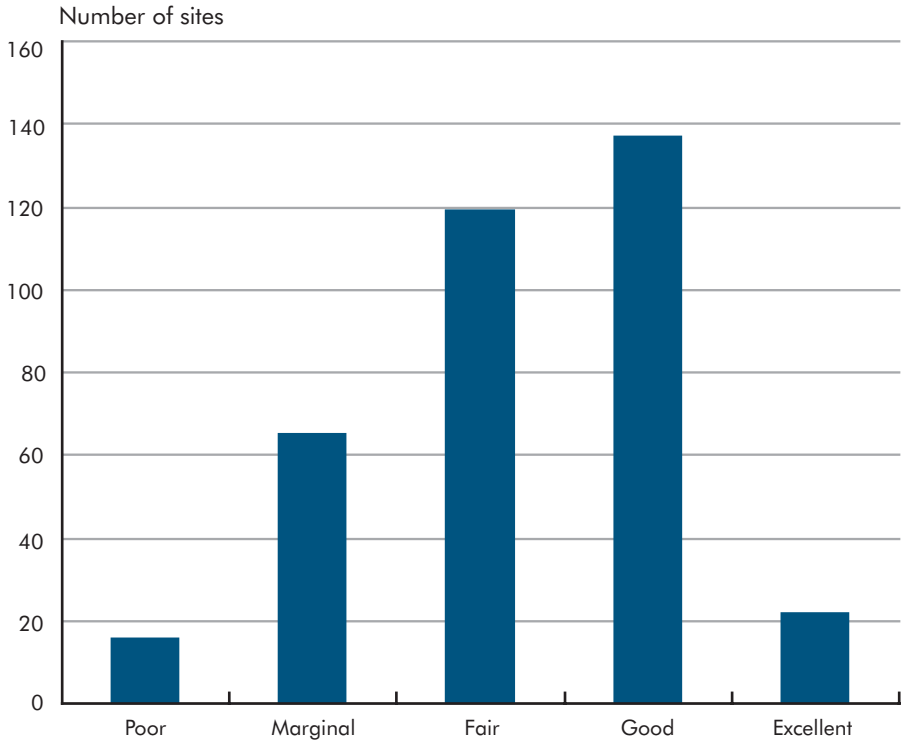
4.2 Status

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 and northern Canada (Box 5). In total, data from 395 sites (Appendix 3, Map A.2) were compiled for the 2003 to 2005 period: 36 for northern Canada and 359 for southern Canada. Further representations of the data were prepared as summaries for Canada's major drainage areas (Map 3).

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. Monitoring networks are generally designed to measure the influence of land-use activities or other stressors on water quality in order to better manage human activities and protect water resources. Hence, there is a higher density of stations in the more populated areas of the country.

The freshwater quality indicator is based on the best available information, but the concentration of monitoring stations in the more heavily settled areas of the country means that the indicator should not be interpreted as representing the state of all fresh water in Canada but, rather, water quality in specific areas of concern. In addition, all sites, whether small rivers, large rivers or lakes, are weighted equally in the indicator.

Figure 11 Status of freshwater quality at sites in southern Canada, 2003 to 2005



Note: The results are for surface freshwater quality with respect to protecting aquatic life. They do not assess the quality of water for human consumption or other uses. Number of sites is 359. Sites in the North are not included, but are presented separately in Box 5. See Map A.2 in Appendix 3 for site locations.

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

4.2.1 National freshwater quality

The national freshwater quality indicator shows that in southern Canada, water quality measured using the WQI for 2003 to 2005 was rated as "excellent" at 22 sites (6%), "good" at 137 sites (38%), "fair" at 119 sites (33%), "marginal" at 65 sites (18%) and "poor" at 16 sites (5%) for their suitability to protect aquatic life. The monitoring network used to generate the analysis included 10 lakes and 349 rivers (Figure 11).

Different water quality parameters 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. However, the parameters included most often in the calculations were phosphorus (344 sites) and different forms of nitrogen: ammonia (295 sites) and nitrates (140 sites). At sites where phosphorus, ammonia and nitrate measurements were reported, they exceeded limits set under the water quality guidelines in over half the collected samples, at 37%, 18%, and 16% of sites respectively. In general, both human activities and naturally high background levels are likely responsible for exceedances of guidelines. Section 4.2.3 focuses on phosphorus as a major issue of concern with regard to surface freshwater quality in Canada based on the WQI.

In last year's report, the freshwater quality indicator for southern Canada (2002 to 2004) was based on 340 monitoring stations. The indicator showed that water quality was "good" or "excellent" at 44% of the sites, "fair" at 34% of the sites, and "marginal" or "poor" at 22% of the sites. This 2007 report examines 359 sites, with 37 new sites for southern Canada and 18 that were not continued due to reduced monitoring. Due to the changes in stations and to improvements in the indicator, year-to-year comparisons cannot be made at this time. In addition, with only three reporting periods to date, it is not yet possible to derive a meaningful national trend in water quality.

Also for the 2006 report, the WQI had been calculated for seven basins in the Great Lakes region using 2004 and 2005 monitoring data. Water quality was rated as "excellent" in one basin (Lake Superior), "good" in three (Lake Huron, Georgian Bay, and the eastern basin of Lake Erie), "fair" in one (the central basin of Lake Erie) and "marginal" in two (Lake Ontario and the western basin of Lake Erie). No new data were available for updating water quality ratings for the present report. However, continuation of the monitoring program will allow for future updates.

4.2.2 Freshwater quality by major drainage area

New for this report is a more detailed representation of the freshwater quality indicator results, including sites from the South and the North, using Canada's major drainage areas (Map 3). This representation is meant to provide more information on the distribution of water quality ratings across the country; it does not allow for a comparison of the major drainage areas. The set of monitoring stations located within each of the major drainage areas was not designed to be fully representative. For example, some of the areas are relatively large, such as the Arctic Drainage Area, yet have relatively few stations—making comparisons among drainage areas and general interpretations about the water quality of these areas problematical at this time. Furthermore, the parameters included in the indicator are not necessarily the same in all areas. Improvements to monitoring coverage and implementation of site-specific guidelines to reflect natural differences among ecosystems will result in more accurate water quality ratings of these major drainage areas in the future.

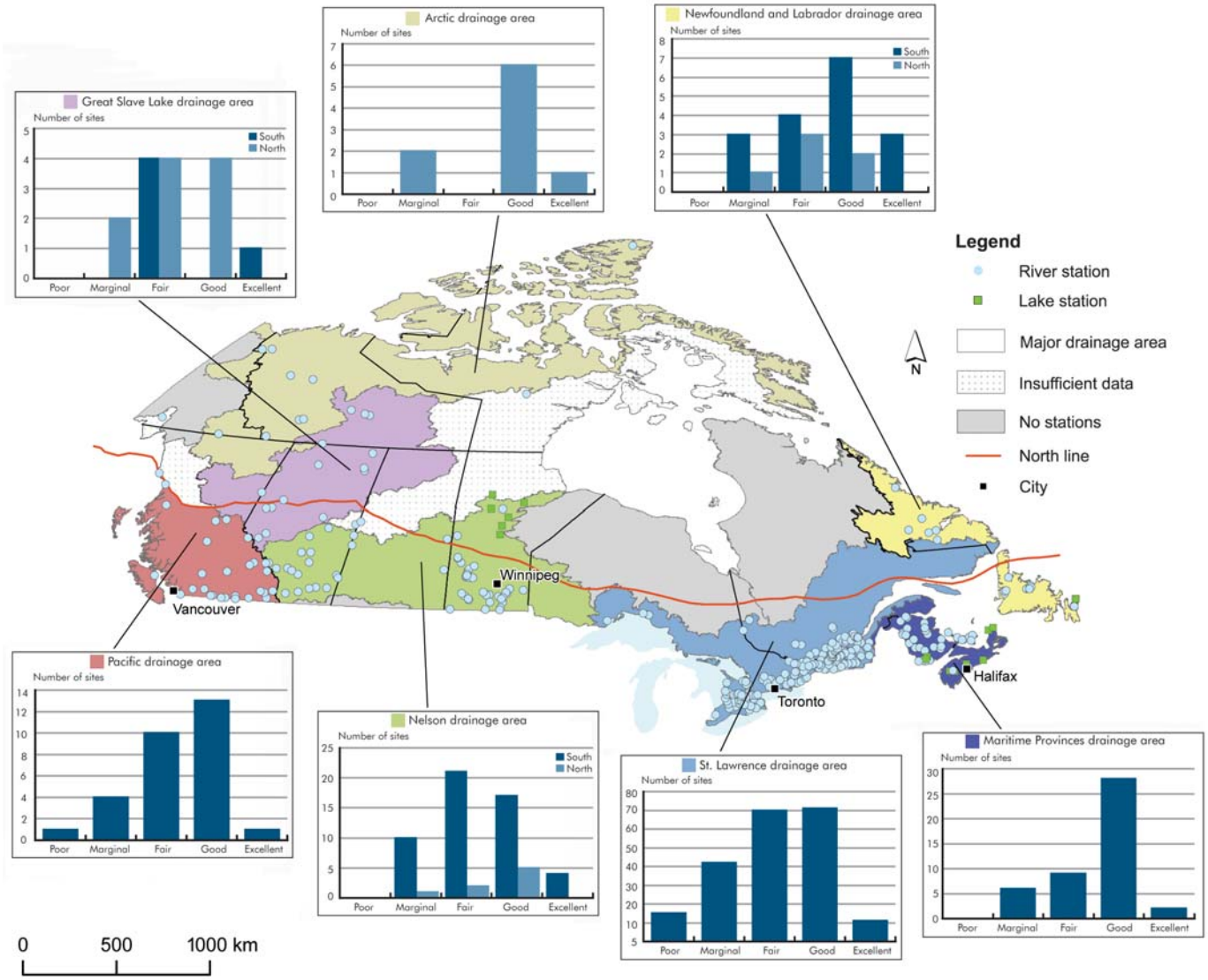
4.2.3 Phosphorus, a national freshwater quality issue

One of the major issues of concern for water quality across Canada continues to be nutrient enrichment (Chambers et al. 2001, Lowell et al. 2005, LWSB 2006, MDDEPQ 2007). Nutrients such as phosphorus and nitrogen are essential elements for the growth and survival of all organisms. An oversupply of nutrients in the environment from human activities, however, can result in excessive and noxious aquatic plant growth, a condition known as "accelerated eutrophication." In water, the decay of excess plant material can reduce the amount of oxygen available for fish and other aquatic animals. Some algal blooms can also be toxic, killing livestock and resulting in shellfish-growing area closures, and representing a risk to human health.

In the absence of human development, phosphorus exists only in phosphate-bearing rock and is introduced into water through soil and rock erosion. Consequently, the natural level of phosphorus in water is influenced by the amounts and types of rock and soil in the area. Water bodies in regions with a lot of soil, such as the Prairies, naturally have high phosphorus levels compared to water bodies in areas with little soil, such as the Canadian Shield.

Throughout the seasons, phosphorus levels in water also exhibit changes that are strongly influenced by the annual natural water cycle. For example, snowmelt and heavy rainfall can lead to high levels of suspended sediments

Map 3 Status of freshwater quality at sites in major drainage areas, 2003 to 2005



Note: The results are for surface freshwater quality with respect to protecting aquatic life. They do not assess the quality of water for human consumption or use. The map is based on the major drainage areas, as defined by the Water Survey of Canada, except for the Newfoundland and Labrador drainage area. The total number of sites represented is 390. Data for several major drainage areas were excluded (5 sites in total), since there were too few sites to report the status of these drainage areas. 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).

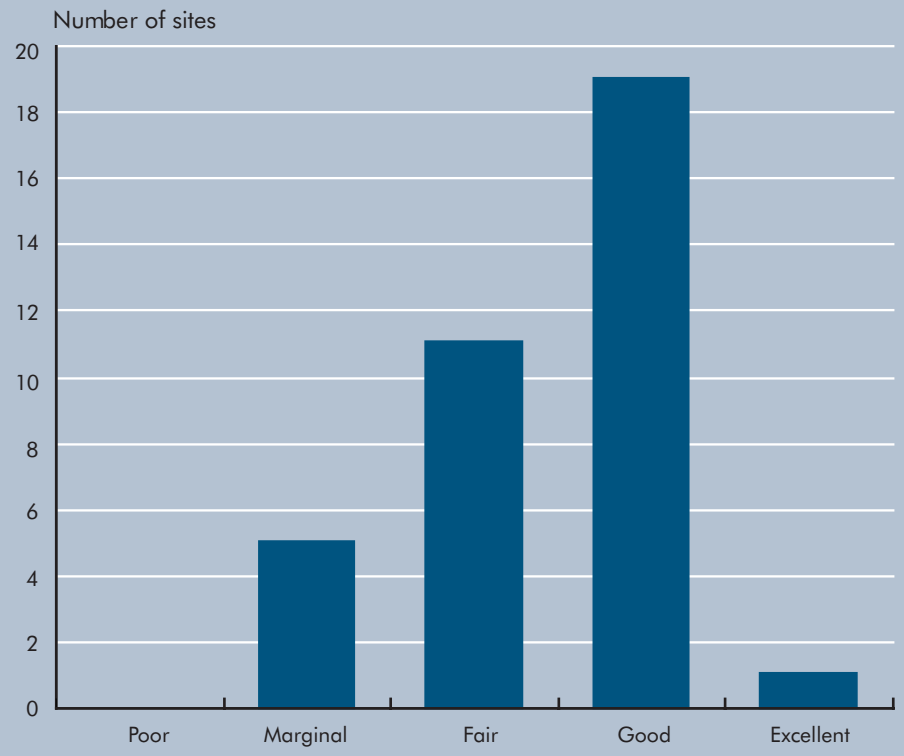
Source: Data assembled by Environment Canada and Statistics Canada from federal, provincial, territorial and joint water quality monitoring programs.

Box 5
Freshwater quality in northern areas

Northern and remote areas* are less populated than those in southern Canada. As a result, they are not exposed to the same pressures from human settlements, and manufacturing and agricultural industries. 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 1 site (3%), "good" at 19 sites (53%), "fair" at 11 sites (31%) and "marginal" at 5 sites (14%). No "poor" sites were reported (Figure 12). The analysis included data from 6 lakes and 30 rivers. Further work is being conducted to assess the degree to which exceedances of limits for water quality guidelines in the "fair" and "marginal" sites can be attributed to human activities or natural processes, such as flows rich in suspended sediments.

Figure 12 Status of freshwater quality at sites in northern Canada, 2003 to 2005



Note: The results are for surface freshwater quality with respect to protecting aquatic life. They do not assess the quality of water for human consumption or use. Number of sites is 36. See Map A.2 in Appendix 3 for site locations.

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

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 2003 to 2005 period.

The WQI was calculated over the period 2003 to 2005 for 36 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.

*The North is delineated on Map A.2 in Appendix 3.

Table 1 Summary of phosphorus exceedances in surface freshwater, 2003 to 2005

Drainage area	Number of sites	Percentage of sites with frequent exceedances[1]
	number	percentage
Canada – North	35	20
Canada – South	344	37
Newfoundland and Labrador – North	5	0
Newfoundland and Labrador – South	16	6
St. Lawrence	209	41
Maritime Provinces	37	19
Nelson River – North	8	63
Nelson River – South	52	54
Great Slave Lake – North	9	22
Great Slave Lake – South	5	20
Pacific – North	3	0
Pacific – South	23	9
Arctic	8	0

Note: 1. "Frequent exceedances" refers to a situation in which over 50% of measured phosphorus values at a site are above the limits set by the water quality guideline for phosphorus.
Source: Data assembled by Environment Canada and Statistics Canada from federal, provincial, territorial and joint water quality monitoring programs.

that are rich in nutrients. These phenomena serve important ecological functions.

Many of the water quality monitoring sites across Canada had frequent phosphorus exceedances, indicating the potentially widespread nature of nutrient enrichment (Table 1). However, some exceedances are attributed to challenges in deriving locally relevant phosphorus guidelines that reflect the natural variation of phosphorus among sites and through the seasons.

Phosphorus releases to the environment

Expanding human populations and human activities have greatly increased the biologically available supply of nitrogen and phosphorus in the environment (Chambers et al. 2001). Phosphorus from human activities can be released from point sources, such as the end of pipes, or through diffuse sources, such as runoff from a field. The largest point source of phosphorus to marine and fresh waters in Canada is municipal sewage—contributing about 5.6 thousand tonnes in 2004, mostly from human waste. Discharge of industrial wastewater added at least another 2.2 thousand tonnes to surface waters, and aquaculture, about 1.4 thousand tonnes (Table 2).

Agricultural activities and septic systems are indirect sources of phosphorus loading to the environment. It is possible to estimate agricultural additions of phosphorus to the soil in the form of chemical fertilizer or animal manure. For 2001, around 573 thousand tonnes are estimated to have been added to cropland in the form of fertilizer and manure (Statistics Canada 2001a, Korol 2002); crop harvesting removed around 302 thousand tonnes (Beauchamp and Voroney 1994, Bolinder et al. 1997, Statistics Canada 2001b). Septic systems are estimated to contribute about 1.6 thousand tonnes of phosphorus a year (Chambers et al. 2001, Environment Canada 2007d). Both of these sources add phosphorus to the soil, but there are no national estimates of loading to water from these sources.

The removal of vegetation along water bodies and the draining of wetlands, although not sources of phosphorus as such, contribute to phosphorus loadings indirectly by not retaining or slowing the progression of phosphorus carried by water running off the land. The use of fertilizers on residential lawns and gardens also intensifies potential phosphorus loadings to water.

4.3 Influencing factors

Water quality can be influenced by a variety of natural phenomena and human activities, acting both at large scales (e.g., acid rain, climate) and at very local scales (e.g., waste effluents). As a result, each monitoring site has a unique set of factors influencing water quality.

Natural phenomena

In many areas, natural phenomena contributed to water quality measurements exceeding guidelines for a number

Table 2 Total estimated phosphorus loadings from major direct point sources to both fresh and marine waters, Canada, 2004 or 2005

Nutrient source	Phosphorus loadings
	1000 tonnes/year
Municipal wastewater	
Sewage treatment plants[1]	5.6
Storm sewers and combined sewer overflows	2.5
Industry (NPRI)[2]	
On-site releases	2.2
Aquaculture	1.4

Notes: 1. Based on 25.4 million Canadians connected to sanitary sewers, some of which are not serviced by a sewage treatment plant.
2. Excludes the sewage treatment plants that reported to the National Pollutant Release Inventory (NPRI), as well as phosphorus transferred to sewage treatment plants from industrial facilities.

Sources: Table updated using methods and loading coefficients found in Chambers et al. (2001). Population estimates and treatment type necessary to calculate loading for municipal wastewater are from the *Municipal Water and Wastewater Survey: 2004 Summary Tables*, Environment Canada (2007d). Data for industrial releases are from the 2005 NPRI (Environment Canada 2006b). Data for aquaculture are from Fisheries and Oceans Canada (DFO) (2005).

of parameters. For example, glacial melt, snowmelt and heavy rainfall can lead to high levels of suspended sediments that are rich in nutrients and metals. As well, the naturally acidic water of bogs and other wetlands can result in lower pH and higher concentrations of certain metals at downstream sites. Rock and soil composition in the drainage area are also strong determinants of background levels of naturally occurring substances in water.

Human activities

The most common human activities that can influence water quality in Canada include urbanization, household behaviour related to water use, farming, industrial activity and mining production, as well as dams, and atmospheric emissions that lead to acidic precipitation. Nearly all of the southern monitoring sites and slightly more than one third of the northern sites are located within inhabited areas of Canada. Similarly, over half of the monitoring sites in southern Canada and one tenth of the northern monitoring sites fall within areas of agricultural activity. As many as 145 sites east of Manitoba are in acid-sensitive areas where deposition of sulphur dioxide and nitrogen oxides continues to be relatively high for the naturally low capacity of soils to buffer against these effects.

Although human activities are present in many monitored watersheds of Canada, management practices can control or reduce impacts on water quality. 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.

4.4 What's next?

The freshwater quality indicator reported here will be improved in future reports. 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 across Canada, and to present water quality trends over time.

In addition to improving the freshwater quality indicator for aquatic life, efforts are under way to develop measures that assess water quality for other important beneficial uses, including drinking water sources, agricultural uses and recreational uses. Surveys to better understand how water is used by the industrial and agricultural sectors are being conducted. A survey of public drinking water treatment plants is also being developed.

Protection of aquatic life

Environment Canada, in cooperation with the provinces and territories, will continue to work towards strengthening water quality monitoring networks, particularly in areas that have less representation (e.g., Saskatchewan, Nova Scotia and the North). In partnership with provinces, territories and other federal departments and agencies (e.g., Parks Canada, Fisheries and Oceans Canada, Agriculture and Agri-Food Canada), Environment Canada will continue to work on enhancing Canada's collective capacity to scientifically assess and report on water quality and aquatic ecosystem health through the application of physical, chemical and biological monitoring measures and approaches.

How well the WQI rates water quality depends on the use of appropriate water quality parameters and guidelines. Parameters and guidelines used in the WQI computation for the protection of aquatic life should be locally relevant, meaning appropriate to the local organisms and local water characteristics. Environment Canada, in consultation with the provinces and territories, is developing a consistent approach to site-specific guidelines across the country in order to better reflect local conditions. In particular, techniques are being evaluated to adjust current guidelines for substances that have naturally elevated concentrations. The water quality guidelines for key substances not yet included in the indicator are also under development.

Source and treated water quality

Source water is defined as "water in its natural or raw state, prior to being withdrawn for treatment and distribution as a drinking water supply." From the source water to the consumer's tap, barriers need to be put in place to reduce or prevent contamination to the drinking water supply, and therefore protect public health. Protecting source water quality is considered the first barrier in a multi-barrier approach to safe drinking water supply (Federal-Provincial-Territorial Committee on Drinking Water and CCME 2004b).

Source water quality is considered an important asset for sustaining our health, environment and economy (NRTEE 2003). This was the basis for choosing to develop a source water quality indicator in Canada. However, source water quality is only indirectly linked to public health since almost all public water supplies treat the water before it is distributed for consumption. Therefore, to link water quality to human health, a treated water quality indicator will form another important component of this initiative.

The purpose of the source and treated water quality indicators is to provide an indication of the quality of source and treated water. These indicators will provide information for use in decision making to promote both source water protection and proper water treatment. Since 2006, work has been carried out on methodology development and two tools that will form part of the indicator calculation.

The first tool is a calculator that compares specific parameters of water quality (source and treated) to drinking water guidelines and calculates a score between 0 and 100, based on methodology developed for the CCME WQI. An additional tool, applicable to the source water quality indicator, provides an indication of the treatment required for specific parameters of water quality to meet drinking water guidelines, and assigns a treatability ranking based on the complexity of the identified treatment.

In order to support the production of these indicators, Statistics Canada has assembled an inventory of public drinking water treatment plants. This inventory will serve as a sampling base for a survey of source and treated water quality to be conducted in the spring of 2008.

Agricultural water

The development of an indicator to report on the suitability of water quality for agricultural uses such as crop irrigation and livestock watering will be investigated. The testing of the applicability of an indicator based on the WQI methodology will be done using a subset of relevant stations from the national indicator. A review of the current water quality guidelines for agricultural use is now under way. This analysis will help determine which guidelines need to be updated or developed for incorporation into the freshwater quality indicator for agricultural water use.

This work will be supported by a new survey: the *Agricultural Water Use Survey*, to be conducted in February 2008. Its objective is to collect nationally consistent data on water used for irrigation. Approximately 2000 farm operations will be asked to provide information on the source and quantity of water used for irrigation by crop type, water management techniques, treatment required, equipment used, and crop production. The results are expected to be published in the summer of 2008.

Recreational water

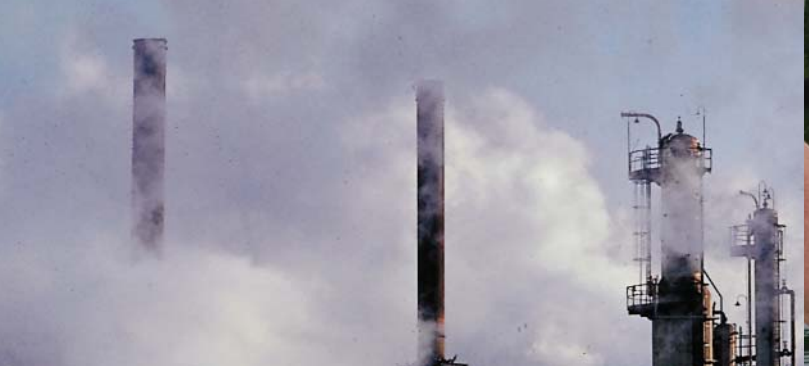
A preliminary investigation has been conducted to develop an inventory of Canadian monitoring programs that collect water quality information relevant to recreational water uses. These are primarily related to swimming or bathing but can include other activities such as waterskiing, windsurfing, fishing and canoeing. *Guidelines for Canadian Recreational Water Quality* are developed by the Federal-Provincial-Territorial Working Group on Recreational Water Quality under the authority of the Federal-Provincial-Territorial Committee on Health and the Environment, and published by Health Canada.

Various divisions of government at all levels monitor water that is used for recreational purposes, as do certain private associations. Many of the programs reflect provincial, municipal or local needs and policies—and thus vary from jurisdiction to jurisdiction. Future work involves the examination of how the existing information

may be best applied in the development of a national freshwater quality indicator for recreational water use.

Industrial water use

In 2007, results from the *Industrial Water Survey* provided information about the quantities of water consumed and costs, sources, treatments and discharge of water used by the primary, manufacturing and thermal-electric power industries in 2006. These results, however, did not include the oil and gas extraction sector. The next version of the survey, to be conducted early in 2008, will attempt to address this data gap.



5 Linking the indicators to society and the economy

This chapter provides context for the three indicators in this report by examining some of the relationships among society, the economy and the environment that influence changes in the air quality, water quality and greenhouse gas (GHG) indicators. This chapter also illustrates some of the costs of environmental stressors to society and the economy.

Although the indicators focus on separate issues and cover different geographic areas and time periods, they are 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.

Activities that burn fossil fuels, such as transportation, emit GHG emissions as well as air pollutants that combine to form ground-level ozone, such as nitrogen oxides (NO_X) and volatile organic compounds (VOC). In addition, industrial processes and the burning of fossil fuels produce NO_X and sulphur oxides (SO_X), which fall as acid precipitation. This precipitation affects waters in sensitive lakes and rivers, harming aquatic organisms, notably in parts of eastern Canada (Environment Canada 2005a).

One of the general findings repeated at both the household level and throughout the economy is that, while energy use is becoming more efficient, overall energy consumption and GHG emissions are still increasing.

5.1 Societal pressures

5.1.1 Population

Population characteristics influence the pressures that Canadians place on the environment. For example, with growing numbers of people living in and around urban areas, the potential for impacts on local and regional air and surface water quality are multiplied.

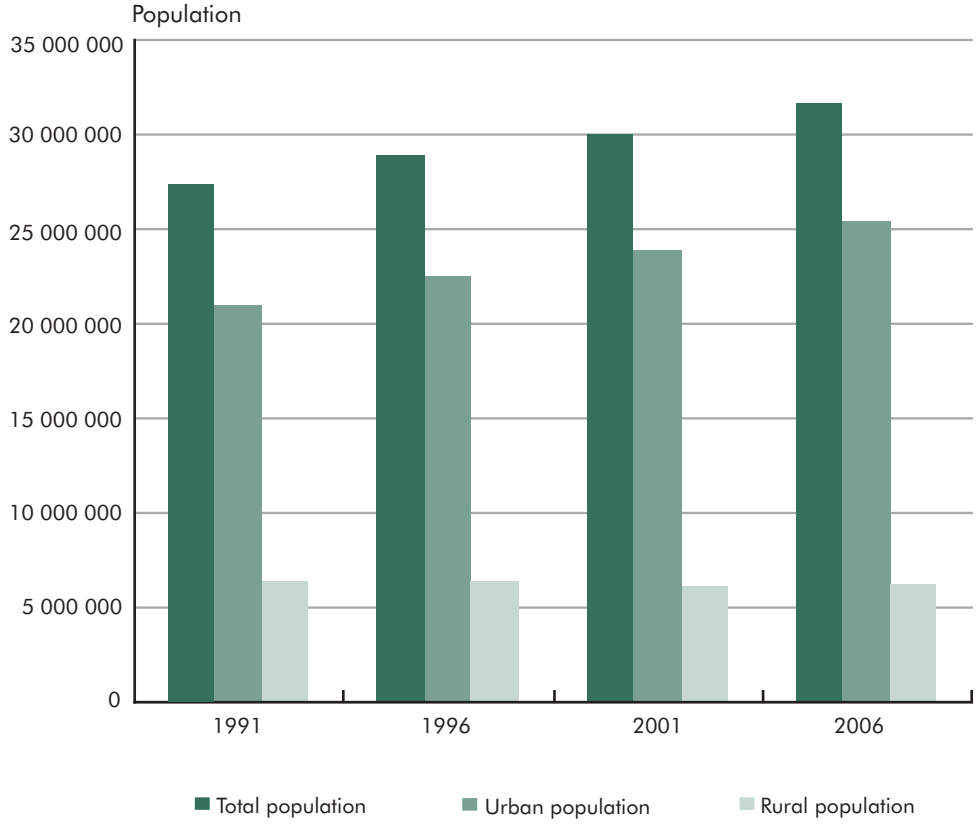
Between 1990 and 2005, Canada's population grew by 17%, from 27.7 million to 32.3 million people (Statistics Canada n.d.a). Although Canada's overall population density is low, the trend towards living in urban centres is continuing. From 1991 to 2006, urban populations increased by 21%, while rural populations decreased by 2% (Figure 13).

Aquatic ecosystems in drainage areas where populations are highly concentrated may experience increased stress from wastewater discharges and other uses. Likewise, aquatic ecosystems in drainage areas with low population but widespread agriculture may also experience increased stress. Population densities range from near zero in the Arctic to over 19 persons per square kilometre in the St. Lawrence major drainage area, whose waters feed into the Great Lakes and the St. Lawrence River. More than 62% of Canadians lived in this area in 2001 (Statistics Canada n.d.b). The Pacific and St. Lawrence major drainage areas are among the most urbanized in the country, with more than four fifths of their population living in urban areas. Meanwhile, agricultural land use is highest across the Prairie region, including the Mississippi and Nelson major drainage areas.

5.1.2 Behaviours

The behaviours of individual Canadians also have an effect on the environment. How they heat and cool their homes or commute to work, what products and services

Figure 13 Total, urban and rural population, Canada, 1991 to 2006



Source: Statistics Canada. n.d. CANSIM 153-0037. In: Statistics Canada. 2007 *Canadian Environmental Sustainability Indicators: Socio-economic Information*. Catalogue no. 16-253-XWE. Ottawa, Ontario.

they choose, and even the recreational activities they participate in have an impact on the air quality, water quality and GHG indicators. There are a variety of factors that influence Canadians' consumption behaviours. Income and prices are key drivers, but climate, geography, trends in housing size and density, and the adoption of technology can also affect how much energy, water or other resources are consumed.

Household energy use

The Canadian Environmental Sustainability Indicator (CESI) initiative has funded several surveys that focus on energy and water use to provide socio-economic context to the indicators. This section features data from one of these surveys, the 2006 *Households and the Environment Survey*, which was developed to gain a better understanding of household behaviour and practices that have, or are perceived to have, positive or negative impacts on the environment.

Households contribute to air and GHG emissions through the use of electric power, home heating fuels and gasoline and diesel. Close to a fifth (17%) of energy consumed in Canada is used directly by households for heat and power (Statistics Canada n.d.c).

With more people choosing to live alone or in smaller households, the number of dwellings has been increasing more quickly than the population (Statistics Canada n.d.d). Larger homes and the greater abundance of electronic devices used by Canadians have also contributed to higher residential energy demand (Natural Resources Canada 2006a). On the other hand, furnaces and appliances have become more energy-efficient, and improved insulation and other building envelope improvements have increased the energy efficiency of new and renovated houses (Natural Resources Canada 2006b).

The type, age and efficiency of home heating systems also have an impact on the amount of energy used and the quantity of emissions. For example, natural gas or hydro-electricity produce fewer GHG emissions and air pollutants than oil, and wood-burning stoves are a particularly large source of air pollutants, producing a third of all fine particulate matter ($PM_{2.5}$) emitted in 2005,

excluding open sources such as dust from unpaved roads (Environment Canada 2007e).

In 2003, two thirds of Canadian households heated their homes using hot-air or hot-water furnaces powered by natural gas or oil. Electric baseboard heating, used by more than a quarter of households, was especially common in Quebec. Stoves burning wood, pellets, coal and other fuels were the main heating equipment for 4% of households (Natural Resources Canada 2006b).

More than a quarter of Canadian households had central air conditioning in 2003 and another 15% had one or more window or room air conditioners, but large regional differences exist. For example, 60% of all residential air-conditioning systems were located in Ontario, and nearly three out of every four households in Ontario and a third of households in Quebec and the Prairies were equipped with air-conditioning systems (Natural Resources Canada 2006b). In Ontario, peak demand for electricity now occurs in the summer instead of the winter as a result of air conditioner usage (Ontario Power Generation Conservation Bureau 2007).

Households can reduce their ecological impact by using less energy; for example, by turning down the thermostat at night during the winter. In 2006, 40% of households had a programmable thermostat, more than double the number in 1994. Of those who owned this type of thermostat and programmed it, two out of three turned down the heat at night. On the other hand, 17% of the households equipped with a programmable thermostat had not, in fact, programmed it (Statistics Canada 2007a).

Switching to more energy-efficient appliances and light bulbs is another way to reduce energy consumption. Over 55% of Canadian households now use compact fluorescent bulbs, which use up to three-quarters less energy than traditional light bulbs (Natural Resources Canada 2005). Between 1994 and 2006, the proportion using at least one compact fluorescent light bulb almost tripled (Statistics Canada 2007a).

Energy is also used by households to run a variety of other devices, including small gasoline engines that power equipment such as lawnmowers. These emit relatively high amounts of pollutants that can adversely affect air quality. In one year, the average gasoline-powered lawnmower emits as much $PM_{2.5}$ as an average passenger car travelling about 3300 km (Environment Canada 2007e). In 2006, an estimated 21% of non-apartment-dwelling households owned a snow blower. When they also had a lawn or garden, 67% of households owned a gasoline-powered lawnmower, and 5% owned a leaf blower (Statistics Canada 2007a).

Personal transportation

After energy use in the home, transportation is the biggest contributor to households' demand for energy. It is also the largest contributor to households' GHG emissions (Statistics Canada n.d.e). In 2005, the volume of gasoline sold at the pump decreased by 1% from the previous year, the first decline in a decade. However, sales increased by 23% from 1990, reaching 36.2 billion litres in 2005 (Statistics Canada n.d.f).

Households' vehicle choices have had an important impact on air pollutant and GHG emissions. From 1990 to 2005, emissions from light-duty gasoline vehicles such as automobiles decreased by 13% for GHGs, 73% for NO_X and 70% for VOC. However, the increased popularity of sport utility vehicles, vans and light trucks has resulted in a 112% increase in GHG emissions from these vehicles. Meanwhile, the NO_X and VOC emissions associated with these light-duty trucks decreased by 32% and 39%, respectively (Environment Canada 2007a, 2007e).

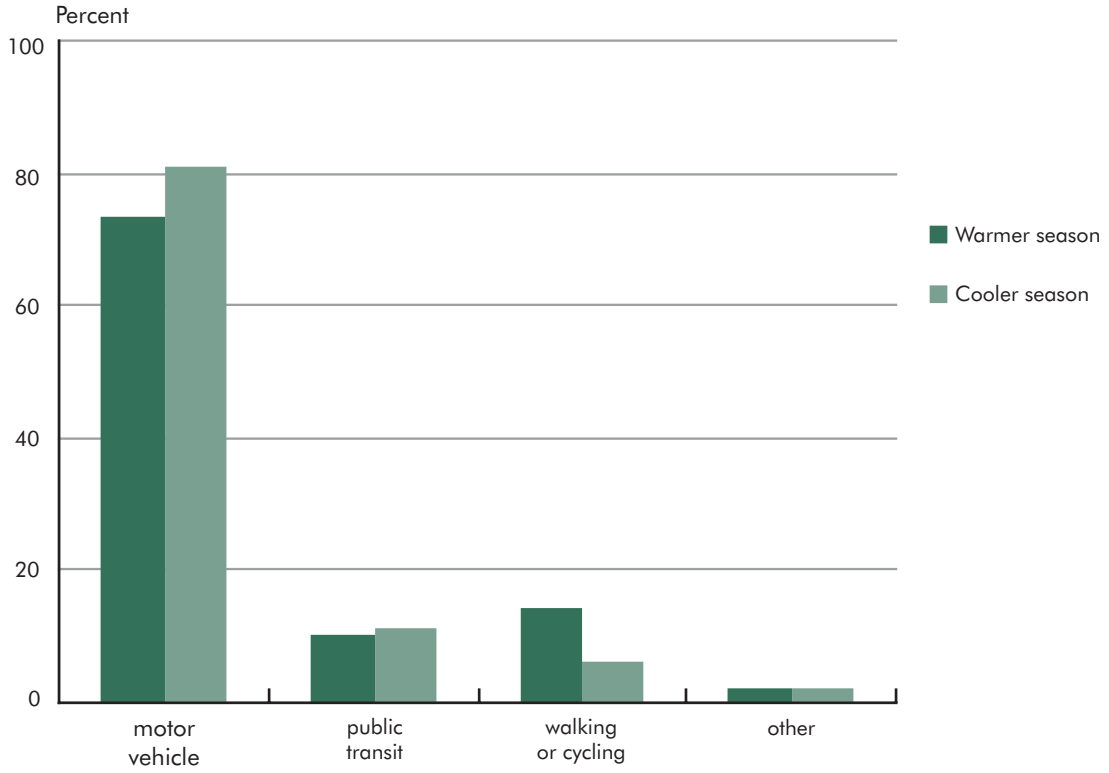
Choosing to drive less also contributes to a healthier environment. In 2006, 83% of households owned or leased a motor vehicle for personal use. Nearly half of them used only one vehicle, another 39% used two vehicles and 12% used three or more vehicles. A majority of households drove their vehicles less than 20 000 km each year (Statistics Canada 2007a).

During the warmer months in 2006, 73% of Canadians working outside the home travelled to work by motor vehicle, 14% walked or cycled, and 10% used public transit. In colder months the proportion of commuters who travelled by car increased to 81% (Figure 14). In both seasons, well over half of all commuters travelled to work in a motor vehicle. This has implications for both air quality and GHG emissions (Statistics Canada 2007a).

Air travel is also becoming increasingly popular, contributing to GHG emissions and other environmental effects. Between 1990 and 2005, the number of passengers travelling on major Canadian airlines rose 51% to 32 million, while the distance travelled increased by more than two thirds to 84 billion passenger-kilometres (Statistics Canada n.d.h).

While motorized watercraft and snowmobiles use very little fuel in comparison to cars and trucks, they can produce a disproportionate amount of air pollution. Twelve percent of households owned these vehicles, with 70% using less than 100 litres of fuel in 2005 (Statistics Canada 2007a). Traditional two-stroke boat engines waste a significant amount of gasoline and oil, which is released directly into air and water as pollution (Environment Canada 2000).

Figure 14 Mode of transportation to work, warmer and cooler months, 2006



Source: Statistics Canada, 2007a. *Households and the Environment Survey*. Catalogue no. 11-526-XIE, Ottawa.

Household-level impacts on water

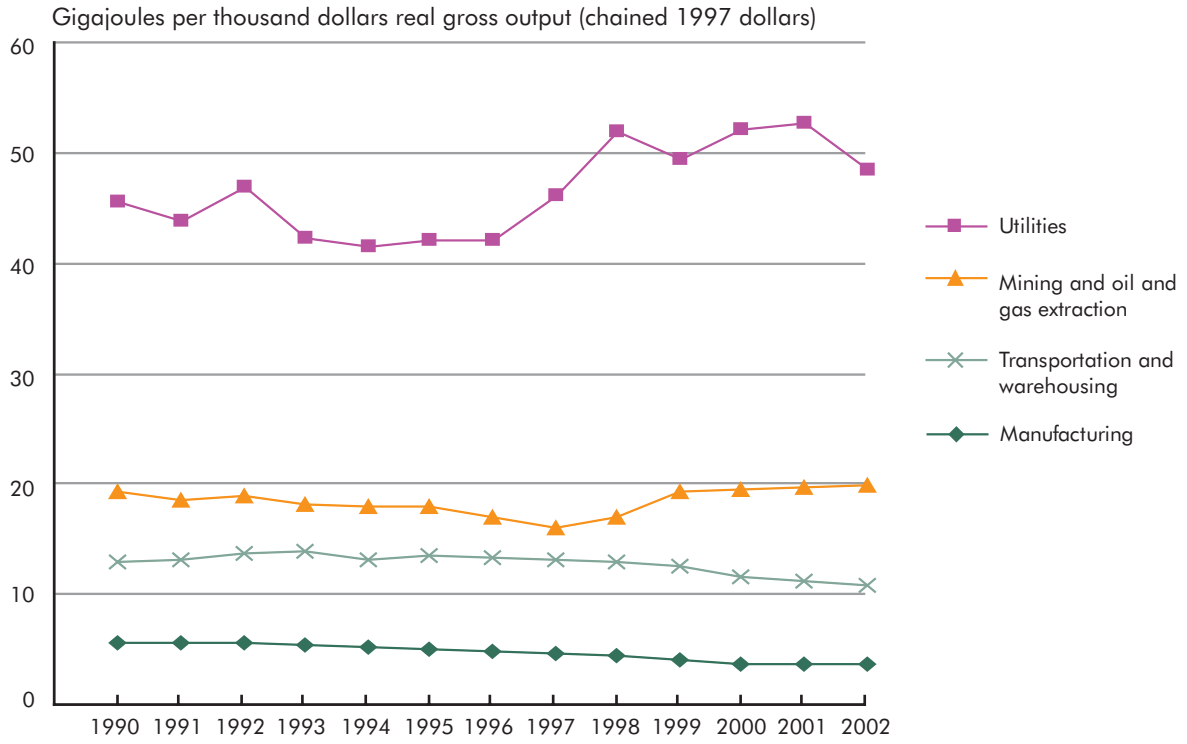
Human settlements can influence water quality through the release of wastewater effluents and contaminated runoff into receiving water bodies. These releases typically contain nutrients, suspended solids, chloride and metals such as copper, iron, lead and zinc. However, hundreds of other substances can be released as well, including industrial chemicals, pesticides, oil and grease, and pharmaceutical products (Environment Canada 2001a). Conventional secondary wastewater treatment systems are designed to remove solid materials and substances associated with domestic wastewater, but may not adequately remove all constituents.

The quality of water in Canada's rivers and lakes is also influenced by individual behaviour. For example, fertilizers and pesticides used on lawns and gardens can make their way into stormwater systems, potentially affecting aquatic life in receiving water bodies. In 2005, 32% of households with a lawn or garden used fertilizers, while 29% used pesticides. The use of chemical pesticides was down only slightly from 1994 levels. In addition, a wide range of household chemicals can make their way into sanitary sewers. Over 39% of households flushed their leftover pharmaceutical products down the drain or put them in the garbage in 2005 (Statistics Canada 2007a). Recent research has shown that these products can harm many aquatic species (e.g., through hormonal disruption).

Also of concern for municipalities is the overall increasing demand for water, which is straining the capacity of existing water and wastewater infrastructure and increasing the costs and energy required for treatment. Municipalities withdrew approximately 15 billion litres of water per day from surface and groundwater in 2004, an increase of 10% since 1991 (Environment Canada 2003, Environment Canada 2007d). Households used 56% of this water—on average, 329 litres per person per day. This was relatively unchanged from the 341-litre average reported in 1991 (Environment Canada 2007d).

Use of water-saving devices, such as water-saving showerheads and low-flow toilets, is increasing. For example, 54% of Canadian households reported having a water-saving showerhead in 2006, as opposed to 42% in 1994 (Statistics Canada 2007a). Summer water-use restrictions are also in place in many municipalities.

Figure 15 Energy use per unit of real gross output, major energy-consuming industries, 1990 to 2002



Note: Figures for 2002 are preliminary.
Sources: Statistics Canada, Environment Accounts and Statistics Division; Statistics Canada, n.d.i, CANSIM 383-0022 Gross output at a detailed industry level, by North American Industry Classification System (NAICS), annual (index, 2002=100).

5.2 Economic pressures

Canada's economy is driven by many forces. Financial and real capital use, natural resource endowments, productivity, trade, and the degree to which Canadians save, consume and participate in the workforce all play a role. Growth in economic activity brings benefits in the form of increased income, but can also lead to increased pressure on the environment. One way of limiting this pressure is to reduce energy use.

Industrial energy use can be studied by measuring energy use per unit of goods and services produced. Ideally, this would be done by dividing energy use in a given industry by some physical measure of the industry's production, say tonnes of cement or bushels of wheat. This is not possible for most industries, as industrial outputs are almost always heterogeneous and, therefore, not easily added together in physical units. A measure of the volume of industrial production is available in monetary terms, however. This is known as real gross output and is equal essentially to the value of an industry's sales corrected for inflation.

In 2002,[14] the following four industry groups accounted for over 73% of total industrial energy use: manufacturing; utility; mining and oil and gas extraction; and transportation and warehousing.[15]

Using a measure of energy use per unit of real gross output, two of these industries improved their performance from 1990 to 2002 (Figure 15). The manufacturing industry used 33% less energy per unit of real gross output in 2002 as compared with 1990. The transportation and warehousing industry decreased its use of energy per unit of real gross output by 15% over the same period. In

14. 2002 is the last year for which detailed energy accounts consistent with real gross output estimates exist.
15. These categories are defined by the North American Industry Classification System.

contrast, the utility industry's energy needs increased by 7% and those of the mining and oil and gas extraction industry increased by 3%.

Looking just at the real gross output of these industries, each one of them increased its real output considerably between 1990 and 2002 (manufacturing, 55%; utilities, 31%; transportation and warehousing, 38%; mining and oil and gas extraction, 49%). These increases meant that absolute energy use increased over the period for each of the industries, in spite of the downward trend in energy use per unit of real gross output for the manufacturing and transportation and warehousing industries. The increase in absolute energy use for each of the sectors (Figure 16) was as follows: manufacturing, 4%; utilities, 39%; transportation and warehousing, 17%; and mining and oil and gas extraction, 54%.

The size, location, technologies and practices of industrial facilities, farms, mines, stores and offices affect the quantity and distribution of pollutants as well. The following sections look in detail at several industries whose activities significantly influence the air quality, GHG emissions and freshwater quality indicators.

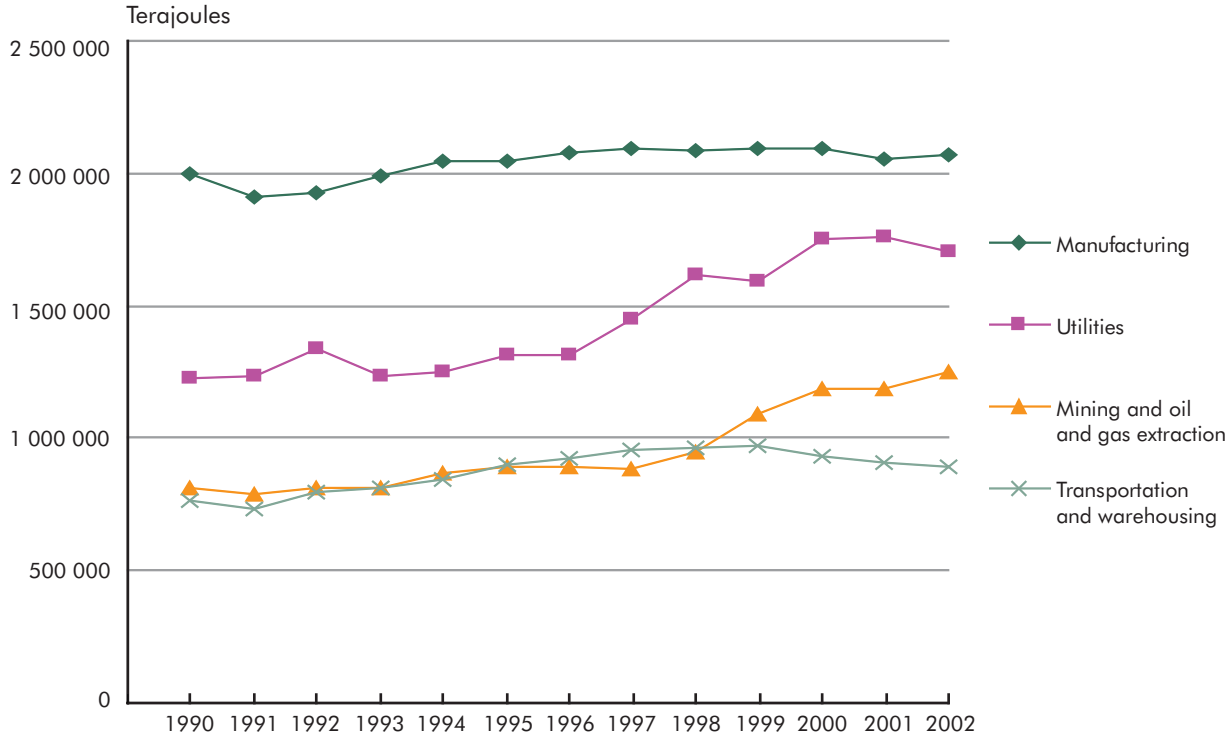
5.2.1 Transportation

Transportation keeps the economy moving by distributing goods and linking people in different communities and countries. Demand for transportation services is rising, driven in part by increased trade with the U.S. (Statistics Canada 2006a).

Transportation, including cars and trucks, transit, airlines, railways, marine transport and pipelines, consumed 31% of all energy used in Canada in 2005 (Statistics Canada n.d.j). A quarter of Canada's total GHG emissions (Environment Canada 2007a), more than half of all NO_X and almost a third of VOC (Environment Canada 2007e), were emitted by transportation activities in 2005. Transportation can also influence water quality—runoff from roads carries a number of substances including silt, nutrients, metals, de-icing salts and petroleum products.

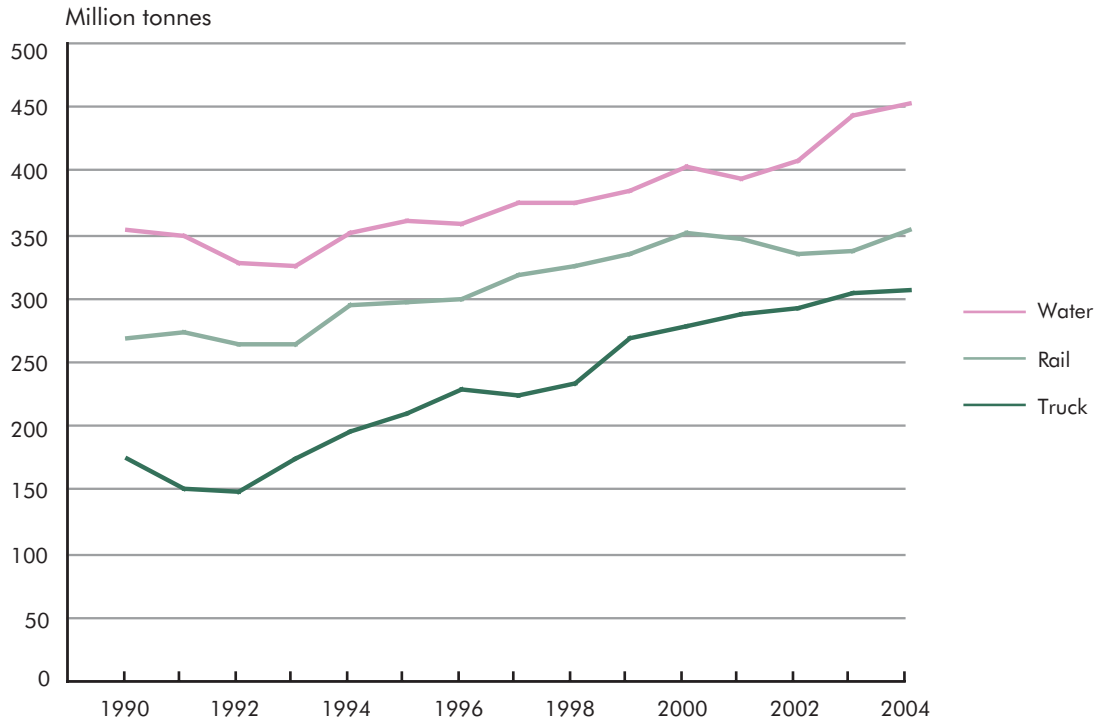
Since 1990, the movement of freight has increased for all modes of transport, but the trucking industry has seen the greatest rise in goods shipped, due in part to the advent of just-in-time delivery (Figure 17). On a

Figure 16 Total energy use, major energy-consuming industries, 1990 to 2002



Source: Based on Statistics Canada. n.d.d, CANSIM 153-0037. In: Statistics Canada. 2007 *Canadian Environmental Sustainability Indicators: Socio-economic Information*. Catalogue no. 16-253-XWE. Ottawa, Ontario.

Figure 17 Freight shipped, by mode, Canada, 1990 to 2004



Note: Data for trucking includes Canada-based long-distance carriers only.
Sources: Statistics Canada. n.d.k, *Trucking in Canada*. Various issues. Catalogue no. 53-222-XIB. Ottawa, Ontario.
Statistics Canada. n.d.l, *Shipping in Canada*. Various issues. Catalogue no. 54-205-XIE. Ottawa, Ontario.
Statistics Canada. n.d.m, *Rail in Canada*. Various issues. Catalogue no. 52-216-XIE. Ottawa, Ontario.

tonne-kilometre (t-km) basis, which takes into account both the weight of shipments and the distance travelled, freight carried by the trucking industry increased 140% to 185 billion t-km between 1990 and 2003 (Statistics Canada n.d.k).

Greenhouse gas emissions from heavy-duty diesel vehicles rose 84% from 1990 to 2005 (Environment Canada 2007a). On the other hand, $PM_{2.5}$ emissions from heavy-duty gas and diesel vehicles fell 59% over the same period, while NO_X increased 9% overall, although these emissions experienced annual fluctuations (Environment Canada 2007e). New regulations limiting the sulphur content of diesel fuel to 15 parts per million and new engine technologies to reduce particulate matter and NO_X from truck engine emissions should help improve air quality in the future.

5.2.2 Energy production

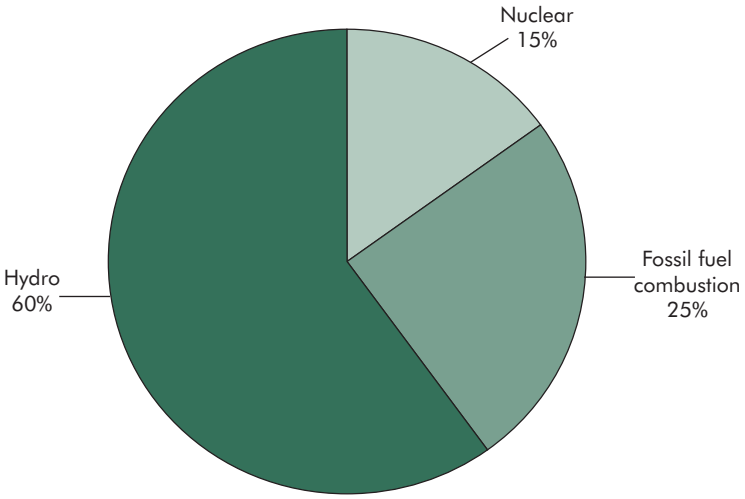
As noted in the chapters on the individual indicators, energy production has a large impact on air quality, GHG emissions and water quality.

Oil, gas and coal production emits air pollutants and GHGs while using large amounts of water. Furthermore, Canada's oil sands are becoming increasingly important, accounting for 42% of total national crude oil and equivalent production in 2005 (Statistics Canada n.d.n). With current technology, these deposits are second only to Saudi Arabia's oil reserves (CAPP n.d.). However, extracting oil from oil sands is more energy-intensive than conventional oil recovery.

The majority of dams in Canada are used primarily for hydro-electric generation, although other uses include irrigation, flood control, water supply, treating mine tailings and recreation. Dams alter the natural flow and shape of rivers, potentially affecting downstream water temperatures, metal concentrations and oxygen levels, preventing the transport of sediments containing nutrients and, for certain spillways, releasing gas bubbles with concentrations dangerous to fish (Fidler and Miller 1997, Environment Canada, 2001a).

In 2005, 60% of electric power was generated from hydro power and 15% from nuclear sources, while the

Figure 18 Electric power generation, by source, Canada, 2005



Source: Statistics Canada. n.d.o, CANSIM 127-0001. In: Statistics Canada. 2007. *Canadian Environmental Sustainability Indicators: Socio-economic Information*. Catalogue no. 16-253-XWE. Ottawa, Ontario.

remainder was produced using fossil fuels (Figure 18) (Statistics Canada n.d.o). Electricity and heat generation accounted for 17% of total GHG emissions in 2005 (Environment Canada 2007a), as well as a quarter of total emissions of SO_X and a tenth of NO_X emissions (Environment Canada 2007e). In addition, in 2005, thermal-electric power generators[16] withdrew 32 138 million cubic metres of water for cooling purposes and discharged 31 247 million cubic metres, mainly into surface water bodies (Statistics Canada 2007b).

5.2.3 Agriculture

Over the past several decades, Canadian crop and livestock operations have grown considerably, becoming larger and more specialized. Between 1981 and 2006, the number of farms decreased by 28%, while cropland areas increased by 16% (Statistics Canada n.d.p).

The agriculture sector is the largest source of atmospheric emissions of ammonia, accounting for 90% of the total, including open sources (Environment Canada 2007e). Ammonia can interact with other air pollutants to lead to the formation of $PM_{2.5}$. It also contributes to emissions of methane and nitrous oxide, both potent GHGs. Greenhouse gas emissions for the agriculture sector reached 8% of total emissions in 2005 (Environment Canada 2007a).

Agricultural activities may also degrade water quality. Exceedances of water quality guidelines for nutrients occur as a result of, for example, the application of nutrients in the form of chemical fertilizer, manure, compost, or sewage sludge to increase crop productivity. High turbidity (suspended solids), pathogens, and the presence of pesticides can result from runoff from fields and the removal of natural vegetation along stream banks. If sound management practices are followed, however, the environmental risks to water quality can be reduced.

Real farm expenditures on chemical fertilizers rose by 54% from 1980 to 2005. Over the same period, fertilized areas increased by 37% to over 250 000 km^2 nationally (Statistics Canada n.d.p). Livestock production is an important source of phosphorus and nitrogen emissions; for the whole of Canada, manure production increased by 13.9% from 1981 to 2001, with the largest amounts produced in southern Alberta, Ontario and Quebec (Statistics Canada 2006b).

Pesticides, which are used to control weeds, insects and other pests, can potentially harm non-target organisms. Effects vary depending on the chemical used and the level and duration of exposure. Pesticides can also contaminate water through runoff and infiltration into groundwater. From 1980 to 2005, real expenditures on

16. Includes fossil fuel electric power generation and nuclear electric power generation.

chemical products such as herbicides, insecticides and fungicides increased by 121% (Statistics Canada n.d.p).

5.2.4 Other industries

In 2005, large industrial and institutional facilities reporting to the National Pollutant Release Inventory discharged at least 115 000 tonnes of effluent into coastal and freshwater bodies. Municipal water and wastewater services discharged 86% of this effluent, with a further 6% coming from pulp and paper mills, 3% from waste treatment and disposal, 1% from metal ore mining and 3% from all other sectors combined. A total of 481 facilities across Canada reported discharges of 84 different substances to either coastal or freshwater bodies, with the largest being ammonia (46% of all emissions), nitrate (45%) and phosphorus (6%) (Environment Canada 2007c). Recent improvements in pollution prevention and control have reduced overall amounts of pollutants released by pulp and paper mills, especially methanol, ammonia and nitrate (Environment Canada 2006b).

Industries are also major emitters of air contaminants and GHGs. According to Environment Canada, industrial emissions of NO_X totaled 804 kilotonnes in 2005, up 56% from 517 kilotonnes in 1990, while industrial emissions of VOC totaled 735 kilotonnes, an increase of 3% from 1990. In contrast, from 1990 to 2005, emissions of $PM_{2.5}$ by industry declined by 42% to 117 kilotonnes (Environment Canada 2007e). From 1990 to 2005, GHG emissions from manufacturing industries decreased by 16%, while emissions in the industrial processes sector were unchanged (Environment Canada 2007a).

5.3 The social and economic costs

Degradation of the natural environment has many costs, including reductions in ecosystem goods and services, impacts on human health, and expenditures to prevent, reduce and treat pollution. Over the coming decades, adapting to climate change will also present significant additional expenses.

5.3.1 Expenditures to protect the environment and our health

Part of the economic dimension of the issues covered by the CESI indicators is the cost associated with reducing GHG emissions and air and water pollution. From purchasing energy-efficient cars and appliances to retrofitting their homes, individual Canadians are already spending to reduce their impact on the environment.

Over the years, Canadians have invested billions of dollars in water and wastewater infrastructure. In 2005, local governments spent close to $4.3 billion on water purification and supply and over $3.6 billion on sewage collection and disposal (Statistics Canada n.d.q). Waterborne diseases and new contaminants such as pharmaceuticals will continually challenge our capacity to treat water and wastewater.

Canadian companies have also substantially increased their spending to mitigate their impact on the environment. Capital and operational spending by primary and manufacturing industries reached $6.8 billion in 2002, a 24% increase from 2000 (Statistics Canada 2004b). Much of this increase resulted from responses to new environmental regulations and industry's efforts to reduce air emissions such as GHGs.

In total, Canadian businesses spent $1.106 billion to reduce GHG 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. In 2004, over a quarter of businesses surveyed introduced new or significantly improved equipment to reduce GHG emissions (Statistics Canada 2006c).

Businesses also invested $428 million in capital spending 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 contributed by the oil and gas, electric power, and petroleum and coal products industries (Statistics Canada 2004b).

5.3.2 Current and potential socio-economic costs of pollution

Based on data from eight cities (Québec, Montréal, Ottawa, Toronto, Hamilton, Windsor, Calgary and Vancouver), Health Canada has estimated 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).

While the air quality indicators focus on human health, pollution also has other socio-economic costs. For instance, elevated levels of ground-level ozone affect vegetation, impairing crop yields and ecosystems. Reducing these ozone levels would therefore have generally beneficial results on crop yields and commercial forest growth. Extensive field experiments conducted under the National Crop Loss Assessment

Network showed that several economically important crop species are sensitive to ozone levels typical of those found in the U.S. (U.S. EPA 1996). There have also been observations of negative impacts of ozone at commonly occurring levels on tree species in field studies. These include the Aspen FACE (Free-Air Carbon Dioxide Enrichment) study where it was shown that the growth of sensitive varieties of aspen could be reduced by up to 31% due to ozone (Percy et al. 2006).

Particulate matter is a significant contributor to acid deposition (Environment Canada 2005a). This has direct socio-economic impacts that include decreased forest growth, detrimental influences on recreational and commercial fishing due to lake acidification, and increased rates of corrosion of buildings and structures, particularly historical buildings and electrical towers. These impacts are considerable; for example, material corrosion caused by acid deposition has been estimated to have cost $975 million in damages in Ontario alone (Ontario Ministry of the Environment 2005).

Particulate matter also impacts the welfare of Canadians in a number of ways. For instance, it leaves visible dirt and grime, increasing the effort and energy required for cleaning. It can also impair visibility, and this can affect the public's enjoyment of scenic vistas and a variety of daily activities both in the places in which they live and work and in the places where they travel for recreation. One study funded by Environment Canada indicated that residents of British Columbia's Lower Mainland would be willing to pay an average of $48 per household per year to improve visibility by 20% during the summer (Haider et al. 2002).

Environmental degradation will potentially have even greater socio-economic costs in the future. For instance, the Intergovernmental Panel on Climate Change (2007) has concluded that North America, among other regions, is vulnerable to climate variability and extremes resulting from climate change and will face environmental, economic and social costs if global efforts fail to reduce GHG emissions. In fact, the report states that North America is already experiencing warming that is affecting natural systems. Expenditures could therefore occur in two areas: reducing GHG emissions to try to prevent the most destructive climate change impacts, and implementing measures to adapt to the climate change impacts that will inevitably occur over the next few decades.

If extreme weather events become more frequent and intense, damage to towns and cities and agricultural crops could also occur. In addition, forest productivity and wildlife could be affected by impacts such as pest disturbances, disease and fire. In humans, continually increasing emissions could lead to pollution-related health problems, heat-related deaths, and a higher incidence of waterborne and vector-borne diseases.

Degradation of water quality has important socio-economic impacts. Economic activities such as fishing, tourism and agriculture can be adversely affected by degraded water quality. For example, a third of shellfish-growing areas on the Atlantic Coast were closed in 1997 due to bacterial or chemical contamination (Statistics Canada 2000). For Nova Scotia alone, closure of shellfish areas results in estimated losses of at least $8 million a year, in addition to the $155 million already lost from 1940 to 1994 (GPI Atlantic, 2000).

Since the 1970s, many pollution prevention and control programs have been initiated to reduce nutrients and toxins in water. These public investments in water quality have had a positive impact on riverfront development or re-development, such as in the Great Lakes. In contrast, aquatic environment degradation such as algal blooms because of natural causes or water pollution, is still causing limitations and costs for recreational and water-related tourism activities. In 2001, 43% of Canadian Great Lake beaches had bacteriological counts exceeding the provincial standard at least once, resulting in a number of temporary closures during the summer season (Environment Canada and U.S. EPA 2003). In 2005, a quarter of all Canadian households were aware of a swimming restriction or closure at a nearby beach. Among those, two thirds chose not to swim because of the restriction (Statistics Canada 2007a).

While the freshwater indicator focuses on aquatic life, water quality can also impact human health. Various microbial pathogens can occur naturally in source water and have been responsible for outbreaks of illnesses in Canada, e.g., *E. coli, Cryptosporidium* and *Giardia* (Environment Canada 2001a). However, in identifying the cause of the illness, it can be difficult to determine whether the source of the microbial pathogen is foodborne or waterborne, or spread by person-to-person contact. Giardiasis, sometimes called "beaver fever," is an intestinal parasitic infection characterized by chronic diarrhea and other symptoms. Community outbreaks may occur by ingesting *Giardia* cysts from fecally contaminated food or unfiltered water. Between 1988 and 2004, the number of new cases of giardiasis in Canada declined by 63%, reaching a point where there were 13 reported cases per 100 000 people in 2004 (Public Health Agency of Canada n.d.). However, estimates from studies in North America and Europe indicate that only about 1% to 10% of cases are reported (Health Canada and Statistics Canada 1999).

Although rare in most parts of Canada, the risk of microbial disease associated with drinking water can be a concern among small and remote Canadian communities, particularly in First Nations communities (OAG 2005). Of the 740 First Nations community water systems assessed in 2003, about 29% (218) were classified as posing a potential high risk to health and safety, primarily based on considerations of operations or drinking water treatment (INAC 2003). As of August 2007, there were 97 boil water advisories in effect in First Nations communities across Canada (Health Canada, n.d.). In 1999, 79 out of 752 surveyed municipalities stated they had issued at least one boil water advisory during the year, the average duration being 39 days (Environment Canada, 2001b). In addition, it is estimated that 20% to 40% of all rural wells in Canada could have nitrate concentrations or coliform bacteria occurrences in excess of drinking water guidelines (van der Kamp and Grove 2001).

5.4 What's next?

Further research will take place to integrate the indicators with the CESI surveys and with measures of socio-economic performance. This will be a key goal for future reports.

The *Households and the Environment Survey* is scheduled to be conducted every two years, with the next version scheduled for late 2007 and early 2008. This iteration of the survey will examine trends in household ownership of energy- and water-consuming equipment.

Results from Statistics Canada's surveys on agricultural water use, industrial water and drinking water plants scheduled for 2007 and 2008 will provide many additional opportunities to link socio-economic activities with the indicators.

6 Conclusion

Canadian Environmental Sustainability Indicator (CESI) reports are produced annually to track changes in air quality, greenhouse gas (GHG) emissions and water quality in Canada. The long-term goal of this report is to enable better decision making that fully takes into account environmental sustainability.

This report shows that pressure on Canada's environment is steady or increasing, and highlights some of the potential consequences for the health and well-being of Canadians and our economic performance. The following summarizes the main conclusions drawn from the three CESI indicators:

Air quality: The ground-level ozone exposure indicator showed an average increase of 0.8% per year between 1990 and 2005, leading to greater health risks for Canadians. The fine particulate matter ($PM_{2.5}$) exposure indicator demonstrated no statistically significant national or regional trends—either increasing or decreasing—in average exposure levels. This would suggest that there has been no change in the health risk associated with ambient $PM_{2.5}$ exposure.

Greenhouse gas emissions: The GHG indicator focuses on total national emissions of GHGs and shows that, in 2005, these emissions reached an estimated 747 megatonnes of carbon dioxide equivalent (Mt CO_2 eq), up 25% from the 1990 total of 596 Mt CO_2 eq. The major sources of this increase were fossil fuel production, transportation and electricity generation.

Freshwater quality: This indicator shows that guidelines for protecting aquatic life are not being met, at least occasionally, at many of the 359 selected monitoring sites across southern Canada, based on information gathered from 2003 to 2005. The compilation of information from across the country demonstrates that jurisdictions can cooperate to sketch a national picture of water quality. However, this indicator is the only one of the three in this report that cannot show a trend at present. The length of the current CESI water quality data records are insufficient to detect significant national trends, although work is under way to address this gap.

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Appendix 1
Description of the air quality indicator

The air quality indicators track measures of Canadians' long-term exposure to ozone and to fine particulate matter ($PM_{2.5}$), two key components of smog that have been linked to health impacts ranging from minor respiratory problems to hospitalizations and even premature death.

Air monitoring

Canada has a coordinated air monitoring network with stations across the country. The ozone and $PM_{2.5}$ data used in this report were collected through the National Air Pollution Surveillance (NAPS) Network, a joint federal, provincial, territorial and municipal program focused on urban air quality, and through the Canadian Air and Precipitation Monitoring Network (CAPMoN), a network operated by Environment Canada that measures rural and remote background levels of air pollutants.

The data collected through NAPS and CAPMoN are subject to strict quality assurance and quality control standards to maintain national consistency. In addition to audits by provincial, territorial and municipal jurisdictions, NAPS sampling stations are also subject to federal audits. This ensures that the data stored in the NAPS database are of the best possible quality.

Stations were grouped into regions by Environment Canada. These regional groupings have changed from previous reports to improve geographical representivity. Stations in eastern Ontario are now grouped with stations in southern Ontario, rather than with the ones in Quebec. Thus, indicator levels for these two regions in this report are not comparable with those in previous reports.

Ground-level ozone

From 1990 to 2005, 260 monitoring stations across the country reported hourly concentrations of ozone. Data sets from 76 of these stations were sufficiently complete for this period to be used for the national trend analysis (Figure 1). The measurement error for hourly ozone concentrations at individual sampling stations is estimated to be ±10% (Dann and Conway 2005).

Fine particulate matter

From 2000 to 2005, 162 monitoring stations reported hourly observations for fine particulate matter ($PM_{2.5}$) concentrations across the country. Data sets from 65 of these stations were sufficiently complete for this period to be used for the national analysis (Figure 3). The measurement error for hourly $PM_{2.5}$ concentrations at individual sampling stations is estimated to be ±20% (Dann and Conway 2005).

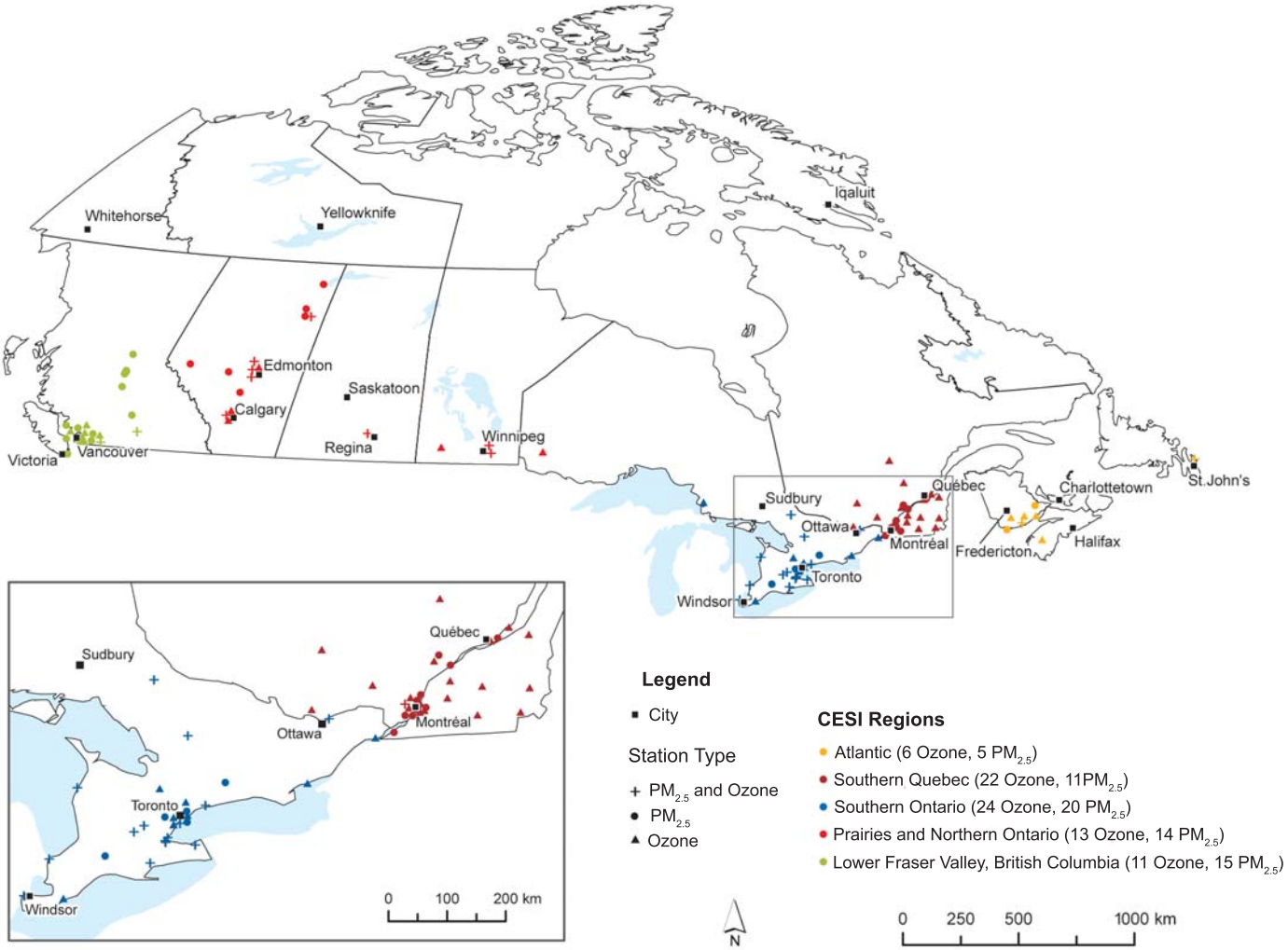
Monitoring of $PM_{2.5}$ started in 1984 in only a few Canadian cities, using a good but labour- and resource-intensive filter sampling method. Gravimetric analysis was conducted by passing air through a size-selective filtering medium which was then collected and sent to a certified laboratory for manual weighing. Other methods that continuously monitor and provide in-situ real-time hourly $PM_{2.5}$ data became available in the mid-1990s and have gradually been deployed to many more sites across Canada. Hence the exposure indicator trend analysis begins in 2000. A comparative analysis between manual weighing and the new automated methods shows good agreement during the warm season.

Computing the exposure indicators

The ozone exposure indicator was calculated using the following steps. For each given station, the ozone was averaged over a running 8-hr period. For a calendar day, this procedure gives 24 8-hr average readings. From these 24 8-hr readings, the daily maximum was then retained. These daily maxima were then averaged over the entire warm season (April 1 to September 30). Finally, these station warm-season averages were averaged nationally or regionally with the value for each station being population-weighted to provide the yearly national and regional exposure indicators covering the period from 1990 to 2005.

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 over a 24-hr period (midnight to midnight), which represents the commonly used unit for assessing exposure to $PM_{2.5}$. These daily averages were then averaged over the entire warm season (April 1 to September 30). Finally, these station warm-season averages were averaged nationally or regionally with the value for each station being population-weighted to provide the yearly national and regional exposure indicators covering the period from 2000 (the first year that the monitoring data was sufficiently extensive) to 2005.

Map A.1 Locations of monitoring stations contributing to the air quality indicators—national and regional



Note: Total number of monitoring stations: 76 for ozone and 65 for $PM_{2.5}$. Regional groupings have changed from previous reports.
Sources: The stations are part of the National Air Pollution Surveillance (NAPS) Network and the Canadian Air and Precipitation Monitoring Network (CAPMoN).

Population-weighted concentrations

Population-weighting the average concentration at each station puts more emphasis (or "weight") on the levels in the more populated areas, thereby providing a better indication of the ozone and $PM_{2.5}$ levels to which a greater proportion of the population may have been exposed.[17]

The warm-season average concentration (C_n) at a given monitoring station was then multiplied by the population (P_n) living within a 40-km radius of the station (C_n*P_n). All the considered C_n*P_n products were then added together and divided by the total considered population, giving the CESI exposure indicator:

$$\text{Exposure indicator} = \frac{P_1*C_1 + P_2*C_2 + P_3*C_3 + \cdots P_n*C_n}{P_1 + P_2 + P_3 + \cdots P_n}$$

where

C_1 = the warm-season average concentration of the daily maximum 8-hr ozone for the ozone exposure indicator, or the warm-season average concentration of the daily 24-hr average concentration for the $PM_{2.5}$ exposure indicator at station 1, and

P_1 = the population living within a 40-km radius of station 1.

Trend computation

The values of the exposure indicators can vary annually. Despite these annual variations, the value may experience an overall increasing tendency, a decreasing tendency or no tendency at all. This overall tendency is estimated by the slope of a straight line fitted through the actual values of the indicators. The slope of this line and its direction of change is what is meant by the "trend."

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, and also to test whether the slope obtained was statistically different from zero at the 90% confidence level. The Sen method is a non-parametric linear slope estimator commonly used in environmental statistics with time series data.

Interpretation of the trend and statistical significance

For the exposure indicators, trends are only reported if the slope is statistically different from zero. If the slope is not statistically different from zero, it means that a slope of zero is one possibility; as such, there may be no upward or downward trend in the values and any annual variations in the values of the indicator are therefore likely due to random errors alone. No test for the stability of the exposure indicators was conducted.

Interpretation of trends in ozone and $PM_{2.5}$ exposure 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.

In the case of the air quality indicators, studies indicate that adverse health effects can occur even with low concentrations of these pollutants in the air (WHO 2005). As a result, an increase in trend slopes of these indicators, regardless of their magnitudes, may signal the potential for increased health risk.

Further details on the air quality indicators are provided on the Government of Canada website (http://www.environmentandresources.gc.ca/default.asp?lang=En&n=229935CE-1) and the Statistics Canada website (www.statcan.ca/bsolc/english/bsolc?catno=16-251-X).

17. This approach is similar to but more general than the pilot method used for the National Round Table on the Environment and the Economy (NRTEE 2003) discussion paper on the Environment and Sustainable Development Indicators, prepared at Statistics Canada.

Appendix 2
Description of the greenhouse gas indicator

The greenhouse gas (GHG) emissions indicator, related data and trends information come directly from Canada's *National Inventory Report, 1990–2005—Greenhouse Gas Sources and Sinks in Canada* (Environment Canada 2007a), an annual report submitted by Environment Canada as required under the United Nations Framework Convention on Climate Change (UNFCCC). 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, released into the atmosphere, of the six GHGs covered under the Kyoto Protocol (see Chapter 3).

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" (GWP) that is specific to that gas. This potential represents the amount of warming over 100 years that results from adding one unit of the gas to the atmosphere, compared with the effect of adding one unit of carbon dioxide. The GWPs for the six greenhouse gases under the Kyoto Protocol are as follows:

- Carbon dioxide: 1
- Methane: 21
- Nitrous oxide: 310
- Halofluorocarbons: 140/11 700
- Perfluorocarbons: 6500/9200
- Sulphur hexafluoride: 23 900

The emissions for each GHG 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, however, 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 emission and removal estimates using 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), and other sections of Environment Canada (data on landfill gas capture, hydrofluorocarbon and perfluorocarbon use, ozone and aerosol precursors). Environment Canada engineers and scientists estimate emissions using methods developed by IPCC as well as methods and models developed in-house specifically for estimating Canadian emissions.

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.

Quality assurance, quality control and verification procedures are part of the 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, international reporting guidelines, domestic and international scrutiny and reliance on Statistics Canada energy survey results all contribute to the quality of the GHG estimates.

The complete *National Inventory Report, 1990–2005—Greenhouse Gas Sources and Sinks in Canada* is available upon request at http://www.ec.gc.ca/pdb/ghg/inventory_report/2005_report/toc_e.cfm.

Box A.1

Statistics Canada's Greenhouse Gas Emissions Account

Statistics Canada's Greenhouse Gas Emissions Account forms the basis for Figure 8. Produced following the concepts of the System of National Accounts, it uses many of the same basic data as the GHG 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 modeling. In particular, this linkage permits the use of Statistics Canada's national input–output accounts to analyse the interplay between production and consumption of goods and services and the GHG 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 GHG intensity of gross industrial output, the GHG intensity of household consumption and the GHG 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 Account 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 Environment Canada's GHG inventory and are applied to the appropriate industries in the System of National Accounts.

The final demand categories outlined in Figure 8 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 or 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.

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 359 locations in southern Canada and 36 locations in northern Canada for a total of 395 sites. These sites were further grouped by Canada's major drainage areas. In the 2006 *Canadian Environmental Sustainability Indicators* (CESI), the WQI was reported for 370 locations nationwide, with 340 in southern Canada, 30 in northern Canada, as well as for 7 basins in the Great Lakes.

The set of monitoring sites was assembled from existing federal, provincial, territorial and joint water quality monitoring programs (Map A.2). 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 the minimum requirements for the timing of the sample collection (2003 to 2005) and the number of samples taken (four per year for rivers and two per year for lakes during spring and fall turnover, 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 currently 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. Sensitivity analysis showed that the reduction of sample requirements in this case did not impact the WQI 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 m^3/sec and drains an area of about 15 km^2, to powerful rivers such as the Mackenzie, which discharges 9910 m^3/sec and drains an area of about 1.8 million km^2 (MRBB 2004). The lakes also vary considerably in size—from Glasgow Lake (0.24 km^2) in Nova Scotia's Cape Breton Highlands to Sipiwesk Lake in Manitoba (454 km^2) (Natural Resources Canada n.d.).

The range of water quality parameters incorporated into the WQI calculations includes

- nutrients (e.g., phosphorus and nitrogen);
- metals (e.g., arsenic and zinc);
- physical characteristics (e.g., pH, dissolved oxygen and turbidity);
- major ions (e.g., chloride and sulphate); and
- some organic compounds (e.g., pesticides).

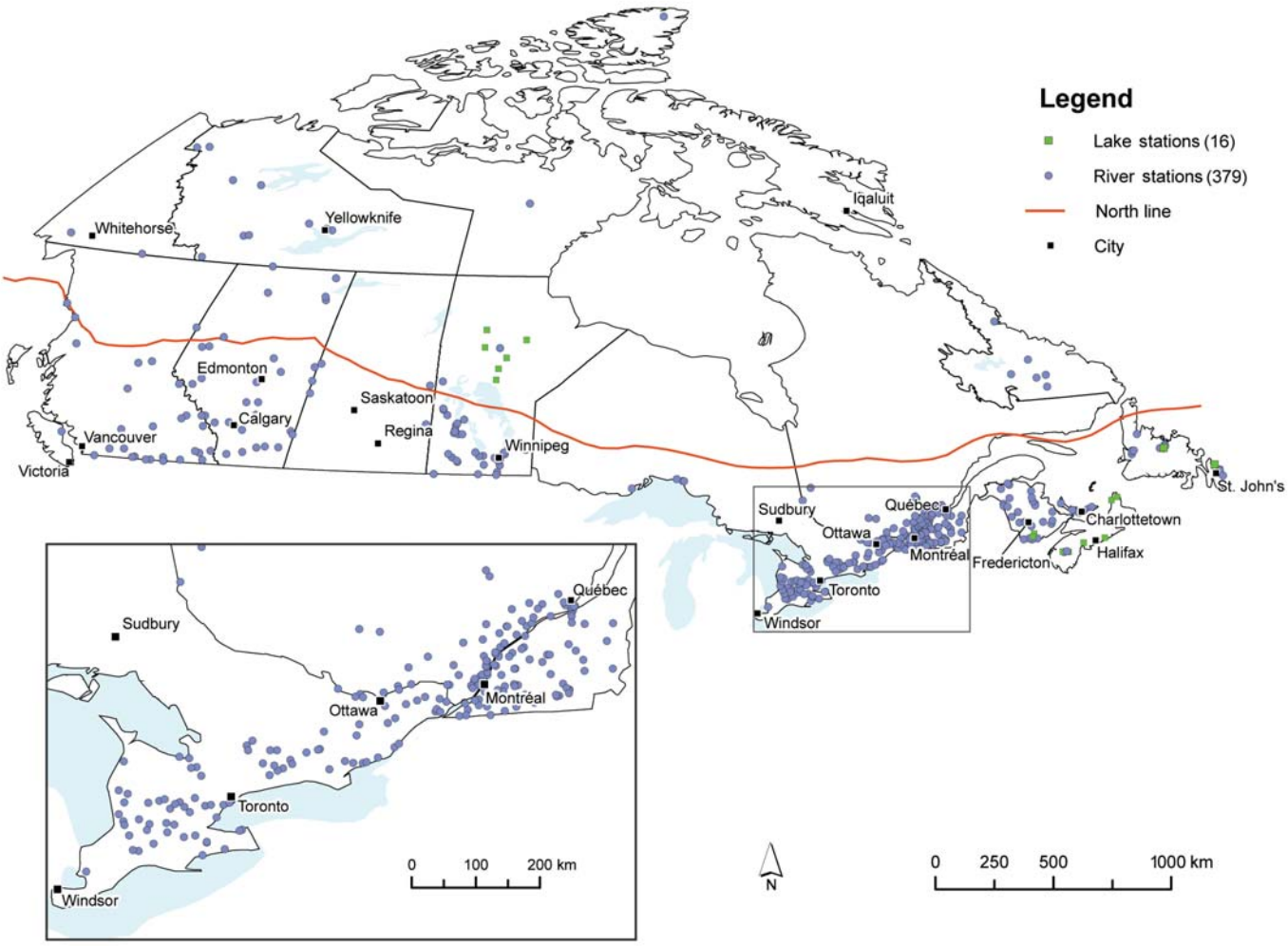
Different subsets of these parameters were selected and applied either uniformly throughout different jurisdictions and regions or, in the case of British Columbia, at individual sites. Generally, Environment Canada and its provincial and territorial counterparts chose which parameters to use in the calculation, based on which parameters 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 parameters 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.

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 parameters are used in the calculations, the implementation of locally relevant water quality guidelines and the development of water quality trends.

How different parameters are combined to produce the index values will also be reviewed and refined.

Further details on the water quality indicator are provided on the Government of Canada website (http://www.environmentandresources.gc.ca/default.asp?lang=En&n=2B589A09-1) and the Statistics Canada website (www.statcan.ca/bsolc/english/bsolc?catno=16-251-X) in the *Data Sources and Methods* report.

Map A.2 Water quality monitoring stations, Canada, 2003 to 2005



Note: 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).

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

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