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# Commissioner of the Environment and Sustainable Development

DECEMBER

## Chapter 5

A Study of Environmental Monitoring

Office of the Auditor General of Canada

*The December 2011 Report of the Commissioner of the Environment and Sustainable Development comprises The Commissioner's Perspective, Main Points—Chapters 1 to 5, an appendix, and six chapters. The main table of contents for the Report is found at the end of this publication.*

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Chapter

# 5

## A Study of Environmental Monitoring

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# A Study of Environmental Monitoring

## Main Points

### What we examined

The federal government collects information about what is going on in the environment to help Canadians make decisions every day. It monitors many different aspects of the environment, including solar flares, weather, air quality, migratory birds, fish, insects that carry human diseases, forests, water quality and quantity, changes in permafrost, and the ecology of national parks.

We conducted this study to develop an inventory of systems the federal government uses in monitoring the state of the environment; to identify the challenges associated with environmental monitoring; and to highlight good environmental monitoring practices. Together these serve as a basis for criteria for future audits of environmental monitoring conducted by the federal government.

We studied the environmental monitoring systems of several federal departments and agencies with responsibilities related to the environment. We interviewed expert officials from those organizations and from other jurisdictions, and reviewed the relevant literature. This included past observations and recommendations by our office; however, we did not follow up to determine what progress had been made.

This document is not an audit report. For this reason, our observations should not be seen as an assessment of the federal government's current practices or performance with respect to environmental monitoring. Because this is a study, it is descriptive and does not include recommendations.

Work for this chapter was completed on 31 July 2011.

### Why it's important

Environmental monitoring is critical to knowing whether the quality of our environment is getting better or worse. Information gathered through environmental monitoring is important to many different decision makers, inside and outside the federal government. With the results of monitoring, the federal government can make informed decisions about how the environment will affect Canadians and how Canadians are affecting the environment. Outside the federal

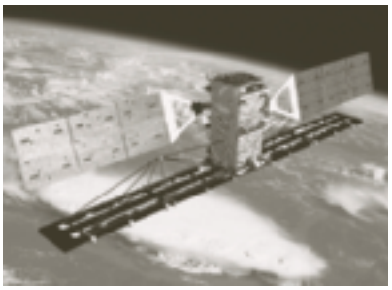
government, the information is used by many people, such as municipal engineers to design flood control systems or public health experts to design effective policies. Timely and effective responses to environmental emergencies, such as spills, are impossible without adequate information. Farmers, hunters, foresters, and fishers all need to know what is happening to the natural resources they rely on.

The Canadian federal government shares responsibilities for environmental monitoring with businesses, local governments, provincial and territorial governments, and other national governments. Based on a Statistics Canada survey of federal science activities, we estimate that the federal government spends more than $500 million each year on different environmental monitoring activities and assigns more than 2,500 people to these activities.

## What we found

- Environmental monitoring generates the critical information that is essential for the federal government to provide sound stewardship of the environment. The government uses the information to assess the current state of the environment, to predict the future environment, and to develop sound strategies for adapting to environmental change. For example, daily weather forecasts rely on a complex set of linked environmental monitoring systems.
- Environmental monitoring systems are most successful when they are well coordinated with other systems, when the right partners participate, when quality is built in from the beginning, when reports are designed to be useful, and when resources are used efficiently. For example, some monitoring systems rely heavily on expensive tools and equipment, such as satellites or scientific research vessels, that need to be managed carefully with respect to their long-term benefits and costs.
- Well-managed environmental monitoring systems can provide a basis for Parliament to hold departments and agencies accountable for their environmental stewardship.

# Introduction



RADARSAT2 satellite supplies information about ground conditions to several different monitoring systems.

Photo: Canadian Space Agency

**5.1** Canadians benefit daily from environmental monitoring in all aspects of their lives. Canadian families rely on weather forecasts to find out whether to bring sunscreen to the beach or brace for a winter storm. Insurance companies have to make provisions for potential claims resulting from flooding on the Prairies, in Quebec, or elsewhere in the country. Arctic communities want to know whether the food they hunt has high levels of toxic chemicals, such as mercury. And fishers on all three coasts depend on the federal government for decisions about how many fish can be caught.

**5.2** Statistical agencies and other organizations collect and analyze a vast array of information about the state of the Canadian economy, such as how many people are employed, what is being exported or imported, and how quickly the economy is growing. This information is supplied to individuals, businesses, investment analysts, and governmental finance departments, among others. Similarly, an **environmental monitoring system** collects information about the environment and distributes it to people who need the information to make decisions. Environmental information is obtained using a vast spectrum of approaches, ranging from radar satellites that peer through clouds, to sophisticated chemical analyzers that measure air quality, to foresters counting the number of trees of certain species and sizes at a given location.

**Environmental monitoring system**—A system that combines the processes of obtaining, assembling, synthesizing, and reporting repeated and systematic measurements or observations of environmental characteristics.

**5.3** The Government of Canada shares responsibilities for environmental monitoring with businesses, local governments, provincial and territorial governments, and other national governments. Based on a Statistics Canada survey of federal science activities, we estimated that every year, the federal government spends more than $500 million on environmental monitoring activities and assigns more than 2,500 people to these activities.

Environment Canada laboratory technicians process water samples to assess water quality.

Photo: Environment Canada

## Focus of the study

**5.4** Because environmental monitoring plays a central role in the everyday lives of Canadians and the way Canada's resources are managed, we decided to provide Parliament with a description of these monitoring activities. Our specific objectives for this study were to document the key challenges associated with environmental monitoring, to describe the active Canadian federal monitoring systems, and to highlight good monitoring practices in other jurisdictions. In addition, this study serves as a basis for future audits

of monitoring systems and for questions that members of Parliament might wish to ask about such systems.

**5.5** We looked at the monitoring activities of the 11 main federal departments and agencies that have environmental monitoring responsibilities:

- Aboriginal Affairs and Northern Development Canada
- Agriculture and Agri-Food Canada
- Canadian Food Inspection Agency
- Canadian Space Agency
- Environment Canada
- Fisheries and Oceans Canada
- Health Canada
- Natural Resources Canada
- Parks Canada
- Public Health Agency of Canada
- Statistics Canada

Based on this examination, we prepared an inventory of national monitoring systems that assess the state of the environment. More details are given in the Appendix.

**5.6** This document is not an audit report. For this reason our observations should not be seen as an assessment of the federal government's current practices or performance with respect to environmental monitoring. Because this is a study, it is descriptive and does not include recommendations.

**5.7** At the same time as this study, we conducted an audit of how environmental scientific activities are managed at Environment Canada and how these activities support decision making (Chapter 2 of this report, Environmental Science). Scientific research complements monitoring as another source of information, providing a foundation for good environmental management.

**5.8** More details about the study objectives, scope, and approach are in **About the Study** at the end of this chapter.

## Observations

### How is information from environmental monitoring used?

**5.9** Environmental monitoring is critical to understanding whether the quality of our environment is getting better or worse. Information gathered through environmental monitoring is important to many decision makers, outside and inside the federal government.

#### Monitoring is essential for making well-informed decisions about the environment and how it will affect Canadians

**5.10** Outside the federal government, many people and organizations use the results of environmental monitoring to manage the environment and the way Canadians interact with it:

- **Health professionals.** Public health officials are concerned about short-term environmental impacts, such as poor air quality and the need to issue smog advisories. They are also concerned about long-term health effects, such as the presence of toxic substances in the environment and human bodies.
- **Planners.** Municipal engineers responsible for designing flood control systems need to know the maximum height to which water levels could rise. When they set premiums, insurance companies need accurate information about current and future environmental risks. If they lack sound information, they pay a real financial cost.
- **Emergency responders.** When an earthquake or a major industrial accident occurs, it is vital to know without delay exactly where it occurred and how severe it is; armed with accurate and timely information, responders can deliver rapid and targeted assistance. Magnetic disturbances caused by solar flares induce electric currents in long conductors, such as power lines and pipelines, and can lead to power system outages or pipeline corrosion. Monitoring information can help emergency managers predict and respond to such events.
- **Resource managers.** Farmers need to know the short-term weather—for example, to help them decide when to harvest their crops. They also rely on information about long-term climate trends—for example, when deciding how to respond to declining water supplies. Mining companies in the North need to know whether changes in permafrost and the extent of sea ice will affect their access to resources.

- **Industries.** Wind power developers need reliable information about wind patterns and bird migration routes to plan their facilities. Major industries need to monitor their own environmental effects to ensure that they comply with regulations. For example, the National Pollutant Release Inventory requires many businesses in Canada to measure and report how much pollution they release into the environment from their facilities.

## The federal government relies on environmental monitoring for crucial management information

**5.11** Within the federal government, environmental monitoring generates information that is essential for several core management functions.

**5.12 Designing environmental management programs.** Environmental monitoring describes the starting point against which targets can be set and progress evaluated. One key step in developing an environmental management program is assessing the current state of the environment. For example, in 2010, the federal, provincial, and territorial governments worked together to produce a report on the status and trends in Canada's ecosystems. Exhibit 5.1 summarizes some of the conclusions in that report, entitled *Canadian Biodiversity: Ecosystem Status and Trends 2010*. This report highlights the key areas of concern.

**Exhibit 5.1 Canadian governments have assessed the status and trends of Canada's major ecosystems**

| |
|---|
| **Forests**—Some are healthy and not changing; some are showing signs of stress and are deteriorating. |
| **Grasslands**—These ecosystems are impaired and deteriorating. |
| **Wetlands**—These ecosystems are showing signs of stress and are deteriorating. |
| **Lakes and rivers**—These ecosystems are showing signs of stress and are deteriorating. |
| **Coastal ecosystems**—Some are healthy and some are showing signs of stress, but all are deteriorating. |
| **Marine ecosystems**—Some marine mammal populations are healthy and are recovering rapidly; other parts of the ecosystems, including commercial fisheries, are impaired and deteriorating rapidly. |
| **Ice ecosystems**—These ecosystems are impaired and deteriorating rapidly. |

Source: Summarized from *Canadian Biodiversity: Ecosystem Status and Trends 2010*

**5.13** A second key step in designing programs is deciding which actions to pursue. Environmental monitoring results provide a basis for designing models that can be used to predict the future consequences of management actions. The predictions could be of the weather tomorrow, the climate in 40 years, or the amount of fish that can be harvested sustainably given population projections. Monitoring results are also used to check and improve the model predictions over time. These kinds of predictive tools can then be used to compare alternative management actions.

**5.14** **Allocating resources efficiently.** Knowing where the problems are makes it possible to target management action efficiently. For example, moose population monitoring done by Parks Canada identified areas of high population density and forest damage, and helped direct corrective action.

**5.15** **Assessing the environmental effects of past and present projects.** When projects are assessed under the *Canadian Environmental Assessment Act* for their possible environmental effects, follow-up programs may be required to determine whether the observed effects are consistent with the predictions and whether actions to mitigate the possible effects are working as planned. Such monitoring programs are put in place for about 5 percent of environmental assessments. The environmental effects are typically restricted to a single location; however, when the effects of more than one project are combined, as in the case of the oil sands region of northern Alberta, project planners may need to consider the cumulative effects of the different projects (Chapter 2 of the 2011 October Report of the Commissioner of the Environment and Sustainable Development, Assessing Cumulative Environmental Effects of Oil Sands Projects). In the case of contaminated sites related to completed or abandoned projects, such as mines, continuing attention may be required if pollutants are being released into the environment.

**5.16** **Evaluating compliance with environmental regulations.** Environmental monitoring produces the information to evaluate performance in relation to regulations. For example, ground-level ozone—a component of smog—increased from 1980 to 2009 in southern Ontario. By comparing smog levels with regulatory limits, authorities can make decisions about how they should respond to protect public health and environmental quality. Compliance monitoring is based on specific regulations and a situation in which non-compliance may result in enforcement action. (Chapter 3 in this report, Enforcing the *Canadian Environmental Protection Act, 1999,*

presents the results of an audit of how Environment Canada enforces the Act.) Industry and the federal government may share the responsibilities for compliance monitoring. Statistics Canada has estimated that Canadian industries spent $329 million on environmental monitoring in 2008, out of a total of about $9.1 billion that they spent on all aspects of environmental protection.

**5.17** Monitoring also provides a way of determining whether regulations and enforcement actions are working as expected. If the regulations are being followed but the state of the environment is not improving as planned, changes may be needed to the regulatory approach.

**5.18** **Promptly identifying problems.** Environmental monitoring may also produce information about emergencies that require an immediate response, as well as processes that take longer to unfold. For example, federal managers may need to act very quickly in response to a disease in wildlife that threatens domestic animals or that potentially affects the food supply for Canadians. Long-term changes in glaciers in the Rocky Mountains with the related consequences for irrigation supplies will demand a different approach.

**5.19** **Complementing scientific research.** Environmental monitoring is closely tied to scientific research. Research can identify and describe the cause-effect relationships that underlie monitoring programs. For example, when managers of a monitoring program choose particular types of water pollutants for measurement, the decision is based on the research documenting the effects of those pollutants on aquatic plants and animals. Researchers can also help design the equipment and methods that allow monitoring programs to ask new questions or obtain more accurate results. In turn, unexpected results from monitoring can trigger new research.

## What environmental monitoring is the federal government doing?

**5.20** Canada's environment is affected by many influences whose origins are beyond our borders. For example, the far-reaching effects of hurricanes that start in the middle of the Atlantic Ocean demonstrate that Canada's weather is part of a global system. The migratory ducks shot by hunters on the Prairies may have crossed several national borders before reaching their destinations in Canada. And the toxic substances that accumulate in Canada's Arctic come from all over the planet.

**5.21** The federal government is directly involved in environmental monitoring for several reasons:

- the need to negotiate with other countries and jointly manage the global environment;
- the need for coordination and consistency within Canada;
- the constitutional division of powers; and
- the federal government's exclusive responsibilities in certain areas, such as oceans and federal lands. Among the lands controlled by the federal government are national parks and national park reserves, which cover 30.3 million hectares (about 3 percent of Canada's land area).

### Legislation and international agreements require Canada to monitor the environment

**5.22** Several federal laws require environmental monitoring, either directly or indirectly. One example is the *Canadian Environmental Protection Act*, which requires the Minister of the Environment to monitor the state of the environment and to report on the results periodically. The approach to meeting this requirement has evolved (Exhibit 5.2). As a second example, the *Canada National Parks Act* requires Parks Canada to report every two years on the ecological integrity of all 42 national parks. The ecological integrity monitoring programs of Parks Canada are designed to support this requirement as well as its legal obligation to perform management planning. In all, over 13 federal laws entail direct or indirect requirements to monitor the environment. In addition, some land claim agreements have required monitoring programs.

**5.23** Agreements with other countries may also lead to monitoring requirements for the federal government. For example, the Great Lakes Water Quality Agreement with the United States includes a requirement for a "coordinated surveillance and monitoring program in the Great Lakes System." The program is intended to

- assess compliance with pollution control requirements,
- track progress on the agreement's objectives,
- provide information for determining how the Great Lakes have responded to control measures, and
- identify emerging problems.

**Exhibit 5.2 Reporting on the state of the environment has evolved since 1986**

Canada has a long tradition of reporting on the state of the environment, based on its monitoring programs. The first comprehensive national report was prepared as a joint effort between Environment Canada and Statistics Canada in 1986. It covered a wide range of topics, from forest ecosystems to contaminants in the environment. Larger and more detailed reports were prepared in 1991 and 1996. Environment Canada then shifted to a different approach using a mix of publications and resources.

In 2004, Environment Canada began working with Health Canada and Statistics Canada on a new set of indicators: the Canadian Environmental Sustainability Indicators. Annual reports were prepared from 2005 to 2008, giving details on air quality, water quality, and greenhouse gas emissions. Since then, the set of indicators has been expanded to include measures of air pollutant emissions, water pollution, water levels, protected areas, and risks to the health or survival of wildlife species. There are plans to expand the set further, notably to support the new Federal Sustainable Development Strategy.

In parallel, Statistics Canada has continued to produce its core compilation of environmental statistics and analysis, entitled *Human Activity and the Environment.* The first issue was released in 1978 and the second appeared with the first state of the environment report in 1986. The compilation now appears annually, with the latest issue released in June 2011. This publication combines analysis of the results of environmental monitoring with the socio-economic information Statistics Canada collects through a variety of surveys and other instruments.

The federal government has led other state of the environment reporting efforts that are more narrowly focused—for example, covering the state of the Great Lakes or national parks, agri-environmental indicators, the status of ecosystems, and (since 1992) the relationships between human health and the environment. The government has contributed as well to several international reports, such as those by the Commission for Environmental Cooperation of North America. In addition, several provinces and territories have prepared state of the environment reports and indicators.

**5.24** As a member of the World Meteorological Organization, Canada has obligations to collect and share weather, water quantity, and climate information with the global community. Of the almost 100 international environmental agreements Canada has signed, more than 33 create monitoring requirements for the federal government. In some cases, international agreements have led to standards or protocols for conducting monitoring to ensure country-to-country compatibility. For example, standards and protocols have been put in place for measuring acid precipitation, stratospheric ozone, persistent organic pollutants, and water quality.

### Current federal monitoring systems track many aspects of the environment

**5.25** To give Parliament a clearer picture of the environmental monitoring conducted by the federal government, we have prepared an inventory of federal monitoring systems. During the study, we did not identify any other recent government-wide attempts to summarize Canada's environmental monitoring. Other recent inventories of

federal monitoring systems have been limited in scope: they focused on the mandate of a single department (such as Fisheries and Oceans Canada) or a specific region (such as northern Canada). The Appendix presents a summary of our approach and the inventory.

**5.26** We identified 94 monitoring systems or clusters of monitoring systems in our inventory. As explained in the Appendix, in some cases we had to combine monitoring systems to avoid a list that would be unwieldy and of limited use to Parliament. The combined systems are listed under the following components of the environment: water, plants and animals, and other (Exhibit 5.3). The monitoring systems for plants and animals outnumber those for other components; this is partly because of the federal government's responsibilities for migratory birds and fisheries, as well as the diversity of species in this component. Note that there are several ways we could have grouped monitoring systems, given the similarities and links between them.

**Exhibit 5.3 Levels of monitoring vary depending on the component of the environment**

| Environmental component | Number of monitoring systems* |
|---|---|
| Air and atmosphere | 20 |
| Water | 19 |
| Soil and landforms | 3 |
| Contaminants in several components | 4 |
| Plants and animals | 32 |
| Ecosystem processes | 3 |
| Human population | 6 |
| Other | 7 |

* In some cases, monitoring systems are clusters of systems.

**5.27** Environment Canada has the widest range and largest number of monitoring systems of any department or agency (Exhibit 5.4). This reflects its responsibilities, including for monitoring weather, air and water; managing toxic substances; and tracking bird populations. Fisheries and Oceans Canada monitors fisheries as part of its mandate to manage fisheries resources. Other departments and agencies have different roles. For example, the Canadian Space Agency does not directly manage monitoring systems, but it contributes data in support of many of the systems in the inventory managed by other departments.

**Exhibit 5.4** **The number of monitoring systems varies across departments and agencies**

| Department or agency | Number of monitoring systems* |
|---|---|
| Aboriginal Affairs and Northern Development Canada | 2 |
| Agriculture and Agri-Food Canada | 5 |
| Canadian Food Inspection Agency | 4 |
| Environment Canada | 41 |
| Fisheries and Oceans Canada | 25 |
| Health Canada | 6 |
| Natural Resources Canada | 9 |
| Parks Canada | 1 |
| Public Health Agency of Canada | 6 |
| Statistics Canada | 1 |

* In some cases, monitoring systems are clusters of systems. Where there is no single lead department, we have included all key departments.

**5.28** Based on information from departments and agencies, we estimated that 55 percent of the monitoring systems were based directly on federal legislation. Systems without a direct legislative basis may still contribute to meeting departmental mandates. For example, while not directly required by legislation, measuring contaminants in bird eggs has helped to

- set regulatory priorities for toxic substances,
- assess the success of the resultant management actions, and
- meet international agreements.

**5.29** The monitoring systems we looked at use a vast range of approaches and methods, depending on what they measure. For example, we asked departments and agencies about the number of monitoring stations in each system. We were told that the system for tracking water flows and levels in Canada's lakes and rivers has approximately 2,117 stations. In contrast, a network of 16 stations measures ultraviolet (UV) radiation; the resulting data is used for calculating the UV index featured in daily weather forecasts across the country.

**5.30** The monitoring systems also vary widely in age, with some systems going back many decades. For example, agricultural research stations have collected soil samples for over 100 years; they can now supply answers to questions that had not been posed when the samples

were first collected. Some of the more recently introduced monitoring systems represent new technologies, new scientific perspectives, or emerging requirements. For instance, satellite-based monitoring coordinated through the Canadian Space Agency and the Canadian Centre for Remote Sensing (part of Natural Resources Canada) is generating a wealth of information about the Canadian landscape and how it is changing.

**5.31** Our past audits of federal monitoring systems found some gaps, such as the more limited coverage of Arctic regions compared to southern Canada. Northern monitoring poses logistical and financial challenges because of the distances and harsh environment. Other assessments have noted that some components of the environment are still poorly understood, and are not monitored regularly or at all; they include insects and some groups of marine species. Monitoring systems in other countries show similar limitations. A recent report by NatureServe Canada, a non-profit conservation organization, commented on the lack of a central repository for information about the geographic range of Canada's plants and animals. Such gaps highlight the trade-offs managers must make between the value of environmental information and the cost and effort required to obtain it.

## What contributes to a successful monitoring system?

**5.32** One of the goals of this study is to identify the characteristics of a successful and effective monitoring system. To do this, we first describe the key features of a well-managed monitoring system, and then identify the main challenges and how they can be met. We also consider some practices in other jurisdictions that might be applicable to the Canadian federal context.

### Successful monitoring systems share similar traits

**5.33** Despite the wide range of monitoring systems in use, we observed that well-managed systems share similar features. We reviewed the literature and consulted with departments and agencies. On the basis of what we learned, we were able to identify eight features that, in our view, represent good practices for designing and putting in place a monitoring system (Exhibit 5.5).

**5.34** Before implementing a specific monitoring system, we observed that it is critical to have a coordinated and strategic vision of

- what needs to be monitored,
- how the different monitoring systems fit together,

- how the information will be reported, and
- how the monitoring results will be used.

Having a strategic vision means understanding the requirements based on departmental mandates and agreements with other jurisdictions. It includes determining which organizations will be involved and what their responsibilities will be, so that there will be no gaps or overlaps. The vision can also spell out how long monitoring systems should be in place and how they should change depending on the results obtained. It can specify the common methods and standards to be used so that results from different systems can be compared and integrated. For example, the vision could specify the use of a common set of geographic boundaries.

**Exhibit 5.5 Well-managed monitoring systems share certain features**

| Features |
|---|
| **1. Design**<br>The design addresses the objectives of the monitoring system, what will be monitored, how the data will be used, what indicators will be prepared, and how stakeholders will be involved. The geographic and temporal details have been determined—for example, frequency, timing, location, and density of monitoring stations. |
| **2. Implementation**<br>The parties responsible for each aspect of the system have been identified and have received the necessary training. The methods and sampling strategies have been tested and documented. Contingency plans are in place to respond to problems. |
| **3. Data collection**<br>Procedures and practices to obtain the data are established and applied. The samples and data records are documented and archived. |
| **4. Quality control**<br>The methods are consistently applied, following guidelines and standards. Other quality controls are in place to maintain the integrity of the data sets. |
| **5. Synthesis and analysis of the data**<br>The data are converted into summary forms, such as maps or graphs. Indicators are calculated and used to compare results to those for other times and locations, using statistically sound methods. |
| **6. Internal reporting and communication**<br>The results are communicated within the organizations responsible for monitoring. The data are available internally with a description of their properties and their limitations. |
| **7. External reporting and communication**<br>The results are communicated to external audiences (the public, Parliament, or international bodies, such as the secretariats responsible for international agreements). Specialized users have access to detailed monitoring results. |
| **8. Audit and review of the system**<br>Audits or evaluations of the monitoring system are conducted to assess whether it is achieving its objectives, and to identify opportunities for improvements. |

**5.35** Well-designed monitoring programs can help reduce the costs associated with environmental management by identifying where the real problems are and enabling governments to target resources effectively. For example, the United Kingdom reduced the amount of data it needed to collect through its air quality monitoring network. It recognized that modelling could provide adequate estimates of air quality, even if not all stations were operated or if they did not collect information on all possible air pollutants. Modelling is increasingly recognized as a complement to on-the-ground monitoring.

### Monitoring systems can present different challenges, depending on their purpose, nature, and size

**5.36** Monitoring systems pose general management challenges in areas such as coordination and governance, coverage, comparability, timeliness, data quality, accessibility, and effective reporting. Our past audit work has documented several instances of deficiencies in these areas. For example, in 2009, we observed that Fisheries and Oceans Canada did not systematically monitor fish habitat.

**5.37** Other challenges emerge specifically from features of the Canadian federal context, such as the division of responsibilities within and between federal, provincial, and territorial levels of government. To reduce costs and avoid duplication, governments often jointly establish and operate monitoring systems—for instance, applying principles such as those developed by the **Canadian Council of Ministers of the Environment**. This collaboration requires establishing the appropriate arrangements, both formal and informal. Still other kinds of challenges may depend on the nature of the monitoring system. For example, federal departments have set up some information collection programs that rely on direct observations by Canadian citizens. The programs may reduce costs but increase requirements for quality control.

**Canadian Council of Ministers of the Environment**—The Canadian Council of Ministers of the Environment is comprised of the environment ministers from the federal, provincial, and territorial governments. These 14 ministers normally meet at least once a year to discuss national environmental priorities and determine work to be carried out under the auspices of the Council.

### Coordination helps ensure that monitoring objectives are appropriate and the right partners are involved

**5.38** Environmental managers in some countries (such as Sweden, Australia, and Finland) have observed that coordination contributes to effective environmental monitoring and helps provide a more complete picture of the state of the environment. The challenge is finding the best way to integrate environmental monitoring into the systems and practices of environmental management. The key aspects include

- setting environmental objectives,

- clarifying roles and responsibilities, and
- setting a strategic direction.

**5.39** **Setting environmental objectives.** Monitoring systems can be more accurately targeted when they are based on national environmental objectives. In Sweden, for example, a set of 16 national objectives has been translated into regional and local objectives. Intermediate targets are now associated with the objectives, and monitoring systems are used for tracking progress toward those targets. Negotiations to achieve these kinds of objectives may be more difficult where different jurisdictions share responsibilities for environmental management, as they do in the United States, Canada, and the European Union.

**5.40** **Clarifying roles and responsibilities.** In previous audits of monitoring programs, we identified the need for the federal government to formally coordinate priorities and activities among its departments and among the different levels of government, such as provinces, territories, and local governments. Coordination among different organizations can reduce duplication, identify gaps, and help ensure nationally consistent approaches. The coordination is particularly important because federal departments and agencies rely on other parties to contribute to their monitoring programs in about 93 percent of the systems included in our inventory.

**5.41** The federal government also needs to coordinate with the governments of other countries in regions such as the Arctic and the Great Lakes, and in dealing with resources such as the fish stocks that move into and out of Canada's exclusive economic zone. For meteorological measurements, the World Meteorological Organization is leading the development of a global "network of networks." Other national and international agencies are promoting a Global Earth Observation System of Systems to improve the tools available for monitoring different aspects of the environment, including monitoring from space.

**5.42** Within the federal government, monitoring responsibilities need to align with the different environmental components so that departments can coordinate their efforts rather than work against each other. For example, do water quantity monitoring programs fit best with programs for rainfall monitoring or programs for water quality monitoring? Who monitors the intertidal zone at the boundary between terrestrial and marine ecosystems? Should fisheries biologists focus on monitoring fish populations or the many facets of the

ecosystem in which those fish live? Both Environment Canada and Fisheries and Oceans Canada have adopted the **ecosystem approach**, which leads to a broader view of environmental management, and which could help answer these kinds of questions.

**Ecosystem approach**—An approach to environmental management that considers all aspects of an ecosystem—air, water, plants, animals, humans and their interactions—when addressing critical environmental issues. This approach also takes into account the social and economic factors relevant to ecosystem health and recovery.

Source: Environment Canada

**5.43** **Setting a strategic direction.** When defining strategies, one needs to set priorities. Priority setting involves identifying the most important monitoring systems, determining where additional resources are most needed, and reallocating resources to higher-priority needs. It also involves identifying the data gaps that need to be filled to inform decision makers about the most important environmental risks and trends. An example of priority setting is Australia's National Plan for Environmental Information, put in place in 2010. It is intended to coordinate and set priorities for the way the Australian government as a whole collects, manages, and uses environmental information. The Canadian Environmental Sustainability Indicators initiative is intended to play a similar role in Canada (Exhibit 5.2).

**5.44** One of the challenges in setting a strategic direction is deciding how to split monitoring efforts between well-understood current issues and new issues. An example of the latter would be the emerging effects of climate change in the Arctic, a matter that requires coordination between circumpolar countries. Throughout our study, we observed repeatedly the value of long-term and consistent information collection.

### Building in quality at every step will yield sound results

**5.45** Statistics Canada and other national and international statistical agencies have identified the features of high-quality statistical information (Exhibit 5.6). The same characteristics may be applied to environmental monitoring systems. As Statistics Canada notes, there may be trade-offs between different features. In addition, the resources available will affect how much and what kind of quality can be achieved by the monitoring system.

**5.46** When sound statistical methods are used to design monitoring systems and analyze data, the resulting reports will be much more credible, especially in the case of controversial matters. For instance, the monitoring programs for the environmental effects of oil sands mining in northern Alberta are undergoing revision, partly to enhance their statistical credibility.

**Exhibit 5.6 Statistics Canada has summarized the characteristics of high-quality information**

**Relevance**
The information sheds light on the issues of most importance to users.

**Accuracy**
The information correctly describes the phenomena it was designed to measure. Accuracy can be measured by the extent of errors in the estimates.

**Timeliness**
The information is available as soon as practical after the period to which it refers. More timely information may mean that it is less accurate.

**Accessibility**
The information is easy to obtain, the public is made aware of it, the format is suitable, and the cost is reasonable.

**Ease of interpretation**
Supplementary information is available to help in interpreting and using the information appropriately. This additional information normally covers the underlying concepts, variables, and classifications; the methods of data collection and processing; and the accuracy of the statistical information.

**Coherence**
The information can be combined with other related information collected at other times within a shared analytical framework. The use of standard concepts, classifications, and common methods promotes coherence.

Source: Adapted from Statistics Canada

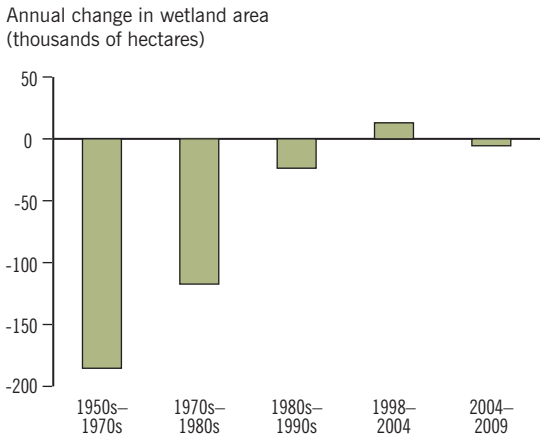
**5.47** Managers can use a variety of approaches to build quality into a monitoring system, depending on the kinds of activities required. For example, certification of laboratories or use of International Organization for Standardization (ISO) standards can result in procedures and frameworks that provide quality assurance in specific areas.

**5.48** The wetland monitoring program set up by the US Fish and Wildlife Service has produced several rounds of measurements and estimates documenting gradually slowing losses of wetlands (Exhibit 5.7). Professional statisticians and biologists were involved in the design of the program and later as independent reviewers. A similar approach could be used to measure land use changes in other contexts.

## Good internal and external reporting provides information that will be useful and used

**5.49** One of the key challenges in preparing reports on the results of monitoring systems is making the link back to environmental indicators, if they exist, and from there to national environmental objectives. These links will help internal and external users understand the implications for environmental management and performance.

**Exhibit 5.7 A sound statistical design underlies the estimates of wetland trends in the United States**




Note: Time frames are approximate.

Source: US Fish and Wildlife Service

**5.50** In general, it is a good practice to make the results of monitoring systems widely available, provided that the information is accompanied by documentation to allow the results to be interpreted properly. Sometimes managers may need to limit access to sensitive information. For example, information about the location of endangered plants is sometimes restricted to prevent damage to the plants and their habitat.

**5.51** The US Geological Survey has created a tool for communicating water quality and water quantity information to the public. The data from sensors around the country is posted on the Internet within a few hours of being collected. Inside and outside the Geological Survey, users can look at current results or can check earlier data to examine seasonal trends. This means, for example, that users can see how heavy rainstorms affect river levels and sediment in the water. Similar tools may be particularly useful to those responsible for responding to extreme weather events.

## Efficient use of resources helps monitoring systems meet their objectives

**5.52** **Managing assets.** Some monitoring systems rely heavily on expensive equipment, such as satellites, radar stations, or scientific research vessels. These assets need to be managed with careful attention to their **life-cycle costs**, the risks associated with using the equipment, and the benefits that may ensue. For example, in the transition from one type of research instrument to another, or from one satellite to its replacements, it is important to ensure continuity and comparability in the data collected. Equipment management and

**Life-cycle costs**—Costs of managing a monitoring system throughout its planning and use. Assessing total life-cycle costs involves taking a broad and long-term view by recognizing all of the costs, as far as practicable, associated with meeting a requirement. Generally, life-cycle costs are divided into four broad categories:

- planning costs, including administrative and other costs;
- acquisition costs, including administrative and design/production costs associated with the goods or services in question;
- operating and use costs, including introduction and contingency costs, and prediction of useful life; and
- disposal costs.

Source: Public Works and Government Services Canada

maintenance is also a concern with new and complex technologies such as DNA-based sampling programs, real-time monitors, and remote autonomous vehicles for underwater measurements.

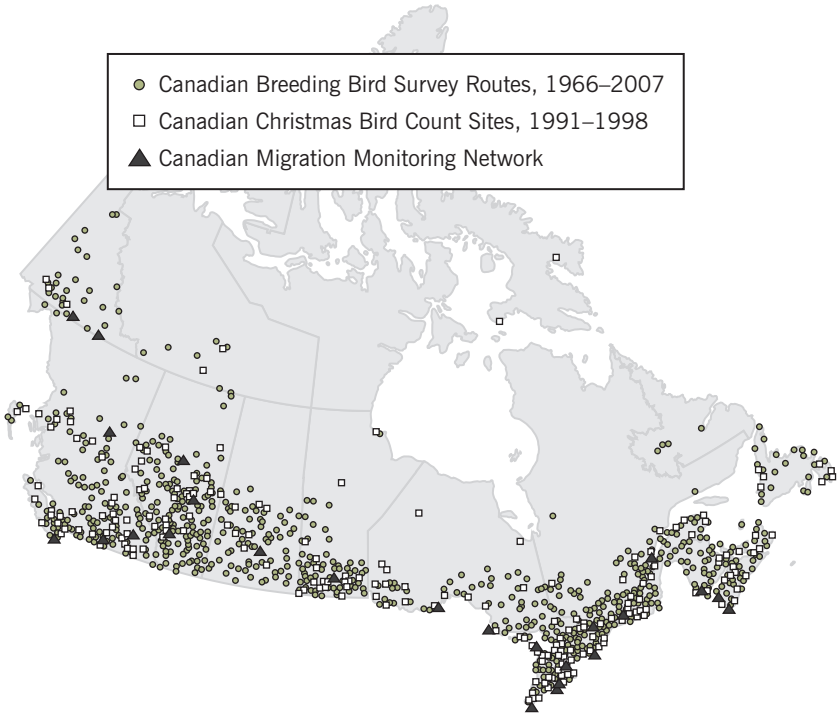
**5.53** The main asset for many monitoring systems is the accumulated data and samples. Managing these kinds of information assets poses similar challenges as managing physical assets. In addition, proper documentation and archiving are necessary so that information can continue to be accessed and used for examining long-term trends. These procedures are especially important with the vast quantities of data flowing from automated data sensors, such as satellites. In the case of biological samples, specialized taxonomic expertise may be required to maintain the material and make accurate comparisons with new samples. Sometimes formal arrangements may be needed to address issues of ownership and control of the data.

**5.54** **Managing human resources.** The people involved in environmental monitoring may be highly specialized experts or local volunteers. For example, to measure biodiversity along the Nova Scotia coast, volunteers collected samples from the coastal area as part of the Natural Geography In Shore Areas program, part of the international Census of Marine Life.

**5.55** What is the best mix of people to deliver a monitoring program and what training should they receive? Sweden, the United Kingdom, and other countries are using citizen volunteers to monitor features of the environment, such as water quality or animal populations. Experts train the volunteers, guide them during the sampling, and perform quality control of the results. The European Environment Agency has put in place Eye On Earth, a system that combines continuous automated reports on air quality across Europe with the qualitative ratings provided by citizens near the monitoring stations. The model of combined systems, with citizens directly involved in monitoring, could be applied to similar situations in Canada.

**5.56** A challenge common to Canada, Australia, and the United States is the uneven geographic distribution of the human population. The distribution affects monitoring programs that rely on human observers—for instance, programs that use volunteer birders to record the trends in population size of bird species (Exhibit 5.8). To compensate for the uneven sampling effort, the programs may have to bear the expense of using professional biologists and arranging transportation and supplies for them.

**Exhibit 5.8 Observations of bird populations are concentrated in southern Canada**




Note: The Christmas Bird Count is not funded or managed by Environment Canada, but is included because it complements the other observation networks.

Source: Canadian Wildlife Service, Environment Canada

**Traditional ecological knowledge**—A cumulative body of knowledge and beliefs, handed down through generations by cultural transmission, about the relationship of living things (including humans) with one another and their environment. It includes the knowledge of elders, current land users, and other community members. Traditional knowledge is an attribute of societies with historical continuity in resource use practices.

Source: Aboriginal Affairs and Northern Development Canada

**5.57** Some managers have used **traditional ecological knowledge** to complement scientific monitoring. This may offer opportunities to expand the capacity and legitimacy of the monitoring system. Nevertheless, it is important to ensure internal consistency, repeatability, and independence. Traditional knowledge has been used, for example, in the Northwest Territories to track the cumulative effects of development projects there.

**5.58 Managing financial resources.** The federal government allocates substantial resources to collect information about the environment and to supply it to Canadians (paragraph 5.3). Monitoring programs require continuity of funding to be able to supply reliable and consistent data, and support detection of long-term trends. The government is only one of the sources of funding for monitoring activities. Examples of other sources include:

- Canada receives money from the United States to monitor migratory birds.
- Cost-sharing agreements with the provinces fund the water quantity monitoring program.

- The fishing industry provides financial support for some of the marine environment monitoring conducted by Fisheries and Oceans Canada.

With external funding, it is particularly important to ensure continuity, control the coordination costs, and ensure independence of the results.

**5.59** One way of reducing costs has been to piggyback some monitoring programs on others, taking advantage of samples that are already being collected. Fisheries and Oceans Canada has used this approach for the wide range of sampling programs being run simultaneously during scientific cruises. Environment Canada has used the same approach for tracking toxic substances under the Chemicals Management Plan. Internationally, cooperation between space agencies has helped reduce total costs.

**5.60** **Using reviews, evaluations, and audits.** Analytical reviews, evaluations, and audits can help promote the efficient use of resources by comparing the intended purposes of monitoring systems with what is actually being achieved in the context of environmental management programs. For example, Environment Canada is reviewing all of its bird monitoring systems to identify needed modifications. In the United States, the Government Accountability Office audited a national set of ecological indicators. It assessed whether changes to US federal monitoring systems might affect the ability of those systems to provide the data necessary to support the indicators.

**5.61** The challenges and solutions we have discussed are interrelated and cannot be treated in isolation. For instance, a statistically sound design for a monitoring system can improve the quality of the information obtained, while reducing the costs to obtain information of that quality. A sound design may also make a clearer link to environmental objectives and produce more credible final reports.

## What questions could parliamentarians ask about environmental monitoring?

**5.62** Parliament has a crucial role in ensuring that the environment is properly managed in Canada: it passes legislation that sets the basic ground rules for the federal government, and it oversees the government's activities. This study provides information to help members of Parliament understand the core issues related to environmental monitoring and carry out their responsibilities. Several pieces of legislation, such as the *Species at Risk Act*, assume that timely and reliable monitoring data is available to make decisions. If the data is unavailable, it may not be possible to implement the law properly. Based on the analysis in this study, we have identified several questions

that members of Parliament may wish to ask when holding departments and agencies to account for their stewardship of the environment.

**5.63** In terms of their legislative responsibilities, members of Parliament may wish to ask the following questions:

- What monitoring is required to report on the state of Canada's environment? Is that monitoring in place?
- What monitoring is required to determine whether environmental legislation is working as intended? Is that monitoring in place?
- What specific steps have been taken to avoid duplication or gaps when working with the provinces and territories?
- What environmental components or geographic regions are not being monitored now? What are the consequences of these gaps?

**5.64** It could be particularly useful for members of Parliament to have a realistic understanding of the challenges associated with environmental monitoring systems as they consider information about federal monitoring systems and the results of audits and evaluations. In terms of their oversight responsibilities, parliamentarians may wish to ask the following questions in relation to particular monitoring systems:

- How does this monitoring system fit into the set of monitoring systems in place?
- What are the priorities for environmental monitoring? How were they established?
- Who is using the information collected by this monitoring system? How does the federal government know the information is being used for its intended purpose?
- How does the federal government ensure that reports are timely and accurate?
- Who is funding the monitoring system? What steps have been taken to ensure continuity of funding, accountability, and independence?
- Did the Office of the Auditor General of Canada or departmental internal audit groups conduct audits and evaluations of this monitoring system? Have the problems identified in their reports been successfully addressed?

## Conclusion

**5.65** In this study, we have summarized the main ways in which environmental monitoring systems are used, described the active Canadian federal monitoring systems, documented the key challenges associated with environmental monitoring, and highlighted good practices for monitoring in other jurisdictions.

**5.66** Outside the federal government, many people and organizations use environmental monitoring results to manage the environment and the ways Canadians interact with it. They include health professionals, planners, emergency responders, resource managers, and major industries.

**5.67** Within the federal government, environmental monitoring generates the information essential for

- designing environmental management programs,
- allocating resources efficiently,
- assessing the environmental effects of past and present projects,
- evaluating compliance with environmental regulations,
- promptly identifying problems, and
- complementing scientific research.

**5.68** Monitoring helps determine baselines against which targets can be set and progress can be evaluated. Information from monitoring can be combined with other information to assess the current state of the environment and to predict its future state.

**5.69** To give Parliament a clearer picture of the environmental monitoring conducted by the federal government, we have prepared an inventory of 94 federal monitoring systems. Among other things, the inventory shows that there are more monitoring systems for plants and animals than other components of the environment. Environment Canada has the widest range and largest number of monitoring systems of any department or agency. This is a reflection of its responsibilities, which include monitoring weather, air, and water; managing toxic substances; and tracking bird populations.

**5.70** We identified some of the main challenges that managers need to meet when putting in place monitoring systems:

- coordinating, including establishing objectives and a strategic direction, and clarifying roles and responsibilities;

- building in quality at every step of monitoring;
- preparing reports that contain useful information; and
- using the available resources efficiently.

**5.71** Practices from other jurisdictions suggest possible ways of meeting some of these challenges in the Canadian context. Our identification of the main challenges and good practices will serve as a basis for criteria in future audits that examine how the federal government conducts environmental monitoring.

**5.72** Environmental monitoring systems are like the systems that take the pulse of our economy: they both provide information to support a very wide variety of uses. Environmental monitoring information helps us deal with questions ranging from the mundane ("Do I need to take an umbrella today?") to the globally significant ("How quickly is the Arctic ice cap melting, and how will this affect the animals and people living in the North and other parts of Canada?"). In this study, we have tried to provide Parliament with some of the essential information it needs about the role of environmental monitoring systems and the challenges the federal government faces in managing such systems.

## About the Study

### Objectives

The overall objective of this study is to document the key challenges associated with environmental monitoring, describe the active Canadian federal monitoring systems, and highlight good practices for monitoring in other jurisdictions.

There are four sub-objectives:

- to describe environmental monitoring and its role in environmental management;
- to prepare an inventory of active federal environmental monitoring systems and document the main properties of these systems;
- to describe the key challenges for environmental monitoring systems; and
- to identify and document good practices in responding to the key challenges, drawing on the experience of other countries and other jurisdictions in Canada.

We did not establish criteria, because this is a study, not an audit.

### Scope and approach

We studied the environmental monitoring systems that have been used by the following 11 entities:

- Aboriginal Affairs and Northern Development Canada
- Agriculture and Agri-Food Canada
- Canadian Food Inspection Agency
- Canadian Space Agency
- Environment Canada
- Fisheries and Oceans Canada
- Health Canada
- Natural Resources Canada
- Parks Canada
- Public Health Agency of Canada
- Statistics Canada

Based on preliminary work, we determined that these were the main entities responsible for monitoring the state of the environment. We interviewed officials from these organizations and obtained documents describing their monitoring systems. The responsibilities for monitoring systems are shared by different parts of these departments and agencies.

We sent a questionnaire to all of the departments and agencies listed. We used the results to prepare an inventory of active federal monitoring systems that collect information related to the state of the environment. Our study focused mainly on the past two fiscal years, especially for the purpose of providing a snapshot of current monitoring systems. We also provided a brief historical perspective and drew on other information related to federal monitoring systems. The Appendix gives details of the inventory.

As part of the study, we assembled a committee of experts from the departments and agencies concerned. The committee provided valuable input and advice.

To better understand common challenges and good practices, we interviewed other Canadian and international experts, and reviewed the relevant literature. This included past observations and recommendations by the Office of the Auditor General of Canada and provincial counterparts. We did not, however, follow up on our past recommendations to determine what progress had been made.

We also interviewed officials from selected organizations in other countries. These included the

- Danish Environmental Protection Agency,
- European Environment Agency,
- Swedish Environmental Protection Agency,
- United Kingdom Department for Environment, Food and Rural Affairs,
- United Kingdom Environment Agency,
- US Environmental Protection Agency,
- US Fish and Wildlife Service, and
- US Geological Survey.

We made our selection from organizations in countries that are recognized leaders and that have legislative systems and issues relevant to Canada's. We spoke with officials of the national audit offices in each of the countries to ensure that we had a good understanding of the context for the interviews.

### Period covered by the study

This study focuses on federal environmental monitoring systems that were in place during the 2009–10 or 2010–11 fiscal year. Some information from outside this period has been used as background.

Work for this chapter was substantially completed on 31 July 2011.

### Study team

Principal: Bruce Sloan
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## Appendix Inventory of federal environmental monitoring systems

Our inventory of environmental monitoring systems lists active federal systems. By "environmental monitoring system," we mean a system that combines the processes for obtaining, assembling, synthesizing, and reporting repeated and systematic measurements or observations of environmental characteristics.

By "observations of environmental characteristics," we mean observations related to the different components of the environment: air, water, land (soil and landforms), plants and animals (including human beings), and ecosystems. We excluded human structures, such as those in the urban environment. We also excluded farmed and domestic animals. Contaminants affecting these components of the environment were taken into account when measured directly in the environment.

By "active system," we mean a system for which the entity managed the data collection in the 2009–10 or 2010–11 fiscal year. By "federal," we mean a system in which the federal government had some responsibility for ongoing operations. If the federal government simply provided funding but gave no direction, we excluded the system from this inventory.

For the purpose of this inventory, we focused on the state of the environment monitoring; we excluded compliance monitoring and monitoring related to individual projects (such as in relation to the assessment of environmental effects). This means, for example, that we excluded monitoring programs for contaminated sites. In addition, we excluded monitoring systems managed by other jurisdictions, where the federal government was only a user of the data.

The inventory focuses on national or major regional monitoring systems (for example, systems monitoring the Great Lakes). In some cases we included monitoring systems with a more restricted scope if they were part of a cluster of similar monitoring systems: that is, if the same approach was applied in different locations. We also used clusters if there were several very similar monitoring systems using the same methods. For instance, there are about 190 monitoring systems that track bird populations; we combined them into four clusters. Similarly, there are several monitoring systems that track aspects of ocean ecosystems; we grouped them by theme for each ocean. We also listed the set of monitoring systems for Canada's 42 national parks as a single monitoring system. We developed these clusters through discussion with the entities regarding the best way to present the monitoring information for our inventory. Of course there are various possible ways of grouping monitoring systems, given their similarities and the links among them.

We also restricted the inventory to systems where the federal government obtains measurements of the environment or of materials previously released into the environment (toxic substances, for example). The inventory excluded situations where the federal government used calculations from other information to estimate releases or environmental conditions. (The inventory excluded, for example, examination of the greenhouse gas emissions inventory and the National Agri-environmental Health Analysis and Reporting Program.) We also excluded samples collected only once, such as soil samples to characterize the soil in a particular location.

We used a questionnaire to obtain details about the monitoring systems in the inventory. We chose the questions to obtain basic and standard factual information about the systems. We pilot-tested the questions internally in the Office of the Auditor General of Canada and with departmental officials.

Even with the tested design of the questionnaire and the definitions of the monitoring systems to be included, several judgments were required about which systems to include and how best to represent them in the inventory. We discussed these judgments with the respondents to ensure the most consistent set of responses possible.

We entered responses to the questionnaire into a spreadsheet containing all of the information supplied. In addition, respondents provided background documents that gave further details about their monitoring programs.

We performed several checks to ensure that the inventory was as complete as possible. These included comparisons with other partial inventories and consultation with entity officials. As a final check on completeness, we asked the deputy head of each department or agency included in the study to identify any major monitoring systems that we had omitted.

The following table lists the monitoring systems (or clusters of monitoring systems) we identified through this process.

| Monitoring system name and description | Lead department or agency |
|---|---|
| **Air and atmosphere** | |
| **National Air Pollution Surveillance Network**<br>In collaboration with provinces and territories, provides accurate and long-term data of a uniform standard across Canada regarding key air pollutants, including ground-level ozone, particulate matter (fine particles in the atmosphere), and nitrogen oxides. | Environment Canada |
| **Canadian Air and Precipitation Monitoring Network**<br>Studies the regional patterns and trends of atmospheric pollutants, such as acid rain, smog, particulate matter, and mercury, in both air and precipitation. | Environment Canada |
| **Global Atmospheric Passive Sampling Network**<br>Determines spatial and temporal trends of persistent organic pollutants, identifies new chemicals in air, and helps assess long-range atmospheric transport. | Environment Canada |
| **Integrated Atmospheric Deposition Network**<br>Monitors trends in toxic pollutants from non-point sources in the air and precipitation in the Great Lakes Basin. (Non-point sources are usually small, diffuse sources, such as runoff from agricultural land.) | Environment Canada |
| **Intercontinental Atmospheric Transport of Anthropogenic Pollutants to the Arctic**<br>Monitors persistent organic pollutants and mercury in the Arctic air. | Environment Canada |
| **Atmospheric Greenhouse Gas Measurement Program**<br>Identifies trends, seasonal variability, and spatial distribution of greenhouse gases and related gases in the atmosphere. | Environment Canada |
| **Canadian Aerosol Baseline Measurements Program**<br>Tracks changes in aerosol (fine particles) composition and concentration in relation to changes in climate, anthropogenic emissions, and changes in natural sources and atmospheric transport patterns. | Environment Canada |

| Monitoring system name and description | Lead department or agency |
|---|---|
| **AEROCAN**<br>Provides a sample of aerosols in the air column. The sample is as representative as possible of national, regional, and local variation across Canada, and contributes to the long-term record of particulate matter in the atmosphere. | Environment Canada |
| **Canadian Operational Research Aerosol Lidar Network**<br>Monitors long-range transport of aerosols that occur naturally (for example, as a result of volcanic venting or eruptions, dust storms, forest and grassland fires) or are caused by human activities, such as the burning of fossil fuels. | Environment Canada |
| **Canadian Ozonesonde Network**<br>Provides regular measurements of ozone concentration from ground level up to an altitude of approximately 36 kilometres. | Environment Canada |
| **Canadian Brewer Spectrophotometer Network**<br>Monitors the recovery of the stratospheric ozone layer by measuring total column ozone, sulphur dioxide, and ultraviolet radiation in the atmosphere. | Environment Canada |
| **Surface Weather and Climate Monitoring Network**<br>Provides real-time data to weather offices for weather warnings and forecasts, and provides a long-term record of surface climate conditions. | Environment Canada |
| **Upper Air Network**<br>Provides a profile of the upper atmosphere, including temperature, humidity, pressure, and winds. Contributes to weather forecasts. | Environment Canada |
| **Space-based Monitoring Network (Geostationary and Polar Orbiting Sub-networks)**<br>Provides satellite images, which are used by meteorologists to determine atmospheric, land, and ocean characteristics. Images are also used for environmental emergencies. | Environment Canada |
| **National Radar Network**<br>Monitors precipitation, thunderstorms, and high-impact weather. Can also detect birds and insects on clear days. | Environment Canada |
| **Aircraft Meteorological Data Relay Program**<br>Uses commercial aircraft to collect data from the upper atmosphere regarding wind, temperature, and pressure altitude. | Environment Canada |
| **Meteorological Service of Canada—Marine Monitoring Network**<br>Provides real-time measurements of weather and the state of the sea, from coastal and Arctic regions of Canada (including the Great Lakes and other large interior lakes, such as Lake Winnipeg and Great Slave Lake). These measurements support weather predictions and contribute to marine safety. | Environment Canada |
| **Canadian Lightning Detection Network**<br>Detects lightning activity. | Environment Canada |
| **Drought Watch Website**<br>Provides near-real-time information about drought or excessive moisture and flood risks in agricultural areas, based on Environment Canada's meteorological data and provincial networks. | Agriculture and Agri-Food Canada |

| Monitoring system name and description | Lead department or agency |
|---|---|
| **Comprehensive Nuclear Test-Ban Treaty Radiological Network**<br>Monitors radioactive compounds in the atmosphere to detect nuclear tests. | Health Canada |
| **Water** | |
| **Fresh Water Quality Monitoring Program**<br>Monitors the status of water quality in Canada's rivers and lakes, as well as changes to aquatic ecosystem health. | Environment Canada |
| **Freshwater Inventory and Surveillance of Mercury**<br>Monitors spatial and temporal trends in fish mercury concentrations across Canada to assess the effectiveness of the Clean Air Regulatory Agenda mercury emission regulations. | Environment Canada |
| **Canadian Aquatic Biomonitoring Network**<br>Assesses freshwater quality and aquatic ecosystem conditions in Canada, using communities of large bottom-dwelling invertebrates. | Environment Canada |
| **Acid Rain Aquatic Effects Monitoring Program**<br>Monitors water chemistry of lakes (and a few streams) to establish the current regional acidification status, trends in acidification, and causes of the trends detected. | Environment Canada |
| **National Hydrometric Program**<br>Provides for the collection, interpretation, and dissemination of both real-time and historical surface water level and flow data. | Environment Canada |
| **Sea and Lake Ice Monitoring Program**<br>Monitors freshwater ice and sea ice conditions to provide information on stage of development, drift, and overall extent of the ice. | Environment Canada |
| **Iceberg Monitoring Program**<br>Monitors icebergs along Canada's east coast, south of latitude 60 degrees north. | Environment Canada |
| **Integrated Satellite Tracking of Pollution**<br>Uses satellites to monitor the marine environment for the accidental or intentional dumping of oily waste products. | Environment Canada |
| **Snow Cover Mapping System**<br>Maps daily snow cover over Canada and in watersheds adjacent to Canadian territory. | Natural Resources Canada |
| **National Glacier-Climate Observing System**<br>Quantifies, and detects trends and other changes to, the mass balance and extent of Canada's land ice (glaciers and ice caps). | Natural Resources Canada |
| **Impact of Agriculture on Water Quality**<br>Evaluates the risk of fecal pollution of water from agriculture, versus other sources, and evaluates the efficacy of agricultural management practices. | Agriculture and Agri-Food Canada |
| **Drinking Water Monitoring System**<br>Measures the presence and levels of a variety of contaminants in raw and treated drinking water at 65 treatment plants across Canada. | Health Canada |

| Monitoring system name and description | Lead department or agency |
|---|---|
| **Marine Environmental Quality—Atlantic**<br>Monitors marine environmental quality (including contaminants) in sediments, biota, and the water column, as well as toxic algal blooms. | Fisheries and Oceans Canada |
| **Marine Environmental Quality—Pacific**<br>Monitors marine environmental quality (including contaminants) in sediments, biota, and the water column, as well as toxic algal blooms. | Fisheries and Oceans Canada |
| **Freshwater Environmental Quality**<br>For a set of lakes in Ontario, conducts monitoring with a focus on ecosystem stresses, including lake acidification and eutrophication (the buildup of nutrients in a water body, leading to excessive plant growth). | Fisheries and Oceans Canada |
| **Physical and Chemical Environment (including Greenhouse Gases)—Atlantic**<br>Measures the hydrographic, physical, and chemical state of the marine ecosystem, including waves, winds, currents, tides, sea level, ice coverage and movement, temperature, salinity, oxygen, macronutrients, and surface chlorophyll. This includes the components of the carbon cycle as well as other climate-related chemicals. | Fisheries and Oceans Canada |
| **Physical and Chemical Environment—Pacific**<br>Measures the hydrographic, physical, and chemical state of the marine ecosystem, including waves, winds, currents, tides, sea level, ice coverage and movement, temperature, salinity, oxygen, macronutrients, and surface chlorophyll. | Fisheries and Oceans Canada |
| **Physical and Chemical Monitoring (including Greenhouse Gases)—Arctic**<br>Measures the hydrographic, physical, and chemical state of the marine ecosystem, including waves, winds, currents, tides, sea level, ice coverage and movement, temperature, salinity, oxygen, macronutrients, surface chlorophyll, and carbon. | Fisheries and Oceans Canada |
| **Greenhouse Gases—Pacific**<br>Measures components of the carbon cycle, as well as other climate-related chemicals. | Fisheries and Oceans Canada |
| **Soil and landforms** | |
| **Canadian Permafrost Monitoring Network**<br>Measures permafrost temperatures and the thickness of the active layer. | Natural Resources Canada |
| **Canadian National Seismograph Network**<br>Monitors signals from seismic sources, including earthquakes and other possible sources (for example, nuclear tests and mining blasts). | Natural Resources Canada |
| **Ecological Long-term Plots Monitoring**<br>Determines the long-term changes in soil productivity and health, water quality, and crop productivity in response to crop production and management practices. | Agriculture and Agri-Food Canada |
| **Contaminants in several components** | |
| **Chemicals Management Plan Monitoring and Surveillance**<br>Monitors chemical substances, including emerging chemicals of concern in air, water, sediment, and biota. | Environment Canada |

| Monitoring system name and description | Lead department or agency |
|---|---|
| **Northern Contaminants Program**<br>Monitors concentrations of contaminants, including persistent organic pollutants and mercury, in air, wildlife, and human residents of the Canadian North. | Aboriginal Affairs and Northern Development Canada |
| **First Nations Food Nutrition and Environment Study**<br>Monitors the health status, traditional foods consumed, contaminants in traditional foods, contaminants in drinking water, pharmaceuticals in surface water, and mercury in hair of First Nations people in Canada. | Health Canada |
| **Colonial Water Bird Contaminant Program**<br>Monitors changes in contaminant concentrations in seabird eggs in the marine and Great Lakes environments over time. | Environment Canada |
| **Plants and animals** | |
| **Acid Rain Biomonitoring Program**<br>Monitors the biological component of aquatic ecosystems in order to determine whether acid rain reduction efforts are sufficient to protect or enable the recovery of sensitive ecosystems across Canada. | Environment Canada |
| **Monitoring Deforestation in Canada**<br>Produces annual deforestation area estimates for Canada. Deforestation is defined as human-induced land use change from forest to non-forest. | Natural Resources Canada |
| **National Forest Inventory**<br>Estimates change in Canada's forest ecosystems. | Natural Resources Canada |
| **Species at Risk Recovery Monitoring**<br>Monitors status of species at risk under the *Species at Risk Act*. | Environment Canada |
| **Coastal Habitat Assessment and Monitoring Project**<br>Monitors marsh bird communities and their habitat in lower Great Lakes coastal wetlands. | Environment Canada |
| **National Wildlife Area (NWA) and Migratory Bird Sanctuary (MBS) Monitoring Program**<br>Monitors, surveys, and tracks ecological integrity and species trends within NWA and MBS. Assesses habitat changes, effectiveness of NWA management prescriptions, species at risk, and bird populations. | Environment Canada |
| **Annual Crop Inventory**<br>Identifies and maps the crops grown in agricultural fields in Canada annually. | Agriculture and Agri-Food Canada |
| **National Crop Monitoring System**<br>Provides weekly crop condition assessments for all of Canada south of latitude 60 degrees north. | Agriculture and Agri-Food Canada |
| **Lower Trophic Levels—Water Column—Atlantic**<br>Monitors organisms living in the water column, such as phytoplankton and zooplankton (13 different activities). | Fisheries and Oceans Canada |
| **Lower Trophic Levels—Water Column—Pacific**<br>Monitors organisms living in the water column, such as phytoplankton and zooplankton (9 different activities). | Fisheries and Oceans Canada |

| Monitoring system name and description | Lead department or agency |
|---|---|
| **Lower Trophic Levels—Benthos—Atlantic**<br>Monitors organisms that live on, in, or near the seabed (27 different activities). These activities exclude monitoring fish and higher organisms. | Fisheries and Oceans Canada |
| **Lower Trophic Levels—Benthos—Pacific**<br>Monitors organisms that live on, in, or near the seabed (14 different activities). These activities exclude monitoring fish and higher organisms. | Fisheries and Oceans Canada |
| **Higher Trophic Levels—Fish—Atlantic**<br>Monitors fish populations, including their abundance, distribution, and biological data (38 different activities). | Fisheries and Oceans Canada |
| **Higher Trophic Levels—Fish—Pacific**<br>Monitors fish populations, including their abundance, distribution, and biological data (21 different activities). | Fisheries and Oceans Canada |
| **Multi-Species Stock Assessment Surveys of Canadian Shrimp Fishing Areas in the Arctic**<br>Monitors northern shrimp, striped shrimp, and Greenland halibut populations to assess the effects of fisheries on these species in the Arctic. Also monitors other species, as well as water temperature and salinity. | Fisheries and Oceans Canada |
| **Community-based Monitoring of Freshwater and Anadromous Fishes in the Western Arctic**<br>Monitors populations of several related fish species (Dolly Varden, Arctic char, and lake trout) to assess the effects of fisheries on these species. | Fisheries and Oceans Canada |
| **Higher Trophic Levels—Marine Mammals—Atlantic**<br>Measures abundance, distribution, contaminant exposure, genetics, and diet of marine mammals in the Atlantic (19 different activities). | Fisheries and Oceans Canada |
| **Higher Trophic Levels—Marine Mammals—Pacific**<br>Measures abundance, distribution, contaminant exposure, genetics, and diet of marine mammals in the Pacific (6 different activities). | Fisheries and Oceans Canada |
| **Community-based Monitoring of Ice Seals—Arctic**<br>Monitors changes associated with global warming in several species of seals, including changes in age/sex structure, diet, reproduction, survival, contaminants, and disease. | Fisheries and Oceans Canada |
| **Aquatic Animal Health—American Oyster Health Surveillance**<br>Detects new occurrences of multinucleated sphere unknown parasitic disease, which can cause oyster mortality, and monitors any emerging diseases in oysters in the Atlantic. | Fisheries and Oceans Canada |
| **Aquatic Invasive Species—Atlantic**<br>Focuses on the early detection and monitoring of biofouling aquatic invasive species and their spread in high-risk ecosystems. Also focuses on assessing and understanding ecosystems at various stages of aquatic invasive species infestation (3 different activities). | Fisheries and Oceans Canada |
| **Aquatic Invasive Species—Pacific**<br>Detects new aquatic invasive species, and geographical spread of existing species (3 different activities). | Fisheries and Oceans Canada |

| Monitoring system name and description | Lead department or agency |
|---|---|
| **Aquatic Invasive Species—Central and Arctic**<br>Monitors and provides early detection of aquatic invasive species in the Great Lakes, and establishes a baseline for aquatic invasive species monitoring in the Canadian Arctic (3 different activities). | Fisheries and Oceans Canada |
| **Canadian Shorebird Monitoring**<br>Provides information on the current population status, distribution, and trends of shorebird species in Canada, including some monitoring in Latin America (about 15 different surveys for approximately 75 species). | Environment Canada |
| **Canadian Landbird Monitoring**<br>Provides information on the current population status, distribution, and trends of land bird species in Canada, largely relying on public volunteers (about 58 different surveys for approximately 250 species). | Environment Canada |
| **Canadian Waterfowl Monitoring**<br>Provides information on the current population status, distribution, and trends of waterfowl species in Canada, as well as the magnitude of harvest of game species (about 80 different surveys covering approximately 50 species). | Environment Canada |
| **Canadian Waterbird Monitoring**<br>Provides information on the current population status, distribution, and trends of waterbird species in Canada, including seabirds, inland colonial waterbirds, marsh birds, and others (about 37 different surveys for approximately 90 species). | Environment Canada |
| **Prairie Habitat Joint Venture Habitat Monitoring Program**<br>Monitors wetland and upland status and trends in the Prairie Habitat Joint Venture area. | Environment Canada |
| **Canadian Shellfish Sanitation Program**<br>Monitors shellfish (bivalve mollusc) harvest areas in Canada. Includes marine toxin monitoring, ongoing water quality monitoring for fecal contamination in the shellfish-growing area, and identification of pollution sources. | Canadian Food Inspection Agency with Environment Canada and Fisheries and Oceans Canada |
| **Interagency Wild Bird Influenza Survey**<br>Detects highly pathogenic strains of avian influenza early, identifies avian influenza viruses circulating in wild bird populations, and tracks genetic changes in the viruses over years. | Canadian Food Inspection Agency |
| **Plant Health Surveillance**<br>Monitors plant pests of quarantine significance, including invasive species. | Canadian Food Inspection Agency |
| **Wildlife Disease Monitoring**<br>Monitors different wildlife diseases in dead and live animals: West Nile virus, Lyme disease, white nose syndrome of bats, rabies, and others. (Avian influenza is listed separately in this inventory.) Monitoring is conducted by the Canadian Cooperative Wildlife Health Centre. | Environment Canada with Canadian Food Inspection Agency, Public Health Agency of Canada, and other federal partners |
| **Ecosystem processes** | |
| **Land Cover Time Series of Canada**<br>Uses satellite observations to provide information on land cover and land cover change at the national scale. | Natural Resources Canada |

| Monitoring system name and description | Lead department or agency |
|---|---|
| **Fire Monitoring, Accounting and Reporting System**<br>Integrates annual burned area mapping with models of fire weather and behaviour and fire ecological effects, resulting in estimates of carbon emissions. | Natural Resources Canada |
| **Lake Ontario Coastal Wetland Vegetation Dynamics Monitoring**<br>Monitors vegetation communities and wildlife habitat in response to a new water level regulation plan for Lake Ontario. | Environment Canada |
| **Human population** | |
| **Canadian Integrated Program for Antimicrobial Resistance Surveillance**<br>Tracks temporal and regional trends in antimicrobial use, and antimicrobial resistance in selected species of enteric bacteria along the food chain and from human cases. | Public Health Agency of Canada |
| **National Integrated Enteric Pathogen Surveillance Program**<br>Detects changes in trends in human enteric disease and in levels of pathogen exposure from food, animal, and water sources. | Public Health Agency of Canada |
| **Lyme Disease Surveillance System**<br>For the information of the public and medical practitioners, identifies the geographic locations where Lyme disease is emerging. | Public Health Agency of Canada |
| **West Nile Virus National Surveillance System**<br>Provides data for the prevention and control of West Nile virus and reduction of the disease's impact on Canadians. | Public Health Agency of Canada |
| **First Nations Biomonitoring Initiative**<br>Monitors First Nations people living on reserves to examine their current exposure to environmental chemicals or contaminants. The Assembly of First Nations is the custodian of the data. | Health Canada |
| **Canadian Health Measures Survey**<br>Collects key information relevant to the health of Canadians, including blood and urine samples, to test for chronic and infectious diseases, nutrition, and environmental markers. | Statistics Canada with Health Canada and the Public Health Agency of Canada |
| **Other environmental components** | |
| **Ecological Integrity Monitoring System**<br>Monitors the ecological integrity of Canada's national parks by measuring, for each major park ecosystem, the biodiversity, ecosystem processes, and sources of stress at both local and landscape scales. | Parks Canada |
| **Marine Protected Areas—Atlantic**<br>Monitors the status and efficacy of marine protected areas in the Atlantic. | Fisheries and Oceans Canada |
| **Marine Protected Areas—Pacific**<br>Monitors the status and efficacy of marine protected areas in the Pacific. | Fisheries and Oceans Canada |
| **Northwest Territories Cumulative Impact Monitoring Program**<br>Collects, analyzes, and synthesizes environmental information to provide cumulative effects information to decision makers. | Aboriginal Affairs and Northern Development Canada |

| Monitoring system name and description | Lead department or agency |
|---|---|
| **Canadian Geomagnetic Observatory Network**<br>Monitors the Earth's magnetic field and geomagnetic disturbances caused by space weather. | Natural Resources Canada |
| **Canadian Radiological Monitoring Network System**<br>Measures radioactivity levels in the environment locally, around major Canadian nuclear facilities, and more broadly across Canada, and collects precipitation and air samples to measure radioactive particulate matter and radioactivity doses. | Health Canada |
| **State of the St. Lawrence Monitoring Program**<br>Monitors and reports information on water, sediment, shorelines, biological resources, and uses of the St. Lawrence River. | Environment Canada |

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