# Primary Environmental Indicators

## 1 Air Quality

Regulations designed to improve air quality trends target six main pollutants: sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), ground level ozone ($O_3$), carbon monoxide (CO), total suspended particulates (TSPs), and lead (Pb).[1] The primary synthetic sources of these pollutants are automobiles and industrial activity such as mining, smelting, production of fossil fuels, pulp and paper and chemicals, and manufacturing. These pollutants are also created by natural sources.

To measure air quality, two types of data are used: ambient concentrations and emissions estimates. Ambient concentrations are the actual amount of a pollutant in the air. They are usually reported in parts per million (ppm), parts per billion (ppb), or micrograms per cubic metre ($\mu g/m^3$). In Canada, the National Air Pollution Surveillance (NAPS) network traces common air contaminants with 461 monitoring instruments located in 198 cities and towns across the country (Shelton 1999).[2] This program commenced in January 1970 with only 43 monitoring instruments in 14 urban centres (Furmanczyk 1987: 2).

Emissions estimates are calculations of the amounts and types of pollutants emitted by various sources over a given period. These calculations are based on many factors, including the level of industrial activity, changes in technology, fuel-consumption rates, vehicle miles travelled, and other activities that cause air pollution. They do not include releases of the pollutants from natural sources. Although emission statistics provide some useful information regarding air-quality trends, they are less reliable indicators than ambient concentrations because they are estimates generated by models rather than actual measures. In addition, frequent revisions in the calculation methods used to estimate emissions make comparisons between years less meaningful than comparisons of annual ambient levels.

In this section, each pollutant is described and then compared to Canada's National Ambient Air Quality Objectives (NAAQOs) for the protection of human health and the environment. Canada has a three-tiered system of objectives that defines maximum desirable, acceptable, and tolerable levels of air pollution for periods of one year, 24 hours, 8 hours or one hour, depending on the pollutant.[3] According to Environment Canada:

> the maximum desirable level defines the long-term goal for air quality and provides a basis for an anti-degradation policy in unpolluted areas of the country. The maximum acceptable level is intended to provide adequate protection against adverse effects on humans, animals, vegetation, soil, water, materials, and visibility. The maximum tolerable level is determined by time-based concentrations of air contaminants. When air pollutants reach this level of concentration appropriate action is required without delay to protect the health of the general population. (Environment Canada 1999b)

Table 1.1 lists Canada's NAAQOs alongside the guidelines of the World Health Organization (WHO). The table also includes a description of the effects on human health and the environment the correspond to each category. When the strictest standard (desirable) is met, there are no effects on human health and the environment.

For each pollutant discussed in the section, we provide a graph showing the average of the stations' annual means. The strictest annual health standard is included so the reader can see instantly whether there are any health concerns associated with that level of pollution. To provide a better illustration of the number of stations meeting the annual standards of Canada's NAAQOs, the tenth, fiftieth, and ninetieth percentiles (the box around each point) of stations meeting the standards are included. The top of the box illustrates the ninetieth percentile for the calculation. This indicates that 90 percent of the stations have an annual mean equivalent to, or below, this level. Similarly, the line in the middle represents the fiftieth percentile and the line at the bottom of the box represents the tenth percentile. They illustrate the levels for which 50 percent and 10 percent of the stations have an annual mean equivalent or below. It is important to note that the number of stations monitoring each pollutant has changed over the years.

The percentage of stations with readings above the NAAQOs short-term standards is also examined (see tables 1.2–1.6). This is calculated by dividing the number of stations with at least one reading above the NAAQOs by the total number of stations. In reading this data, it is important to note that one reading above the standard may not be critical, considering that some stations have several thousand readings in a year. Also a single day's exceedence can be influenced by meteorological factors such as temperature, sunlight, air pressure, humidity, wind, rain, and so on. Despite these limitations, the data provides a good complement to the annual data, illustrating changes in the number of stations meeting short-term concentration objectives.

## Sulphur dioxide

Sulphur dioxide ($SO_2$) is a colourless gas that, in sufficient concentrations, has a pungent odour. There is concern about levels of $SO_2$ since it is a precursor to acid rain. Acid rain in sufficient concentrations can cause the acidification of lakes and streams, accelerate the corrosion of buildings and monuments, and impair visibility. As a result, in 1985 Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland created the Canadian Acid Rain Control Program, agreeing to cut total annual $SO_2$ emissions to 2.3 million tones by 1994 (Statistics Canada 1998: 44). They surpassed this target by 1993. In 1991, Canada signed the Canada/United States Air Quality Agreement for the reduction of $SO_2$ and $NO_x$ emissions. Canada's obligations under this agreement include the establishment of a permanent national limit on $SO_2$ of 3.2 million tonnes by the year 2000 (USEPA 1995d: ES-1). Canada has met this objective since 1992.

Although acid rain remains a topical concern, there is a debate among scientists whether acid rain does indeed damage forests and crops as well as endanger wildlife and human health. After ten years of study, the United States National Acid Precipitation Assessment Program (NAPAP) concluded that acid rain has had little or no effect on wildlife, forests, crops, or human health (Bast, Hill, and Rue 1994: 74–81). In fact, it cites cases in which acid rain has had a positive effect on soil and lakes as it can enhance vital nutrients and reduce pH levels where alkalinity is a problem. There is also uncertainty about the natural acidic levels for different lakes. A chemist named Edward Krug argues that some lakes are becoming more acidic because of less human influence. Whereas slash-and-burn timbering practices in the early 1900s resulted in uncontrolled erosion and, consequently, in large deposits of alkaline topsoil in nearby lakes, more sustainable forestry practices have reduced erosion and have allowed the lakes to return to their natural acidic levels (Easterbrook 1995: 169).

Some Canadian scientists, however, estimate that even with full implementation of the Canada/United States Air Quality Agreement, close to 800,000 $km^2$ in south-eastern Canada will receive levels of acid rain that could have a negative effect on the environment. They have estimated that a further 75-percent emission reduction in parts of eastern Canada and the United States is necessary to protect sensitive ecosystems in the area (Statistics Canada 1998: 45).

### Trends for sulphur dioxide

Figure 1.1 shows that the ambient level (the average of the monitoring stations' annual means) for $SO_2$ decreased by 60.6 percent in Canada between 1974 and 1997. Since 1990, over 90 percent of the individual stations have reported annual means meeting Canada's strictest annual health standard. Figure 1.2 shows the downward trend in annual mean concentrations of $SO_2$ for three cities across Canada.

During the period from 1977 to 1997, there were also significant reductions in the number of stations with readings exceeding the 1-hour and 24-hour objectives (table 1.2). In 1997, only 20.7 percent of stations failed to meet 1-hour desirable objectives, compared to 42.2 percent in 1977. Similarly, in 1977, 10.3 percent of stations had readings exceeding the 1-hour acceptable level, down from 19.3 percent in 1977.[4] In 1997, 17.2 percent of stations had readings exceeding the 24-hour desirable level and 3.4 percent of stations exceeded the 24-hour acceptable level. No stations have exceeded the 24-hour tolerable level in the past decade.

Emissions of sulphur dioxide ($SO_2$) in Canada fell 59.7 percent between 1970 and 1997 (figure 1.3). The increased use of control devices by industry has contributed to the decline in emissions. Improvements in the processes used, smelter closures, acid-plant adoption, the use of low-sulphur coal, the adoption of coal blending and washing procedures, and the conversion to cleaner fuels (e.g., natural gas and light oil) have also contributed to the decline (USEPA 1996a: 29). Emissions by industrial sources decreased by 37.6 percent between 1980 and 1995. The greatest decline, however, was in combustion and incineration sources where emissions decreased 59.1 percent and 58.4 percent, respectively, over the same period. Figure 1.4 illustrates the sources of $SO_x$ for 1995. The main contributor to $SO_x$ emissions is industrial sources, particularly, the non-ferrous mining and smelting industry.

## Nitrogen dioxide

Nitrogen dioxide ($NO_2$) is a highly reactive gas that is readily formed through the combination of nitric oxide (NO) with oxygen. This reaction is typically a natural process, occurring through lightning, volcanic activity, bacterial action in soil, and forest fires. Most of the nitrogen oxide compounds needed for this reaction however, originate from human activities. Nitrogen oxides ($NO_x$) are the sum total of NO, $NO_2$, and other oxides of nitrogen. The combustion of fossil fuels by automobiles, power plants, industry, and household activities all contribute to their concentrations in the environment.

Levels of $NO_x$ in the environment are of concern since they combine with volatile organic compounds (VOCs) in the presence of sunlight to form ground-level ozone. This process contributes to the formation of urban smog. Nitrogen oxides also play a major role in atmospheric photochemical reactions that contribute to acid rain. Although the ambient levels of all nitrogen oxides are a concern, environmental agencies generally track $NO_2$ since NO is so readily converted to $NO_2$ in the environment. $NO_2$ is also the easiest to detect because of its presence in higher concentrations.

### Trends for nitrogen dioxide

From 1974 to 1997, the Canadian annual mean decreased 21.6 percent, from 21.3 to 16.7 ppb. Figure 1.5 illustrates that throughout this period the composite annual mean has remained below the strictest health standard (the "desirable" level). Figure 1.5 also illustrates that 90 percent of the stations have, throughout this period, been below the maximum acceptable level and, since 1990, have been below the desirable level. All stations have met the desirable level since 1992, with the exception of one exceedence in 1996. Cities across Canada have shown a marked decline since the earliest available data in 1986 (see figure 1.6).

Trends in short-term concentrations similarly illustrate improvements in the concentration of nitrogen dioxide (table 1.3). In 1977, 13.6 percent of monitoring stations reported readings that exceeded the 1-hour maximum acceptable level standard, and 15.9 percent had readings exceeding the 24-hour maximum acceptable level. By 1997, all readings at all stations met both the 1-hour and 24-hour maximum acceptable levels.

Emissions data for $NO_x$ show a trend opposite to that of ambient levels. Canadian emissions increased 51.3 percent from 1970 to 1996 (figure 1.7). This increase in the emissions of $NO_x$ is puzzling in light of the reduction in ambient $NO_2$. In considering this discrepancy, it is important to recall that emissions data are estimates and ambient data are more reliable as they are actual measurements from the air.

Figure 1.8 illustrates the breakdown of sources of $NO_x$ emissions for 1995. Transportation accounts for over one-half of the total level of emissions.

## Ground-level ozone

Ground-level ozone ($O_3$) is a colourless and highly irritating gas. It is formed just above the earth's surface through the reaction of $NO_x$ and volatile organic compounds (VOCs). Since this chemical reaction is facilitated by the presence of heat and sunlight, ozone is typically more of a concern during the summer months.

Since ozone is the main contributor to urban smog, regulators target emissions of VOCs to combat the problem. VOCs are a subgroup of hydrocarbons (HCs); they enter the atmosphere through evaporation of automotive fuel (from the fuel tanks of automobiles), paints, coatings, solvents, and consumer products, such as lighter fluid and perfume. VOCs also occur naturally as a result of photosynthesis.

Increasing levels of ozone have led regulators to develop more stringent standards. In 1998, 12 Canadian

Ministers of the Environment endorsed the Canada-Wide Agreement on Environmental Harmonization. This agreement included a commitment to develop Canada-wide standards for both ground-level ozone and particulate matter. These new standards were accepted in November, 1999 for endorsement in May, 2000. Much of the concern about ozone levels stems from the Canadian study of $NO_x$ and VOC (Environment Canada 1997a) that states that the current 1-hour maximum acceptable level for ozone does not fully protect human health. It also reports that there is "no discernible human health threshold for ground-level ozone," meaning that any improvement in ambient ozone levels is expected to have public health benefits (Environment Canada 1997a: 3).

### Trends for ground-level ozone

The level of ambient ozone increased from 14.7 ppb to 21.7 ppb (47.6 percent) between 1974 and 1997 (figure 1.9). During this period the Canadian mean (the average of the annual means measured at all stations) has consistently been above the maximum acceptable level. One can also see from figure 1.9 that less than 50 percent of individual stations across the country have reported annual means below the maximum acceptable level.

Data on the percentage of stations with readings exceeding short-term concentration objectives also suggests that ozone is increasingly becoming a concern (table 1.4). Although the number of stations reporting readings above 1-hour maximum acceptable and tolerable levels has decreased, the number of stations reporting readings above the 1-hour desirable level has increased. In 1977, 95 percent of stations reported readings above the desirable level. This percentage increased to 97.9 percent in 1997.[5] For 22 stations, more than 5 percent of their total readings are above the desirable level.[6]

VOC emissions, which contribute to the formation of ground-level ozone, increased 27.1 percent between 1980 and 1997. However, as illustrated in figure 1.10, emissions have remained relatively constant since 1985. This trend illustrates that ambient ozone levels do not directly or predictably reflect VOC emissions. Yet, it is interesting to examine the source of VOC emissions since it provides a guideline for targeting ozone levels. Figure 1.11 demonstrates that the main sources of VOCs are industry and open sources. In particular, the oil and gas industry accounts for 19.3 percent of emissions and forest fires contribute 25.2 percent.

## Carbon monoxide

When fuel and other substances containing carbon burn without sufficient oxygen, carbon monoxide (CO), a colourless, odourless gas is produced. Trace amounts of CO occur naturally in the atmosphere but most emissions come from automobiles. Levels of CO are of particular concern to monitoring organizations because of their effect upon human health: CO reduces the capacity of red blood cells to carry oxygen to body tissues. Since CO poisoning occurs as a result of short-term exposure, health guidelines do not include annual recommendations for ambient CO levels. However, 8-hour and 1-hour guidelines are available.

### Trends for carbon monoxide

Annual ambient levels of CO have improved significantly in Canada over the past two decades. Between 1974 and 1997, levels declined from 2.3 to 0.6 ppm, a 73.9 percent reduction. As illustrated in figure 1.12, this decline can be seen in all stations. In 1974, the highest annual mean measured at an individual station was 5.1 ppm whereas in 1997 it was 1.3 ppm. Ninety percent of stations have reported annual means below 1.1 ppm since 1991.

Table 1.5 displays the percentage of stations with readings exceeding NAAQOs levels. Whereas, in 1977 68.8 percent of stations had readings above the 1-hour desirable level, in 1997 the percentage of stations with exceedences fell to only 4.3 percent.[7] The number of stations with readings exceeding the 8-hour desirable level declined from 85.4 percent to 17.4 percent. All stations have kept readings below 1-hour and 8-hour maximum acceptable levels since 1992.

Carbon monoxide emissions declined 12.4 percent between 1970 and 1997 (figure 1.13). These reductions can partially be attributed to cleaner automobiles and more fuel-efficient industrial processes. To meet strict motor-vehicle regulations adopted in the early 1970s, exhaust-gas recycling systems (EGRS) were installed and some older vehicles were retired. This has led to vastly reduced emissions per vehicle. For example, North American cars built in 1993 emitted 90 percent less $NO_x$, 97 percent less hydrocarbon, and 96 percent less CO than cars built two decades earlier (Bast, Hill, and Rue 1994: 111). There has also been an 87.5 percent reduction in CO emissions from incinerators between 1980 and 1995. Figure 1.14 illustrates the composition of CO emissions for 1995. The two main sources are transportation (39.2 percent) and open sources (mainly forest fires).

## Total suspended particulates

Suspended particulates are small pieces of dust, soot, dirt, ash, smoke, liquid vapour, or other matter in the atmosphere. Sources may include forest fires and volcanic ash as well as emissions from power plants, motor vehicles, and waste incineration, and dust from mining.

Particulates are an irritant to lung tissue and may aggravate existing respiratory problems and cardiovascular diseases. Once lodged in the lungs, certain particulates may contribute to the development of lung cancer. The smallest particulates pose the greatest threat to human health because they are able to reach the tiniest passages of the lungs. Yet, Canada's National Ambient Air Quality Objectives (NAAQOs) focus only on total suspended particulates. In 1998, 12 Canadian Ministers of the Environment endorsed the Canada-Wide Agreement on Environmental Harmonization. This agreement included a commitment to develop Canada-wide standards for both particulate matter and ground-level ozone. These new standards were accepted in November, 1999 for endorsement in May, 2000.

#### Trends for total suspended particulates

Data from 1975 to 1997 show a 52.6 percent reduction in the ambient levels of total suspended particulates in Canada. Ninety percent of stations have reported annual means below the maximum acceptable level since 1983 (figure 1.15). Since 1990, 90 percent of stations have also met maximum desirable levels. Although the maximum station reading has decreased by 56.2 percent since 1974, some stations continue to report annual means above the maximum acceptable level.

The number of stations with readings above the short-term concentration standards also has decreased over the past two decades (table 1.6). In 1977, 81.7 percent of stations had readings exceeding the 24-hour maximum acceptable level. This number decreased to 37.8 percent in 1997. Similarly, in 1977, almost ten percent of stations had readings above the tolerable level whereas only 2.7 percent did in 1997.[8] Levels of total suspended particulates have been decreasing steadily in cities across Canada since 1986, the earliest year for which data are available (see figure 1.16).

Despite decreases in ambient levels of total suspended particulates, emissions estimates have increased since 1985 (figure 1.17). However, 1996 levels are 9.0 percent lower than estimated 1980 levels. Figure 1.18 shows that most of the emissions of total suspended particulates are from transportation (59.8 percent of total suspended particulates originate from dust on roads).

## Lead

Lead is a soft, dense, bluish-grey metal. Its high density, softness, low melting point, and resistance to corrosion make it of value in the production of piping, batteries, weights, gunshot, and crystal. Until recently, automobiles were the source of most lead emissions although small quantities of lead are naturally present in the environment. Lead is the most toxic of the main air pollutants. When it is ingested, it accumulates in the body's tissues. In high concentrations, it can cause damage to the nervous system and the brain, seizures, and behavioural disorders. In addition, recent evidence suggests that exposure to lead may be associated with hypertension and heart disease (USEPA 1995c: 2–6). Since lead is the most toxic of the main air pollutants, environmental and health guidelines for lead are stricter than those for other air pollutants. Canada is committed to reducing levels as low as technologically feasible, although no explicit objectives have been set. The maximum set by the World Health Organization (WHO) for the protection of human health is 1.0 $\mu g/m^3$.

#### Trends for lead

The decline in ambient lead concentration is the greatest success story in the efforts to reduce air pollution. Ambient lead concentration fell 88.2 percent in Canada between 1974 and 1997 (figure 1.19). Although the Canadian average has been below the WHO's standard throughout this period, it was not until 1982 that all individual stations reported means below the health standard. By 1990, all stations had reduced their annual means to less than one-tenth of WHO's standard (0.1 $\mu g/m^3$).

In Canada, emissions fell 73.9 percent from 1978 to 1995 and automobile emissions fell 87.8 percent from 1973 to 1988 (figure 1.20). Note the dramatic decrease in concentrations of lead between 1988 and 1990 in cities across Canada (see figure 1.21). Most of this reduction was due to the introduction of unleaded gasoline and the elimination of lead compounds in paints and coatings.

## Air quality in selected cities

To assess overall air quality in urban areas, Environment Canada uses the Index of the Quality of Air (IQUA). This index converts individual pollutant concentrations to a scale ranging from 1 to 125. On this scale, 0 to 25 is "good," 25 to 50 is "fair," 50 to 100 is "poor," and 100 to 125 is "very poor." These intervals match the NAAQOs, with the desirable, acceptable and tolerable levels defining the limit of each section. The advantage of using the IQUA scale is that it converts all the air pollutant data to a common scale so that an average can be obtained. This average is a good measure of overall ambient air quality.

Table 1.7 shows the number of good, fair, and poor days in each major urban centre from 1990 to 1995. Data show that the number of poor days for half of the cities are low but variable: St John's, Halifax, Montreal, Quebec City, Ottawa, and Vancouver have consistently had less than ten poor days throughout the year. Regina and Winnipeg have reported fewer than 10 days of poor air quality since 1993. Some cities have even reported no poor quality days during this period. For example, Vancouver, Regina, and St John's did not have any poor air quality days in 1995.

Although the time period for this data is too short to determine trends, the variation among years is interesting to note. Over this period, there was little change in the number of poor days in most of the urban areas, although some cities have had decreases in the number of good days. Toronto reported 268 good days in 1992 but only 169 in 1995. Similarly, Hamilton had 236 good days in 1992 but only 184 in 1995. Most cities reported at least 200 good days in any year.

**Table 1.1 National Ambient Air Quality Objectives**

| | Desirable | Acceptable | Tolerable | WHO |
|---|---|---|---|---|
| **Sulphur Dioxide (ppb)** | | | | |
| **1 hour** | 172 | 334 | na | 130 |
| **24 hours** | 57 | 115 | 306 | 38–58 |
| **Annual** | 11 | 23 | na | 15–23 |
| **Effects on Human Health and the Environment** | no effect | increasing damage to sensitive species of vegetation | odorous, increasing damage and sensitivity exhibited in vegetation | |
| **Nitrogen Dioxide (ppb)** | | | | |
| **1 hour** | na | 213 | 532 | 210 |
| **24 hours** | na | 106 | 160 | 80 |
| **Annual** | 32 | 53 | na | |
| **Effects on Human Health and the Environment** | no effect | odorous | odour and atmospheric discoloration; increasing reactivity among asthmatics | |
| **Ground Level Ozone (ppb)** | | | | |
| **1 hour** | 51 | 82 | 153 | 50–100 |
| **24 hours** | 15 | 25 | na | |
| **Annual** | na | 15 | na | |
| **Effects on Human Health and the Environment** | no effect | increasing damage to some species of vegetation | decreasing performance by some athletes exercising heavily | |
| **Suspended Particulate (μg/m$^3$)** | | | | |
| **24 hours** | na | 120 | 400 | 150–230 |
| **Annual** | 60 | 70 | na | 60–90 |
| **Effects on Human Health and the Environment** | no effect | decreasing visibility | visibility decreased, soiling through deposition, increasing sensitivity of patients with asthma and bronchitits | |
| **Carbon Monoxide (ppm)** | | | | |
| **1 hour** | 13.1 | 30.6 | na | 26 |
| **8 hours** | 5.2 | 13.1 | 17.5 | 9 |
| **Effects on Human Health and the Environment** | no effect | no detectable impairment but blood chemistry is changing | increasing cardiovascular symptoms in smokers with heart disease | |

Sources: Canada guidelines: Environment Canada 1999b; WHO guidelines: USEPA 1995c: 7-4; Environment Canada 1991c.

**Table 1.2 Percentage of Stations with Readings Exceeding Sulphur Dioxide Standards**

| | 1 hour objectives | | 24 hour objectives | | | Total number of stations |
|---|---|---|---|---|---|---|
| | > Desirable | > Acceptable | > Desirable | > Acceptable | > Tolerable | |
| **1977** | 42.2 | 19.3 | 53.0 | 22.9 | 1.2 | 83 |
| **1982** | 35.8 | 8.6 | 40.7 | 6.2 | 2.5 | 81 |
| **1987** | 23.6 | 6.9 | 18.1 | 2.8 | 0.0 | 72 |
| **1992** | 22.1 | 10.4 | 18.2 | 3.9 | 0.0 | 77 |
| **1997** | 20.7 | 10.3 | 17.2 | 3.4 | 0.0 | 58 |

Source: data provided by Shelton 1999; calculations by authors.

**Table 1.3 Percentage of Stations with Readings Exceeding Nitrogen Dioxide Standards**

| | 1 hour objectives | | 24 hour objectives | | Total number of stations |
|---|---|---|---|---|---|
| | > Acceptable | > Tolerable | > Acceptable | > Tolerable | |
| **1977** | 13.6 | 0 | 15.9 | 0 | 44 |
| **1982** | 16.3 | 0 | 8.2 | 0 | 49 |
| **1987** | 0 | 0 | 752 | 2 | 49 |
| **1992** | 0 | 0 | 0 | 1.6 | 61 |
| **1997** | 0 | 0 | 0 | 0 | 78 |

Source: data provided by Shelton 1999; calculations by authors.

**Table 1.4 Percentage of Stations with Readings Exceeding Ozone Standards**

| | 1 hour objectives | | | Total number of stations |
|---|---|---|---|---|
| | > Desirable | > Acceptable | > Tolerable | |
| **1977** | 95.1 | 78 | 14.6 | 41 |
| **1982** | 96 | 78 | 2 | 50 |
| **1987** | 93.4 | 54.1 | 3.3 | 61 |
| **1992** | 94.1 | 48.5 | 0 | 68 |
| **1997** | 97.9 | 56.7 | 0 | 141 |

Source: data provided by Shelton 1999; calculations by authors.

**Table 1.5 Percentage of Stations with Readings Exceeding Carbon Monoxide Standards**

| | 1 hour objectives | | 8 hour objectives | | | Total number of stations |
|---|---|---|---|---|---|---|
| Year | > Desirable | > Acceptable | > Desirable | > Acceptable | > Tolerable | |
| **1977** | 68.8 | 4.2 | 85.4 | 12.5 | 4.2 | 48 |
| **1982** | 50.0 | 7.7 | 88.5 | 11.5 | 5.8 | 52 |
| **1987** | 22.6 | 0 | 54.7 | 5.7 | 3.8 | 53 |
| **1992** | 7.1 | 0 | 35.7 | 0 | 0 | 56 |
| **1997** | 4.3 | 0 | 17.4 | 0 | 0 | 46 |

Source: data provided by Shelton 1999; calculations by authors.

**Table 1.6 Percentage of Stations with Readings Exceeding Total Suspended Particulate Standards**

| Year | 1 hour objectives > Acceptable | 1 hour objectives > Tolerable | Total number of stations |
|---|---|---|---|
| **1977** | 81.7 | 9.6 | 104 |
| **1982** | 66.1 | 2.8 | 109 |
| **1987** | 58.0 | 2.0 | 100 |
| **1992** | 46.1 | 0.0 | 89 |
| **1997** | 37.8 | 2.7 | 74 |

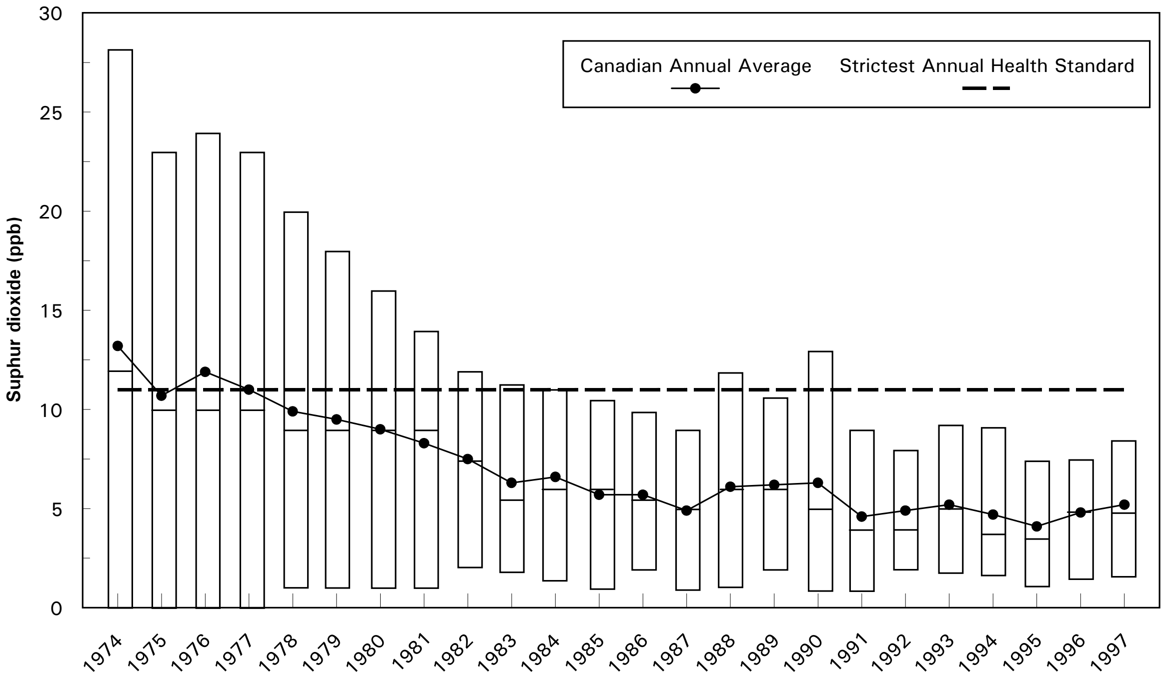
Source: data provided by Shelton 1999; calculations by authors.

**Table 1.7 Air quality of selected cites: number of days in each year rated "good," "fair," or "poor"**

| | 1990 | | | 1991 | | | 1992 | | | 1993 | | | 1994 | | | 1995 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Good | Fair | Poor | Good | Fair | Poor | Good | Fair | Poor | Good | Fair | Poor | Good | Fair | Poor | Good | Fair | Poor |
| **St. John's** | 340 | 25 | 0 | 344 | 21 | 0 | 351 | 15 | 0 | 363 | 2 | 0 | | | | 357 | 8 | 0 |
| **Halifax** | | | | | | | | | | 339 | 24 | 1 | 342 | 22 | 1 | 334 | 30 | 1 |
| **Montreal** | 287 | 75 | 3 | 303 | 59 | 4 | 294 | 66 | 6 | 303 | 59 | 3 | 308 | 54 | 3 | 265 | 95 | 5 |
| **Quebec** | 313 | 52 | 0 | 293 | 72 | 0 | 287 | 72 | 7 | 295 | 70 | 0 | 322 | 42 | 1 | | | |
| **Ottawa** | 299 | 65 | 1 | 310 | 50 | 4 | 303 | 59 | 4 | 308 | 48 | 9 | 314 | 48 | 3 | 309 | 53 | 3 |
| **Toronto** | 213 | 136 | 16 | 181 | 155 | 29 | 268 | 89 | 9 | 243 | 110 | 12 | 183 | 168 | 14 | 169 | 183 | 14 |
| **Hamilton** | 199 | 138 | 28 | 193 | 142 | 31 | 236 | 112 | 19 | 222 | 121 | 22 | 210 | 133 | 22 | 184 | 158 | 23 |
| **Winnipeg** | 247 | 103 | 15 | 274 | 68 | 23 | 305 | 48 | 13 | 309 | 53 | 3 | 298 | 67 | 0 | 289 | 69 | 7 |
| **Regina** | 244 | 102 | 19 | 307 | 58 | 0 | 292 | 55 | 19 | 315 | 43 | 6 | 306 | 59 | 0 | 322 | 43 | 0 |
| **Edmonton** | 207 | 158 | 0 | 234 | 117 | 14 | 200 | 152 | 15 | 216 | 136 | 12 | 213 | 135 | 18 | 270 | 82 | 14 |
| **Calgary** | 216 | 149 | 1 | 174 | 156 | 35 | 206 | 142 | 18 | 200 | 121 | 44 | 210 | 132 | 23 | 219 | 123 | 22 |
| **Vancouver** | 326 | 37 | 2 | 319 | 39 | 7 | 340 | 26 | 0 | 333 | 32 | 0 | 352 | 12 | 1 | 357 | 8 | 0 |

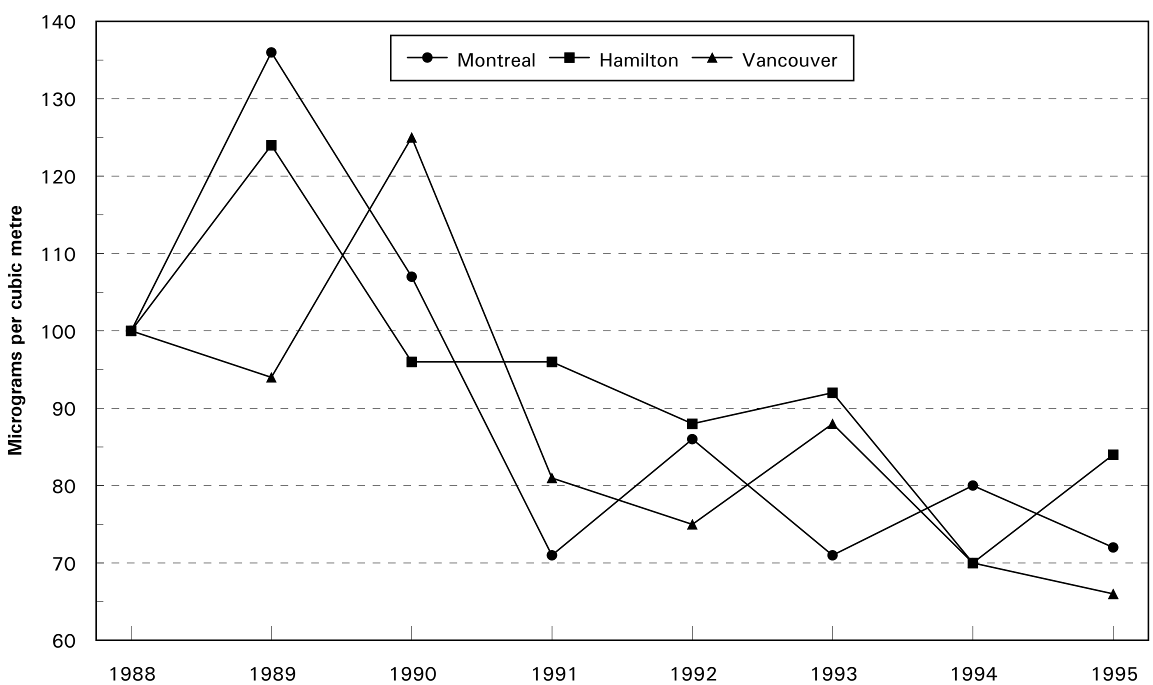
Source: Statistics Canada 1998: 59–60.

**Figure 1.1 Ambient Levels of Sulphur Dioxide (ppb)**



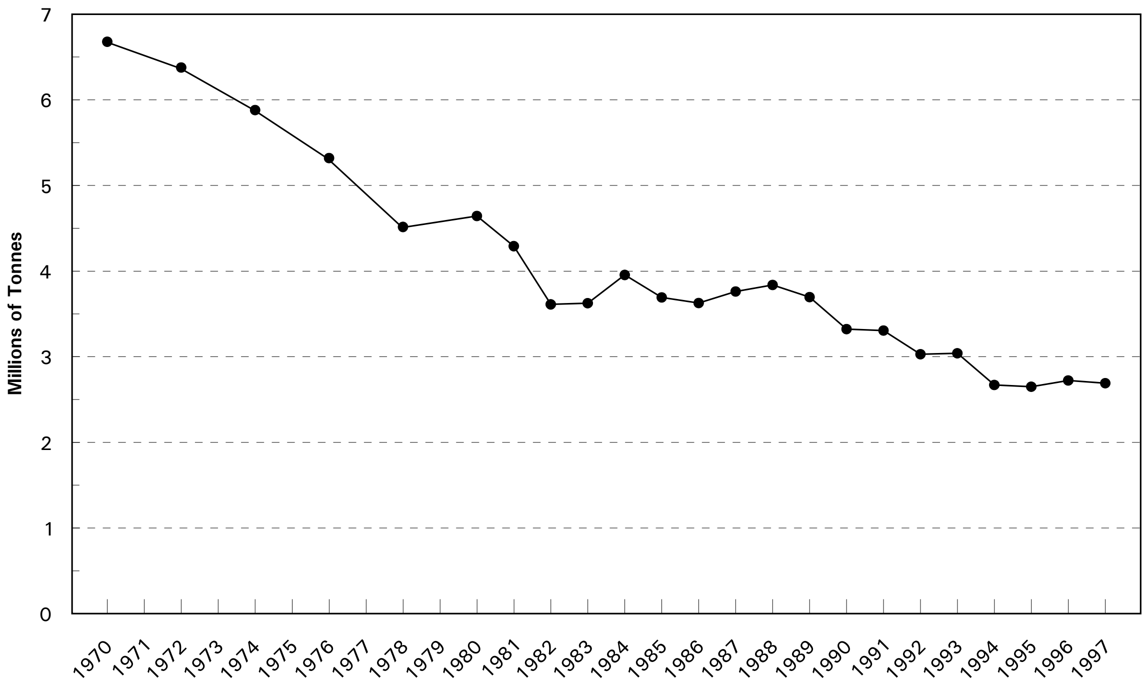

Source: data provided by Shelton 1999; calculations by authors.

**Figure 1.2 Ambient Levels of Sulphur Dioxide in Montreal, Hamilton and Vancouver**



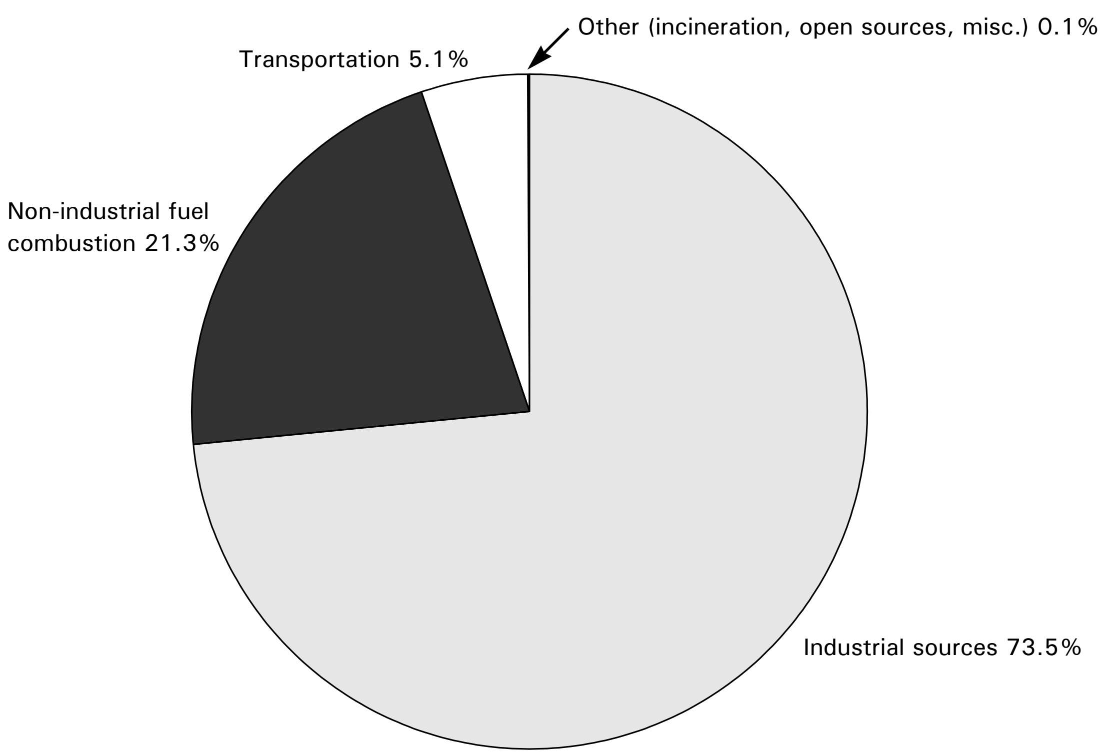

Source: OECD 1999: 55. (This figure includes the three cities for which data are available from the OECD.)
Note that this figure shows annual mean concentrations presented as values relative to the base-year 1988. The1988 base-year levels are 14.0 μg/m$^3$ for Montreal, 25 μg/m$^3$ for Hamilton, and 16 μg/m$^3$ for Vancouver.

**Figure 1.3 Sulphur Dioxide ($SO_2$) Emission Estimates**



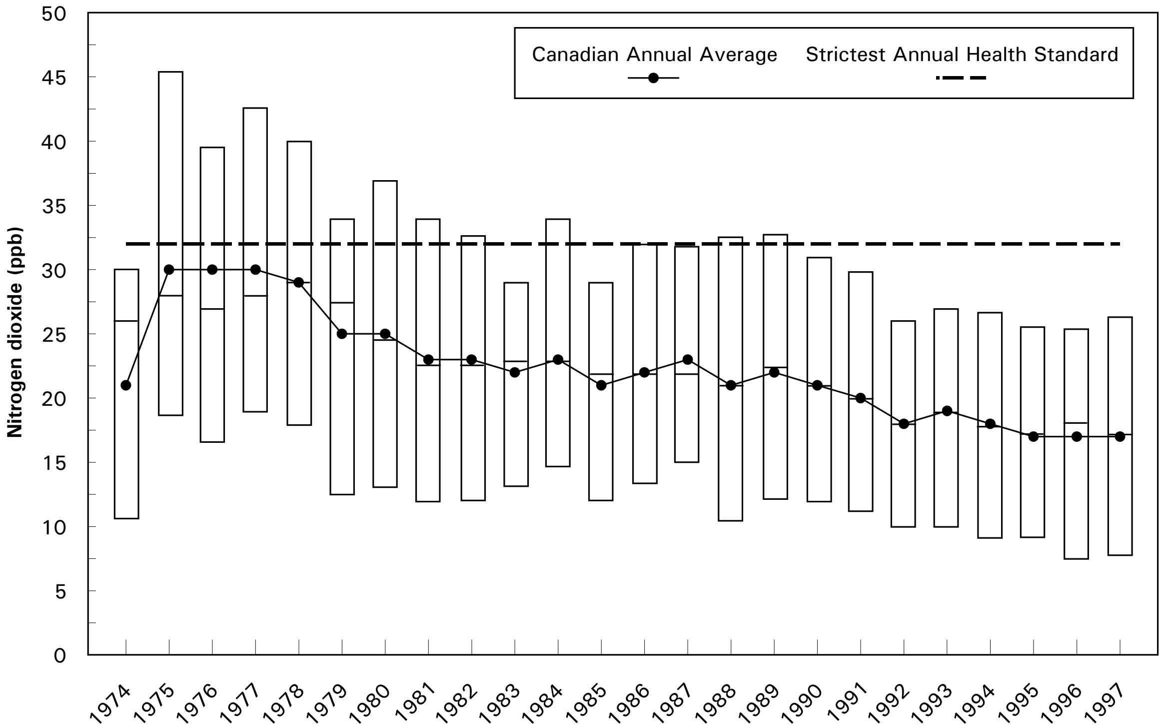

Source: OECD 1999.

**Figure 1.4 Sulphur Oxide ($SO_x$) Emissions by Source, 1995**



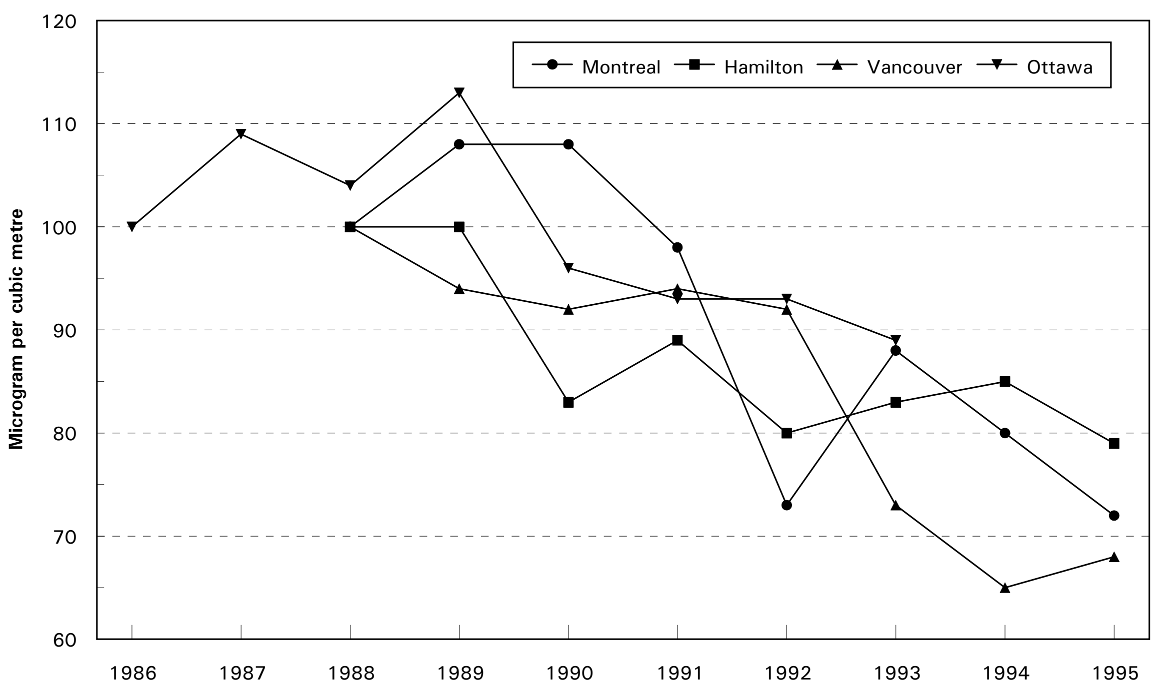

Source: Environment Canada 1998a; note that data does not include natural sources.

**Figure 1.5 Ambient Levels of Nitrogen Dioxide (ppb)**



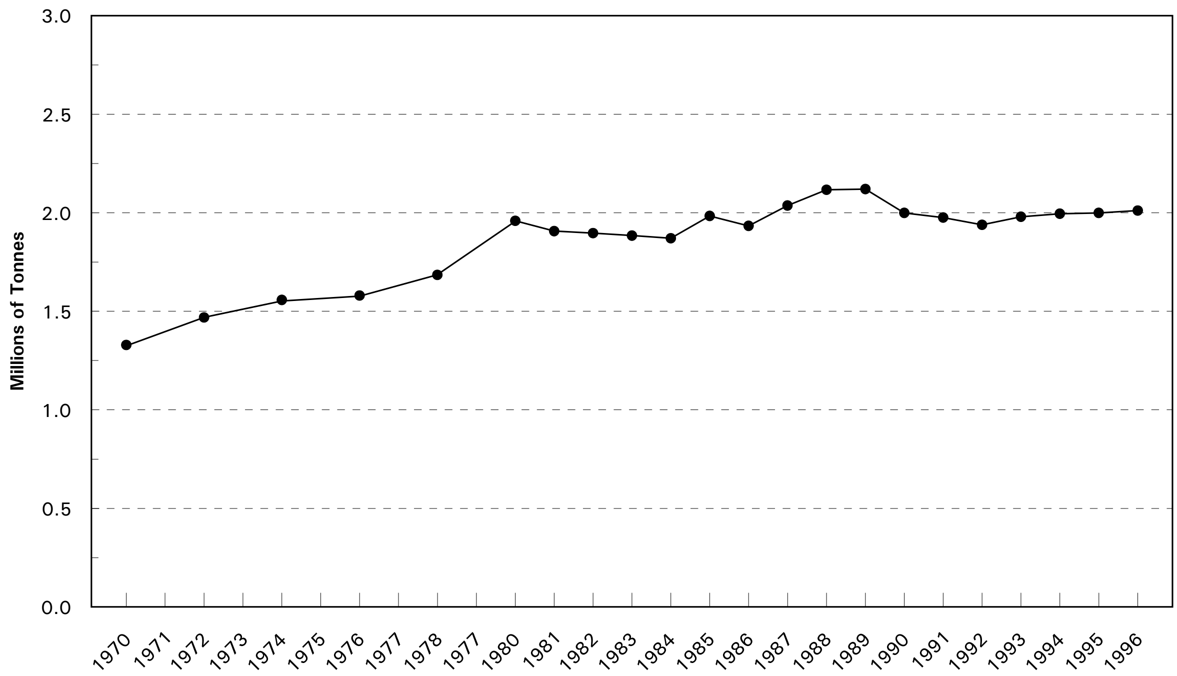

Source: data provided by Shelton 1999; calculations by authors.

**Figure 1.6 Ambient Levels of Nitrogen Dioxide (ppb) in Montreal, Hamilton, Ottawa, and Vancouver**



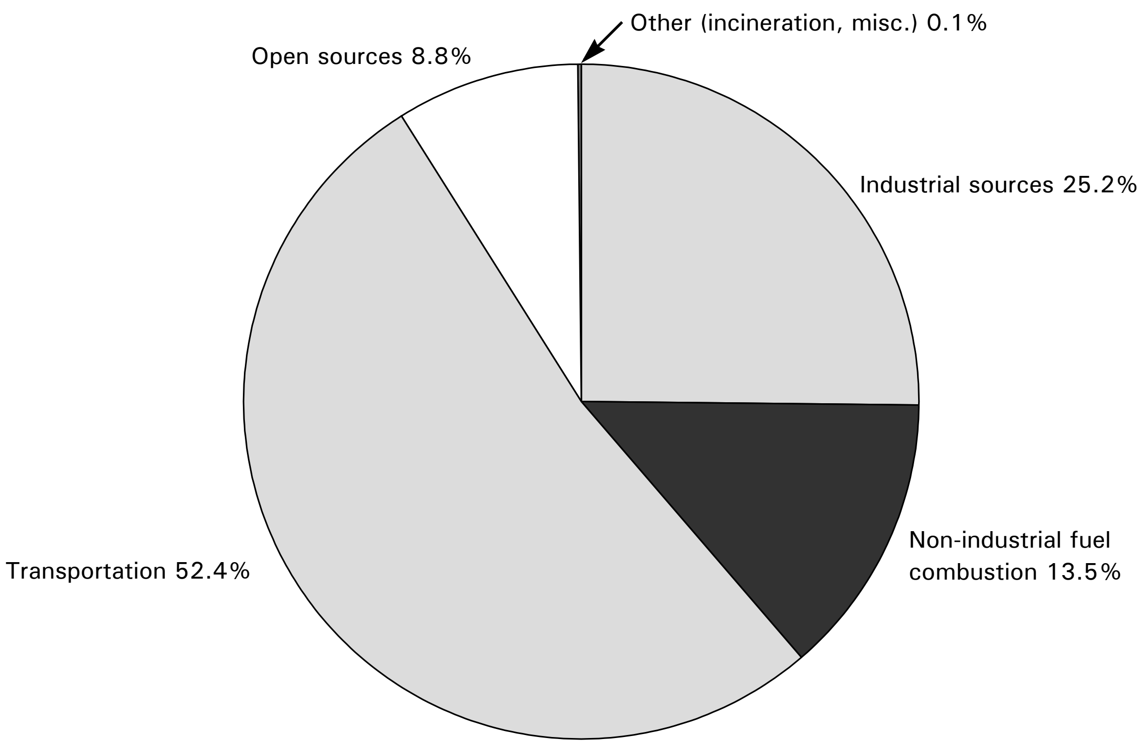

Source: OECD 1999: 58. (This figure includes the four cities for which data are available from the OECD.) Note that 1988 base-year levels are 48.0 $\mu g/m^3$ for Montreal, 46 $\mu g/m^3$ for Hamilton, 45 $\mu g/m^3$ for Ottawa, and 51 $\mu g/m^3$ for Vancouver.

**Figure 1.7 Nitrogen Oxide Emission Estimates**



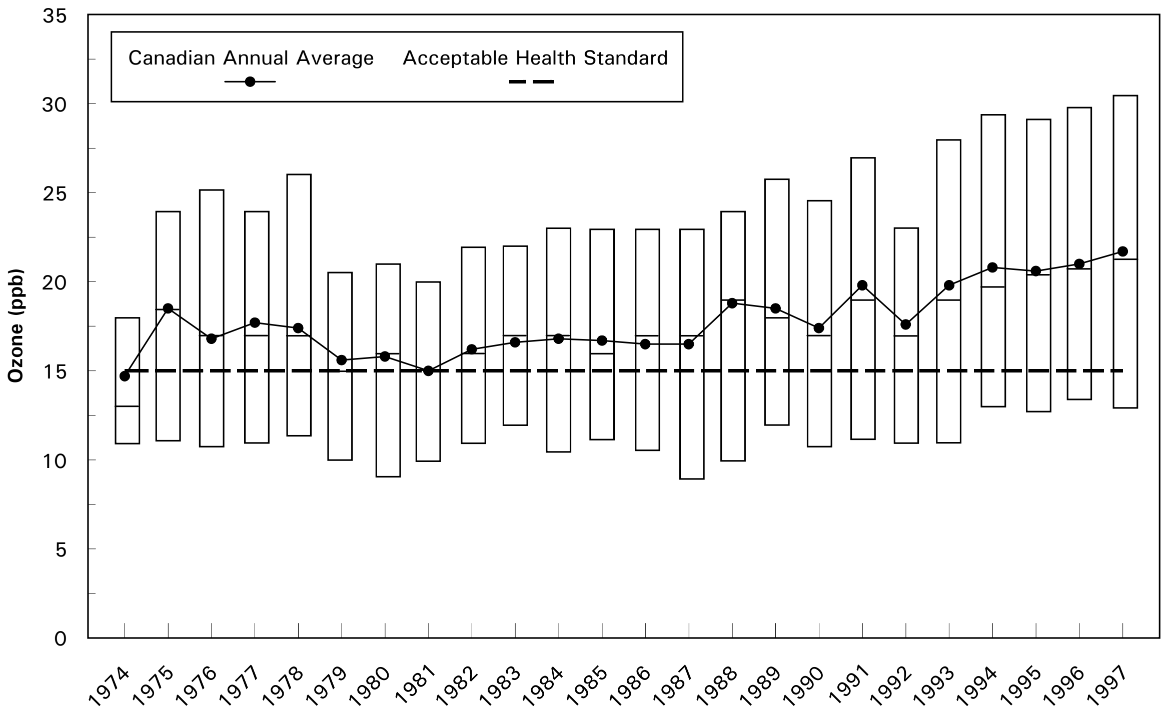

Source: OECD 1999

**Figure 1.8 Nitrogen Oxide Emissions by Source, 1995**



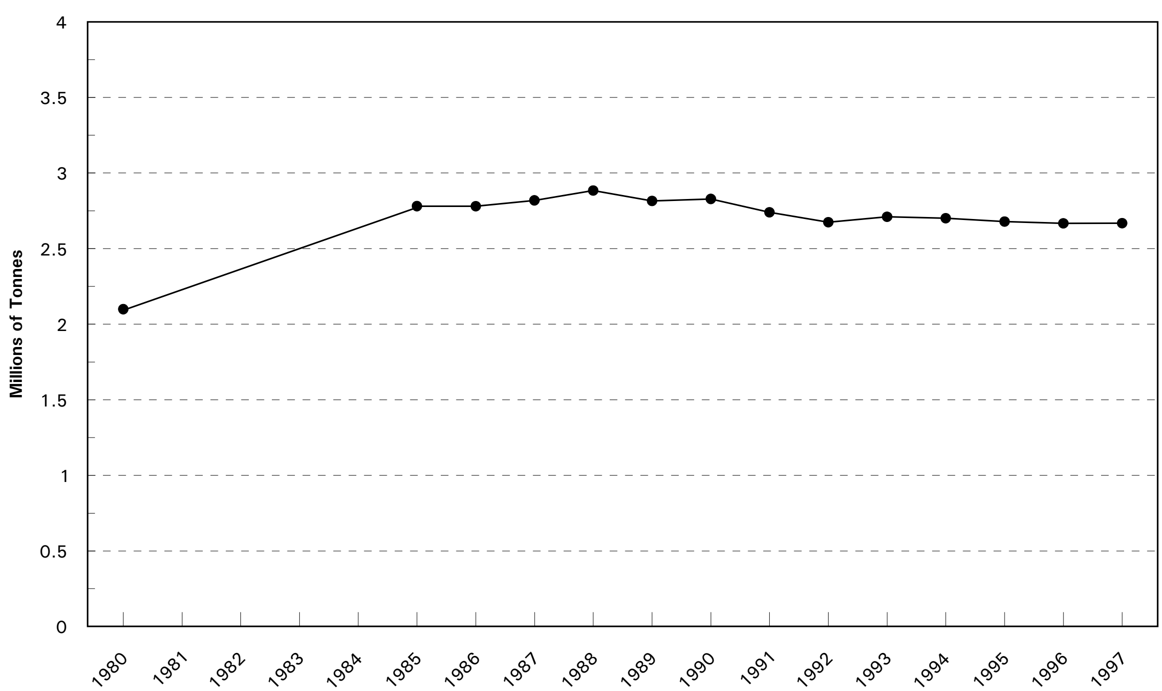

Source: Environment Canada 1998a; note that data does not include natural sources.

**Figure 1.9 Ambient Levels of Ground Level Ozone (ppb)**



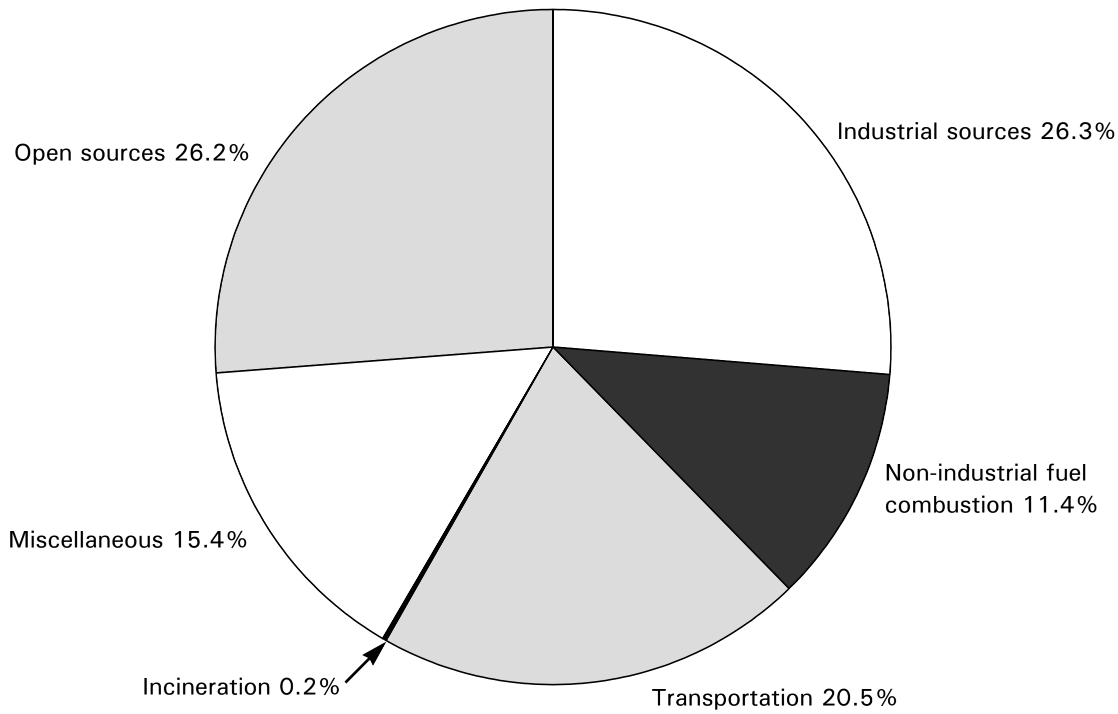

Source: data provided by Shelton 1999; calculations by authors.

**Figure 1.10 Volatile Organic Compounds Emissions Estimates**



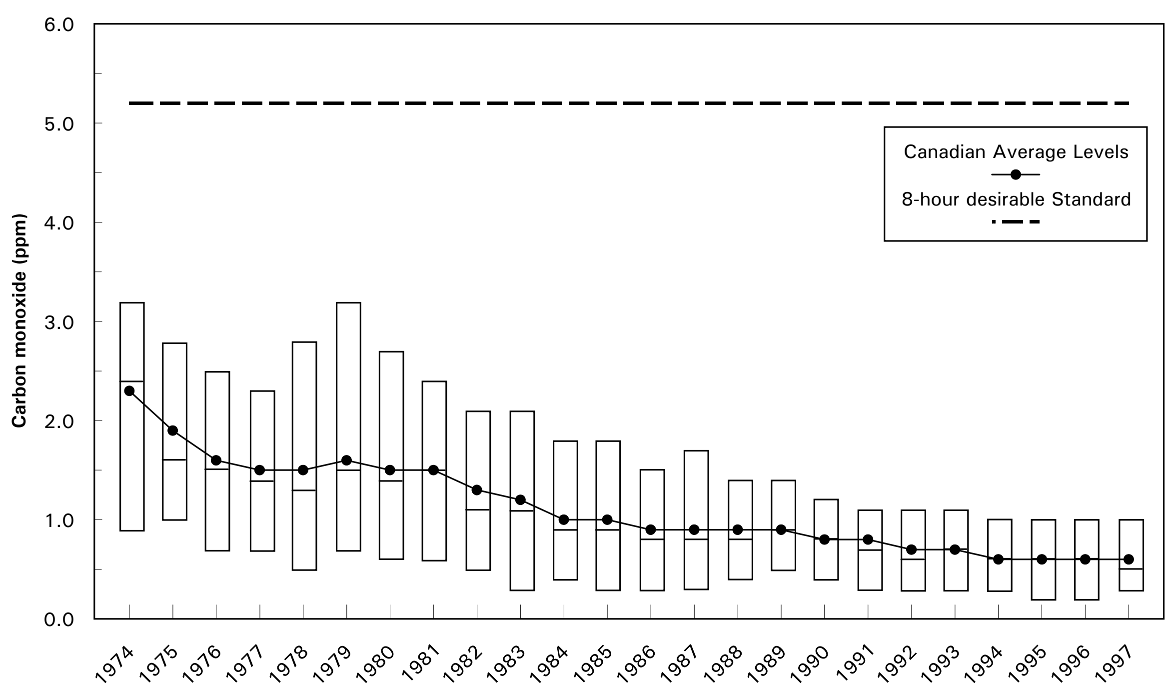

Source: OECD 1999

**Figure 1.11 Volatile Organic Compound Emissions by Source, 1995**



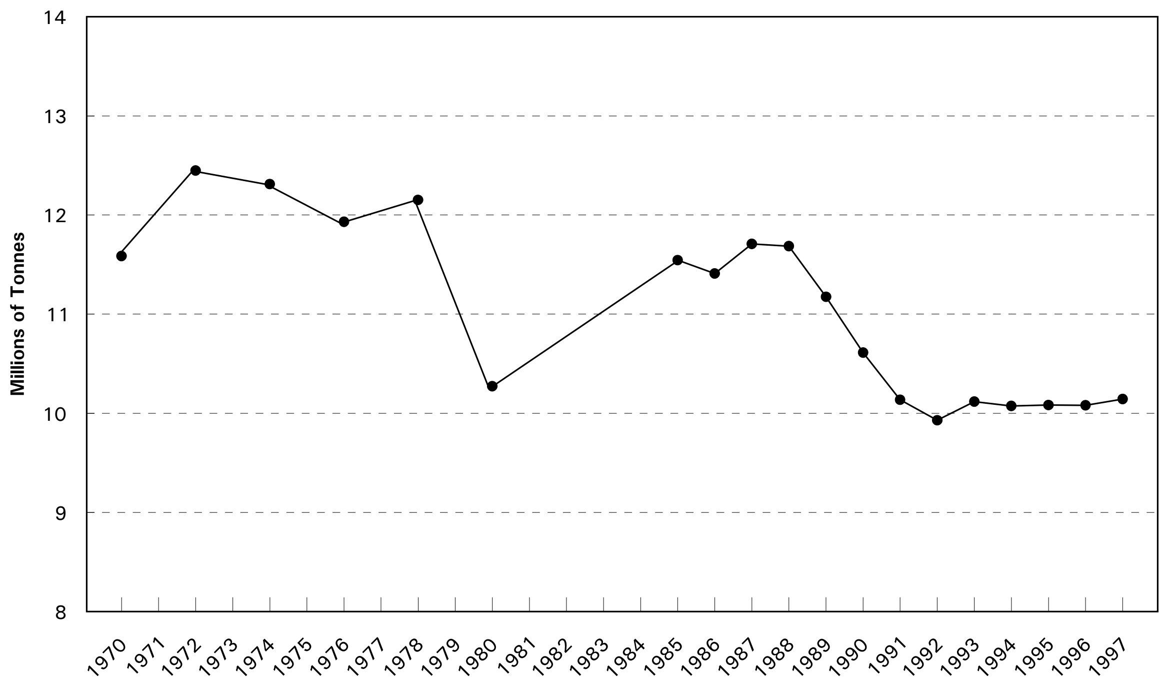

Source: Environment Canada 1998a; note that data does not include natural sources.

**Figure 1.12 Ambient Levels of Carbon Monoxide (ppm)**



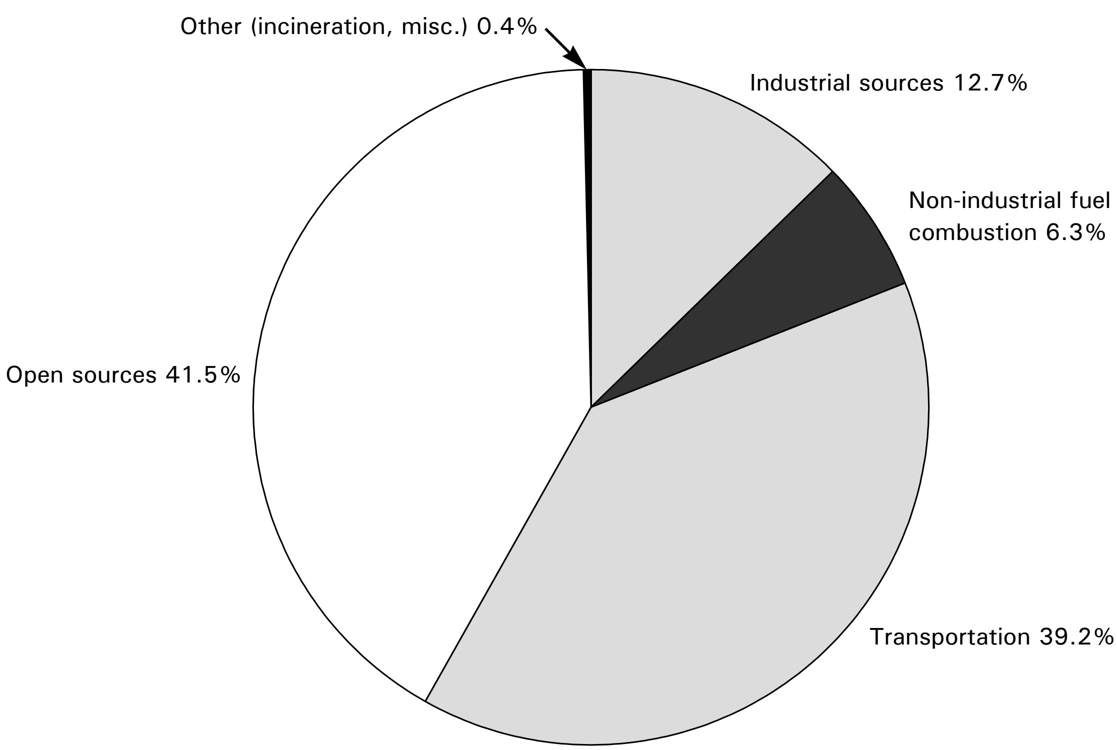

Source: data provided by Shelton 1999; calculations by authors.

**Figure 1.13 Carbon Monoxide Emission Estimates**



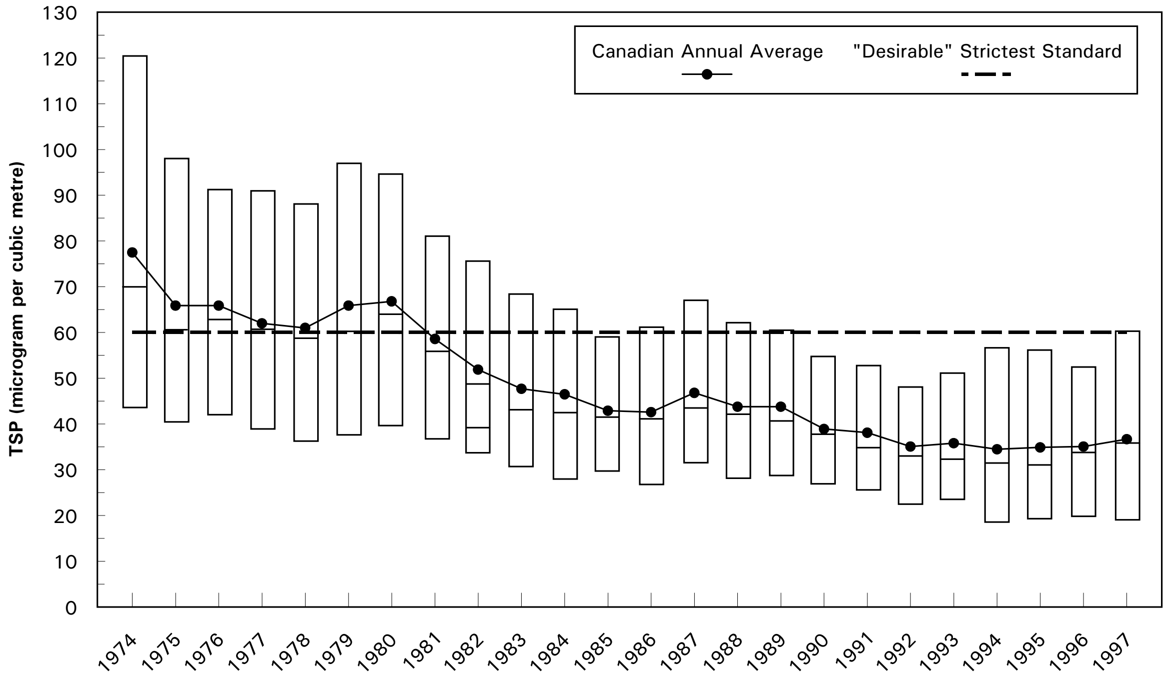

Source: OECD 1999

**Figure 1.14 Carbon Monoxide Emissions by Source, 1995**



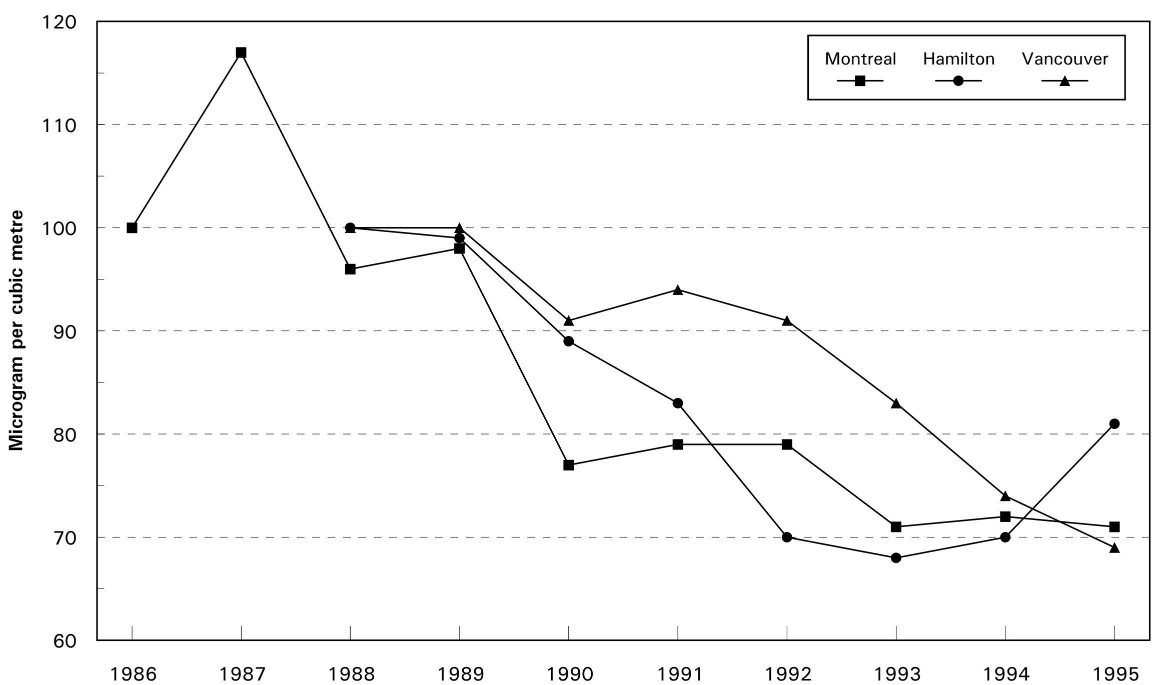

Source: Environment Canada 1998a; note that data does not include natural sources.

**Figure 1.15 Ambient Levels of Total Suspended Particulates (μg/m³)**



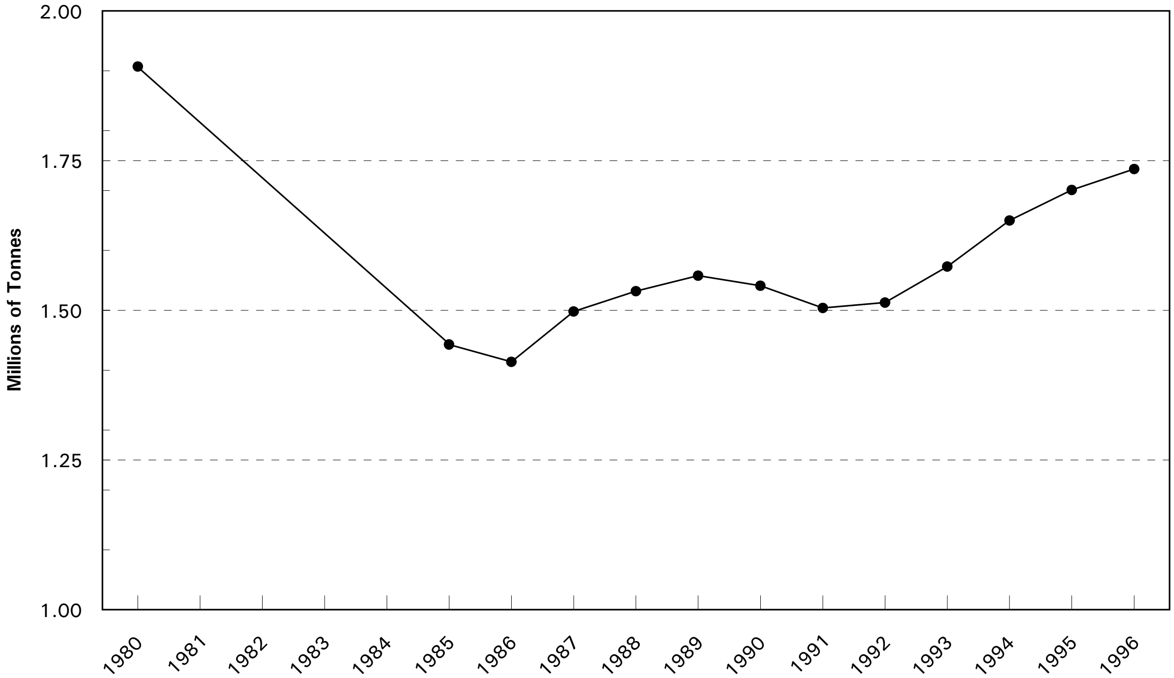

Source: data provided by Shelton 1999; calculations by authors.

**Figure 1.16 Ambient Levels of Total Suspended Particulates (μg/m³) in Montreal, Hamilton, and Vancouver**



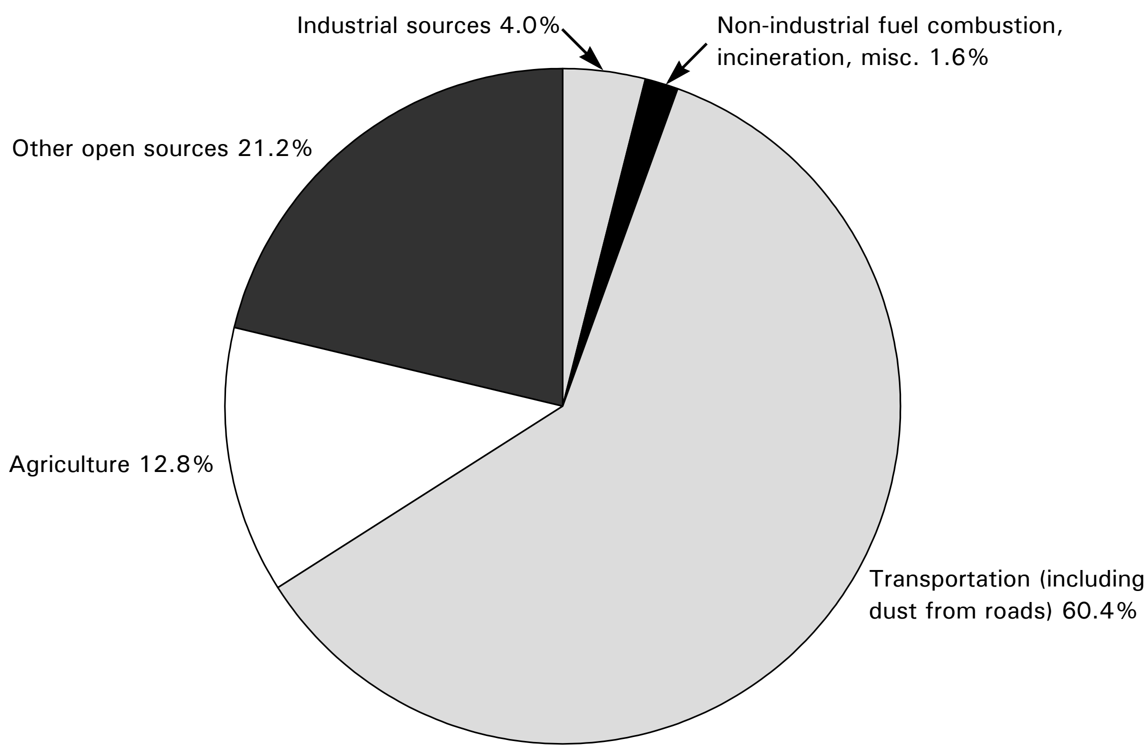

Source: OECD 1999: 61. (This figure includes the three cities for which data are available from the OECD.) Note that 1988 base-year levels are 48.0 μg/m³ for Montreal, 81 μg/m³ for Hamilton, and 35 μg/m³ for Vancouver.

**Figure 1.17 Total Suspended Particulate Emission Estimates**



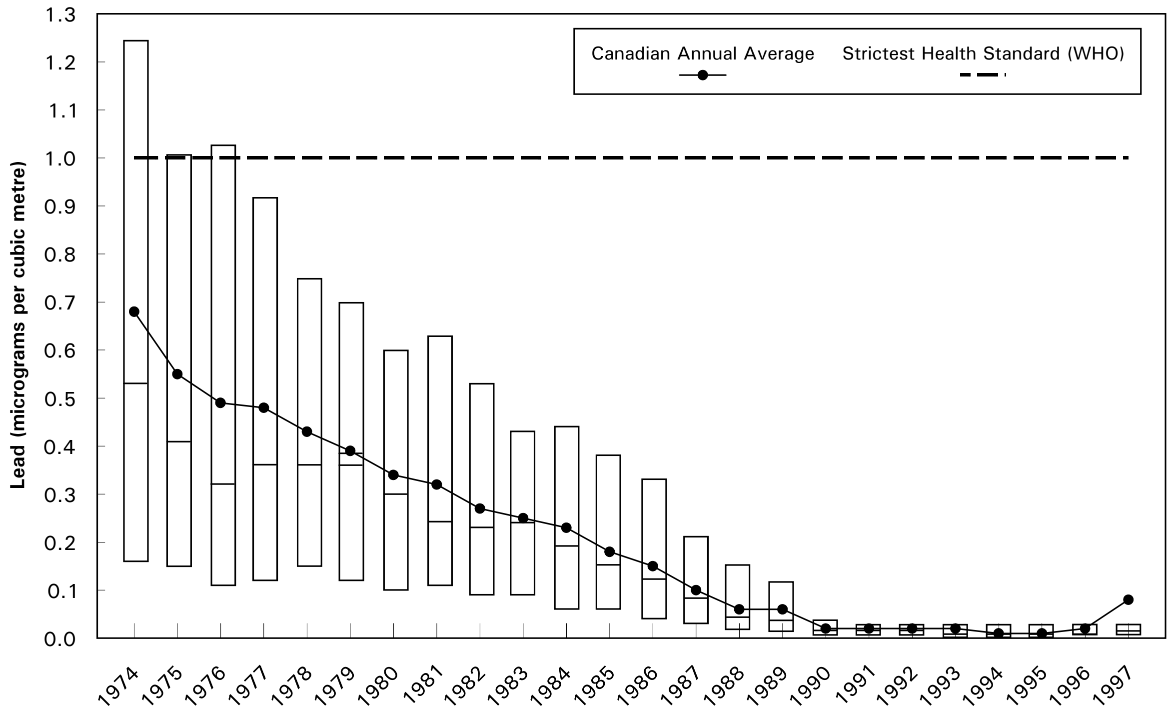

Source: OECD 1999

**Figure 1.18 Total Suspended Particulate Emissions by Source, 1995**



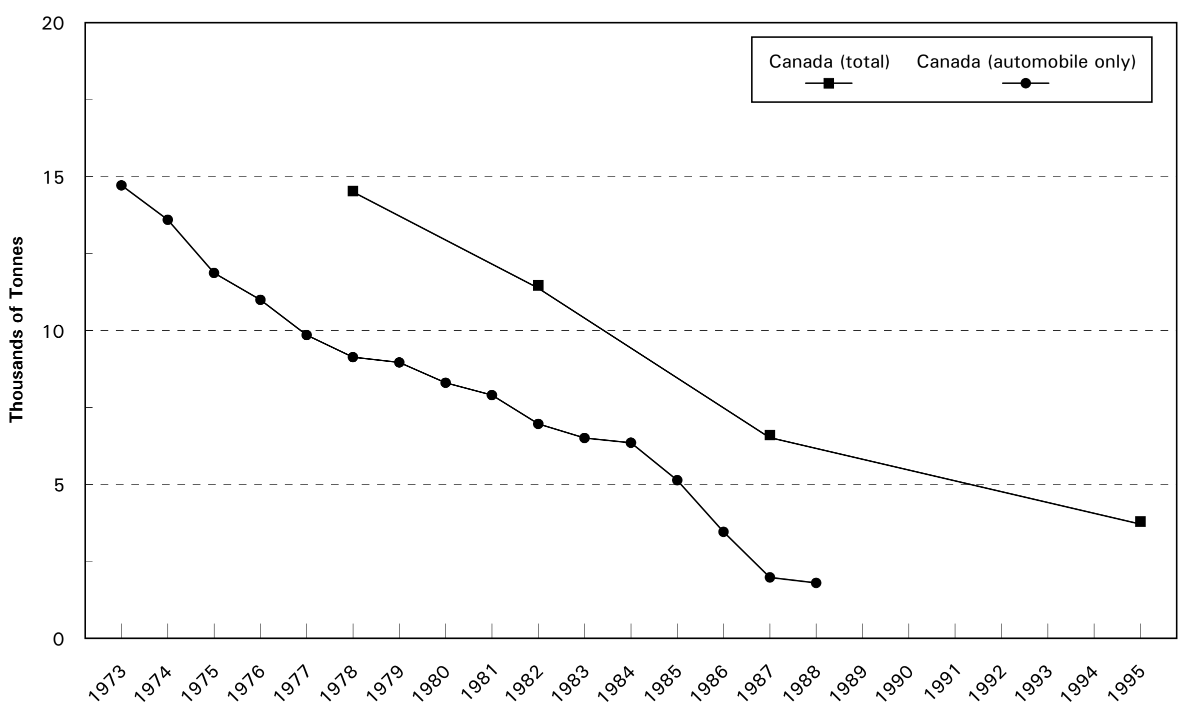

Source: Environment Canada 1998a; note that data does not include natural sources.

**Figure 1.19 Ambient Levels of Lead (μg/m³)**



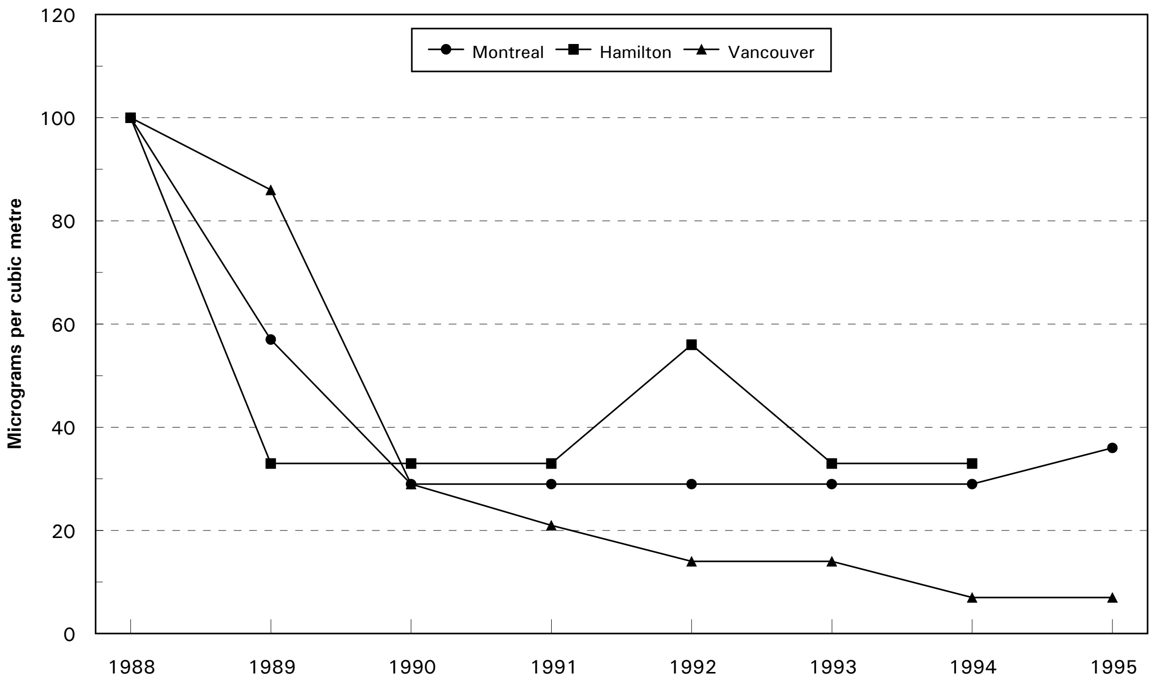

Source: data provided by Shelton 1999; calculations by authors.

**Figure 1.20 Lead Emission Estimates**




Source: OECD 1999

**Figure 1.21 Ambient Levels of Lead in Montreal, Hamilton, and Vancouver**




Source: OECD 1999: 65. (This figure includes the three cities for which data are available from the OECD.) Note that 1988 base-year levels are 0.07 μg/m³ for Montreal, 0.09 μg/m³ for Hamilton, and 0.14 μg/m³ for Vancouver.

# 2 Water Quality

## Assessing water quality

Water quality is among those environmental problems most difficult to assess on a nation-wide basis. The data used in this section do not represent complete information about ambient water quality due to the lack of available data and the magnitude and complexity of measuring water quality.

The effects of both natural and manufactured contaminants upon water quality vary with water conditions (source, velocity, volume, depth, pH level), photosynthetic activity, and variations within a day as well as from season to season. In addition, inconsistencies in data collection are apt to occur due to overlapping jurisdictions and budget considerations.

Currently, there are attempts in Canada to start a national index of water quality; some regional representatives, however, are resisting the setting of national standards by a central planning committee. Due to the enormous geographic size and diversity of this country, water quality cannot be quantified effectively with one or two general measures. There are different parameters for different regions. For example, the Canadian Council of Ministers of the Environment (CCME) has decided that a Water Quality Index should be constructed by technical subgroups, one from each province and one from the federal government. In discussion, the CCME established general parameters for developing a national index of water quality in Canada.

## Water pollutants

There are two sources of water pollution: point and non-point sources.[9] Point sources refer to industrial discharge pipes and municipal sewer outlets that discharge pollutants directly into the aquatic ecosystem. Non-point sources refer to indirect sources of pollution such as run-off from agriculture, forestry, urban and industrial activities, as well as landfill leachates and airborne matter. Water quality also varies naturally. Some bodies of water are of poor quality due to inherent chemical, physical, and biological characteristics. Water pollution from human activities includes nutrients, heavy metals, persistent pesticides, and other toxics.

Nutrients like phosphorus and nitrogen can cause significant degradation of water quality by accelerating eutrophication,[10] which depletes levels of dissolved oxygen. Phosphorus and nitrogen are found in fertilizers and livestock manure (Environment Canada 1991c: [9]26). Government regulation stipulates a reduction of the amount of phosphate in detergents in an effort to improve water quality. Lower phosphate levels in lakes and streams, however, do not always result in higher levels of dissolved oxygen and improved water quality as plants continually recycle phosphorus from sediments.

Heavy metals occur in water from the weathering of rocks. They also reach the water system directly from industrial and mining activity. Some severe cases of metal contamination are caused by abandoned mines. Non-point sources such as urban storm-water and agricultural run-off also contribute to metal contamination. High concentrations of heavy metals can affect the quality of drinking water and harm aquatic life as the metals accumulate in organs and tissues (bioaccumulation).[11]

Pesticides and toxics like polychlorinated synthetic compounds (DDT and PCBs) can also accumulate in biological organisms. The effects of these compounds on animals such as birds include growth retardation, reduced reproductive capacity, diminished resistance to disease, and birth deformities.

## Water treatment

Industrial and municipal sewage is usually treated before being released into rivers, lakes, streams, or oceans. Primary waste-water treatment removes solid waste mechanically; secondary treatment employs biological processes to break down dissolved organic material; tertiary treatment removes additional contaminants, including heavy metals and dissolved solids.

The proportion of the municipal population in Canada provided with waste-water treatment increased from 72 percent in 1983 to 93 percent in 1994 (see figure 2.1) (Environment Canada 1988c). As figures 2.1 through 2.6 show, Quebec had the greatest increase in access to waste-water treatment: between 1983 and 1994, there was a dramatic increase of 660 percent in the proportion of the municipal population served by some form of waste-water treatment.

## Water quality in Canada

Canada does not have federally legislated water-quality objectives. The Canadian Council of Ministers of the Environment (CCME) established the Canadian Water Quality Guidelines in 1985 to provide a basis for designing site-specific water-quality objectives. The guidelines recommend concentrations for supporting and maintaining several categories of water use including aquatic life, drinking, recreational, agricultural, and industrial use. Water must meet requirements for biological (bacteria, viruses, protozoan), radiological (radioactive isotopes), physical (taste, odour, temperature, turbidity, colour), and chemical factors.

Provincial governments legislate standards and regulations for water quality in Canada, although the federal government offers advice and leadership. Municipalities are responsible for testing drinking water for coliforms and residual chlorine.

Detailed site-specific reports on water quality provide "snapshot" evidence that Canadian drinking water is generally good. Most Canadian municipalities treat drinking water through chlorination, ozone treatment, or ultraviolet radiation. Environment Canada conducted a four-year study of the quality of drinking water in the Atlantic provinces, which revealed that of the 150 substances tested none was present in levels that exceeded the maximum acceptable guidelines (Environment Canada 1990a). A study carried out in 1986 by the Canadian Public Health Association showed that levels of very few of the 161 substances measured in treated tap water from the Great Lakes exceeded the guidelines (Canadian Public Health Association 1986). Further, a 1990 study of the Great Lakes by the Toronto Board of Health could detect only 42 of the substances for which they were testing; none was present in levels that exceeded the guidelines (Kendall 1990).

Although raw data on Canadian water quality exist in a federal database, the information is not in a format that can be used to evaluate water quality on a national level. The provinces, however, are taking a greater role in monitoring water quality. British Columbia, Alberta, Saskatchewan, Manitoba, and New Brunswick have developed site-specific objectives and maintain a record of goal attainment.

The provinces test water at sites located upstream or downstream from urban centres and industrial facilities, on transboundary rivers and streams, and on bodies of water that are used for recreation. Figure 2.7 illustrates the success of British Columbia, Alberta, Saskatchewan, and Manitoba in attaining water quality objectives. It should be noted that the number and type of bodies of water tested, and of pollutants examined, varies from province to province and within provinces from year to year. Details of provincial reporting are described below.

#### British Columbia

There are two general measures for assessing water quality in British Columbia. The province has published objectives and attainment records for water quality since 1987 based on the *British Columbia Surface Water Quality Objectives* (see figure 2.7). Since 1985, the province has jointly operated federal-provincial monitoring stations in partnership with Environment Canada under the Canada-British Columbia Water Quality Monitoring Agreement.

A new report on water quality, the *1996 British Columbia Water Quality Status Report*, reviews the quality of 124 bodies of water including river sections, lakes, marine bays or inlets, and ground-water aquifers. This report provides a detailed index developed from objectives and attainment records (including the number, frequency, and magnitude of objectives exceeded), rating bodies of water as "poor," "borderline," "fair," "good," or "excellent." These are described in the report as follows.

> Excellent (0–3) means all uses of water are protected and none are threatened or impaired. Good (4–17) means all uses are protected with only a minor degree of threat or impairment. Fair (18–43) means most uses are protected but a few are threatened or impaired. Borderline (44–59) means several uses are threatened or impaired. Poor (60–100) means most uses are threatened, impaired or even lost. (British Columbia Ministry of Environment, Lands, and Parks 1996)

The report rated only nine of 124 water bodies as borderline or poor; nine were rated excellent, 44 were rated good and 62 were rated fair. (see figure 2.8). Unfortunately, although data from previous years have been collected, they are not reported in this format, making analysis of trends impossible.

The report describes the source of threats to water quality and recommends methods for maintaining and restoring the quality of British Columbia's water. Of all Canadian provinces, British Columbia has developed one of the most comprehensive monitoring and reporting program on water quality (British Columbia Ministry of Environment 1993: 2–45; Rocchini 1996).

Levels of toxic contaminants in British Columbia have been decreasing over the last 20 years. As figure 2.9 shows, samples taken from the eggs of a colony of Great Blue Herons located near the University of British Columbia show a marked decline in levels of PCBs, DDE, dioxins, and furans. Between 1977 and 1996, PCBs decreased by 55.8 percent and DDE by 62.5 percent. (PCBs and DDE are discussed in greater detail in the Great Lakes section of this report.) Dioxins and furans are the chemical by-products of a number of industries including pulp-and-paper production. The 95.4 percent decrease in levels of these contaminants between 1982 and 1994 is due in part to recent changes to processes in the pulp-and-paper industry and to a reduction in contaminated effluent entering the province's waterways.

### Alberta

On any given year, water quality is assessed at over 300 sites throughout Alberta. Twenty of these stations make up Alberta's long-term river network. These sites, some of which have been active for almost 30 years, are sampled on a monthly basis and tested for an extensive list of water-quality variables. Data from 12 of these stations, representing the province's six major river systems, are currently used for the *Alberta Surface Water Quality Index*. The *Index* is calculated by comparing the results of tests for 20 substances to the *Alberta Ambient Surface Water Quality Interim Guidelines*. Subsets of these variables are used to determine the suitability of river water for recreational and agricultural uses, and for the protection of aquatic life. The stated goal is to bring water quality downstream of developed areas in line with the water quality upstream. The index uses four arbitrary categories to describe quality according to the percent of tests meeting guidelines at each site: "good" (96–100 percent), "fair" (86–95 percent), and "not acceptable" (70 percent and below).

Alberta's *Index* is currently being revised to include a new set of variables and guidelines. The formula is also being changed to include the number of variables not meeting guidelines and the amount by which they do not meet guidelines as well as the percent of all tests that do not comply with guidelines. The rating system for the new index will also change (Saffran 1999).

### Saskatchewan

The *Saskatchewan Surface Water Quality Objectives* are used as a guide in assessing the quality of surface water in the province. Priority is given to rivers affected by populated centres and locations where water quality might be threatened. Saskatchewan collects data from 15 regularly monitored stations that test for 70 pollutants (there are numerical guidelines for acceptable levels of some of the pollutants only). Sites are monitored on a monthly basis for nutrients, salts, and bacteria, on a quarterly basis for metals, and three times per year for certain pesticides. Saskatchewan continues to monitor for long-term trends and admits that this data cannot be considered reflective of overall water quality but gives instead a "snap shot" of water quality in the major rivers of southern and central Saskatchewan (Hallard 1997). A recent study of ground water examined the contamination of well-water by pesticides. This is of concern because 45 percent of Saskatchewan residents rely on private wells for drinking water. The study determined that although one or more pesticides were detected in all but two of the wells, all concentrations were significantly lower than the maximum acceptable under the *Guidelines for Canadian Drinking Water Quality* (McKee 1999).

### Manitoba

Manitoba's goal in monitoring water quality is to identify changes between upstream and downstream locations and to develop focused maintenance and protection programs. The results are cross-referenced with *Canadian Water Quality Guidelines* and *Manitoba Water Quality Objectives*. Manitoba uses, with minor modifications, the water quality index developed by British Columbia; as applied by Manitoba this index considers 25 variables. Manitoba monitors up to 70 water-quality variables at 35 sites located on 28 rivers and lakes. Using the category descriptors "poor," "marginal," "fair," "good," and "excellent," it assigns a ranking based on the number of objectives met, and the magnitude and frequency of exceedences, i.e., incidents when pollution exceeds objectives (Williamson 1996).

Manitoba is particularly concerned about the effects on water quality of the larger facilities for intensive production of livestock and value-added food processing facilities. Programs are underway to reduce the impact of food-processing waste and to assist the irrigating community in developing sustainable irrigation practices. Many Manitobans who reside outside municipal water systems rely on their own water supply and changes in water quality affect these people and their livestock directly. The water quality trend in Manitoba has changed little from 1991 to 1995: 96 percent of monitoring sites remain steadily at the high end of the "fair" rating (see figure 2.10). The overall rating for the Red River tends to be of slightly poorer quality downstream of Winnipeg than upstream but also remains at the high end of "fair." Flooding of the Red River in 1997 slightly elevated fecal coliform levels and there were trace concentrations of several organics; nevertheless, bacterial levels remain relatively low at all sites (Williamson 1997).

### Ontario

Ontario has performed periodic water-quality assessments at specific sites; the Toronto waterfront is one example. Although there is no federal-provincial agreement on water quality, there is cross-border cooperation on water quality in the Great Lakes between the Canadian and American federal governments through the International Joint Commission (IJC), an advisory group of Canadians and Americans. Ontario has 250,000 bodies of water and measures from 10 to 200 variables of water quality at thousands of sites. Four databases contain raw data: Great Lakes, Inland Rivers and Streams, Inland Lakes and Drinking Water Surveillance. The raw data, however, have not been compiled in a form that can be analyzed to determine general trends in water quality.

The Drinking Water Surveillance Program conducted 245,000 tests in 1996 and 1997 and 99.98 percent of the sites tested met the health related drinking water objectives (Ontario Ministry of the Environment 1998).

### Quebec

Quebec is the first province to carry out an overview of the status and trends of the water quality of its rivers. The Ministry of the Environment and Wildlife operates 386 monitoring stations located in 40 watersheds to measure nitrogen, phosphorus, fecal coliforms, pH, turbidity, and suspended solids. These readings, as well as biological surveys and measurements of toxic chemicals in fish, artificial substrates and water are conducted on a monthly basis. The province does not set water quality objectives but instead studies point sources to determine the nature of local or regional use of the water body and how it must be preserved or restored. Goals can vary from one site to the next on the same river as the use of that river changes.

Since 1978, Quebec has committed more than $6 billion towards improving waste-water treatment. The successes of the program are evident in the 660 percent increase between 1983 and 1994 in the proportion of the municipal population served by some form of waste-water treatment. Phosphorus loading from municipal wastewaters has decreased by an estimated 55 percent between 1979 and 1994. Improvements to treatment of mill effluents in the province's pulp and paper industry have also contributed to an improvement in water quality, leading to a 75 percent decrease in loading by suspended particles from 1980 to 1994 (Painchaud 1997).

### New Brunswick

New Brunswick has not developed provincial objectives. At the moment, monitoring data is usually compared with the *Canadian Water Quality Guidelines* for aquatic life. New Brunswick examines 32 variables in various lakes and rivers throughout the province. Data is collected from baseline stations providing data over the long term, stations providing background information for specific projects in the short term, and downstream stations measuring the effects of point and non-point sources of pollutants. Natural waters in many areas tend to be poor in nutrients (especially phosphorous) and acidic—some natural pH values fall below the *Canadian Water Quality Guideline* of pH 6.5. Naturally high levels of aluminum and iron often exceed the guidelines (Choate 2000).

### Newfoundland

The province of Newfoundland monitors up to 35 water-quality variables at approximately 56 sites located on rivers and lakes throughout the province. The goals of the monitoring program include collecting data on background and ambient water quality of major rivers and basins, detecting and measuring trends in water quality, and assessing fresh-water aquatic health and the suitability of water for various beneficial uses. Newfoundland maintains its own water-quality database, which is updated every two to three years. A report, the *State of Water Quality in Newfoundland*, based on the water quality index developed by British Columbia, is currently under preparation (Goebel 1997).

**Nova Scotia**

Nova Scotia follows the *Canada Water Quality Guidelines* but has not set site-specific objectives. It does not perform ambient monitoring but uses short-term projects to monitor and improve the water in problem areas. Residents rely equally on surface and ground water for drinking and Nova Scotia's drinking water is generally good. Concerns specific to certain areas arise primarily due to mining and industrial activity (Cameron 1996).

**Prince Edward Island**

Prince Edward Island has not established water-quality guidelines of its own but uses the national water-quality criteria as developed and maintained by CCME. Currently, 26 sampling sites are located in 6 watersheds. Residents of Prince Edward Island rely exclusively on ground water for drinking water, which is judged according to national guidelines developed jointly by Health Canada and the provinces. In 1996, "Evaluation and Planning of Water Related Monitoring Networks on PEI" was incorporated into a new agreement, the *Canada-PEI Water Annex to the Federal/Provincial Framework Agreement for Environmental Cooperation in Atlantic Canada*, between Environment Canada and the province's Department of Fisheries and Environment. In January 1996, Prince Edward Island signed an agreement with the federal government to establish a Watershed Inventory Project to examine 12 watersheds incorporating 26 rivers. Initiatives include a multi-year, program to sample drinking water for pesticides according to several parameters, and the release of an educational booklet entitled *Water on PEI: Understanding the Resource, Knowing the Issues* (Raymond 1997).

**Yukon**

The Department of Indian Affairs and Northern Development (DIAND) manages the water resources of the Yukon Territory. Water-quality objectives have not been set for any water bodies as most water bodies in the region are considered pristine. DIAND and Environment Canada jointly operated 19 monitoring stations in 1996. Baseline monitoring of rivers and streams was ended in September 1996 in preparation for the end of the Arctic Environmental Strategy of the Canadian government's *Green Plan*. Raw data is collected but has not been correlated into readable information due to budgetary constraints. Prevention of pollution through enforcement of water-use licenses is the sole strategy used to maintain water quality. Most communities treat sewage in lagoons, discharging it to ground or wetlands; two communities discharge treated sewage to surface water (Whitley 1997).

**Northwest Territories**

The water-quality objectives of the Northwest Territories comply with the CCME water-quality guidelines and site-specific water-quality objectives. DIAND and the Territory's Department of Environment currently cooperate in maintaining 50 active federal, federal-territorial, and territorial stations that monitor water quality. The federal government has collected data on 30 to 60 variables from about 100 stations reporting on 80 bodies of water in the Northwest Territories. Site-specific objectives have been established in some locations to account for unique natural occurrences and human activity. Several individual reports have been generated from the data (Haliwell 1997).

## The Great Lakes

The Great Lakes (from west to east, Lakes Superior, Michigan, Huron, Erie and Ontario) are the largest system of fresh surface water on earth, containing roughly 23,000 $km^3$ of water or 18 percent of the world's supply (GC & USEPA 1995). Due to the vastness of this resource, the lakes provide tremendous economic and ecological benefits to the surrounding area. The Great Lakes basin, which includes the lakes and over 760,000 $km^2$ of land that drains into them, has a large concentration of industrial capacity, housing one-quarter of American industry and almost 70 percent of American and Canadian steel mills (USEPA 1995: 496). It also supports a large agricultural base: nearly 25 percent of Canadian agricultural production and 7 percent of American production is located in the basin (GC & USEPA 1995). In addition to economic benefits, the Great Lakes provide drinking water for over 23 million people and support recreation and a variety of other uses for the one-tenth of the United States' population and the one-quarter of Canada's population who live in the basin (GC & USEPA 1995).

Although for many years it was believed that the Great Lakes were too big to develop serious pollution problems, modern settlement did initially cause deterioration in water quality. Agricultural development increased the amount of silt and nutrients in streams and along shorelines, and growing urbanization and industrialization produced large amounts of waste water and toxic contaminants that were discharged directly into the lakes. As a result, by the 1960s, sewage, fertilizer run-off, and chemical wastes had caused serious degradation to Lake Erie, and the other lakes showed signs of similar trouble.

As a result of the water degradation, there have been a variety of pollution abatement initiatives at both the regional and international level over the past 30 years. In 1972, the Great Lakes Water Quality Agreement (GLWQA) between the United States and Canada set a management framework for controlling pollution, researching problems, and measuring progress. It focused primarily on targeting levels of phosphorous discharged in the lakes. Revisions to the GLWQA in 1978 and 1987 broadened the mandate to the whole ecosystem, focusing on the impacts of both point and non-point pollution on all living organisms. Since 1994, the over-all conditions and trends of a variety of indicators developed to evaluate the state of the Great Lakes ecosystem have been examined through the biennial State of the Lakes Ecosystem Conferences (SOLEC). The findings from these conferences are summarized and made available to the public through the *State of the Great Lakes Reports*.

In addition to developing better mechanisms to evaluate trends in the Great Lakes, the GLWQA has developed action plans to restore the Great Lakes. The two main programs are Lakewide Management Plans (LaMPs) and Remedial Action Plans (RAPs). Lakewide Management Plans (LaMPs) were created to address the most critical pollutants that affect whole lakes or large portions of them. Remedial Action Plans (RAPs) are more regionally focused. They are designed to rehabilitate the 43 Areas of Concern (AOCs). AOCs are designated geographical areas where several beneficial uses, such as fishing or swimming, are impaired. There are currently 42 AOCs: 11 located in Canada, 26 in the United States, and 5 in connecting channels. These programs continue today alongside a variety of other local initiatives run by numerous grass-root organizations and special-interest groups.

Through these efforts, water quality has improved. Levels of toxic contaminants released into the basin have steadily decreased and some key contaminants are no longer released at all. There have been note-worthy reductions in organic material, solids, and phosphorous as well. As a result of the RAPs, the harbour in Collingwood, Ontario, which was once identified as an AOC, has been successfully restored.

Despite these improvements, most regulatory bodies and environmental groups call for further action to improve water quality in the Great Lakes. The International Joint Commission (IJC), an advisory group of Americans and Canadians, states in the introduction to their *Ninth Biennial Report on Great Lakes Water Quality* (1998) that, although concern about phosphorous has largely been addressed and solved, concern about toxic substances has not. Similarly, the USEPA's *National Water Quality Inventory* recognizes the improvements in water quality but states that less visible problems, such as unfavourable conditions for aquatic life, continue to degrade the Great Lakes. The *State of the Great Lakes Report* also illustrates that many indicators are improving but are still not at the "good" level.

In this section, to evaluate trends in Great Lakes water quality, two main pollutants are examined: toxic contaminants and excess nutrients. The importance of measuring these pollutants to determine water quality is explained in the previous section. Trends examined in the 1997 edition of *State of the Great Lakes* are also discussed. These indicators focus both on reducing specific pollutants and on minimizing the negative impacts of pollution on human and wildlife populations.

### Trends for toxic contaminants

The levels of pesticide contamination found in herring gull eggs fell considerably between 1974 and 1996.[12] The concentration of Dichloro-diphenyl-dichloro-ethylene (DDE)[13] fell 86.4 percent in Lake Ontario and 82.6 percent in Lake Superior from peak levels in 1975 (figure 2.11). In Lakes Huron and Erie, DDE concentration levels fell 88.4 percent and 82.5 percent respectively. Lake Michigan, likewise, had a 81.7 percent reduction between 1977 and 1996.[14]

Levels of polychlorinated biphenyls (PCBs)[15] and hexachloro-benzenes (HCBs)[16] also showed drastic reductions during the same periods. PCBs fell 89.4 percent in Lake Ontario, 85.8 percent in Lake Huron, 79.7 percent in Lake Superior, 80.8 percent in Lake Michigan, and 78.6 percent in Lake Erie (figure 2.12). The level of hexachloro-benzenes (HCBs) peaked in 1977 and fell 95.0 percent in Lake Ontario, 91.9 percent in Lake Erie, and 83.3 percent in Lake Michigan by 1996. Decreases in Lakes Superior and Huron were 84.6 percent and 78.9 percent, respectively, between 1974 and 1995 (figure 2.13). Available data also indicate a decrease in the already low levels of the pesticides Dieldrin and Mirex in herring gull eggs.[17]

Even with these improvements, there are still concerns about the level of toxic contaminants in the Great Lakes. PCB concentrations in fish in various areas of the basin continue to exceed the International Joint Commission's objective of 0.1 μg of PCBs per gram of fish tissue. Restrictions on the consumption of fish also remain in all of the Great Lakes and contaminated sediments remain in some local areas (Environment Canada & USEPA 1995b: 3, 25). There is also concern about the presence of other toxic contaminants. Including the pollutants mentioned above, scientists have detected 362 contaminants in the Great Lakes (32 metals, 68 pesticides, and 262 other chemicals). One-third of these contaminants have acute or chronic toxic effects (Environment Canada & USEPA 1995b: 3). As a result of these concerns, many regulatory agencies recommend further reduction in contaminant concentrations.[18]

### Trends for nutrient levels

Annual phosphorous loadings have decreased in all the Great Lakes (figure 2.14). Between 1976 and 1991, total phosphorous loadings decreased by 27.9 percent in Lake Erie and 17.5 percent in Lake Ontario. Reductions in Lakes Superior, Huron, and Michigan were 24.0 percent, 7.1 percent, and 47.7 percent, respectively. Lake Superior and Lake Michigan have met their target load levels to prevent excessive algal growth since 1985 and 1981. Lakes Huron, Erie, and Ontario met their targets in 1989 and 1990 but have since experienced increases in total loadings.[19]

These improvements have come about to a large degree because of reductions in municipal phosphorous loadings. Municipal phosphorous discharges decreased by 71.4 percent in Lake Erie, 46.4 percent in Lake Ontario, 29.2 percent in Lake Huron, 72.0 percent in Lake Michigan and 11.9 percent in Lake Superior between 1976 and 1991 (see figure 2.15; Richardson 1999). This is largely because of limits placed on the phosphorous concentration in detergents in 1972; 70 percent of total inputs of phosphorus are from detergents from municipal wastes (Environment Canada & USEPA 1995a: 3). Other reductions can be attributed to better control practices in industrial processes and agriculture.

As a result of these reductions, spring phosphorous levels have decreased. These reductions were 59.6 percent in Lake Ontario between 1971 and 1993 (figure 2.16).[20] This, in turn, has led to a decrease in the amount of algal bloom, which is measured by the amount of *chlorophyll a* present in the lakes. In Lake Ontario, the amount of *chlorophyll a* decreased by 54.3 percent between 1975 and 1993 (Richardson 1999). Since 1980, the Upper Lakes have reduced levels of algal biomass below 2.0 μg/L, the level defined as below that of nuisance condition (Environment Canada & USEPA 1995a: 9). Lake Ontario met this goal from 1987 to 1991. Eutrophication or undesirable algae, however, still present problems in 18 of the 43 areas identified by the IJC as having the most severe problems (Environment Canada & USEPA 1995a: 10).

Nitrogen levels have also increased since 1971 (figure 2.17). Between 1971 and 1993, nitrogen levels increased 49.8 percent in Lake Ontario. Despite these increases, levels remain well below the threshold of 10 milligrams per litre for safe drinking water.

### Trends from State of the Great Lakes 1997 Report

The State of the Great Lakes 1997 report, illustrates an overall improvement in the Great Lakes. Table 2.1 illustrates the indicator ratings and trends for the Great Lakes aquatic near-shore ecosystem.[21] For this report, each indicator is first classified as "good," "mixed," or "poor." These ratings reflect the impact of the stressors on the ecosystem. A poor rating means there is a significant negative impact; a rating of mixed tells us that the impact is less severe; and good indicates that the impact or stress is removed and that the state of the ecosystem component is restored to a presently acceptable level (Environment Canada & USEPA 1997b: 13–14).

As illustrated in table 2.1 most indicators for the near-shore aquatic ecosystem are showing improvement. Similar to the trends discussed above, levels of toxic substances and nutrients are improving. Advisories on the consumption of fish and the status of native species and their habitats are also showing improvement. Fish have returned to some harbours from which they had all but disappeared,[22] and the number of double-crested cormorants, a water bird that all but vanished from the Great Lakes in the 1970s, has climbed to 12,000 nesting pairs (USEPA 1995e: 497). Overall, the state of the Great Lakes aquatic near-shore ecosystem is rated in mixed condition and improving.

In the report, other indicators also show improvements in the Great Lakes. In the land-use indicators section, wastewater quality and sewage quality, based on nutrient and toxic loadings, are classified as mixed and improving. Ground-water quality, based on area and the number of contaminated wells is mixed and deteriorating although the area and number of overall contaminated sites is mixed and improving (Environment Canada &USEPA 1997b: 37).

**Figures 2.1–2.6 Percentage of Canadian municipal populations served by wastewater treatment**

**Figure 2.1 Canada**

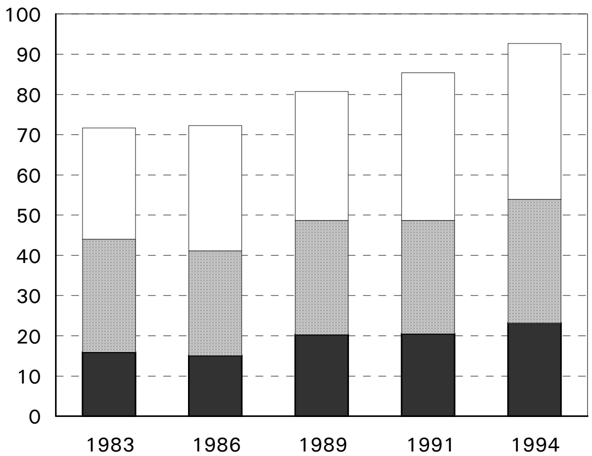



**Figure 2.2 Atlantic Provinces**

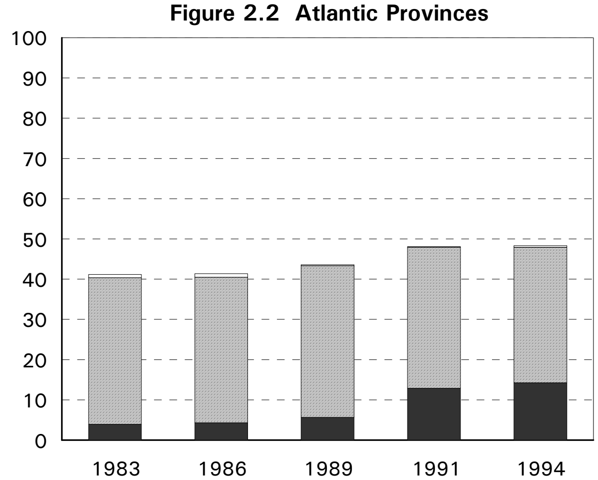



**Figure 2.3 Quebec**

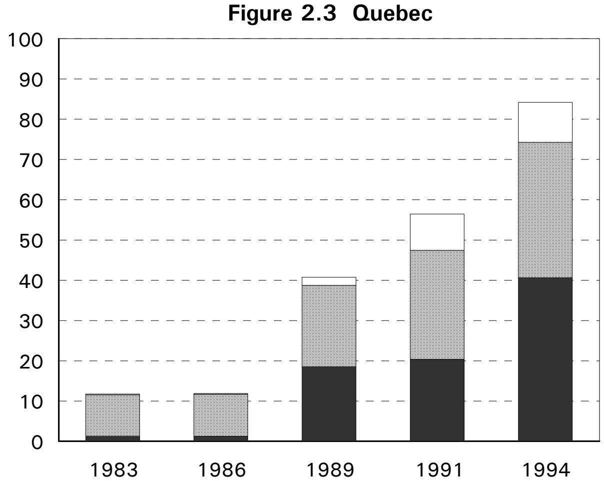



**Figure 2.4 Ontario**

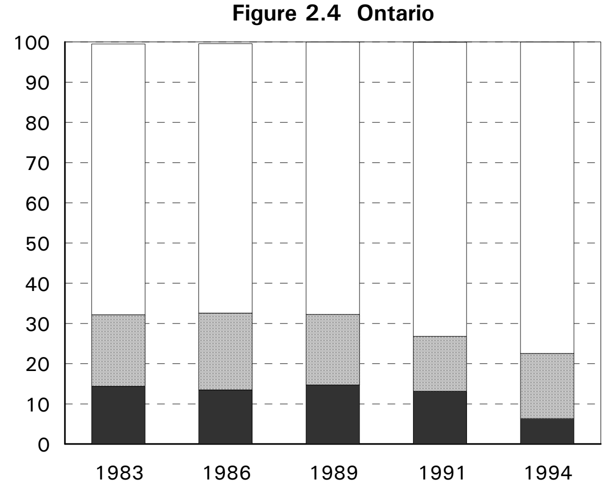



**Figure 2.5 Prairie Provinces**

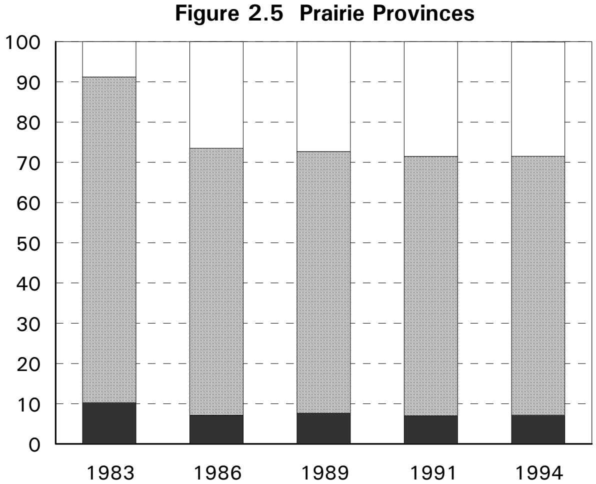
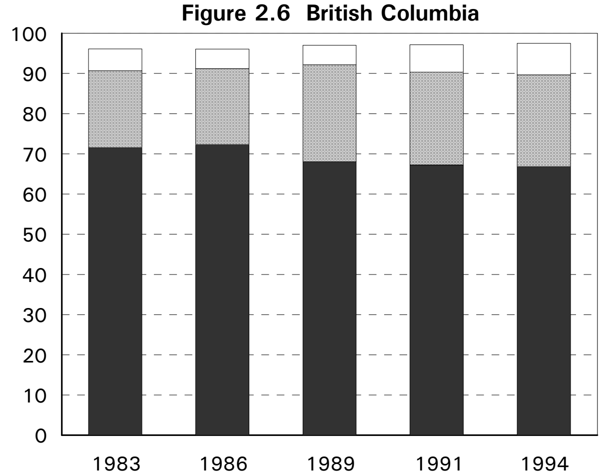


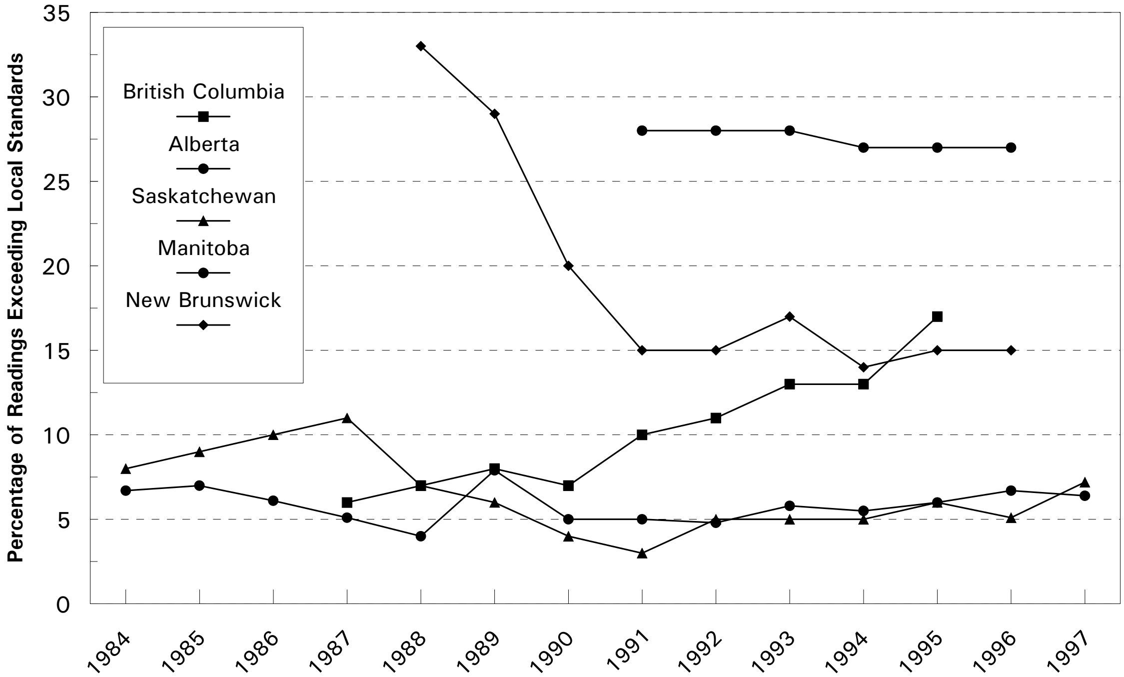

**Figure 2.6 British Columbia**




Primary treatment | Secondary treatment | Tertiary treatment

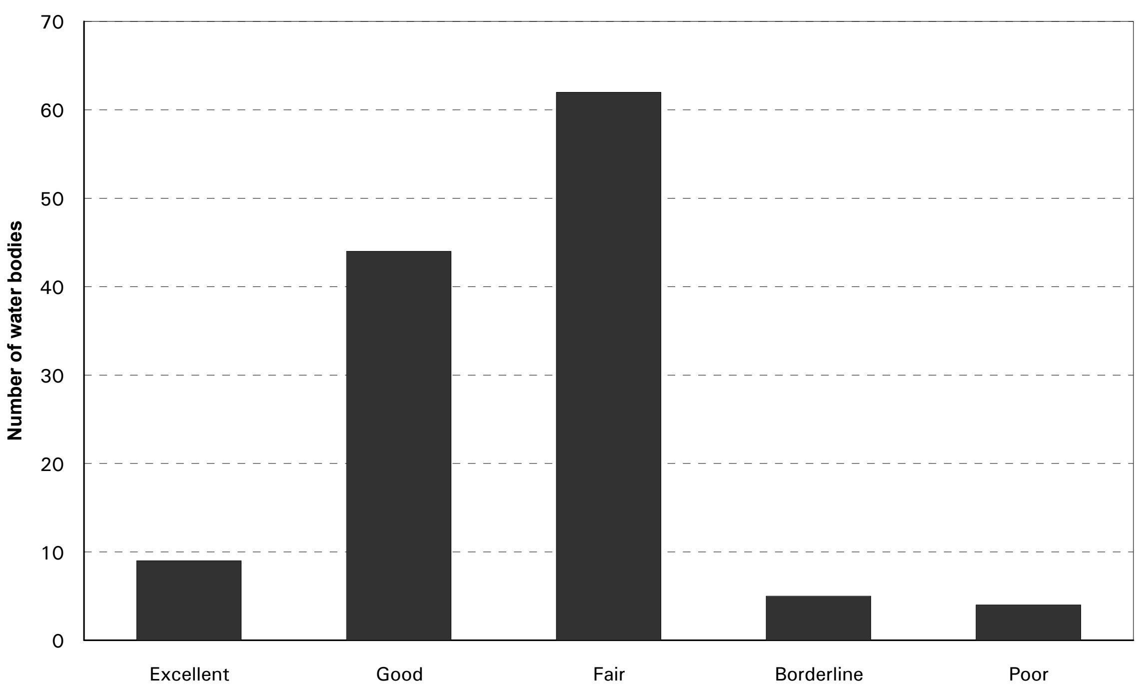
Source: Environment Canada 1998c.

**Figure 2.7 Water Quality in Canada**



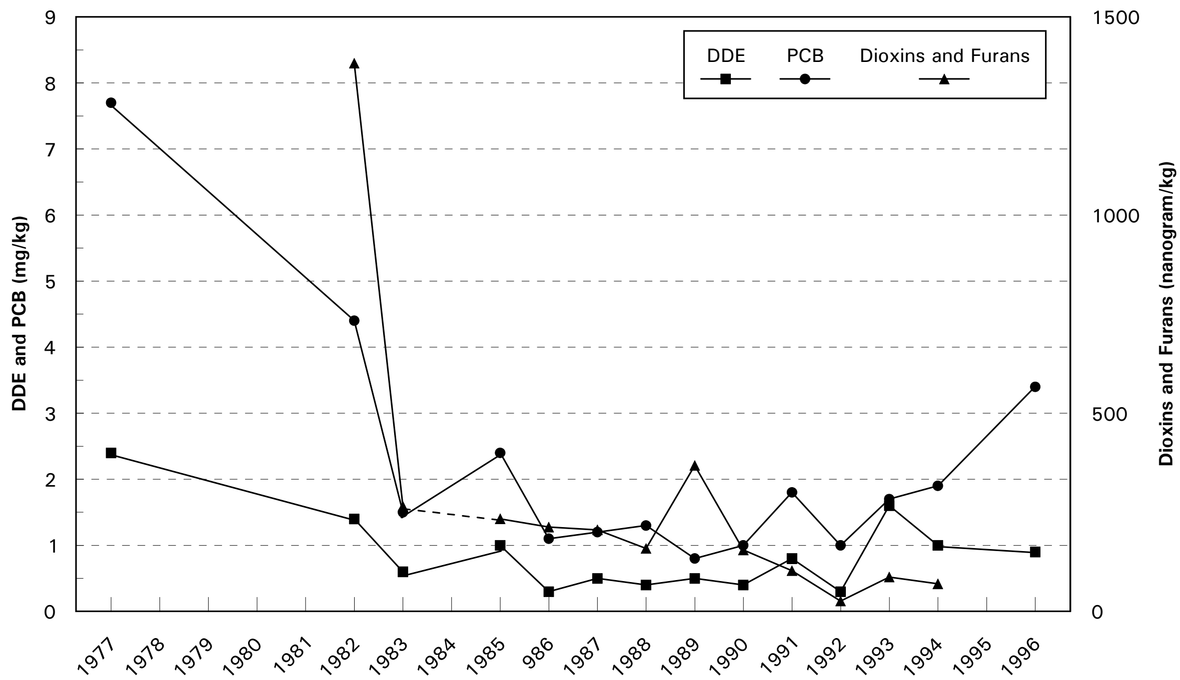

Sources: Swain 1997; Saffran 1999; Hallard 1997; Williamson 1997; Choate 1997; Jain 1999.

**Figure 2.8 Summary of Water Quality in Selected Bodies of Water in British Columbia**



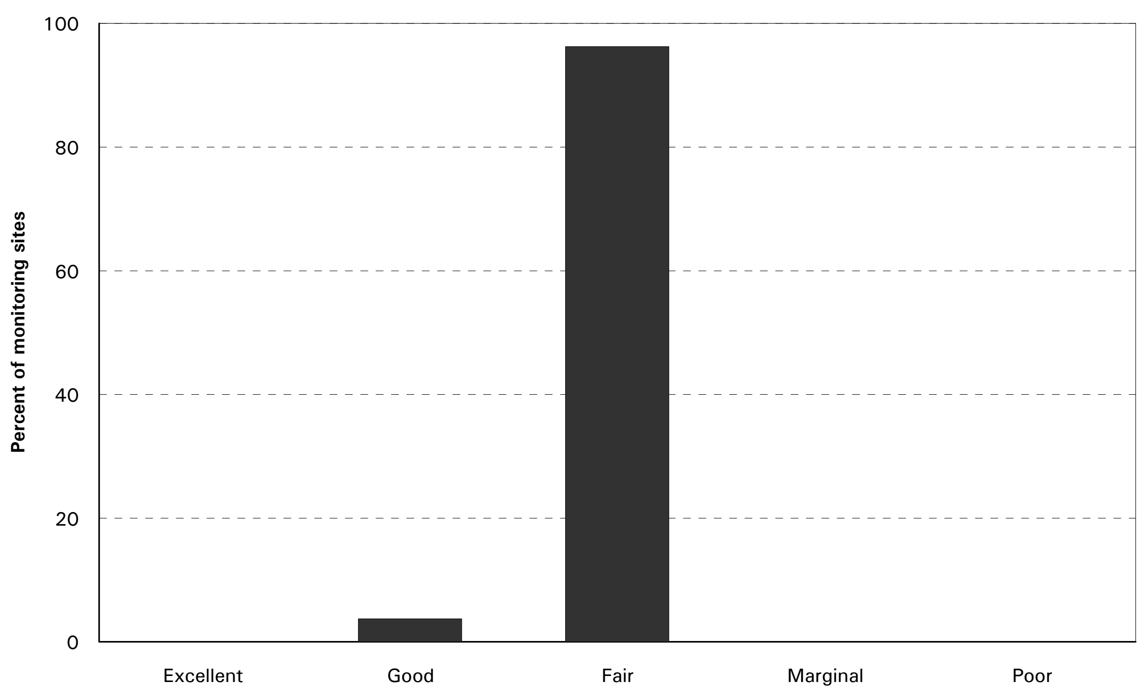

Source: British Columbia Ministry of Environment, Lands, and Parks 1996.

**Figure 2.9 Status and trends in contaminants in great Blue Heron eggs from a colony at UBC**



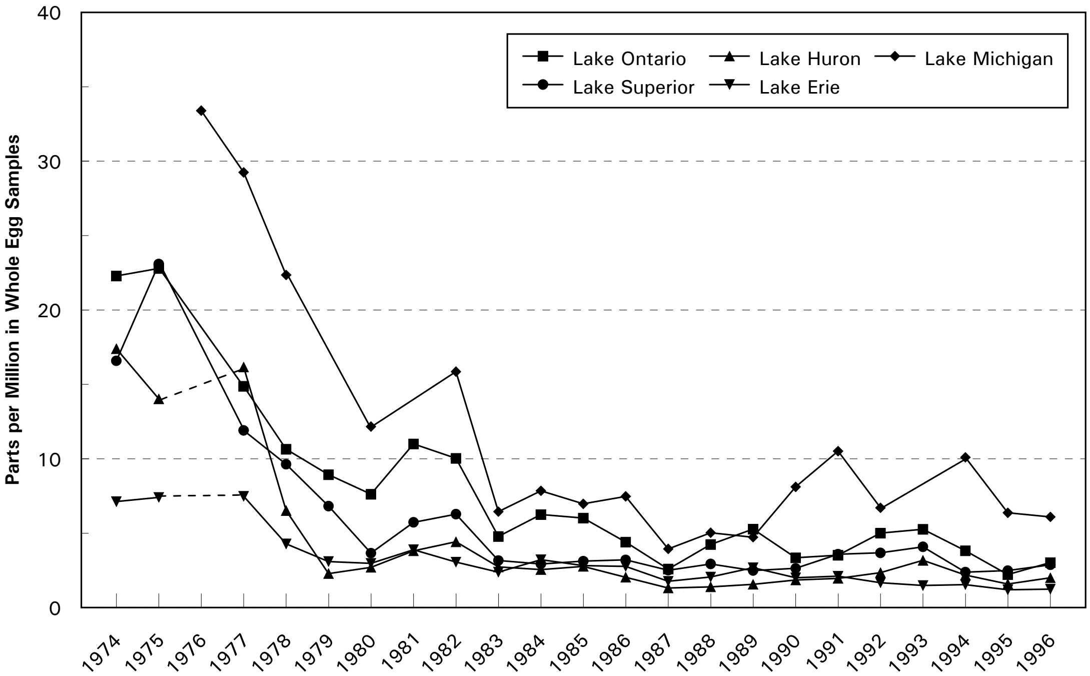

Source: BC Ministry of Environment, Lands and Parks 1999.

**Figure 2.10 Water-Quality Index Summary for the Prairie Ecozone in Manitoba, 1991–1995**



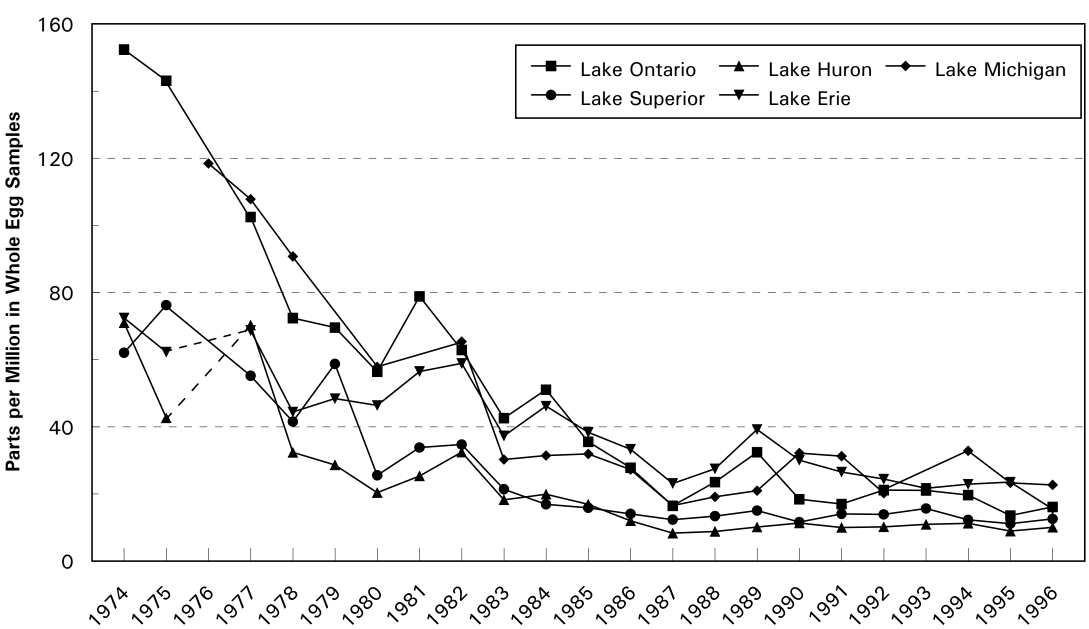

Source: Manitoba Environment 1997.

**Figure 2.11 DDE Levels in Herring Gull Eggs in the Great Lakes**



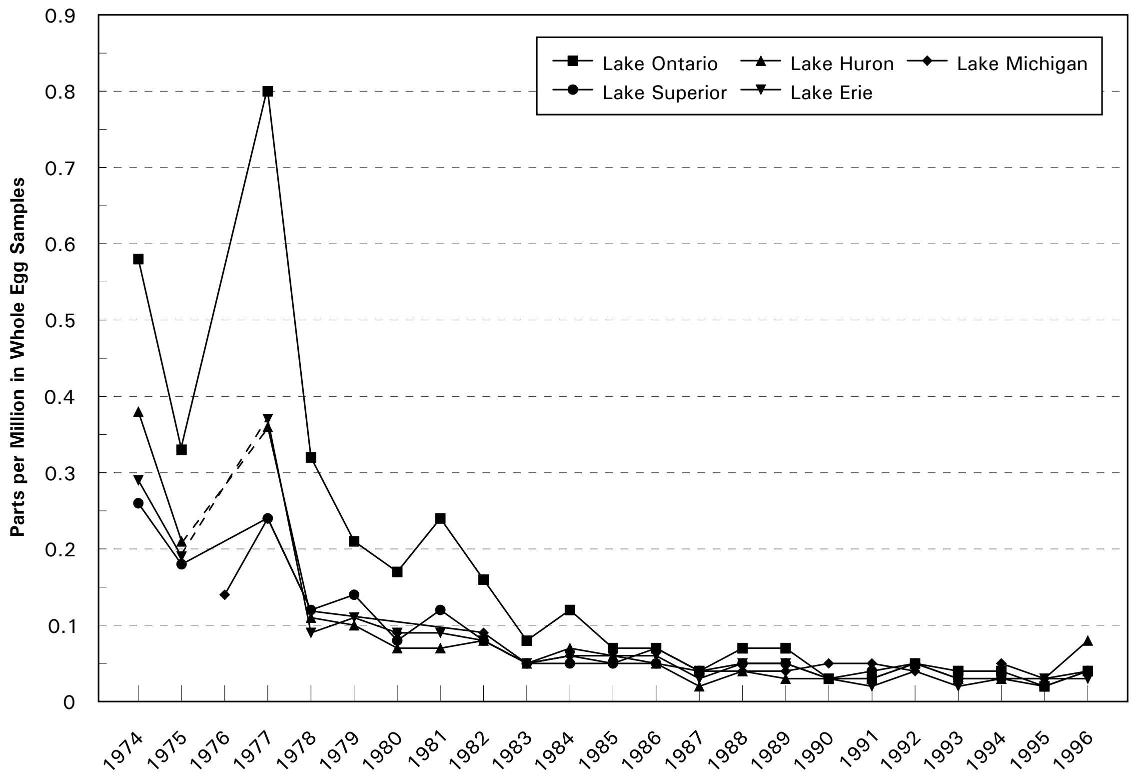

Source: Council on Environmental Quality 1996: 334–38.

**Figure 2.12 PCB Levels in Herring Gull Eggs in the Great Lakes**



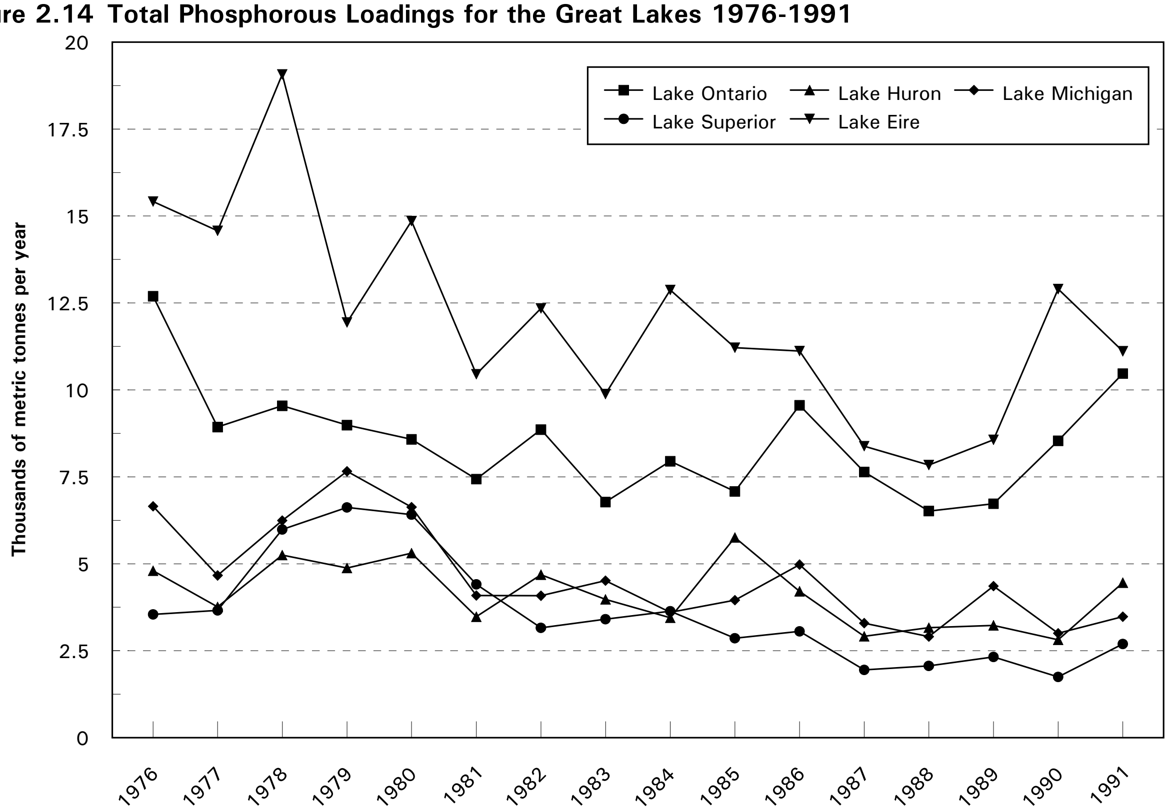

Source: Council on Environmental Quality 1996: 334–38.

**Figure 2.13 HCB Levels in Herring Gull Eggs in the Great Lakes**



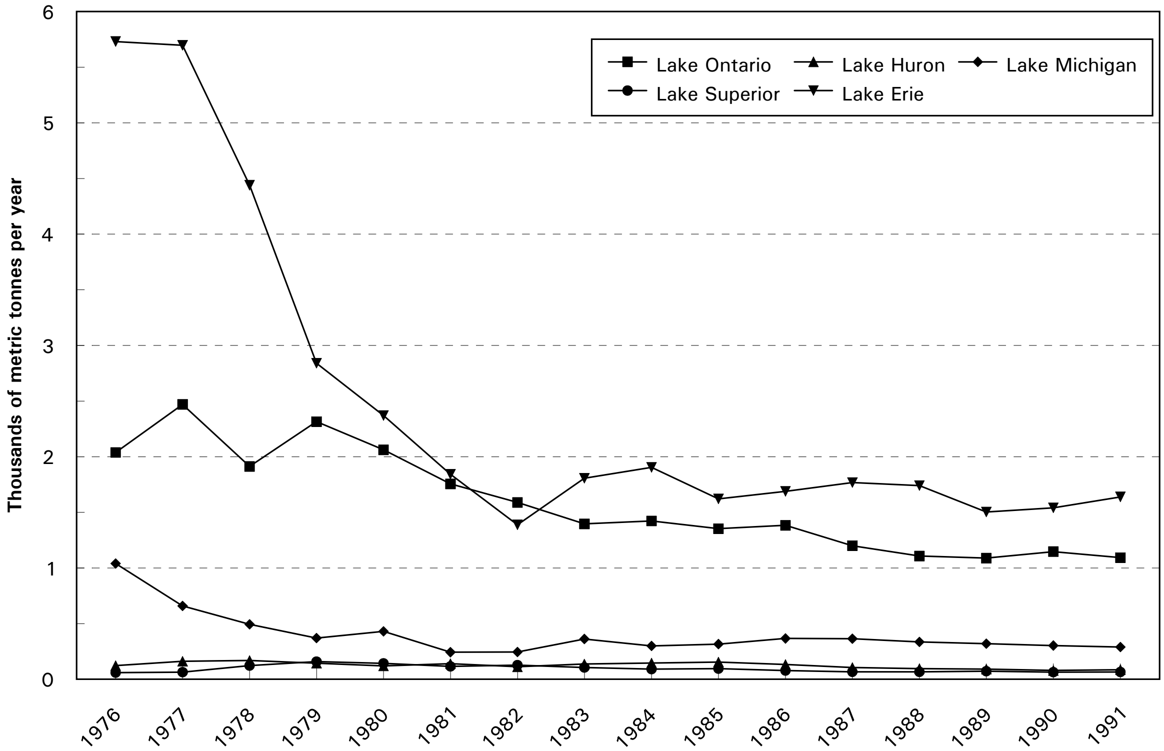

Source: Council on Environmental Quality 1996, 334-338

**Figure 2.14 Total Phosphorous Loadings for the Great Lakes 1976-1991**



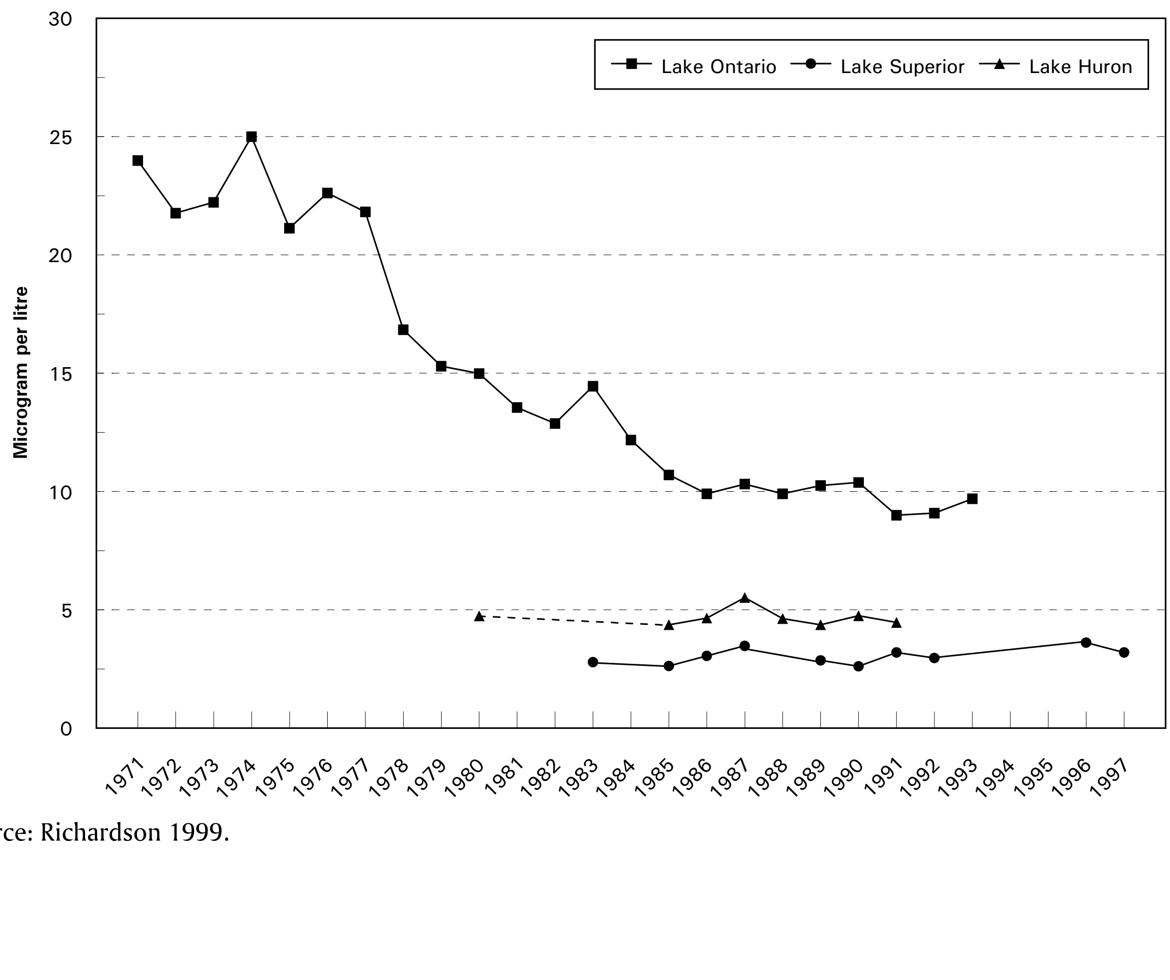

Source: Richardson 1999.

**Figure 2.15 Municipal Phosphorous Loading for the Great Lakes, 1976–1991**



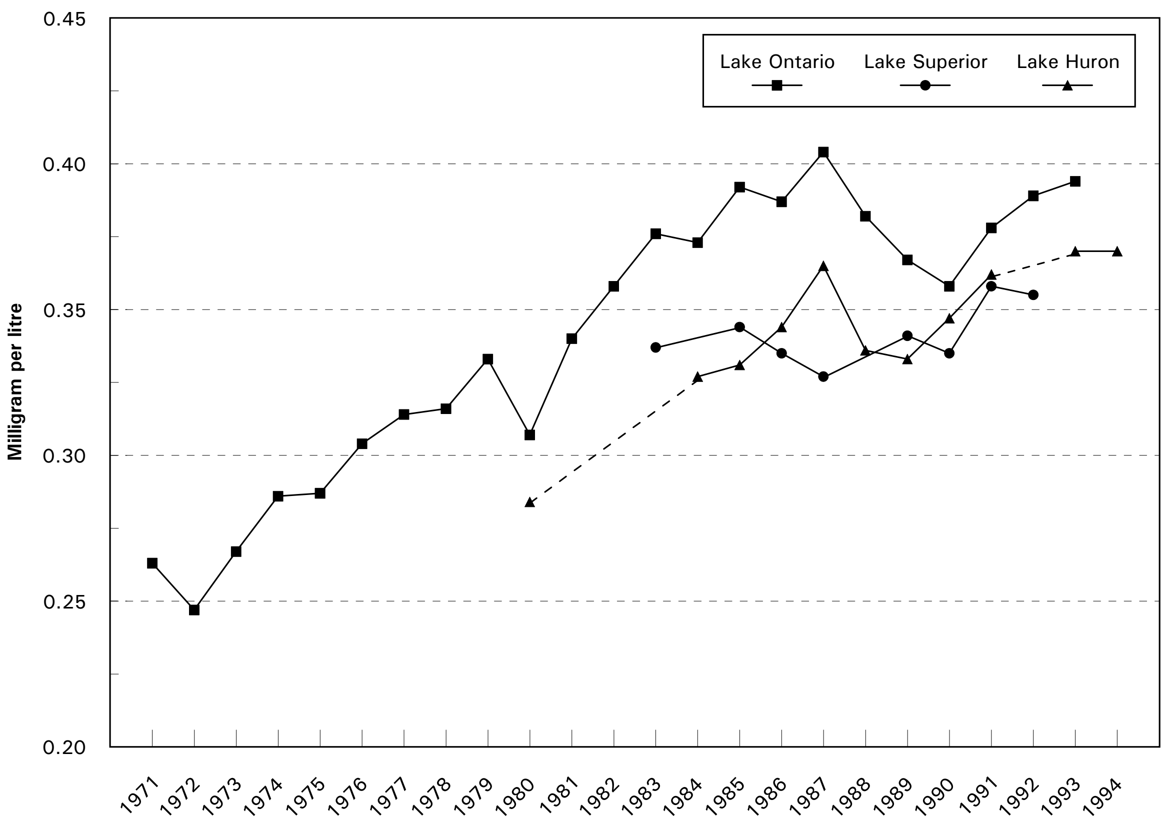

Source: Richardson 1999.

**Figure 2.16 Spring Total Phosphorous Trends**




Source: Richardson 1999.

**Figure 2.17 Nitrate/Nitrite Concentrations in the Great Lakes**




Source: Richardson 1999.

**Table 2.1 The State of the Great Lakes' Aquatic Ecosystem**

| Indicators | Condition | Trend |
|---|---|---|
| **Desired Outcome: Healthy fish and wildlife** | | |
| Effect of exotic species | poor | deteriorating |
| Status of native species and their habitats | mixed | improving |
| **Desired Outcome: Virtual elimination of persistent toxic substances** | | |
| Levels of persistent toxic substances in water and sediment | mixed | improving |
| Concentrations of persistent toxic substances in fish and wildlife | mixed | improving |
| **Desired Outcome: Reduced nutrient loading, eliminating eutrophication** | | |
| Dissolved oxygen concentrations of bottom waters | good | improving |
| Water clarity / algal blooms | mixed | improving |
| **Desired Outcome: Healthy human populations** | | |
| Fish consumption advisories | mixed | improving |
| Beach closings (median number of consecutive days closed for a given year) | inadequate data | unknown |
| Drinking water quality | good | stable |
| Acute human illness associated with locally high levels of contaminants | inadequate data | unknown |
| Chronic human illness | inadequate data | unknown |
| **Overall state of the Great Lakes aquatic nearshore ecosystem** | mixed | improving |

Source: Environment Canada & USEPA 1997b: 25, table 4.

# 3 Solid Waste

Solid waste has become a leading environmental issue in recent years. Occasionally, it is even billed as a "crisis" because of the popular belief that there is a lack of space for landfills. However, a single square of land, about 71 km (44 miles) on each side and about 37 metres (120 feet) deep, could accommodate all the garbage generated in the United States for 1000 years (Wiseman 1990). Canada would require about one-tenth of this area.[23]

The management of solid waste involves decreasing the amount of solid waste generated (reduce and reuse) and disposed (recycle and recover). Canada has adopted ambitious targets. The Canadian Council of Ministers of the Environment (CCME) has set a nation-wide goal of 50 percent reduction per capita from 1988 level, by the year 2000. A second initiative, the National Packaging Protocol (NaPP), targets the 35 percent to 40 percent of solid waste that is composed of discarded packaging and aims to reduce the level of discarded packaging to 50 percent of the 1988 level by the year 2000 (see Environment Canada 1991c: 25, 4).

## Reduction and reuse

The composition of municipal waste in Canada is (by weight) 28 percent paper and cardboard, 34 percent food and garden refuse, 11 percent plastics, 7 percent glass, 8 percent metals, and 13 percent textiles and other (OECD 1999: 166). A report by the Ontario Ministry of the Environment and a comprehensive study in the United States both show that discarded packaging accounts for about one third of waste (Environment Canada 1991c: [25]7; Franklin Associates 1992).

There are several reasons to expect that the generation of solid waste will increase as a country's wealth increases. The first and most obvious is that rising incomes lead to rising consumption. The increase in single-person households and the number of women in the workplace also may increase the amount of solid waste generated because both increase the consumption of small packaged items.

Most solid waste is buried in landfill sites. Canada disposes of 67.2 percent of its solid waste in landfills and only incinerates 3.0 percent (Christenson 1996). The heavy reliance on landfills has caused the fear that North America is running out of space for landfills but this popular belief is unfounded: North America is not running out of space for landfills. Although many landfills are close to capacity, this is because they are designed to have a short life span. Thus, they are always scheduled to reach capacity and close within a few years of opening. There is no shortage of room for landfills. It is not scarcity of land that inhibits the siting of landfills and incinerators but rather the high price of land close to urban areas and political pressure. When a site is chosen for garbage disposal, it becomes unavailable for other uses and communities worry about odour, dust, litter, and scavenging animals that have been associated with landfills in the past. New sanitary landfill technology now being used greatly reduces these problems.

### Trends in reduction and reuse

The OECD tracks the total solid waste and the amounts generated per capita by municipalities.[24] Overall municipal waste increased 16.9 percent in Canada between 1980 and 1996 although solid waste generated per capita decreased 3.9 percent between 1980 and 1996 in Canada (figure 3.1).

## Recycling and recovery

Concern that we are running out of space for landfills has made recycling an increasingly popular alternative to disposal. In the 1970s, most municipalities opened community recycling depots. Local governments, grocery stores, newspaper publishers, and the plastics, packaging, and soft-drink industries jointly fund the Blue Box program through which household newspapers, bottles, and cans are collected on a designated day. Some municipalities have expanded collection to include cardboard and rigid plastic containers.

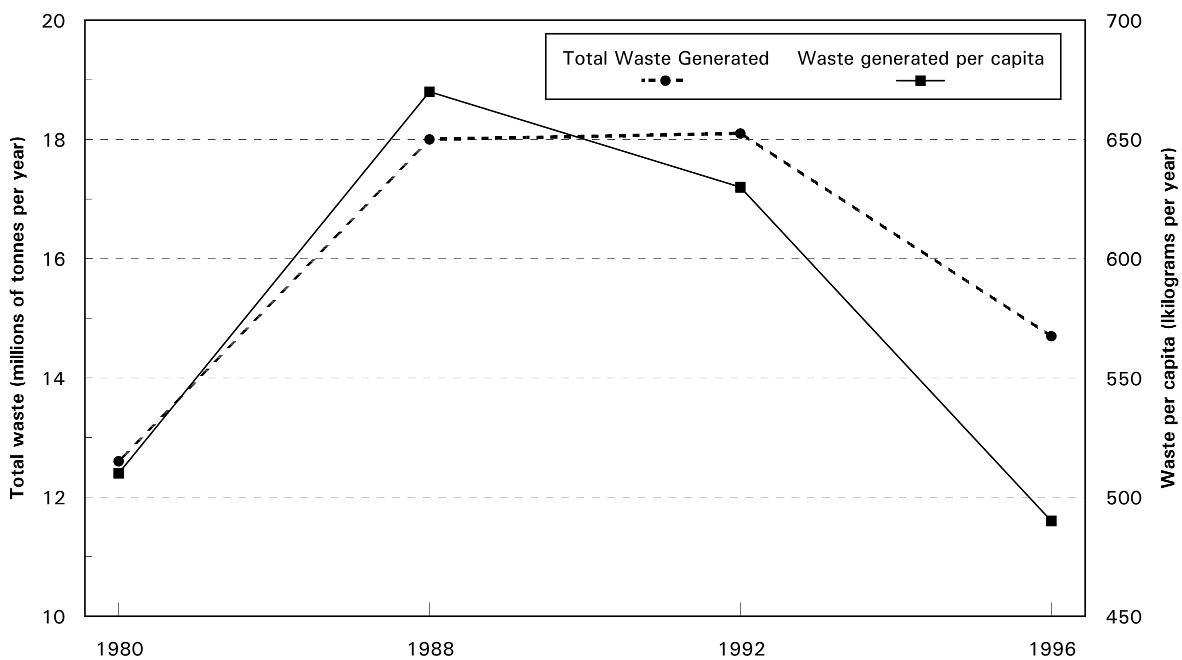
Recycling, composting, and resource recovery all affect the total amount of waste disposed but recycling is not always economically feasible. In many cases, manufacturing products from recycled materials requires more resources and energy than manufacturing the same products from primary raw materials—often using recycled materials produces more pollution.

In addition, using materials that can be recycled is not always environmentally desirable (Wiseman 1992). In many cases, manufacturing products from recycled materials requires more resources and energy and causes more pollution than does manufacturing the same products from primary raw materials. For instance, McDonald's decision to discontinue the use of polystyrene hamburger packaging has had several unfortunate resource trade-offs. It requires 30 percent less energy to produce a polystyrene package than it does to produce the paperboard alternative; this means 46 percent less air pollution and 42 percent less water pollution (Scarlett 1991). Finally, recycling is not possible for all products. For example, it is impossible at current prices and with current technology to recycle burned out light bulbs, since these contain glass, interior coatings, adhesive cement, and two or three different metals (Environment Canada 1991c: 25, 7).

### Trends in recycling and recovery

According to the OECD, paper and cardboard recycling in Canada was 20 percent of consumption in 1980 but increased to 32 percent by 1992.[25] Glass recycling climbed from 12 percent to 17 percent of consumption over the same period (figure 3.2).[26]

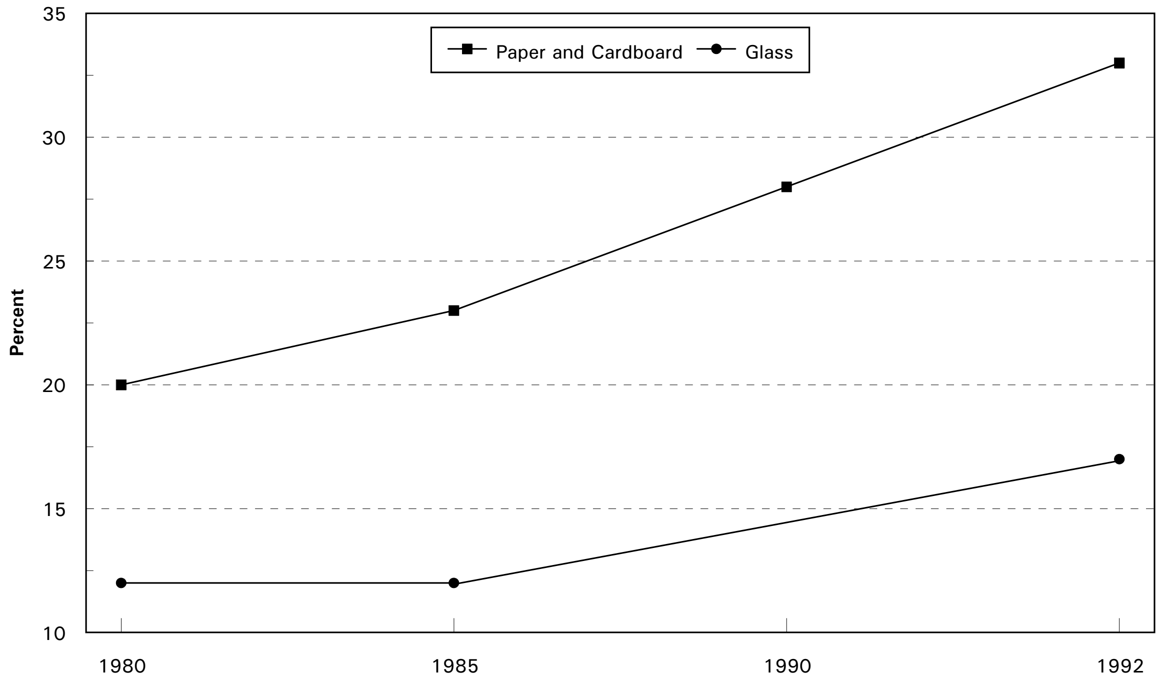
**Figure 3.1 Total and per-capita municipal solid waste generated in Canada**




Source: OECD 1999.

Note: 1996 data exclude 976,289 tonnes of sewage sludge.

**Figure 3.2 Recycling Rates in Canada**




Source: OECD 1999.

# 4 Land

Canada is the second largest country in the world, spanning an area of 9,970,610 square kilometres. Of this area, 755,180 $km^2$ is covered by freshwater. The remaining 9,215,430 $km^2$ is land. (Statistics Canada 1998: 22).

Despite this large land base, there are conflicts over the use of the land. One concern is human encroachment upon wilderness areas: as urban and agricultural lands expand, fewer areas are left in their natural state. An example of this conversion of land for human use is the draining of wetlands for agricultural purposes. The other main concern is about urban expansion into agricultural land. Urban centres were originally established close to prime agricultural land and, as populations increased, urban development began to infringe upon farmland.

To examine land use and condition, this section begins with a general discussion of land cover and use in Canada. Protected areas, agricultural land and wetlands are then examined separately in greater detail.

## Land cover and use

Figure 4.1 illustrates Canada's land cover. Forests cover the largest portion of Canada's total area accounting for 45 percent. Tundra—the northern land that is permanently frozen—covers 23 percent of Canada's total area and wetlands cover 12 percent. The smallest cover is urban space, which accounts for less than 1 percent of total land cover.[27]

Land area can also be classified according to its use (figure 4.2). According to a report published by Environment Canada, only 6.8 percent of Canada's land is used for agricultural purposes and 0.2 percent is built-up urban areas. Land that is either currently used for forestry or with the potential to be harvested in the future accounts for 24.5 percent. The other activities category, which is defined to include hunting, trapping, mining, energy developments and transportation, largely includes undisturbed land.

### Protected areas

Protected areas are "portions of ecosystems in which human activities are carefully managed and certain activities that harm ecological processes are prohibited" (Environment Canada 1996c: record 8362). In Canada, there are over 60 types of protected areas; parks, wildlife areas, ecological reserves, and forest reserves are some examples. Approximately 3,500 of these protected areas are under federal jurisdiction. Over 12,000 are managed by non-government organizations (Wiken 1999). These areas have been established to resist encroachment by other land uses, to preserve wildlife and natural monuments and to promote education and awareness.

The categories of the World Conservation Union (formerly the International Union for the Conservation of Nature and Natural Resources) provide one method of classifying protected areas. There are 6 classifications within this system: (I) Nature Reserves and Wilderness Areas, (II) National Parks, (III) Natural Monuments (added in 1994), (IV) Habitat/Species Management Areas, (V) Protected Landscape or Seascape, (VI) Managed Resource Protected Areas. Each of these categories involves a different defining characteristic for the areas and a different level of management.

***Trends in protected areas***

Figure 4.3 illustrates the expansion of protected areas in Canada over the past century. The areas are divided according to the World Conservation Union's categories: Categories I and II include nature reserves used for scientific research or monitoring, and wilderness areas and national parks established to preserve and protect natural conditions. Categories III to VI include heavily monitored areas such as natural monuments, habitat/species management areas, protected landscapes and managed resource protected areas. Total protected areas accounted for 9.6 percent of Canada's total area in 1997, for 7.9 percent in 1994, for 5.6 percent in 1983, and 2.6 percent in 1963. Protected land should continue to increase as the Government of Canada has committed itself to increasing protected areas to 12 percent of the nation's land base by the year 2000 (Anderson, Laflamme, & Brand 1995: 110).

Protected areas are located in all provinces (table 4.1). Quebec has the largest area of protected land: 158,050 $km^2$ or 10.3 percent of the provincial land base.

Prince Edward Island has the least amount of protected land: 78 $km^2$ or 1.4 percent of the province. Table 4.1 also shows that the majority of protected areas are under provincial or territorial jurisdiction (54.1 percent), followed by those under federal jurisdiction (37.6 percent), and those under joint management (8.2 percent). This is a change from the early 1900s when large conservation areas were mostly under federal jurisdiction.

### Agricultural land

Agricultural land is valued by Canadians because it provides food, income, and jobs. Farming generated $12 billion in 1996, accounting for 11 percent of Saskatchewan's gross domestic product (GDP) and 2 percent of the national GDP (Statistics Canada 1998: 337). In 1993, 391,000 Canadians were employed operating farms and an additional 1 million were employed in Canada's agri-food sector (Environment Canada 1996c: record 5551).

Eleven percent of Canada's large land base is capable of supporting some form of agriculture and almost 5 percent is suited for producing crops (Environment Canada 1996c: record 5552). This key farmland is located primarily in two regions: the interior grassland found in the southern half of the prairie provinces (Alberta, Saskatchewan, and Manitoba) and the belt that runs diagonally along the shores of Lake Ontario, Lake Erie and the St Lawrence waterway (see figure 4.4). Of this area suited for producing crops, only half of it is classified as prime agricultural land (Acton & Gregorich 1995: 11).

Much of the arable land in Canada is in use today. To assess the state of agricultural land in Canada, this section examines trends in both the quantity and quality of the land.

#### *Trends in agricultural land*

Between 1971 and 1996 the total area of farmland in Canada remained relatively constant (figure 4.5). However, the use of this land has become more intensive as the amount of cropland increased by 25.6 percent.[28] During this same period, the amount of land not worked for at least a year (summer fallow) decreased by 42.0 percent. Improved pasture—land improved by seeding, draining, irrigation, etc.—increased by 7.0 percent and unimproved land decreased by 10.2 percent.

Although there has been little change in the total amount of agricultural land on the national level, provincial data shows that there is variation from region to region. Table 4.2 displays the total amount of agricultural land in each province in 1976 and 1996, alongside the percentage change. The largest decrease in total agricultural area during this period was in Ontario (a decrease of 644,845 ha or 10.3 percent), followed by Quebec (a decrease of 552,732 ha or 13.8 percent) and New Brunswick (a decrease of 80,761 ha or 17.3 percent). Considering that most of the agricultural land in Quebec and Ontario is located along the densely populated shores of Lake Erie, Lake Ontario, and the St Lawrence River, some of this decrease can be attributed to urban development.

Nevertheless, there is no data to support the argument that the agricultural land converted to other uses is of higher quality than the new land brought into agricultural use. At present, there is no national database showing the capability versus the actual use of land in the various sectors. Without such data, it is not possible to conclude that prime agricultural land is being farmed or converted to other uses (Environment Canada 1996c: record 4664). Further, claims that the conversion of prime agricultural land to other uses results in a net loss ignores the increasing productivity of all agricultural land. According to a study by United States Department of Agriculture (USDA), the Canadian agricultural sector was 206 percent more productive at the end of the 1980s than at the beginning of the 1960s (USDA 1994). This growth in output far outweighs any threat posed by incremental urban expansion into farmlands.

The data also illustrate that there have been improvements in the quality of soil.[29] The most common cause of deterioration of the quality of soil is erosion, a natural process that removes topsoil, reduces the amount of organic matter in the soil, and breaks down soil structure. Some farming practices contribute to erosion: for example, cropping practices like summer fallow leave soil unprotected and can make erosion by wind and water worse. Erosion also occurs through natural processes such as weathering.

Implementation of soil-conservation practices has significantly reduced the risk of erosion by wind in the past few decades.[30] In the prairie provinces, the risk of wind erosion decreased by 7 percent between 1981 and 1991.[31] This reduction has been attributed largely to conservation tillage (two-thirds of the decrease) with the remaining decrease attributed to changes in cropping systems (for example, summer fallow) (Acton & Gregorich 1995: 71).

The risk of erosion by water in Canada decreased by 11 percent between 1981 and 1991. This reduction has been achieved from changes in cropping practice (5 percent reduction) and tillage practices (6 percent reduction). There is variation among provinces largely because some crops are less suitable to conservation practices. For example, Prince Edward Island has had an increase in erosion since it produces potatoes, which are not suitable for some conservation practises employed for other crops (Acton & Gregorich 1995: 72).

Other indicators besides erosion also demonstrate improvements in soil quality. Whereas levels of organic matter in Canada's uneroded agricultural soils have declined by 15 percent to 30 percent since cultivation began, they are now being maintained or increased in many Canadian croplands (Acton & Gregorich 1995: 40, 45). There have also been positive trends in soil structure and decreases in the amount of land susceptible to soil salinization (Acton & Gregorich 1995: xiii).

## Wetlands

Wetlands are areas of land that are covered with water all or most of the time or are sufficiently saturated with water to promote aquatic processes. Environment Canada defines wetlands to include bogs, swamps, marshes, fens, and shallow open water. Wetlands protect land from flooding and shorelines from erosion and act as filtration systems by breaking down nutrients and neutralizing disease-causing pathogens. They also provide habitat for a wide range of species. Canadian prairie wetland, for instance, provides habitat for 50 percent of North America's waterfowl (Environment Canada 1991c: [17]10).

In the past, wetlands were considered waste areas to be drained and converted to economically productive uses. Over one-seventh of Canada's pre-settlement wetlands are believed to have been converted to other uses (Natural Resources Canada 2000). Farming subsidies contributed to the destruction of this sensitive habitat. Until recently, the Canadian Wheat Board Act determined grain delivery quotas based on the total areas seeded and left fallow. This encouraged farmers to cultivate marginal land rather than leave it in its natural form (Environment Canada 1991c: [26] 6). The Maritime Marshland Rehabilitation Act (1943) was designed to discourage reversion of arable land to original wetland coverage (Environment Canada 1991c: [20] 6). This trend seems to be reversing; recent studies show that wetland loss from agricultural conversion has dropped sharply (Tolman 1994).

As more is discovered about the function and value of wetlands, it is becoming clear that they play a reinforcing, rather than a strictly competing, role in agriculture and urban development. Wetlands provide direct economic benefits in southern Canada. Wild rice and cranberries, peat, and sphagnum moss are harvested from wetlands (Natural Resources Canada 2000) and they support many socioeconomic functions such as hunting, trapping, fishing, tourism, and recreation. It is also becoming clear that they can play a reinforcing role in traditional agriculture and urban development. For example, wetland preservation can help conserve and purify ground water and protect against drought. One study estimates that wetlands provide over 10 billion dollars in benefits to Canadians every year (Environment Canada 1991a: 4).

Wetlands are extensive in Canada. The most recent estimates suggest that wetlands cover 148 million hectares or 16 percent of Canada's land base (Rubec 1999); this is nearly 25 percent of the world's wetlands (Environment Canada 1991c: [26] 7). Wetlands are found across the country but predominantly in Ontario, the Northwest Territories, and Manitoba (see table 4.3). Since 1986, the OECD survey reports indicate that Canada has suffered no net loss of wetlands (see figure 4.6).

Canada has adopted many conservation programs in the past decades in recognition of the ecological and economical importance of wetlands. In 1981, Canada became a contracting party to the Ramsar Convention, an intergovernmental treaty that strives to provide "the framework for international cooperation for the conserving of the World's wetland habitat" (Canadian Wildlife Service 1995). In 1990, the Canadian government established the North American Wetlands Conservation Council (Canada). In 1991, Canada adopted the Federal Policy on Wetland Conservation, making Canada the first nation to formalize wetland policy on a national level.

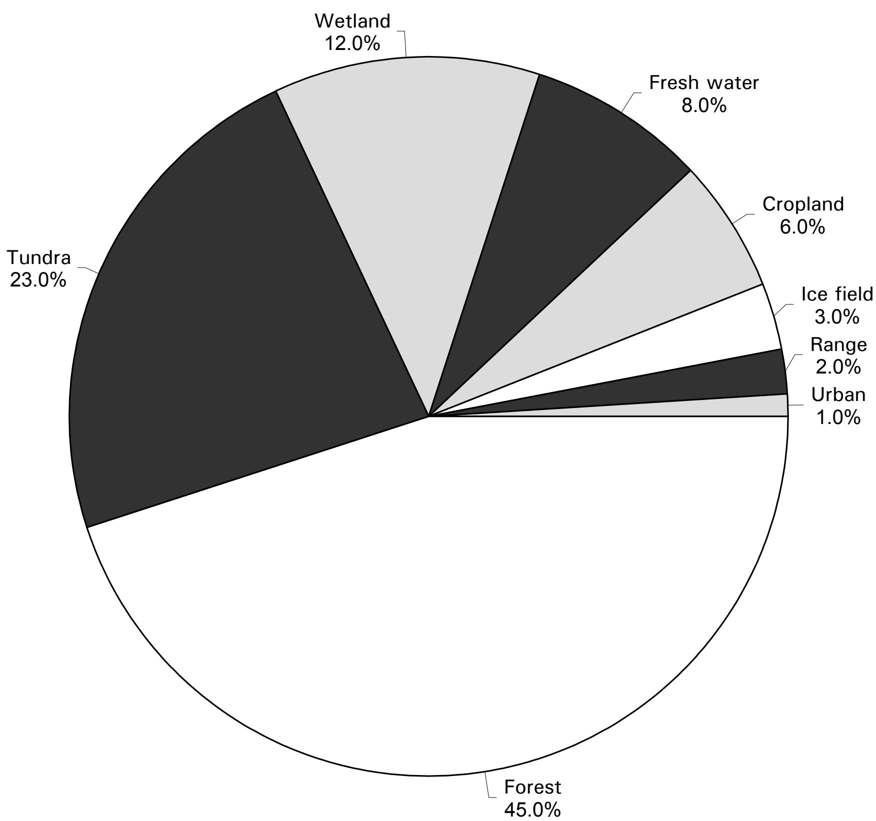
Through the Ramsar Convention, a *List of Wetlands of International Importance* has been developed based on "ecological, botanical, zoological, hydrological, fisheries and human use criteria" (Canadian Wildlife Service 1995). As of 1995, 33 Ramsar sites were designated in Canada, representing 30 percent of the total wetland area designated world-wide under the Convention to date, though they are only a fraction of the wetlands in Canada. These Ramsar wetlands cover a surface area of 13 million hectares and are diverse in type and size, ranging from 244 hectares to over six million hectares in size (Canadian Wildlife Service 1995).

The main conservation efforts, however, have been through the North America Waterfowl Management Program (NAWMP), a billion-dollar wildlife-conservation program that grew out of public concern in the mid-1980s over the loss of North American wetlands. The initial objective of the program was to restore waterfowl populations to the average levels in the 1970s. Canada and the United States first signed this international conservation program in 1986. Mexico joined the agreement in 1994. Through joint ventures between public and private agencies this billion-dollar program has identified the key habitats necessary to protect waterfowl populations and has developed plans for the restoration and protection of these areas. As of 1994, Canada had secured 3,355 $km^2$ of wildlife habitat, which includes some wetlands, through the program's joint ventures (Environment Canada 1996c).

Private organizations such as Ducks Unlimited and the Nature Conservancy play an important role. They have become the two largest private stewards of Canada's 1.1 million hectares of non-government conservation lands (Statistics Canada 1994: 214–15). Industry has also been an active player in protecting key areas. Shell Oil gave a large holding in British Columbia to the Nature Conservancy of Canada in 1992; MacMillan Bloedel donated Cathedral Grove in the 1940s; and New Brunswick's Bowater-Mersey Forest Products Limited has entrusted areas of ecological importance, including wetlands, to government and non-government conservation groups (Environment Canada 1996c).

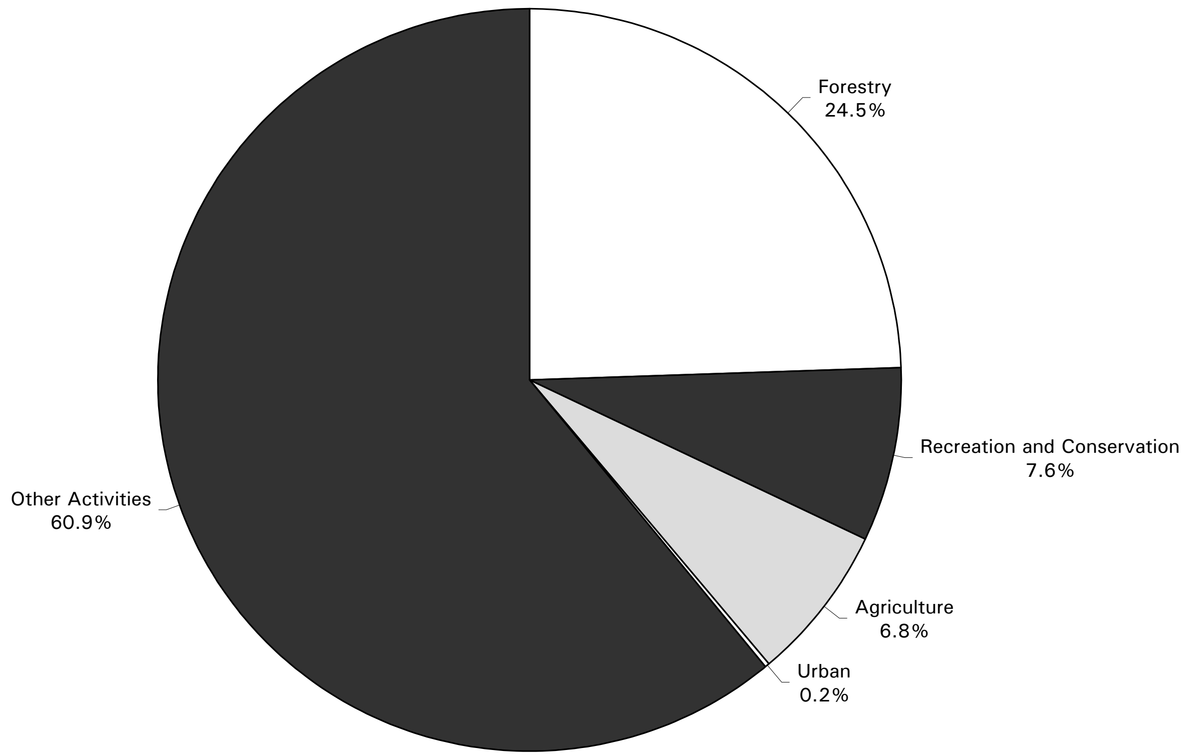
Although there are many initiatives to protect wetlands, it is difficult to evaluate overall trends as there is a considerable degree of natural fluctuation.

**Figure 4.1 Land Cover in Canada**



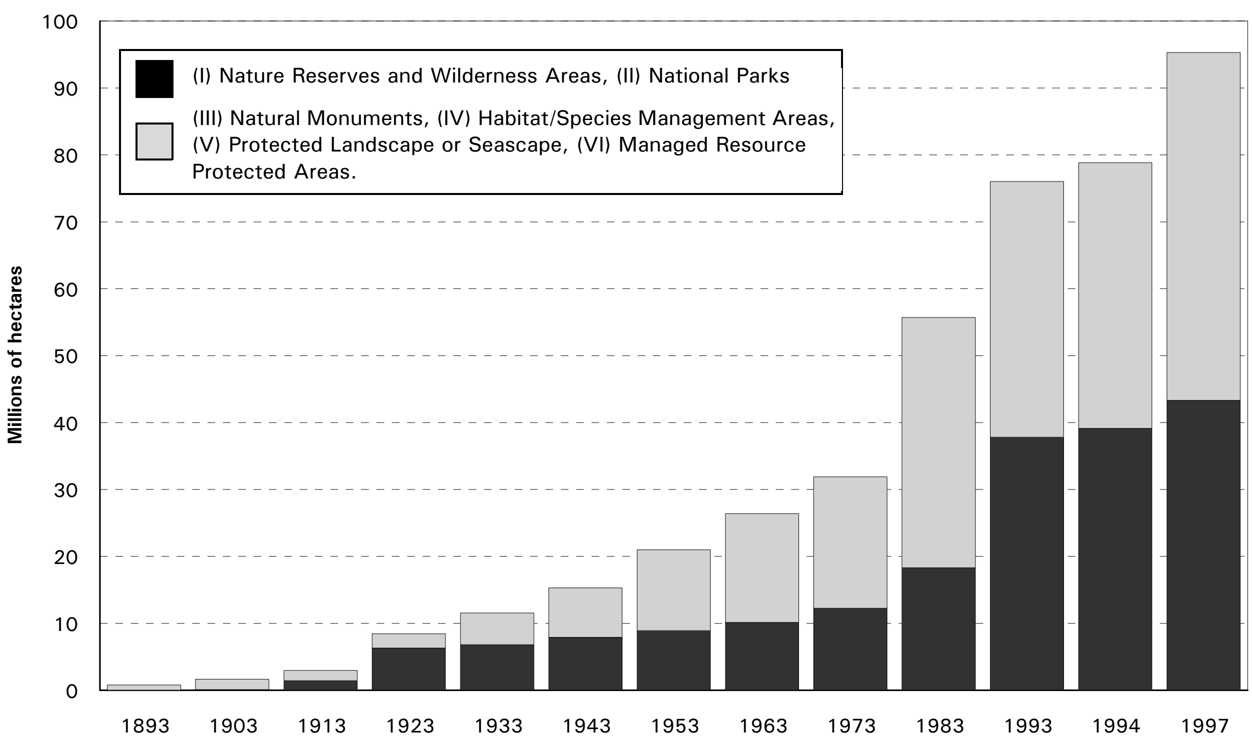

Source: Statistics Canada 1996: 7.

**Figure 4.2 Land Use in Canada**



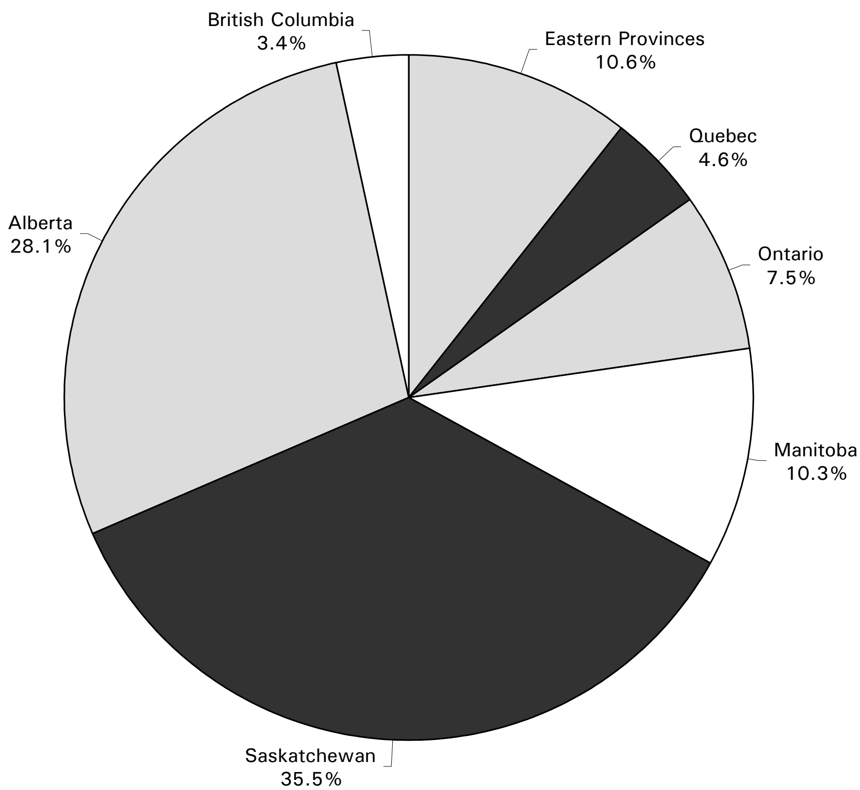

Source: Environment Canada 1996c: record 4668.

**Figure 4.3 Protected Areas in Canada, 1893–1997**



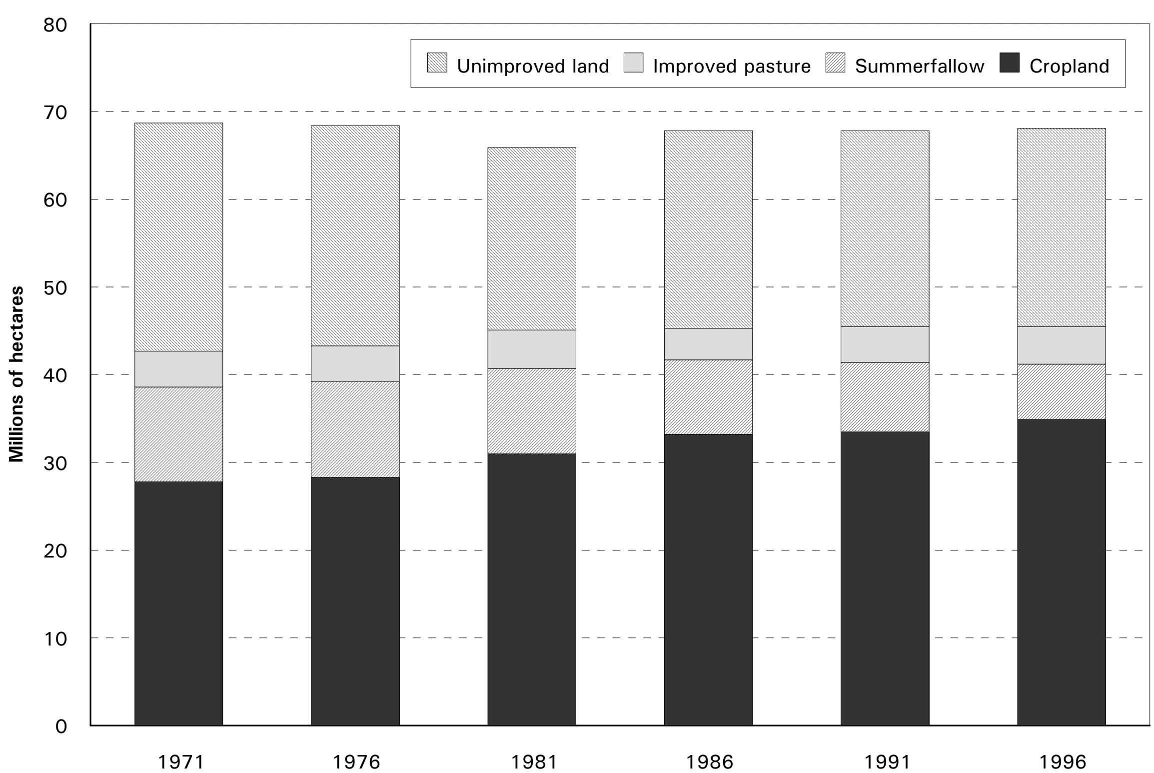

Source: Environment Canada 1996c: record 8374; World Conservation Monitoring Centre 2000.
Note: 1997 includes data for (III) Natural Monuments, which was previously unavailable.

**Figure 4.4 Location of Total Farmland in Canada, 1996**



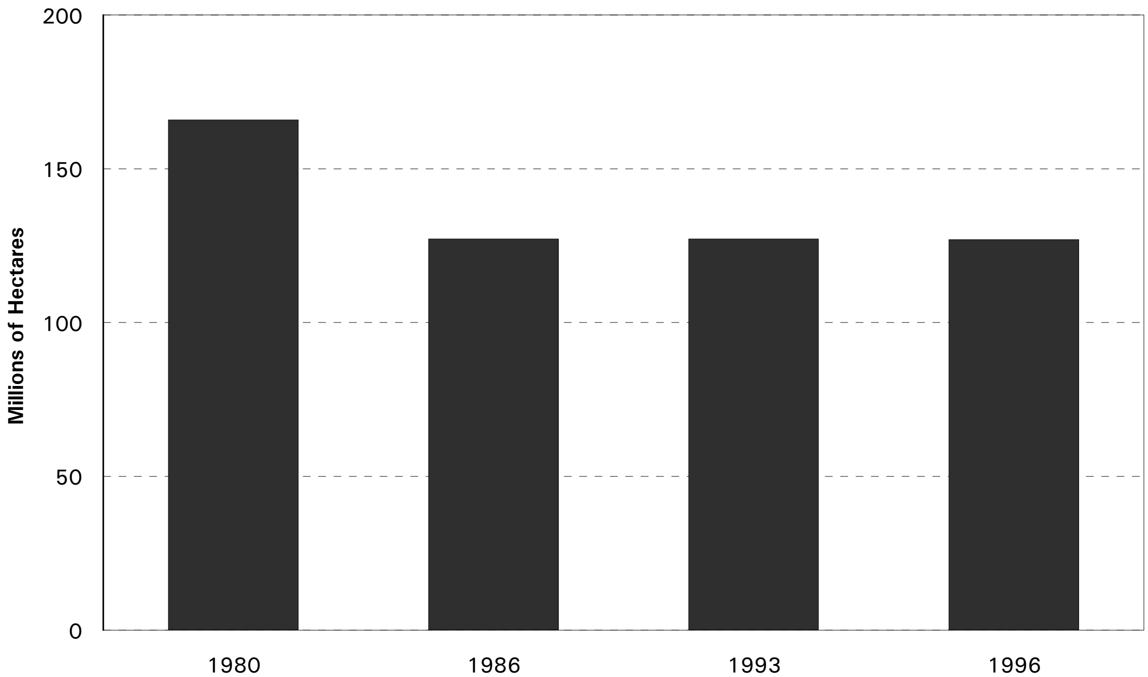

Source: Statistics Canada 1997.

**Figure 4.5 Total Farmland in Canada, 1971–1996**




Source: Statistics Canada 1997: 70.

**Figure 4.6: Area of Wetlands in Canada**




Sources: OECD 1993, 1995; Environment Canada 1996c.

**Table 4.1 Protected Areas (in km$^2$) by Jurisdiction**

| | Federal | Provincial/ Territorial | Private Landowner | Other | Total | Percentage of Province |
|---|---|---|---|---|---|---|
| **Newfoundland** | 2,353 | 5,005 | 0 | 0 | 7,358 | 1.8 |
| **Prince Edward Island** | 27 | 51 | 0 | 0 | 78 | 1.4 |
| **Nova Scotia** | 1,415 | 1,485 | 0 | 287 | 3,187 | 5.7 |
| **New Brunswick** | 508 | 3,449 | 0 | 0 | 3,957 | 5.4 |
| **Quebec** | 6,527 | 151,509 | 11 | 3 | 158,050 | 10.3 |
| **Ontario** | 2,413 | 50,088 | 0 | 10,147 | 62,648 | 5.9 |
| **Manitoba** | 2,979 | 46,046 | 0 | 14,913 | 63,938 | 9.8 |
| **Saskatchewan** | 5,136 | 11,788 | 0 | 11,635 | 28,559 | 4.4 |
| **Alberta** | 63,180 | 3,338 | 0 | 0 | 66,518 | 10.1 |
| **British Columbia** | 7,483 | 59,372 | 0 | 2,337 | 69,192 | 7.3 |
| **Yukon** | 40,422 | 9,030 | 0 | 0 | 49,452 | 10.2 |
| **Northwest Territories** | 344,820 | 345,702 | 11 | 65,786 | 756,319 | 7.1 |
| **Total for Canada** | 477,263 | 686,863 | 22 | 105,108 | 1,269,256 | 79.4 |

Source: Environment Canada 1996c: record 4722.

**Table 4.2 Total Agricultural Land in Canada by Province, 1976–1996, in millions of hectares**

| | 1976 | 1996 | % change |
|---|---|---|---|
| Newfoundland | 0.03 | 0.04 | 35.3 |
| Prince Edward Island | 0.30 | 0.27 | −10.4 |
| Nova Scotia | 0.49 | 0.43 | −13.4 |
| New Brunswick | 0.47 | 0.39 | −17.3 |
| Quebec | 4.01 | 3.46 | −13.8 |
| Ontario | 6.26 | 5.62 | −10.3 |
| Manitoba | 7.70 | 7.73 | 0.4 |
| Saskatchewan | 26.51 | 26.57 | 0.2 |
| Alberta | 20.21 | 21.03 | 4.1 |
| British Columbia | 2.45 | 2.53 | 3.3 |
| Total | 68.43 | 68.06 | −0.5 |

Source: Statistics Canada 1997: 70.

**Table 4.3 Distribution of Canadian Wetlands (by province, from largest to smallest area of wetlands)**

| | Thousands of hectares | % of Canadian wetlands | % of province or territory |
|---|---|---|---|
| Ontario | 29,000 | 23.0 | 33 |
| Northwest Territories | 27,800 | 22.0 | 9 |
| Manitoba | 22,500 | 18.0 | 41 |
| Alberta | 13,700 | 11.0 | 21 |
| Quebec | 12,200 | 10.0 | 9 |
| Saskatchewan | 9,700 | 8.0 | 17 |
| Newfoundland | 6,800 | 5.0 | 18 |
| British Columbia | 3,100 | 3.0 | 3 |
| Yukon | 1,500 | 1.0 | 13 |
| New Brunswick | 540 | 0.4 | 8 |
| Nova Scotia | 180 | 0.1 | 3 |
| Prince Edward Island | 9 | 0.007 | 1 |

Source: Twolan-Strutt 1995: 4.

# 5 Natural Resources

## Fresh Water

Fresh water is an important resource. It is used for drinking, irrigation, and diluting waste. It supports recreation, tourism, transportation, and fish and wildlife. It is a critical input into many industrial processes, including manufacturing, mineral extraction and the generation of thermal power. Water also has aesthetic value.

Canada is a nation rich in water. Including water captured in glaciers and the polar ice-caps, Canada's watersheds contain about 9 percent of the world's renewable water resources and 20 percent of the world's total freshwater resources (Foreign Affairs and International Trade 1999: 2). Sixty percent of Canada's water resources drain north to the Arctic Ocean, leaving roughly 40 percent readily available to most of Canada's population, which lives within 300 km of the southern border (Statistics Canada 1998: 12).

Despite the abundance of fresh water in Canada, there are concerns about the availability of water because of a number of regional shortages. In 1994, approximately 17 percent of municipalities with water systems reported water shortages. Reasons for these shortages ranged from drought to inadequate storage capacity and distribution systems (Environment Canada 1998d).

Concern about water management has also arisen because of the number of proposals for water diversions and bulk removals. These proposals include projects to transfer water both within Canada and to the United States. Currently, the provinces have the primary responsibility for water management. However, in 1999 a federal strategy was launched that proposed to amend the *International Boundary Waters Treaty Act* to give the federal government regulatory power to prohibit bulk removals, particularly from the Great Lakes. It also proposed to develop, in partnership with the provinces and territories, a "Canada-wide accord on bulk water removals to protect watersheds" (Foreign Affairs and International Trade 1999: 1).

There is also concern in Canada about the amount of water used since much use is perceived as wasteful. Canada's per-capita demands on water resources are the second highest in the world, about 326 litres per person per day (Environment Canada 1998d). Less than 3 percent of municipally treated water used in households is used for drinking (Environment Canada 1999a); 65 percent is used in bathrooms and, during the summer, approximately three-quarters of the treated water used domestically is sprayed onto lawns (Environment Canada 1996c: record 16441). Outside of households, rates of recirculation of industrial water used are low and low investment into municipal delivery and treatment systems has led to 14 percent of municipal water being lost through leaks in pipes (Environment Canada 1999a).

To promote water conservation, Environment Canada recommends in its *State of the Environment Report* that "we should pay a fair price that will recover the full cost of water delivered to the tap, one that is based on actual quantity used" (Environment Canada 1996c: record 16430). In Canada, the government subsidizes much of the cost of water use; charges for irrigation water only recover about 10 percent of the actual cost of the services, and municipalities pay up to 65 percent of residential costs (Environment Canada 1996c: record 16420; Palda 1998: 62). Some municipalities charge a flat rate for the use of water. As a result, consumers make decisions on how much water to use without considering the true cost.

Studies show that when people are required to pay the full cost of the water they use, there are significant improvements in water conservation. Economists Julie Hewitt and Michael Hanemann conducted a study in Denton, Texas and found that demand for water in the summer fell 16 percent for every 10 percent increase in price, holding all other factors constant (Palda 1998: 63). Similarly, in 1994, Canadian households paying for water by volume used 39 percent less than households paying a flat rate (Environment Canada 1998d: 4).

Changing water prices to reflect the true cost would finance the repairs that are needed in the municipal water and sewage systems. One study by Environment Canada estimates that the cost of repairing neglected municipal systems is between $7 and $10 billion

(Environment Canada 1996c: record 16429). If 1994 water prices were to double to 172 cents per 1000 litres, in five years this price increase would provide enough income to fix all the leaky municipal water pipes. Considering that between 14 to 30 percent of treated water is lost through leaky pipes, these repairs would address some of the regional shortages (Environment Canada 1996c: record 16431). To put this increase in price in perspective, consider the high demand for bottled water at an average cost of $1500 for 1000 litres (Environment Canada 1996c: record 16432).

To evaluate trends in the use of fresh water, this report considers water use by sector from 1972 to 1991. Water use can be measured by two different indicators: (1) total water withdrawals, which are the total amount of water extracted and (2) total water consumption, which is the amount of water withdrawn that is not returned to a body of water after use. This section examines data for both indicators.

### Trends for fresh water

Between 1972 and 1991, total water withdrawals in Canada increased by 87.4 percent (figure 5.1). The greatest increase during this period was in thermal power generation, where water withdrawals increased by 204.2 percent, from 9.8 billion cubic metres to 28.4 billion cubic metres. The second highest increase during this period was in municipal water withdrawals, which increased from 3.2 billion cubic meters to 5.1 billion cubic metres, a 61.6 percent increase. Agricultural use increased by 39.8 percent to 4.0 billion cubic metres.

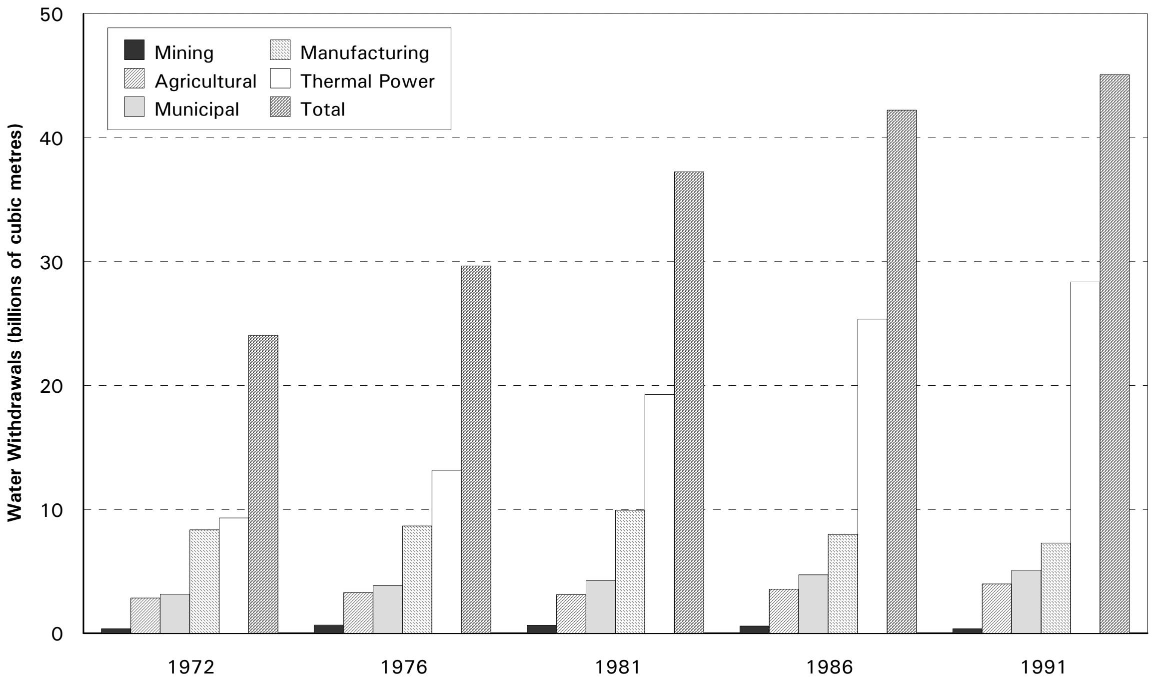
Figure 5.1 also shows that thermal power generation withdraws the most freshwater resources in Canada, accounting for 63 percent of total withdrawals in 1991. Other industrial sources, such as manufacturing, agriculture, and mining accounted for 16 percent, 8.9 percent, and 0.8 percent of withdrawals, respectively. The remaining 11 percent of total water withdrawals were for municipal water use.

It is important to note that in some sectors water withdrawals decreased during the same period. Water withdrawals in manufacturing decreased by 12.8 percent. This decrease is due, in part, to the more efficient use of water through technical advancement and recycling efforts. An example of such initiatives is a steel plant located in Quebec that was able to reduce total volume of water used by 36 percent through water recirculation (Environment Canada 1998d). This conservation of water not only benefits the environment but also lowers operating costs because of the energy saved by pumping less water.

Even though water withdrawals are increasing, figure 5.2 shows that Canadians withdraw less than 2 percent of their renewable fresh water annually. Of this water withdrawn only a small portion of water is actually consumed. In 1991, Canadians withdrew 45 095 million cubic metres of water but only 1.9 percent of the water used was not returned after use (Statistics Canada 1998d: 62).

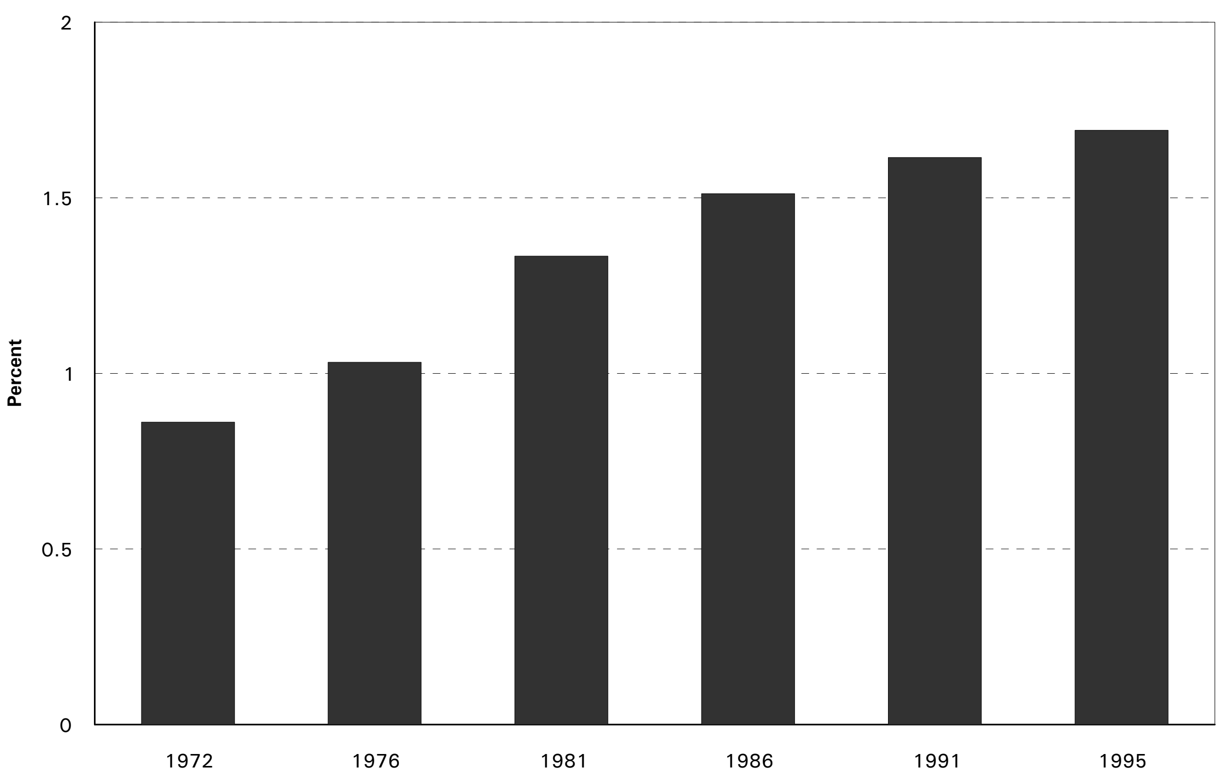
Figure 5.3 shows total water withdrawals in 1991 by region. Ontario is the major user, accounting for 63.2 percent of withdrawals. This high usage is a result of the large population, the heavy reliance on thermal power generation and the proximity to the Great Lakes, Canada's largest source of surface fresh water. Total water consumption, however, is greatest in the Prairie provinces at 67.6 percent, largely because agricultural withdrawals account for 48.4 percent of the regional total (figure 5.4). Whereas only as little as 23 percent of water withdrawn can be recycled in agricultural uses, thermal generation returns more than 99 percent of the water withdrawn to the source (Statistics Canada 1989: 1–7).

**Figure 5.1 Total Fresh Water Withdrawals in Canada, 1972–1991**



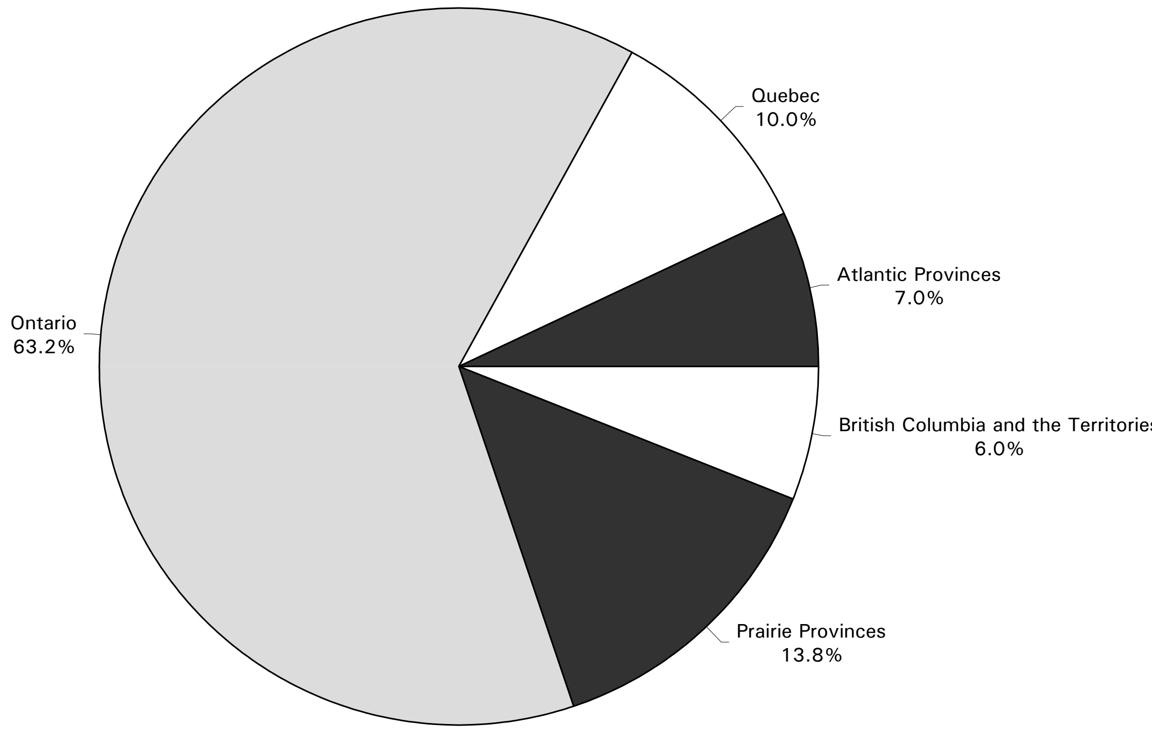

Source: Statistics Canada 1998: 62; Supply & Services Canada 1985: 16–18.

**Figure 5.2 Withdrawals as a Percentage of Renewable Fresh Water Resources**



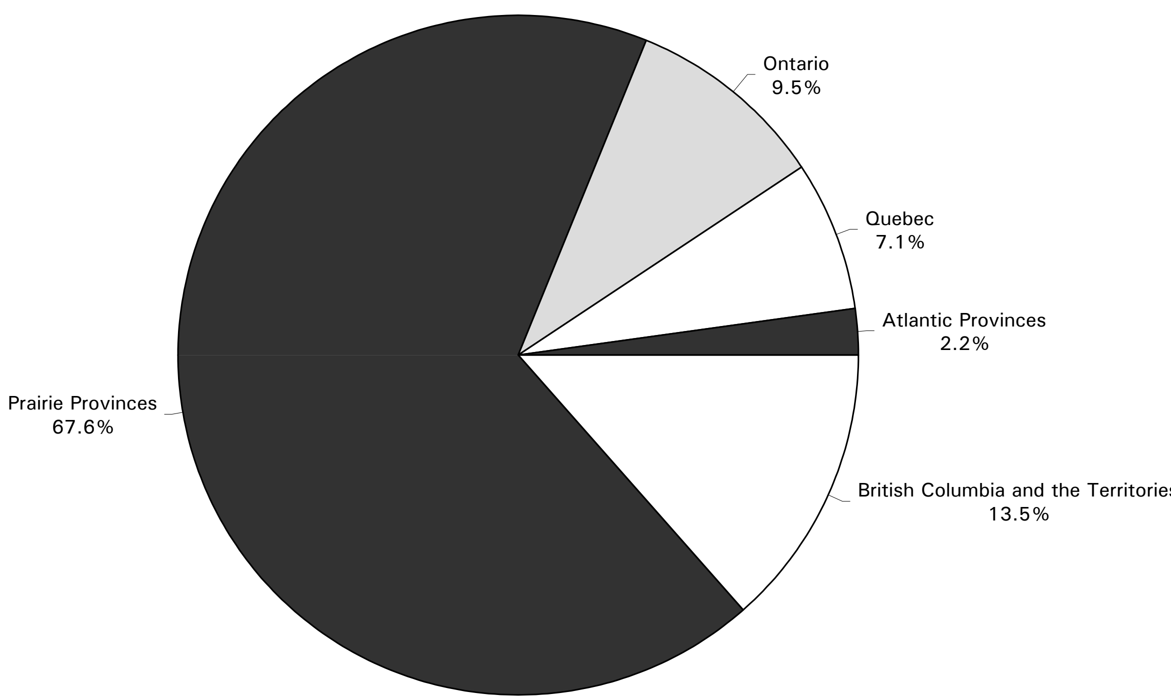

Sources: estimate of renewable fresh water resources from OECD 1999: 72; total withdrawal data from Statistics Canada 1998: 62; OECD 1999: 72; Supply & Services Canada 1985: 16–18.

**Figure 5.3 Total Water Withdrawals by Region, 1991**




Source: Statistics Canada 1998: 62.

**Figure 5.4 Total Water Consumption by Region, 1991**




Source: Statistics Canada 1998: 62.

## Forests

Canadian forests cover 45 percent of the nation's landmass and account for 10 percent of the world's forested area (CFS 1998: 6; Environment Canada 1996c: record 9879). There are eight forest regions in Canada, ranging from the Boreal Forest Region, which stretches from British Columbia to New Brunswick, to the small deciduous forest region located just north of Lake Erie and Lake Ontario. Of Canada's forests, 67 percent are softwoods, 15 percent are hardwoods, and 18 percent are mixedwoods (CFS 1998: 22). Canadian forests contain an estimated 180 species of trees (CCFM 1997: 1).

Canada's forests have many important ecological functions. Forests serve as an important carbon sink, absorbing carbon dioxide from the air and releasing oxygen. They improve soil quality by preventing or slowing erosion and sheltering non-forested land. Forests also provide diverse habitats for an estimated 93,333 species of plants, animals, and micro-organisms (CCFM 1997: 1).

In addition to their ecological value, forests play an important role in Canada's economy. Canada's forest industry is the world's largest exporter of wood and paper products, contributing 31.7 billion to the country's net balance of trade in 1997 (CFS 1998: 4). The forestry industry also provided employment to over 365,000 Canadians directly and to 465,000 indirectly in 1997 (CFS 1998: 22).

In Canada, the government owns the majority of the forested land: 71 percent of forests are owned by the provincial governments, 23 percent are under federal jurisdiction, and 6 percent are managed privately by an estimated 425,000 landowners (CFS 1998: 5). As illustrated in table 5.1 there is variance amongst provinces in the percentage of forests that are privately owned. There is a higher percentage of privately owned forests in the Maritime provinces, largely because of patterns of colonization: whereas early settlers coming to the east coast were given large areas of land as an incentive to come to Canada, the Crown retained ownership of most forested land in areas settled later (CFS 1998: 41).

Not only do the provinces own most of Canada's forested land, under the Canadian Constitution they are also responsible for forest management. This responsibility includes determining and monitoring harvesting levels and practices in Canada as well as ensuring regeneration. To fulfil this responsibility, each province allocates to business operators permits or specific rights to harvest timber on Crown land. These licenses are typically for periods of 15 years to 25 years and carry with them the responsibility of ensuring successful regeneration. In addition to meeting standards set out in the licence, licensees are encouraged to meet the national standards for Sustainable Forest Management that were developed in 1996 by the Canada Standards Association. Compliance with these standards is voluntary (Armson 1999: 25–26).

To allocate harvesting permits the government determines acceptable harvesting levels for specified areas by the allowable annual cut (AAC). The AAC calculation is not a measure of total new growth but rather a measure of growth available for commercial harvesting. It is calculated by considering the quantity and quality of species, the accessibility of the trees, growth rates, sensitivity of the site, and potential or existing competing uses.

To evaluate trends in forests, this section examines trends in harvesting, replanting, and regeneration. The preservation of old-growth stands and the practice of clear-cutting are also addressed separately since they remain topical environmental concerns.

### Harvesting, replanting, regeneration

The area of forest harvested in Canada increased by 48.7 percent between 1975 and 1995 (figure 5.5). The largest increase was in Quebec at 164.6 percent. This increase is substantially higher than that of the other two main roundwood-producing provinces, British Columbia and Ontario, where the area harvested increased by 20.8 percent and 7.6 percent, respectively.[32] In the Prairie provinces, the area harvested increased by 60.0 percent (Manitoba 18.1 percent; Saskatchewan 25.2 percent; and Alberta 107.1 percent). In the Maritime provinces, the area harvested increased by 23.0 percent (Newfoundland 25.7 percent; Prince Edward Island 95.7 percent; Nova Scotia 83.3 percent, New Brunswick 3.8 percent).

Figure 5.5 also shows the location of the areas harvested. In 1995, 35.3 percent of the total area harvested was located in Quebec, 20.9 percent was in Ontario, 18.7 percent was in British Columbia and 8.0 percent and 7.2 percent was in the Prairie and Maritime provinces.

Although harvest areas are increasing, only a small portion of Canada's forest resources is harvested each year (figure 5.6). Of Canada's 418 million hectares of forestland, 56 percent (234.5 million hectares) are classified as commercially viable forests. However, of these 234.5 million hectares only 28 percent (119 million hectares) are being managed for timber purposes. Only 1 million hectares were actually harvested in 1997. This is 0.4 percent of commercial forests and less than 0.2 percent of total forests—less than the amount of forest lost annually to natural events: approximately 0.5 percent of Canada's total forests are lost to outbreaks of fire or infestation by insects each year (CFS 1998: 5).

Harvest levels have also remained within the defined sustainable limits. Figure 5.7 shows that the national harvest level has remained below the Allowable Annual Cut (AAC) throughout the period from 1970 to 1996. Data for both hardwood and softwood up to 1993 similarly shows that, with the exception of 1989, harvest levels for hardwood and softwood have remained below their respective AACs (Environment Canada 1996c: record 5731).

Most provincial harvest levels are below the AAC as well (table 5.2). The percentage of the AAC that is actually harvested is especially low in Manitoba (22 percent). Nova Scotia is the only province where the harvest level exceeds the AAC. Although it appears that British Columbia has also harvested above its AAC level, the AAC for this province does not include all private lands whereas the harvest level does. Harvest levels in British Columbia have been below the AAC in the past few years.

While harvest levels have been increasing, there has also been an increase in the amount of harvested land that is replanted. Table 5.3 displays the area that is replanted annually as a percentage of the area harvested from 1975 to 1995. During this period, the percentage of harvested land replanted in Canada more than doubled from 18.7 percent to 43.1 percent. In 1995, the percentage of harvested area replanted in British Columbia was 108.9 percent, in Ontario, 30.6 percent, and in Quebec, 21.2 percent. Since 1975, these values have increased by 170 percent, 100 percent and 80 percent, respectively: although harvesting levels are increasing, the area replanted is increasing at a greater rate. In British Columbia and Alberta for some years the percentage of area harvested that is replanted is greater than 100 percent: in these years more areas were replanted than harvested.

Trend data also illustrate that Canadian forests that are harvested are being successfully regenerated. Figure 5.8 shows the forest-regeneration status of harvested land from 1975 to 1995. The data is presented cumulatively meaning that each year displays the status of the area harvested that year as well as all previous years back to 1975. For example, the area displayed for 1975 represents the regeneration status of the area harvested during 1975. The area displayed for 1976 shows the regeneration status of the area harvested in both 1975 and 1976 and so on.

The four classes in figure 5.8 are defined by the National Forestry Database Program as follows:

- *Non-production*: Areas such as roads, landings, and non-forestry developments that have no timber-production objective. These areas also include land where erosion, a rising water table, or other forms of site degradation make a site unsuitable for forestry purposes.
- *Understocked*: Disturbed forest land that will require silvicultural treatment to meet stocking standards.
- *Stocked*: Disturbed forest land that has regenerated naturally or through planting and seeding. This class includes some recently disturbed areas that are expected to regenerate within an acceptable time without further silvicultural treatment.
- *Enhanced*: Stocked areas that meet density control standards. These are areas in which the required number of trees per hectare is distributed evenly over the regenerated are for optimal growth. (CCFM 1996: 5–6)

With the exception of the non-production class, these categories are progressive. An understocked area that is replanted properly should eventually reach stocked status. A stocked area will become enhanced as the trees grow and density-control objectives are met. Although data on fully regenerated areas are not displayed on the graph, it is expected that all areas classified as stocked or enhanced will fully regenerate naturally.

As illustrated in figure 5.8 , the area of harvested land that is understocked is no longer increasing. Instead, it peaked at the 1992 level of 2.4 million hectares and has levelled off since. This illustrates that even though harvesting levels are increasing, more land is being properly regenerated. The Canadian Council of Forest Ministers attributes this decrease in understocked land in proportion to the total amount harvested to expanding silviculture programs (CCFM 1996: 13). It is important to note that, although 20 percent of the cumulative area harvested was classified as understocked in 1995, most of this land is reported as understocked because of a time lag between treatments and observable results.

### Old-growth forests

An old-growth forest is defined broadly as "a forest dominated by mature trees that has not been significantly influenced by human activity" (CCFM 1997: 124). Under this definition, old-growth forests could have one or more of the following characteristics: very large trees, very old trees, a distinct species composition, a multilayered canopy, a large accumulation of organic matter (Kimmins

1997: 144–46). The old-growth stage may be reached at different ages depending on the location of the site and the species of the trees.

Old-growth forests have considerable environmental and commercial value. Public interest in the conservation of old-growth forests focuses on the ecosystem as a whole: these forests contain a reservoir of gene diversity, provide habitat for diverse wildlife, and have recreational and aesthetic value. Foresters appreciate old-growth forests as a source of high-value timber. Approximately 90 percent of all territory logged in Canada is virgin forest, which usually has a higher volume of wood than the younger forests that will replace them (Environment Canada 1995a). Not all these virgin forests are old-growth forests, however, as natural disturbances such as fire and insects will alter forests untouched by humans.

The controversy over old-growth forests arises because these environmental and commercial uses are mutually exclusive. Even though rapid tree growth can produce large trees in some climates in 100 to 150 years (Kimmins 1997: 148), today's commercial cutting cycle of 50 to 80 years means that once harvested, old-growth ecosystems will not be re-established. As a result, while only 25 percent of professional foresters agreed with the statement that "most old growth forests should be protected," 86 percent of the public supported the view (CFS 1992: 41).

It is difficult to measure trends in old-growth forests since there is no comprehensive national inventory of Canada's old-growth forests and the definition for such forests remains vague. Data from the national forest inventory, however, do provide an inventory for commercial forests. These data suggest that there has been a decrease in the amount of old-growth forest. It reports that between 1981 and 1995 the total amount of mature, old or mixed-age forest fell from 103.87 million hectares to 102.23 million hectares, a difference of 1.64 million hectares. This decrease is quite small, however, as in 1981 44.29 percent of commercial forests were in the category of mature, old, or mixed-aged forests whereas the 1995 the level was only slightly lower at 43.59 percent (CFS 1998: 37).

A recent inventory of old-growth forests in British Columbia found that there is still a large amount of old-growth forest in the province.[33] Old-growth forest covers 26.8 percent of the province, younger forest covers 36.1 percent, and 37.1 percent is unforested. Over seven percent of British Columbia is covered with forests older than 250 years. Many of these forests are over 400 years old, especially in the wetter areas along the coast and interior wet-belt. Old-growth forests represent 50 percent of spruce strands, 62 percent of hemlock stands, 87 percent of coastal stands of red cedar and 63 percent of interior stands of red cedar. Of these old growth forests, 13 percent, or 3.2 million hectares, is estimated to be in protected areas[34] (MacKinnon & Vold 1998: 310–14).

Although these data provide a glimpse of old-growth forests, more complete data are needed to examine the state of old-growth forests in Canada. Discussions on the total amount of old-growth forest are often meaningless since some of the ecological values attributed to old-growth forests are dependent upon not only the amount of old-growth forest but also the size and shape of the remaining patches (MacKinnon & Vold 1998: 310). Data on the location of old-growth forests are necessary as well. The report for British Columbia predicts that, even if the total amount of old-growth forest remains constant, there will be a redistribution of these forests; there will be more old-growth forests at higher elevations because of fire suppression and fewer in lower elevations due to harvesting. For a national overview, data on old-growth forests in other jurisdictions is also necessary.[35]

### Clear-cutting

Clear-cutting is the silvicultural practice of completely clearing an area of all trees other than seedlings and occasional saplings. It is the most popular method of harvesting since it has many benefits. First, it is often more economically viable. Not only is clear-cutting less expensive than more selective harvesting practices but it also reduces reforestation costs since it facilitates site preparation and weed control. Second, in converting an unmanaged forest to a managed forest, clear-cutting is safer for forest workers than other harvesting methods since there is a lower risk of injury or death. Finally, clear-cutting is sometimes a better environmental practice since it is more compatible with cable systems that reduce the number of roads used to gain access to the area (Kimmins 1997: 80–82).

Despite these benefits, clear-cutting remains a contentious issue because of its misapplication in sensitive ecosystems. Clear-cutting, by definition, involves the removal of the forest in a particular area. This means that as new vegetation replaces the harvested trees there is a change in the plant species growing in the area. This, in turn, could negatively affect the level of nutrients and micro-organisms in the soil and the wildlife that lives in the areas. When clear-cutting is not performed properly, it can also damage watersheds and the ecosystems of rivers since the exposed land has a higher risk of soil erosion. Many people also oppose clear-cuts since they are not aesthetically pleasing.

In Canada, almost 90 percent of trees logged over the past two decades have been harvested by clear-cutting. The size of these clear-cut areas, however, has decreased over the past decade. A study conducted by the Canadian Pulp and Paper Association (CPPA) in 1990 found that the average clear-cut sizes in Ontario, Quebec, and British Columbia were 110 ha, 69 ha, and 49 ha, respectively, with 8 percent of Quebec's clear-cuts larger than 200 ha. In contrast, recent provincial legislation in Quebec reduced the limit for clear-cut sizes from 250 ha throughout the province to 150 ha within boreal forest, 100 ha in mixed-wood forests and 50 ha in southern deciduous forest. Similarly, in British Columbia clear-cuts have been limited to 60 ha in the northern part of the province and 40 ha in the southern part. Provided that these smaller sizes do not increase fragmentation of the forests, the smaller size should assist in minimizing some of the negative effects of clear-cutting (Environment Canada 1996c: record 5734).

**Table 5.1 Ownership of Canada's Forests (millions of hectares)**

| | Total Forest Area | Federal (%) | Provincial (%) | Private (%) |
|---|---|---|---|---|
| **Newfoundland** | 22.5 | 0 | 99 | 1 |
| **Prince Edward Island** | 0.29 | 1 | 7 | 92 |
| **Nova Scotia** | 3.9 | 3 | 28 | 69 |
| **New Brunswick** | 6.1 | 1 | 48 | 51 |
| **Quebec** | 83.9 | 0 | 89 | 11 |
| **Ontario** | 58 | 1 | 88 | 11 |
| **Manitoba** | 26.3 | 1 | 94 | 5 |
| **Saskatchewan** | 28.8 | 2 | 97 | 1 |
| **Alberta** | 38.2 | 9 | 87 | 4 |
| **British Columbia** | 60.6 | 1 | 95 | 4 |
| **Yukon** | 27.5 | 100 | 0 | 0 |
| **Northwest Territories** | 61.4 | 100 | 0 | 0 |
| **Canada** | 417.6 | 23 | 71 | 6 |

Source: CFS 1998: 22–28.

**Table 5.2 Provincial and Territorial Harvest Levels and AAC, 1996 (million cubic metres, except Ontario in millions of hectares)**

| | Harvest Level | Annual Allowable Cut | % of AAC harvested |
|---|---|---|---|
| **Newfoundland** | 2.1 | 2.6 | 80.8% |
| **Prince Edward Island** | 0.4 | 0.5 | 80.0% |
| **Nova Scotia** | 5.6 | 5.3 | 105.7% |
| **New Brunswick** | 10.8 | 11.2 | 96.4% |
| **Quebec** | 35.9 | 58 | 61.9% |
| **Ontario** | 0.212 | 0.4 | 53.0% |
| **Manitoba** | 2.1 | 9.7 | 21.6% |
| **Saskatchewan** | 4 | 7.6 | 52.6% |
| **Alberta** | 20 | 24 | 83.3% |
| **British Columbia** | 72.1 | 71.6 | 100.7% |
| **Yukon** | 0.38 | 0.5 | 76.0% |
| **Northwest Territories** | 0.18 | 0.24 | 75.0% |

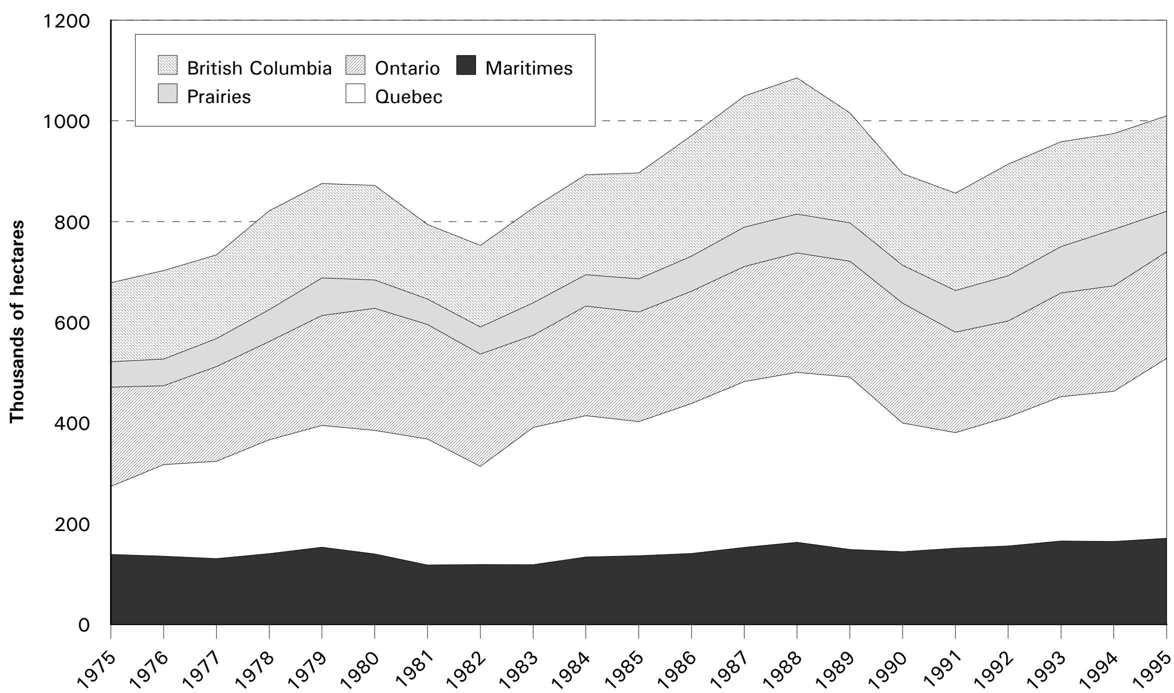
Source: CFS 1998: 22–28.

**Table 5.3 Percentage Replanted of Area Harvested Annually**

| | Canada | NF | PE | NS | NB | QC | ON | MB | SK | AB | BC | YT | NT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1975** | 18.7 | 0.0 | 5.5 | 5.2 | 7.1 | 11.8 | 15.3 | 12.6 | 20.9 | 23.4 | 40.2 | 0.0 | 0.0 |
| **1976** | 17.1 | 0.0 | 7.5 | 4.7 | 8.7 | 8.4 | 16.7 | 6.2 | 20.7 | 25.2 | 34.2 | 0.0 | 0.0 |
| **1977** | 16.5 | 0.0 | 7.5 | 8.2 | 11.1 | 8.6 | 14.1 | 4.6 | 27.8 | 25.6 | 33.6 | 0.0 | 0.0 |
| **1978** | 15.6 | 0.0 | 5.9 | 10.2 | 12.0 | 6.2 | 14.1 | 6.1 | 27.0 | 32.3 | 29.6 | 0.0 | 0.0 |
| **1979** | 16.3 | 1.0 | 4.7 | 7.9 | 15.7 | 5.8 | 14.1 | 2.3 | 27.9 | 33.5 | 34.0 | 0.0 | 0.0 |
| **1980** | 16.8 | 2.4 | 22.7 | 10.2 | 25.7 | 5.6 | 13.3 | 4.9 | 34.2 | 14.7 | 33.9 | 0.0 | 0.0 |
| **1981** | 20.3 | 13.8 | 17.3 | 13.9 | 33.8 | 6.4 | 16.8 | 15.6 | 22.0 | 26.9 | 45.0 | 0.0 | 0.0 |
| **1982** | 23.8 | 10.0 | 13.8 | 12.1 | 31.0 | 8.8 | 17.1 | 21.1 | 38.2 | 19.4 | 51.1 | 0.0 | 0.0 |
| **1983** | 25.6 | 13.2 | 23.2 | 19.4 | 24.5 | 9.5 | 26.6 | 18.2 | 32.4 | 21.6 | 50.3 | 0.0 | 0.0 |
| **1984** | 26.9 | 13.8 | 18.9 | 16.1 | 23.4 | 10.4 | 29.1 | 16.3 | 22.2 | 47.1 | 50.4 | 0.0 | 0.0 |
| **1985** | 29.1 | 16.8 | 16.6 | 22.1 | 22.3 | 14.7 | 33.3 | 37.0 | 26.8 | 26.7 | 48.2 | 0.0 | 0.0 |
| **1986** | 31.8 | 4.6 | 36.7 | 26.8 | 23.6 | 21.7 | 33.0 | 37.3 | 23.2 | 37.9 | 48.2 | 0.0 | 0.0 |
| **1987** | 37.4 | 25.3 | 40.1 | 23.4 | 21.3 | 28.0 | 32.9 | 46.1 | 12.1 | 33.0 | 65.0 | 0.0 | 0.0 |
| **1988** | 38.9 | 22.8 | 39.4 | 28.1 | 19.3 | 29.6 | 35.3 | 56.8 | 31.8 | 43.9 | 62.7 | 0.0 | 0.0 |
| **1989** | 42.6 | 17.4 | 30.7 | 26.6 | 22.5 | 30.1 | 37.0 | 54.8 | 26.9 | 58.2 | 79.8 | 0.0 | 0.0 |
| **1990** | 53.2 | 16.1 | 33.2 | 28.2 | 27.6 | 43.4 | 33.9 | 60.7 | 32.4 | 54.3 | 115.2 | NA | 24.6 |
| **1991** | 54.6 | 15.2 | 45.5 | 21.5 | 21.2 | 45.2 | 42.0 | 94.4 | 37.4 | 61.3 | 103.0 | NA | 8.8 |
| **1992** | 47.6 | 18.4 | 42.8 | 21.5 | 16.6 | 37.9 | 37.7 | 62.6 | 34.7 | 66.6 | 83.4 | NA | 13.6 |
| **1993** | 43.9 | 13.2 | 39.0 | 12.0 | 13.4 | 29.5 | 35.8 | 51.4 | 34.0 | 61.3 | 91.5 | 27.4 | 11.6 |
| **1994** | 46.5 | 15.5 | 22.7 | 13.1 | 16.6 | 24.4 | 35.1 | 53.5 | 29.2 | 68.3 | 114.0 | 20.3 | 15.9 |
| **1995** | 43.1 | 17.5 | 26.7 | 14.4 | 16.5 | 21.2 | 30.6 | 40.2 | 34.5 | 107.6 | 108.9 | 74.3 | 16.2 |

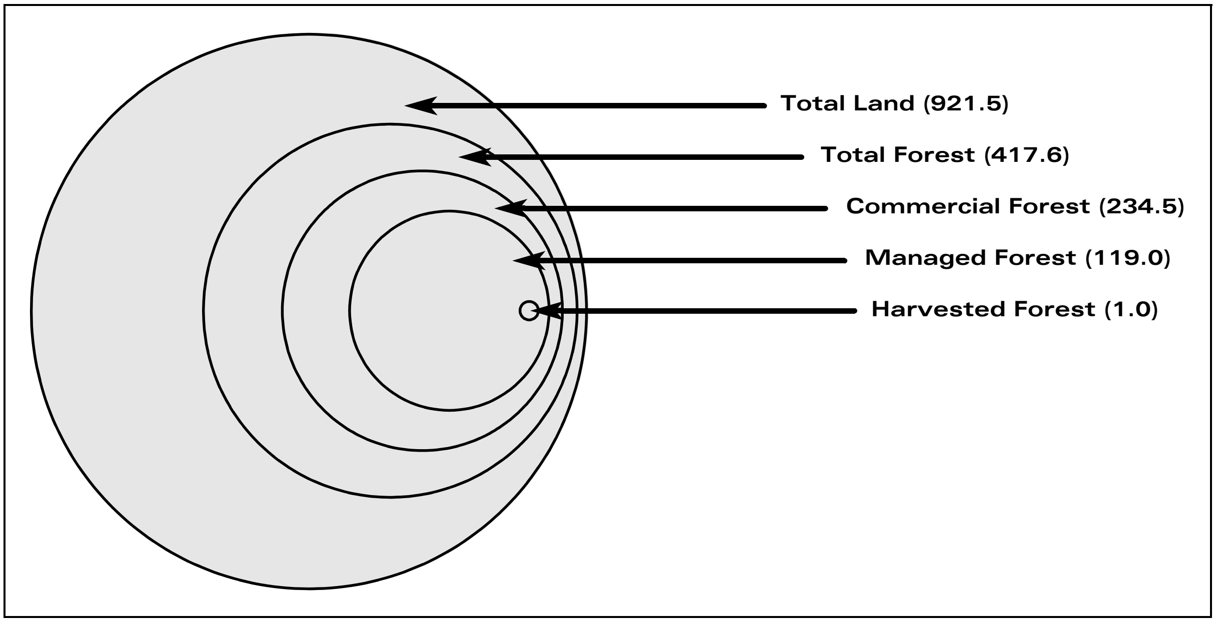
Source: Statistics Canada 1999a: databank numbers F3314, F3344, F3350, F3356, F3362, F3368, F3374, F3380, F3386, F3320, F3326, F3332, F3338; Statistics Canada 1999b: databank numbers F3483, F3583, F3603, F3623, F3643, F3663, F3683, F3703, F3723, F3503, F3523, F3543, F3563.

**Figure 5.5 Total Area Harvested, 1975–1995**



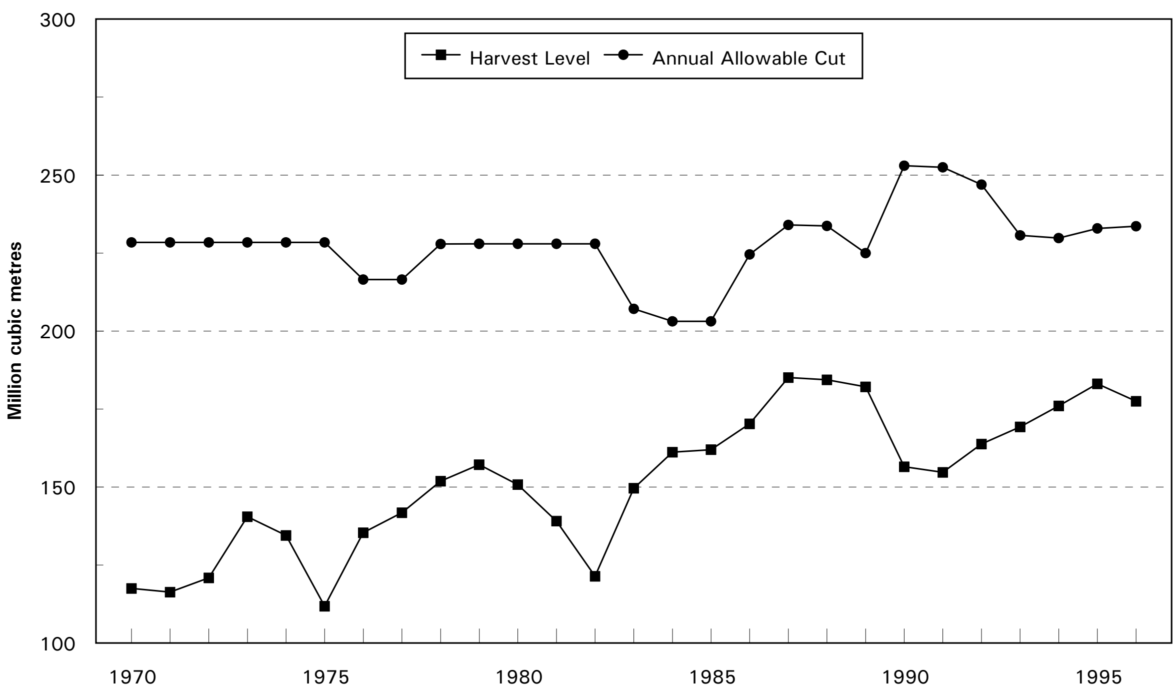

Source: Statistics Canada 1999a: databank numbers F3314, F3344, F3350, F3356, F3362, F3368, F3374, F3380, F3386, F3320, F3326, F3332, F3338.

**Figure 5.6 Canada's Forests (millions of hectares)**



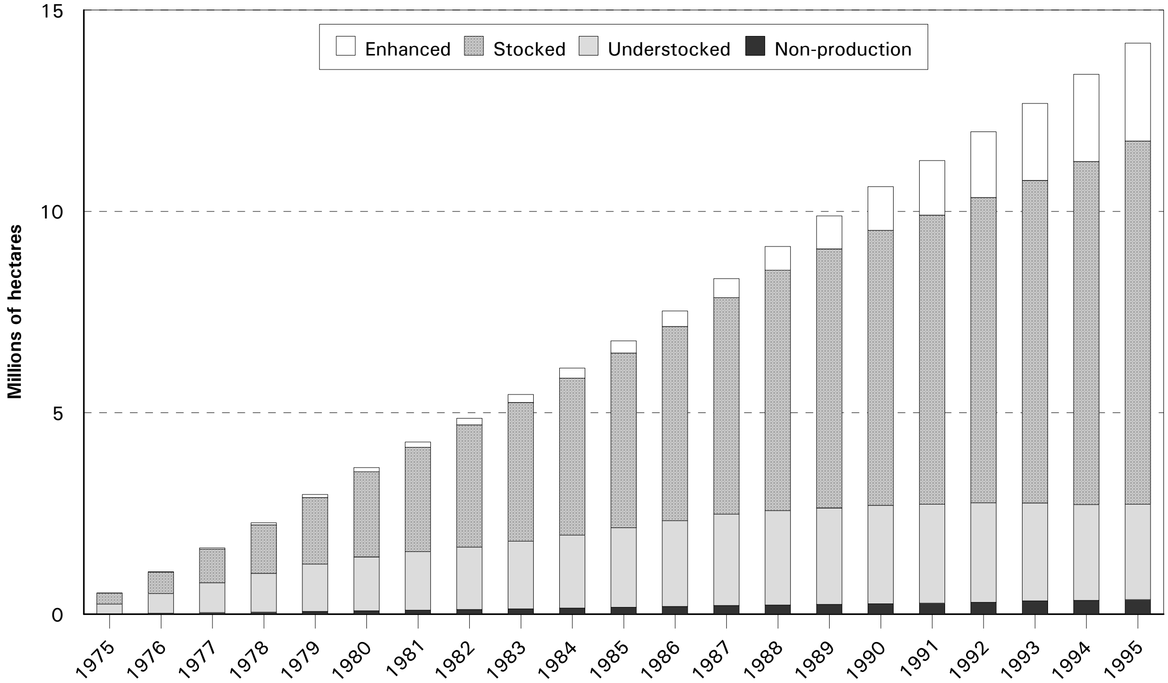

Source: Adapted from CFS 1998: 6.

**Figure 5.7 Annual Harvest and Annual Allowable Cut in Canada**




Source: data from 1970 to 1995 from Environment Canada 1997d; data from 1996 from Canadian Forest Service 1998. Notes 1: Ontario measures its AAC in hectares, whereas all other provinces and territories measure AAC in cubic metres. Note 2: British Columbia does not include all private lands in its AAC. Saskatchewan, Alberta and Ontario do not include any private lands. Note 3: Harvesting data only considers data for industrial roundwood even though the harvest level for fuel-wood or firewood for a single province may range as high as 2.2 million cubic metres. Note 4: Harvesting levels on federal lands are not included.

**Figure 5.8 Cumulative Forest Regeneration Status at One-Year Intervals, 1975–1995**




Source: Haddon 1999; calculations by authors.
Note: national data was obtained by summing up provincial data. With the exception of Alberta and British Columbia, these numbers are based on estimates; only Alberta and British Columbia complete a comprehensive survey of cut-blocks. Data for the Northwest Territories is not included; however, the total harvested area since 1975 for the Northwest Territories is less than 5000 hectares.

## Energy

Canada has large reserves of important energy resources such as petroleum, natural gas, coal, and hydroelectric potential. By drawing on these resources, Canada's energy sector plays an important role in the global energy market. Canada is the world's third largest producer of natural gas and the eleventh largest producer of crude oil (CAPP 1999). Canada's energy sector also contributes substantially to our domestic economy. In 1998, approximately 7 percent of the gross domestic product and 8 percent of total merchandise exports were attributed to the energy industry, which employed about 280,000 Canadians (NEB 1999a: 2).

Canadians not only produce a great deal of energy; they are also amongst the world's most intensive users of energy. Canada ranks as the world's sixth largest user of primary energy (Environment Canada 1997b: 1).[36] Environment Canada lists several reasons for this high use of energy: the cold climate, an energy-intensive industrial base, a large land area, and a widely dispersed population. Canada's energy consumption is also high because of the high standard of living (Environment Canada 1996c: records 6039–40).

In this section, trends for both energy consumption and production are examined. Consumption trends are interesting since they illustrate changes in energy use and efficiency over time. Production trends address concerns about Canada running out of energy reserves.

### Trends in energy consumption

Figure 5.9 illustrates total domestic energy consumption by end use.[37] During this period, energy consumption increased by 89.3 percent; generation of electricity at 180.7 percent showed the most significant increase. Residential use increased by 33.9 percent, commercial use, by 49.0 percent, and industrial use, by 58.9 percent. Energy consumption per capita has also increased by 37.7 percent over the past two decades (figure 5.10).

In 1997, the largest uses of primary energy in Canada were for the production of electricity (25.6 percent) and industrial purposes (22.4 percent). Over 16 percent went to transportation, 12.3 percent was used residentially, and 7.6 percent was used by the commercial sector. The remaining 15.6 percent was used for non-energy purposes[38] or was lost or consumed by energy producers during extraction or refinement. This distribution has changed from 1971 where industry was the largest user at 26.7 percent and electricity production accounted for only 17.3 percent.

Although both total and per-capita energy consumption have increased in the past two decades, Canadians have become more efficient users of energy. Between 1971 and 1997 energy consumption per dollar of real gross domestic product (GDP) fell steadily (figure 5.11); GDP increased by 119.2 percent whereas energy consumption increased by only 89.3 percent. This decline in energy consumption per capita is likely due to a combination of factors including improvements in energy efficiency and structural changes in the economy away from activities that require the use of more energy. One report studied the decline in energy demand between 1971 and 1988 and attributed 65 percent of the decline to energy efficiency and the remaining 35 percent to structural changes in the economy (Environment Canada 1996c: record 6052).

*Energy Efficiency Trends in Canada 1990–1996*, a report by Canada's Office of Energy Efficiency, similarly illustrates that Canadians are becoming more energy efficient (Natural Resources Canada 1998). This report reviews trends in energy efficiency and energy use for the five key end-use sectors: residential, commercial, industrial, transportation, and agriculture. To evaluate improvements in energy efficiency during this period, it calculates changes in energy intensity, adjusting for weather and the structure of the economy. Changes in energy intensity is a good measure of energy efficiency improvements as it is a calculation of the change in the amount of energy needed to produce a fixed amount of output. An increase in energy intensity is a decrease in efficiency. The findings of the report are displayed in table 5.4.

The greatest improvements in energy intensity were in transportation with freight, which improved 15.4 percent, and passenger transportation, which improved 6.6 percent. This change is due to the introduction of more efficient vehicles and the retirement of older inefficient vehicles. Residential energy intensity decreased 6.3 percent as a result of the introduction of more efficient space heaters and appliances. Commercial energy intensity fell by 3.7 percent, largely due to the improvement in buildings and equipment as well as energy management practices. Industrial energy intensity increased 1.4 percent over this period but there were improvements in some industries. While energy intensity increased in industries like pulp and paper (8.6 percent), mining (20.2 percent), chemicals (13.9 percent), and cement (5.4 percent), it decreased in petroleum refining (8.6 percent), smelting and refining (8.3 percent), iron and steel manufacturing (1.2 percent) and other manufacturing industries (13.4 percent).

### Trends in energy production

During the period from 1971 to 1997, total production of primary energy increased by 115 percent with the largest increases in coal (368 percent) and nuclear (190 percent) (figure 5.12). Natural gas and petroleum, the two largest sources of energy, rose by 172.3 percent and 56.5 percent. Production of renewable energy sources also expanded as hydroelectric generation increased 116 percent and other renewables increased 16 percent.

The sources used to produce energy have changed greatly over the past few decades. Whereas crude oil accounted for 46.0 percent of total energy produced in 1971, it accounted for only 31.3 percent in 1997. During this same period natural-gas production expanded from 30.6 percent to 38.7 percent of total production. Nuclear power increased as a source from 1971 to 1997, though its operations have contracted to less than 2 percent of total energy production during the past few years. Alternative energy sources such as solar and wind power have increased in the past decade but remain small scale, producing only about 1/10 000$^{th}$ of the energy consumed in Canada (Environment Canada 1996c: record 6048).

A large portion of the energy produced is exported. In 1998, exports of crude oil were estimated at 209,900 cubic metres per day, a 34 percent increase from 1994 (NEB 1998: 8). Exports of natural gas totalled 87.4 billion cubic metres in 1998, approximately 55 percent of Canada's total production of natural gas (NEB 1998: 13). These high rates of production and exportation, coupled with the fact that oil and natural gas are non-renewable resources, have led some to predict that Canada will run out of oil and natural gas in the near future. Contrary to these predictions, the total amount of crude oil and natural gas discovered has increased throughout the past two decades (figures 5.13 & 5.14) and additions to established reserves continue to replace a percentage of the amount produced.

Yet, concerns about production levels remain since reserve additions are not fully replacing the amount of natural gas and oil produced. With the exception of 1983 and 1997, annual net production has exceeded annual gross reserve additions of crude oil (CAPP 1998).[39] Similarly, natural gas additions have generally been below production levels since 1985 (CAPP 1998). For oil, this negative net change in reserves can be partially attributed to decreasing oil prices that have encouraged producers to switch from drilling oil wells to drilling for natural gas (NEB 1999c: 1).

While examining figures 5.13 and 5.14, it is important to remember that they display only data on *established* reserves. For crude oil, it has been estimated that an additional 4,615 million cubic metres of crude oil are undiscovered and another 1,031 cubic metres can be extracted from existing reserves because of technological advances (NEB 1999b). As a result, at the end of 1997 Canadians had extracted only 7.2 percent of their total estimated recoverable crude oil and bitumen resources. Similarly, there is a large amount of undiscovered natural gas: it is estimated that Canadians have produced between 14 and 17 percent of their economically recoverable natural-gas resources (NEB 1999c).[40]

In making a decision on the optimal level of energy production, many factors beyond current production levels need to be considered. For example, there will be greater ecological and economic costs as more oil is extracted from oil sands because of decreasing conventional oil reserves. Oil-sands projects not only tend to disturb more land per unit of oil produced than conventional projects but also to produce large amounts of contaminated sludge. The process of extracting oil from the sands is also more energy intensive, requiring approximately 9 to 12 cubic metres of oil sands to produce 1 cubic metre of bitumen (Environment Canada 1996c: record 6128). To be upgraded, this bitumen then needs to be processed.

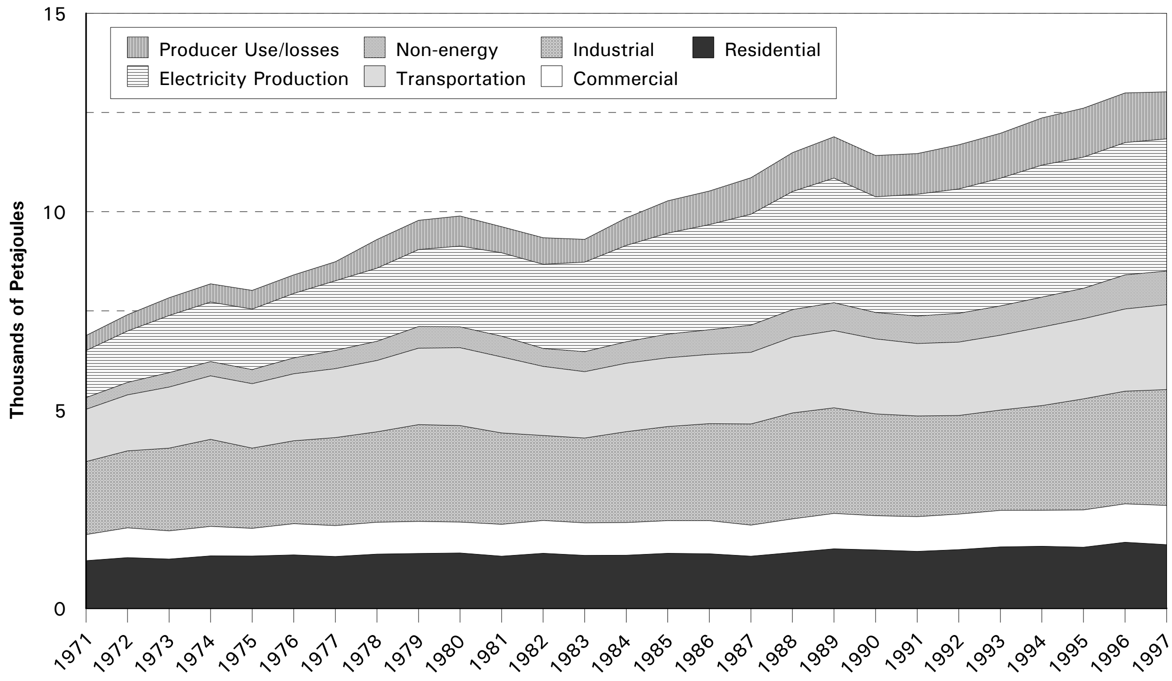
The economic benefits of current production levels must also be considered. In 1997, the "upstream"[41] crude-oil and natural-gas industry employed 83,000 people directly and 130,000 indirectly. With the addition of the "downstream" sector, the industry employed 447,000 Canadians (CAPP 1999). This industry also provides much revenue to the government: in 1997, industry payments to government for royalties, income taxes, and bonus payments totalled $8 billion (CAPP 1999). In reducing production levels these jobs and revenue may be lost.

**Table 5.4 Change in Energy Use and Intensity by Sector, 1990–1996**

| | Percent of secondary use | Change in Energy Use (percent) | Change in Energy Intensity |
|---|---|---|---|
| Residential | 19.0 | 12.3 | −6.3 |
| Commercial | 13.1 | 12.0 | −3.7 |
| Industrial | 38.3 | 11.8 | 1.4 |
| Transportation | 26.6 | 10.2 | |
| Passenger | 17.3 | 9.8 | −6.6 |
| Freight | 9.3 | 11.0 | −15.4 |
| Agriculture | 2.9 | 9.3 | NA |

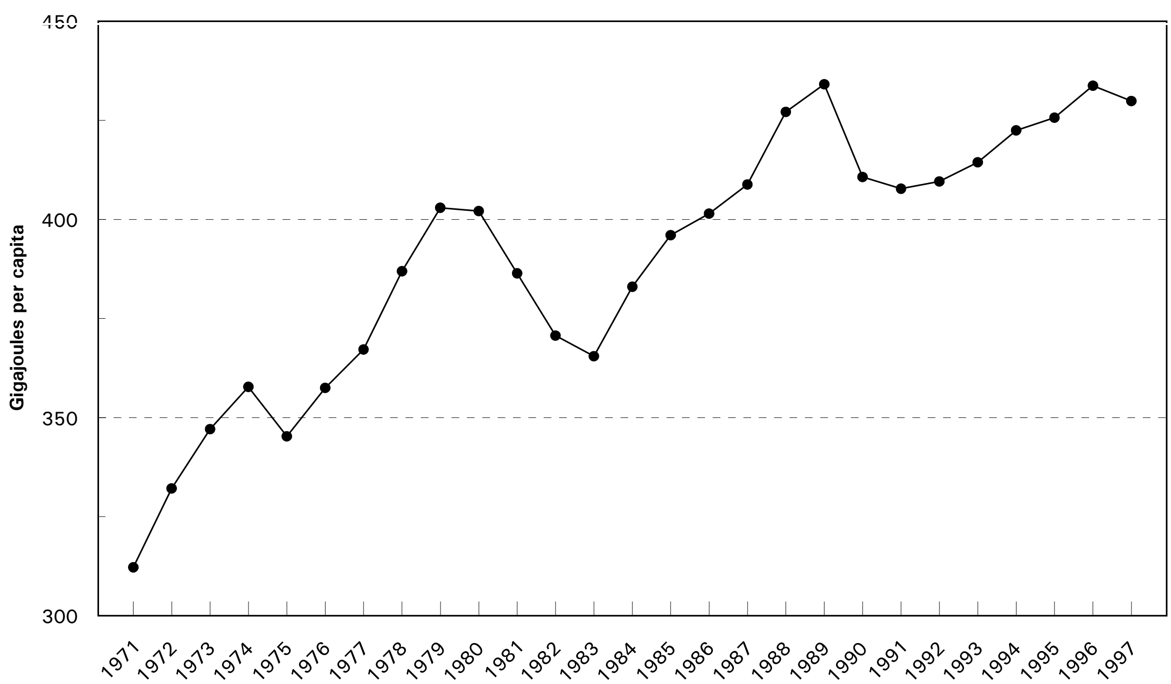
Source: Natural Resources Canada 1998.

**Figure 5.9 Energy Consumption by End-Use Sector, 1971–1997**



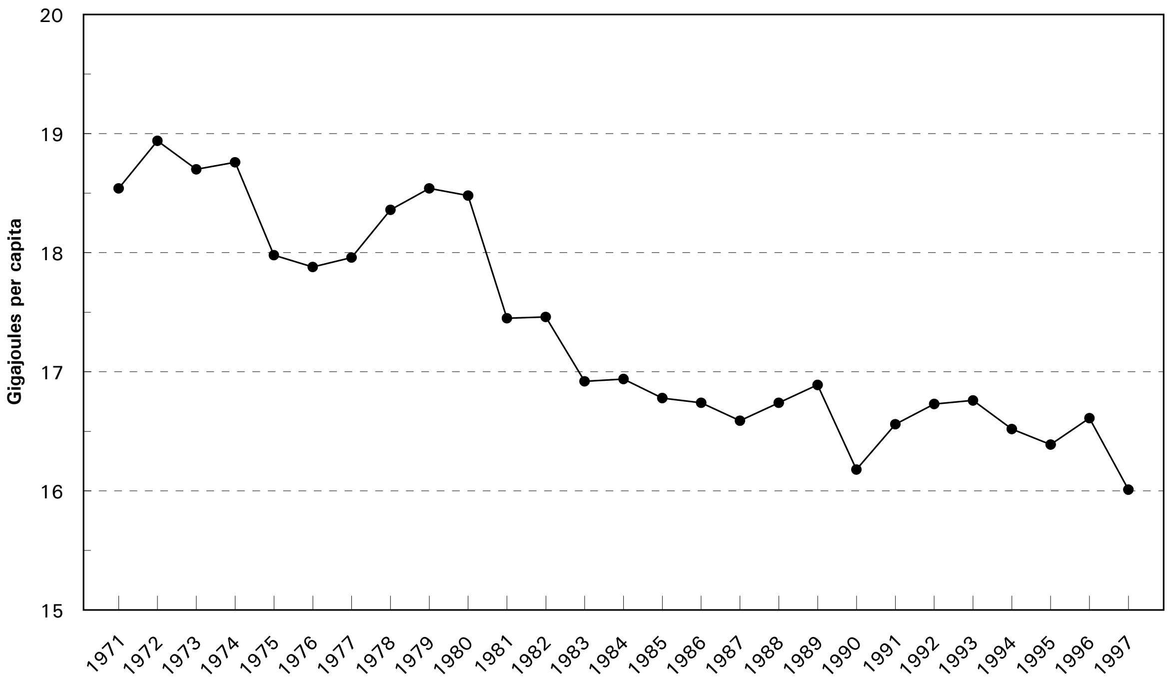

Source: NEB 1999a.

**Figure 5.10 Energy Consumption per Capita**



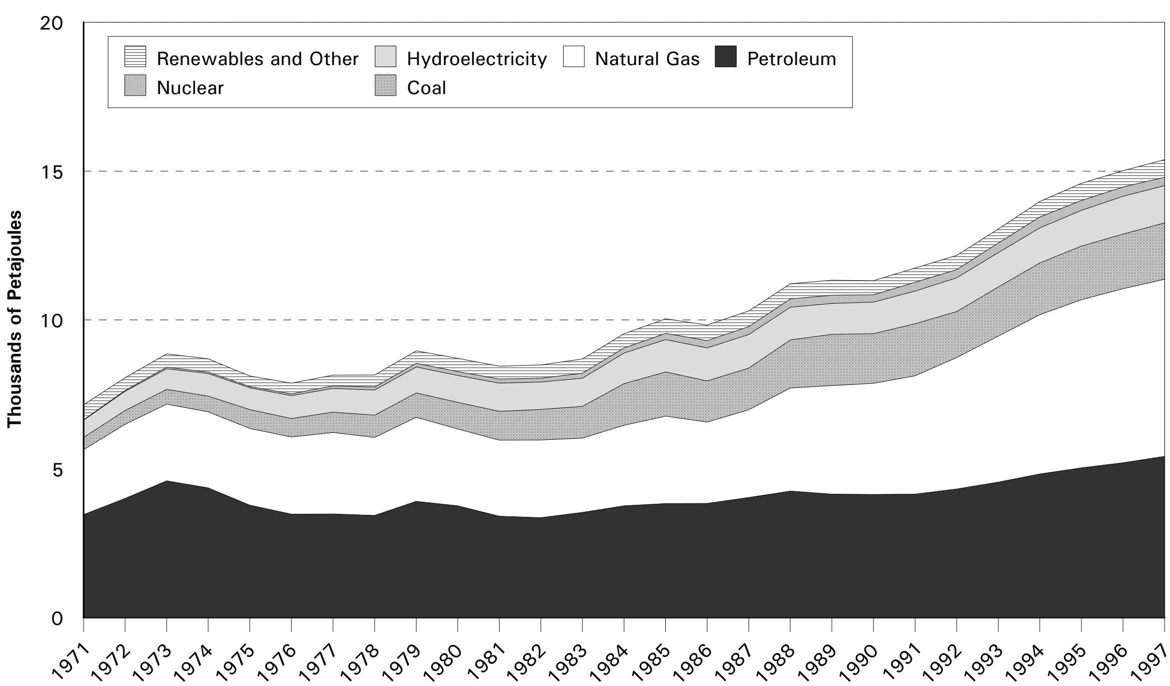

Source for population data: Statistics Canada1999e: various years; source for total consumption: NEB 1999a.
Note: Total energy consumption is defined here as the sum of total residential, commercial, industrial, transportation and non-energy uses, as well as the energy needed to produce electricity and producer consumption and loses.

**Figure 5.11 Energy Consumption per dollar of Real GDP**



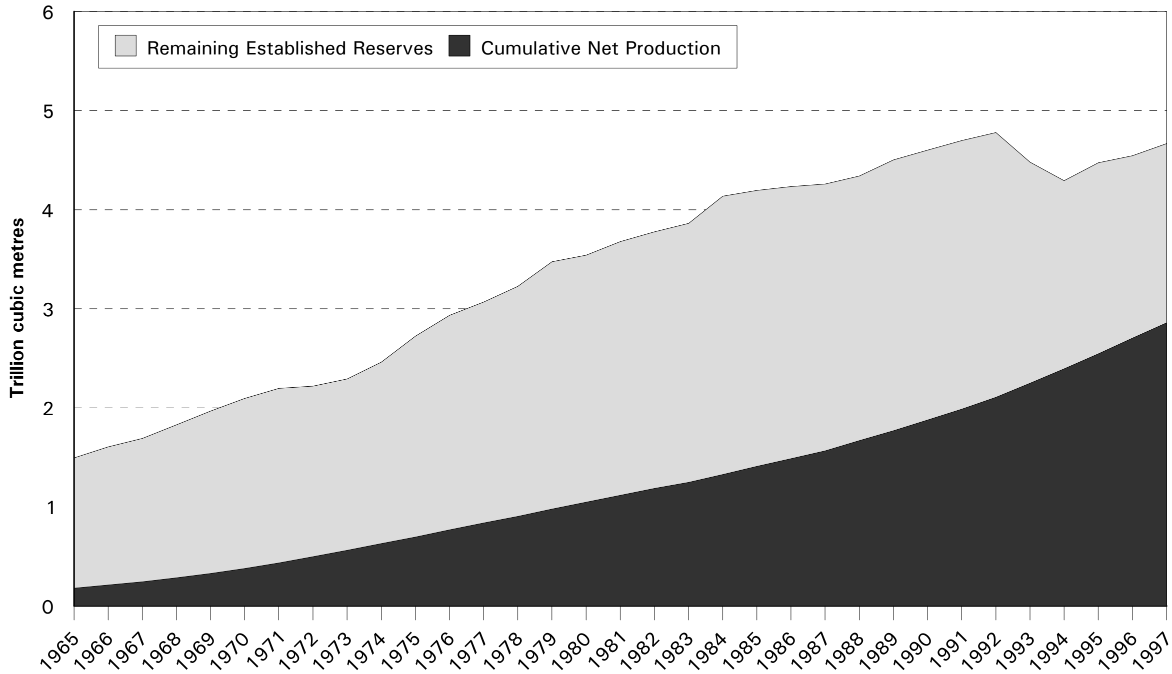

Sources: total consumption: NEB 1999a; GDP: Statistics Canada 1999d; 2000.
Note: Total energy consumption is defined here as the sum of total residential, commercial, industrial, transportation and non-energy uses, as well as the energy needed to produce electricity and producer consumption and loses.

**Figure 5.12 Primary Energy Production by Type, 1971–1997**



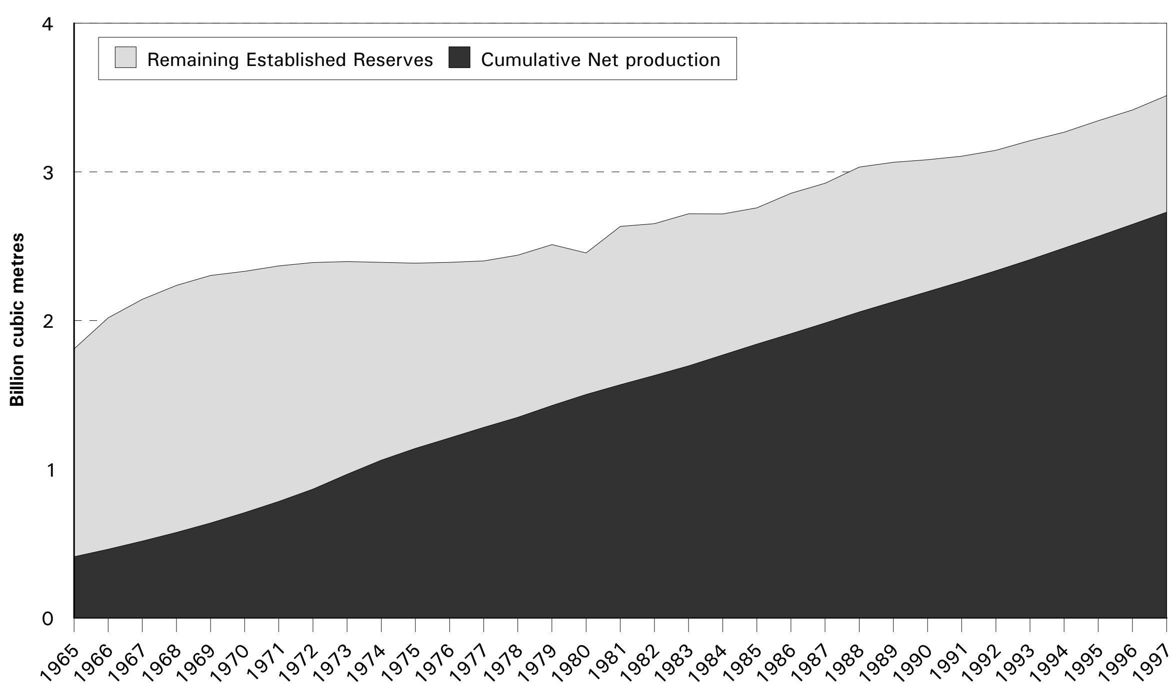

Source: Statistics Canada 1999c.

**Figure 5.13 Natural Gas Production and Remaining Established Reserves, 1965–1997**




Source: Canadian Association of Petroleum Producers 1998.
Note 1: Arctic islands gas reserves included for first time in 1975 but removed in 1993. Note 2: Mackenzie Delta gas reserves included for first time in 1974 but removed in 1994. Note 3: East Coast Offshore booked first time in 1997. Note 4: Cumulative net production for 1965 includes data from 1955 to 1965.

**Figure 5.14 Crude Oil Production and Remaining Established Reserves, 1965–1997**




Source: Canadian Association of Petroleum Producers 1998.
Note 1: East Coast Offshore reserves booked in 1981, Arctic Islands booked in 1985 and Mackenzie Delta/Beaufort Sea booked in 1985. Note 2: Cumulative net production for 1965 includes data from 1951 to 1965.