Catalogue 11-528E, No. 2 – Occasional

Environmental Perspectives

2

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Statistics Canada
National Accounts and Environment Division
System of National Accounts

Environmental Perspectives 2

Studies and Statistics

Published by authority of the Minister responsible for Statistics Canada

June 1995

Price: Canada: $35.00
United States: US$42.00
Other Countries: US$49.00

Catalogue No. 11-528E, No. 2

ISBN 0-660-15573-7

Ottawa

Version française de cette publication disponible sur demande (n° 11-528F, n° 2 au catalogue).

Note of Appreciation

Canada owes the success of its statistical system to a long-standing co-operation involving Statistics Canada, the citizens of Canada, its businesses and governments. Accurate and timely statistical information could not be produced without their continued co-operation and goodwill.

Over 50% recycled paper including 10% post consumer fibre

Canadian Cataloguing in Publication Data

Main entry under title:

Environmental Perspectives

(Studies and statistics)
Issued also in French under title:
Perspectives sur l'environnement.
ISBN 0-660-15573-7
CS11-528E, no. 2

1. Environmental indicators -- Canada.
2. Environmental protection -- Canada.
3. Conservation of natural resources -- Canada.
I. Statistics Canada. National Accounts and Environment Division.
II. Statistics Canada. System of National Accounts Branch.
III. Title.
IV. Series.

HC113.5 E58 1995 333.7'0971
C95-988015-1

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Symbols

The following standard symbols are used in Statistics Canada publications:

- .. figures not available
- ... figures not appropriate or not applicable
- \- nil or zero
- -- amount too small to be expressed
- p preliminary figures
- r revised figures
- x confidential to meet secrecy requirements of the Statistics Act

Prefixes of the International System of Units

Prefix	Multiplication factor	
peta	10^{15}	1 000 000 000 000 000
tera	10^{12}	1 000 000 000 000
giga	10^{9}	1 000 000 000
mega	10^{6}	1 000 000
kilo	10^{3}	1 000
hecto	10^{2}	100
deca	10^{1}	10
deci	10^{-1}	0.1
centi	10^{-2}	0.01
milli	10^{-3}	0.001
micro	10^{-6}	0.000001
nano	10^{-9}	0.000000001
pico	10^{-12}	0.000000000001

Abbreviations

1986$	1986 dollars
°C	degrees Celsius
cm	centimetre
ha	hectare
hr	hour
kg	kilogram
km	kilometre
km^2	square kilometre
kPa	kilopascal
kt	kilotonne
L	litre
m	metre
m^2	square metre
m^3	cubic metre
mg	milligram
mm	millimetre
Mt	megatonne
ng	nanogram
nec	not elsewhere classified
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
SIC	Standard Industrial Classification
t	metric tonne
tC	metric tonne of carbon
TJ	terajoule
US$	United States dollars

Preface

Environmental Perspectives: Studies and Statistics is devoted to disseminating the results of analytical projects and development of data detailing the relationship between the environment and the economy. This publication appears annually between issues of the quinquennial ***Human Activity and the Environment***, which was last published in 1994.

Whereas ***Human Activity and the Environment*** is a comprehensive compendium of environmental-economic data, this publication presents a selection of data and analysis that reflect the current environmental statistics program at Statistics Canada.

The first chapter in this edition provides an overview of the three main directions of work in Statistics Canada's environmental statistics program: Environmental Information Systems, Environmental Surveys and Environmental Accounts. The remainder of the publication is organized according to these three themes.

Environmental Information Systems

- Chapter 2 provides an example of how the environmental information system was used to measure the impact of changing socio-economic trends on a selected geographic ecosystem: the Waterton Lakes National Park.

Environmental Surveys

- Chapter 3 highlights some results from the 1993 Local Government Waste Management Survey.

Environmental Accounts

- *Natural resource stock accounts:* In Chapters 4 and 5 the joint pilot projects between the Ontario Ministry of Natural Resources and Statistics Canada on the quantification and valuation of timber stocks for the province of Ontario are described. Chapter 6 assesses Canada's endowment of coal, by province, in both physical and value terms.
- *Natural resource use accounts*: Chapter 7 presents the development of a resource use account for water which follows the Canadian Input-Output Account model.
- *Waste output accounts*: Chapter 8 presents carbon dioxide emissions for 1981-1990 based on the Canadi-Input-Output Account model.This work demonstrates how waste output data are linked to economic activity.
- *Environmental protection expenditure accounts:* Chapter 9 presents environmental protection expenditures made by each of the levels of government in Canada.

Finally an annex provides a set of broad economic, social and environmental statistics for Canada's provinces and territories.

Acknowledgements

This publication was prepared by the Environmental Statistics sub-division of the National Accounts and Environment Division under the direction of Philip Smith, Director and Cynthia Baumgarten, Assistant Director. The editor was Rick Moll.

The authors were:

Alice Born
Murray Cameron
Christine de Boer
Véronique Dumas
Susan Ecclestone
Gerry Gravel
Tony Johnson
Anik Lacroix
Greg Lawrance
Rick Moll
Marcia Santiago
Philip Smith
Robert Smith
Doug Trant
Hélène Trépanier
Kevin Van Tighem

Dale Austin, Tracey Bushnik, Phillip Fong, Jeff Fritzsche, Joe Filoso, Craig Gaston, Julie McAuley and Debbie MacDonald all provided valuable technical help and/or editorial advice. The French translations were edited by Pierre Gagnon, Tara Gray, Jocelyn Lapierre, Anik Lacroix and Hélène Trépanier. The marketing and technical assistance of Mitzi Ross and Susie Boyd is also acknowledged.

1 Statistics Canada's Environmental Statistics Program

by Philip Smith[1]

Introduction

Resource depletion and environmental degradation are widely recognized today to be serious and growing problems. To understand and address these problems, governments and citizens need good environmental statistics. Yet the world's statistical systems, developed mostly this century, were not designed with this requirement in mind. They were set up primarily to provide information about human population and socio-economic development rather than about the environment - although these fields are certainly quite intimately related. Only within the last decade or two, as environmental issues have taken on more prominence, have statistical agencies started to reorient their focus.

The term 'environmental statistics' encompasses a vast breadth of subjects. It refers, firstly, to quantitative information about the physical environment: pollutant concentrations in air, water and soil, the size and character of forest, fish, wildlife and mineral stocks and the extent of biodiversity. But it also applies to economic, or value data: expenditures by businesses, households and governments for pollution abatement and control facilities and equipment, spill cleanup costs, land, lumber, fish and mineral market values and so on. Moreover, the phrase can refer to a variety of other related socio-economic data: on modes of transport, energy intensities, recycling behaviour, the extent of fertilizer and pesticide usage, cancer incidence and so on. Time series data provide information about changes related to the environment while spatial data shed light on the geographical distribution of environmental assets and problems. Environmental statistics provide us with an evolving picture of the physical world we live in and connect the main elements in that picture to the everyday actions of humanity.

In Canada, environmental data are collected by several federal, provincial and municipal government departments. The ministries of forestry, fisheries, energy, mines, agriculture, health, transportation, industry and, of course, environment all have monitoring and regulatory responsibilities that relate partly to the environment and that, of necessity, involve the gathering of environmental information. Statistics Canada also collects environmental data through its survey activities, and, equally importantly, it has responsibility for assembling data from other departments in the form of integrated environmental statistics.[2]

This chapter describes Statistics Canada's environmental statistics program. It begins with a short history of the program's evolution over the last two decades. Then the main elements of the current program - surveys, administrative data and environmental accounts - are discussed. This chapter concludes with some thoughts about future directions for the program.

History of the environmental statistics program

The *raison d'être* of Statistics Canada's environmental statistics program is to compile and publish integrated statistical information about the state of Canada's natural environment and the manner in which it affects and is affected by human activities. Environmental statistics are derived in four ways:

- by recasting existing household and business survey information, collected for other purposes, in a manner that makes it more useful for the analysis of environmental issues;
- by launching new surveys directly addressing questions that are of interest from an environmental perspective;
- by exploiting administrative and regulatory databases maintained by federal, provincial and municipal government departments as part of their normal responsibilities; and
- by constructing new time series estimates through the application of scientific and technical coefficients to socio-economic data.

During the initial years of the program, in the mid 1970s, efforts concentrated on the first of these approaches: making

1. The author is Director of the National Accounts and Environment Division at Statistics Canada. A version of this paper was presented at the 1994 joint statistical association meetings, in a session entitled "Environmental Assessments in the NAFTA Era", on August 15, 1994.

2. Article 3 of the Statistics Act, legislated in 1918 and amended several times since, establishes Statistics Canada:
a) to collect, compile, analyze, abstract and publish statistical information relating to the commercial, industrial, financial, social, economic and general activities and condition of the people;
b) to collaborate with departments of government in the collection, compilation and publication of statistical information, including statistics derived from the activities of those departments;
c) to take the census of population of Canada and the census of agriculture of Canada;
d) to promote the avoidance of duplication in the information collected by departments of government; and
e) generally, to promote and develop integrated social and economic statistics pertaining to the whole of Canada and to each of the provinces thereof and to coordinate plans for the integration of those statistics.

use of existing survey data to shed light on how human activities exert stress on natural ecosystems. The results of this early work were published in March 1978 in a new compendium called ***Human Activity and the Environment*** (Statistics Canada Cat. No. 11-509E).

A new geographical framework based on watersheds (or drainage basins)[1] was adopted in this publication. By reorganizing existing data within watershed regions instead of the more usual census enumeration areas or political boundaries of provinces and municipalities, the information could be seen in quite a different light. Watershed boundaries, defined by the Water Survey of Canada Division of Environment Canada, are coded and transferred to the National Topographic System maps used by Statistics Canada. Census data are then aggregated by including, in each drainage region, the data for all census enumeration areas for which the population centroid (essentially a centre of gravity concept) lies within the watershed boundary. Similarly, manufacturing data from the survey of manufacturing establishments are allocated to watersheds based on the Standard Geographical Code of the municipality in which the establishment is located.

This first edition of ***Human Activity and the Environment*** presented a collection of statistics on population, agriculture, forests, fisheries, transportation, manufacturing and energy. A variety of relevant time series were brought together in an environmental database and much of the information was displayed by watershed, although in certain cases, particularly where geographical detail was unavailable, data were presented at the all-Canada level only. Industrial activities were reclassified according to the degree of stress they exert on the environment:

- *High stressor industries* were those associated with the initial stages of manufacturing, characterized by large-scale bulk refinement and concentration processing of raw materials drawn from the environment. These industries typically require high-energy input per unit of output and are often identified as the high polluters.
- *Medium stressor industries* were largely those associated with the second level of processing where materials undergo a transformation for specialized purposes required for the next and final stage of production, although some finished-goods manufacturing is included as well where special polluting problems exist.
- *Low stressor industries* were mostly those that produce final goods, with processes distinguished by relatively low material and energy inputs and high labour inputs per unit of output. In terms of process activity, they tend to fall under the headings of assembly, construction or packaging.

The environmental statistics program moved in some new directions during the early and mid-1980s. For one thing, several new administrative data sources were explored and developed, beyond the Statistics Canada survey sources already being used. For another, there was a perceived need for an improved organizing framework for environmental statistics, which led to the development of the "Stress-Response Environmental Statistical System" (STRESS)[2]. This framework recognizes three main elements: (1) stresses imposed on the environment by human actions and events in nature, (2) responses by the environment to these stresses, and (3) actions by people to modify the character and intensity of the stresses that their activities exert on the environment. The system is summarized in Table 1.1.

The second edition of ***Human Activity and the Environment***, issued in March 1986, was organized around the STRESS framework, with chapters on population, harvesting, extraction and depletion of non-renewable resources, environmental restructuring, the generation of waste products, the responses of biological species to environmental stress, and collective and individual human responses. The statistical information it provided was greatly expanded compared to the first edition.

Tabulations were arrayed by watershed, as in the first edition, and also by ecozone[3] and by province. Statistics were also included on the physiography and climate of Canada and on major geophysical and meteorological events affecting the environment. The chapter on the generation of waste products was the largest and most ambitious, dealing separately with mining, manufacturing, thermal energy generation, transportation activity, household consumption and municipal waste. It drew upon a wide range of Statistics Canada data sources including the censuses of mines and manufactures, the surveys of electrical power and industrial consumption of energy, a wide variety of transportation survey data and population census data. Several databases from Environment Canada were also utilized, including most of those listed in Text Box 1.1. Other chapters presented information from Canada's Forest Inventory (established by the Canadian Forest Service), the census of agriculture, the survey of fertilizer trade, statistical databases main-

1. Watersheds are the heights of land which divide drainage basins, river basins or valleys, which in turn refer to surface drainage catchment areas. For example, a mountain range can form a drainage basin boundary separating two catchment areas. Drainage basins form a hierarchy, with five major basins at the top, draining into the Atlantic Ocean, Hudson Bay, the Arctic Ocean, the Pacific Ocean and the Gulf of Mexico. Beneath these five basins are 218 sub-drainage basins and 917 sub-sub-drainage basins. This geographical framework is useful for environmental analyses because water is vital for all life and flowing water conducts pollutants between ecosystems.

2. See Friend and Rapport, 1979 and Friend, 1981.
3. Ecozones are natural regions delineated by distinctive sets of biotic resources (flora and fauna) and physical resources (soils, bedrock, physiography, climate). They constitute fairly homogeneous geographical spaces that are useful for monitoring the impact of natural and human stresses on the environment. At the highest level, there are 15 ecozones. Beneath these are 47 ecoprovinces, divided into 177 ecoregions, divided into 5,395 ecodistricts. Ecozones, like drainage basins, transcend national boundaries and there is a need for better international standards in this area.

Table 1.1
The STRESS Organizational Framework

Stresses on the environment				Environmental response statistics	Human response statistics
Stressor categories	Activity categories	Activity statistics	Environmental stress statistics		
Natural source stresses	Geophysical and meteorological events and processes	Floods, storms, earthquakes	Rates of erosion, landscape change	Changes in air, water, soil characteristics Changes in biotic state	Environmental restructuring
Harvesting	Agriculture Forestry Fisheries	Production	Changes in soil characteristics Depletion of stocks	Changes in biotic state including population size, regenerative capability	Conservation Changes in methods of farming, harvesting Legislation, fish quotas
Extraction and depletion of non-renewable resources	Metals and non-metallic minerals Fossil fuels	Extraction	Depletion of resources Substitution	Substitution for scarce resources leads to impacts indirectly from wastes and restructuring associated with use of substitutes	Conservation
Environmental restructuring	Land conversion Restructuring water systems Transport networks Resource development	Construction of homes, dams, reservoirs, railways, highways Exploration for resources	Land converted, changed in character	Changes in air, water, soil characteristics Changes in biotic state including species diversity, population size (due to habitat change)	Changes in rate and location of land conversions Land use legislation Park creation
Generation of waste residuals	Mining Manufacturing Energy generation Transportation Households	Production Consumption Vehicle movements	Waste generated Emissions of wastes to air, water, soil Disposal of toxics	Changes in air, water, soil characteristics Changes in biotic state including species diversity, population size Human health effects	Pollution abatement through process change, activity termination Legislation Conservation
Population	Population dynamics	Population growth, migration			Population control, resettlement

tained by the international fisheries commissions and Fisheries and Oceans Canada, the International Commission on Large Dams, the Canadian Wildlife Service and the National Museums of Canada.

Text Box 1.1
Environment Canada Databases

- Canada Land Inventory (CLI)
- Hydrometric Database (HYDAT)
- Industrial Water Use Survey (INSURVS) database
- Municipal Water Use Database (MUD)
- Municipal Waterworks and Wastewater Database (MUNDAT)
- National Air Pollution Surveillance (NAPS) database
- National Analysis of Trends in Emergencies (NATES) database
- National Emissions Inventory System (NEIS) database
- National Inventory of Hazardous and Toxic Wastes (NIHTW) database
- National Pollutant Release Inventory (NPRI) database
- National Water Quality Database (NAQUADAT)
- Ocean Dumping Permit (ODUMP) control database
- Park Use Related Data System (PURDS) database
- Residual Discharge Inventory System (RDIS) database
- Regulated industries databases (pulp & paper, non-ferrous foundries, ferrous foundries, petroleum refining, mines)

The year 1986 also marked the publication of the first ***State of the Environment Report for Canada***, a joint effort by Statistics Canada and Environment Canada.[1] This volume provided a comprehensive and wide-ranging assessment of the condition of Canada's farmlands, forests, waters, wildlife and other natural resources and of the implications of changes in those conditions for Canadians. It adopted the ecozones framework and made considerable use of the statistical information presented in ***Human Activity and the Environment***.

In the late 1980s, Statistics Canada announced the establishment of a new spatially referenced database known as the Environmental Information System (EIS). Structured as a geographical information system, this database contains socio-economic and biophysical microdata from the censuses of population and agriculture, from the surveys of

1. The working relationship between Statistics Canada and the federal and provincial environment departments has grown stronger through the 1980s and into the 1990s. Statistics Canada contributed substantially to the most recent ***State of the Environment Report for Canada***, issued by Government of Canada in 1991 and has assisted with the preparation of several provincial reports as well, Statistics Canada has also worked closely with the Canadian Council of Ministers of the Environment (CCME) on a number of environmental statistics projects.

manufacturing and mining and from a number of other sources. The EIS can be used to analyze, through mapping techniques and cross-tabulations, environmental problems on various scales ranging from national issues to local watershed concerns. Aggregations are easily accomplished for studies relating to particular river basins, ecoregions or urban areas. Since in most cases comparable data are available for all of the census years 1971, 1976, 1981, 1986 and 1991, the database can answer questions about changes over time as well as about spatial dispersion. Some examples of EIS applications have been an analysis of the impact of creeping urbanization on the Jock River valley near Ottawa, a study of land use change around Riding Mountain National Park in Manitoba and an assessment of population exposure to air pollutants in metropolitan Toronto. Custom tabulations from this database, sufficiently aggregated to protect respondent confidentiality, are available to the general public.[1]

The third edition of ***Human Activity and the Environment*** was published in September 1991. It updated the statistics presented in the previous edition with data from the 1986 census and introduced some new tables to address emerging environmental issues, notably greenhouse gas emissions and the spread of the zebra mussel in the Great Lakes. The stress analysis that had been applied to manufacturing industries in previous editions of the book was extended and improved upon considerably, using an input-output approach. In addition, the STRESS framework, used in the 1986 edition, was revamped and renamed the Population-Environment-Process (PEP) framework. It is illustrated in Figure 1.1.

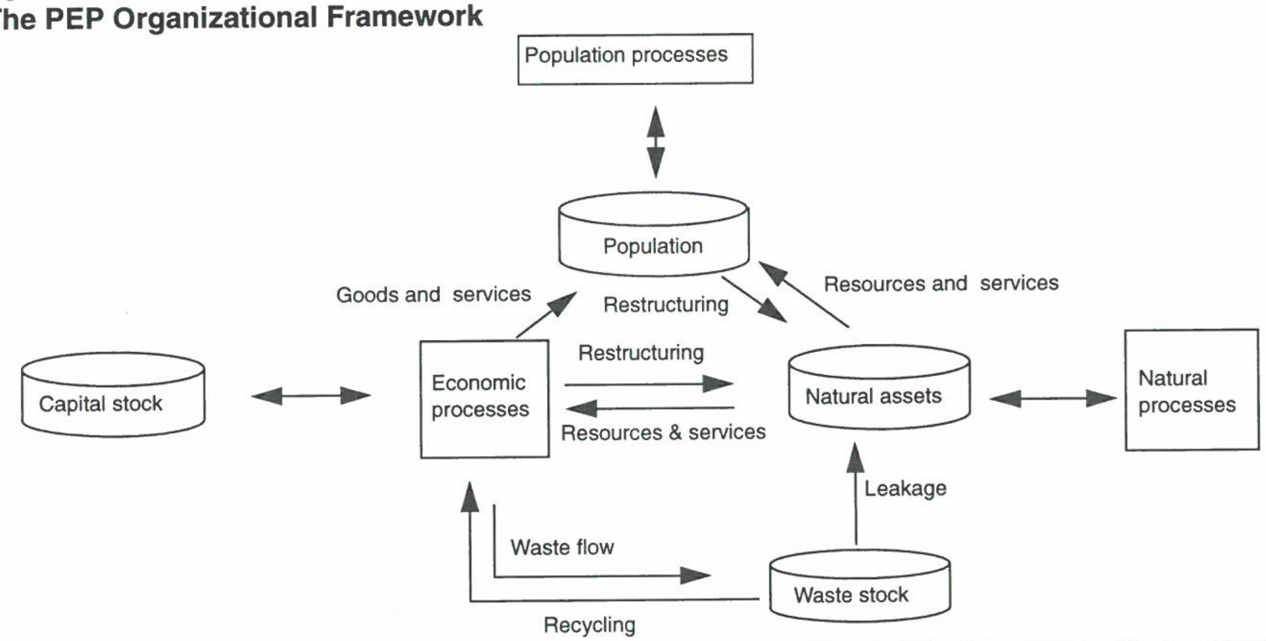
1. Selected data from the EIS are also available on E-Stat, Statistics Canada's CD-ROM product for use by schools.

In the PEP framework, the key elements are the population, the socio-economic system and the natural environment. Each element is characterized by stocks (or states, represented by barrels), processes (or activities, represented by boxes) and interactions with other components (flows or restructuring, represented by arrows). There are four state variables in the system: the population, the produced capital stock, natural assets (the non-produced capital stock) and the stock of waste products. Three kinds of processes involve and affect these state variables: population processes (birth, death, migration), socio-economic processes (production and consumption) and natural processes (storms, earthquakes, photosynthesis). Finally, interactions occur among the states and processes in the form of flows (ground water withdrawals, harvest of forests, sport fishing) and restructuring (the impact of human visits to wilderness areas, agricultural development, dam-building).

More recently, there have been further additions and improvements to the program. An annual publication[2] entitled ***Environmental Perspectives: Studies and Statistics*** (Statistics Canada Cat. No. 11-528E) made its début in March 1993. It contained a set of thirteen articles reviewing recent survey and analytical work at Statistics Canada in the general area of environmental statistics.[3]

2. ***Human Activity and the Environment*** is normally published at five year intervals, following the quinquennial census, and ***Environmental Perspectives*** will be published in the four intervening years.
3. It is planned that in future years ***Environmental Perspectives*** will also contain a varied collection of environmental time series indicators.

Figure 1.1
The PEP Organizational Framework



The fourth edition of ***Human Activity and the Environment*** was published in June 1994, containing fresh data from the 1991 census. The PEP framework continues to provide the organizing structure for the book. Results from several pilot surveys designed to fill important environmental data gaps are also included and there are new chapters outlining recent work in the area of environmental accounting and providing international and interprovincial comparisons.

While new survey work has been severely constrained by tight budgets, substantial progress is being made, as will be discussed in the next section. Renewed attention is also being focused on the exploitation of administrative data sources, as will be explained in the subsequent section. In addition, the environmental statistics program was expanded significantly in 1991 when the government gave Statistics Canada a new mandate to develop a comprehensive set of environmental accounts, as a satellite to the existing Canadian System of National Accounts. This recent development will be reviewed in the last major section of this chapter.

Surveys

Statistics Canada is mandated to conduct surveys of Canadian households, businesses and governments,[1] and to report continuously to the general public on the results. The survey program includes comprehensive censuses of population and agriculture, carried out every five years. In addition, there are annual, quarterly and monthly surveys of manufacturing, mining, agriculture, construction, transportation, finance, and other industries; of prices; of employment and earnings; of the labour force status of the population; of social conditions, including health, welfare and justice matters; and of education, culture and tourism. Surveys on other special topics are also conducted from time to time.

Few of the surveys conducted by Statistics Canada have an explicitly environmental focus, yet many provide information that is quite valuable for environmental analyses. The census of population shows where the environmental stresses associated with urban growth are being most keenly felt. The census of agriculture yields important data about land use change, and about pesticide and fertilizer usage, that, organized by watershed or by ecozone, can be associated with changes in water quality and human health. Other social and economic surveys on family expenditures, transportation, trade, industrial production, health and a host of other subjects are also relevant.

In the past few years, Statistics Canada has put increasing emphasis on the development of new surveys to fill key environmental data gaps. Surveys have been conducted in five areas:[2]

1. There are roughly 10 000 000 households, 1 500 000 businesses and 5 000 governments in Canada.

1. *Households and the environment*[3]

In this survey, households are asked about their access to and usage of recycling, special waste disposal programs, disposable diapers, lawn and garden pesticides and fertilizers, programmable thermostats, energy-efficient lighting, low-flow shower heads, water purifiers, bottled water, and public transit. The survey is conducted as an adjunct to the labour force survey.

2. *Pollution abatement and control expenditures by business and government*[4]

The purpose of this survey is to gather information from businesses and government departments about annual capital and operating expenditures on pollution abatement and control (PAC) facilities and equipment. PAC expenditures are defined as outlays for retrofit construction and/or machinery, meaning facilities or equipment that are separately identifiable, that have been installed for PAC purposes and that are not an integral part of the plant production equipment. The survey also seeks information about quantities of major substances abated or controlled and about sales and own use of PAC-recovered materials.

3. *Private sector waste management industry*[5]

This survey gathers data pertaining to the operating revenues, expenses, employment, capital expenditure and tonnage of waste material processed by business establishments engaged in the collection, haulage, disposal and/or recycling of waste products.

4. *Municipal government waste management practices*[6]

In this survey, municipalities of all types are questioned about their practices and associated costs with respect to the collection, transportation and disposal of garbage, recycling and the handling of hazardous waste. The survey is paired with the private sector waste management industry survey, as some municipalities contract out for waste management services while others provide the services directly.

5. *Packaging*[7]

The national packaging survey collects information from business establishments in all major industries on their use, reuse, recycling and disposal of industrial packaging. Some 32 packaging categories are defined in the survey, spanning six broad groups of materials: plastic, wood, textiles, glass, metal and multi-material packaging.

These surveys are pilot efforts. The first has been done three times, the fourth and fifth have each been conducted twice and the other two, only once. Means are being sought

2. Two other environmental surveys, ***Water Use in Canadian Industry*** and ***The Importance of Wildlife to Canadians***, have been conducted by Statistics Canada several times over the past two decades, under the sponsorship of Environment Canada.
3. Statistics Canada, 1994.
4. Statistics Canada, 1992a.
5. Statistics Canada, 1992c.
6. Statistics Canada, 1993a, p. 69-74.
7. Statistics Canada, 1993a, p. 63-66.

to establish them all on a regular basis so that time series can be developed.

There are many other areas where more survey information is required. One is waste products, where better time series data are needed on emissions, by type of material, by industry. The National Pollutant Release Inventory (NPRI) survey, being developed by Environment Canada, is expected to fill part but not all of this data gap. Improved information about garbage generation, by type of material, by municipality is also needed. More regular and complete survey data are required as well in the area of environmental expenditures, on both the demand and the supply sides. There is increasing policy interest in the characteristics of the 'industry' that supplies the market for pollution abatement and control facilities and equipment.[1] Wildlife is yet another area where good data are lacking, although many of the requirements here can only be satisfied by scientific inquiries, rather than business and household surveys.

Administrative data

Statistics Canada draws a lot of statistical information from administrative data sources. Customs data, income and sales tax records, public accounts and regulatory data all yield detailed information with relatively high quality and high frequency, coupled with relatively low marginal acquisition cost and no marginal response burden. Under the Statistics Act, the Bureau has the responsibility and the authority to access these data sources and to produce and publish statistical series from them.[2]

Regulatory data from Environment Canada are a very important source of environmental information. As was noted previously, ***Human Activity and the Environment*** includes a wide range of statistics drawn from the MUNDAT, NAPS, NATES and NAQUADAT regulatory databases and some others. Statistics Canada also makes use of administrative data from the Canadian Forestry Service, Fisheries and Oceans Canada, the Canada Centre for Remote Sensing and several other agencies.

Still, there is an enormous wealth of environmental information remaining in administrative databases that has not yet been brought to light and exploited. Finding and extracting this information is not a simple task, since the datasets are widely dispersed within and among government departments and since they are stored in a wide variety of often poorly documented formats, using differing concepts.

Substantial progress has been made recently in identifying these databases and exploring their potential. Statistics Canada has conducted two exhaustive searches, one of federal government departments and another of provincial government departments, to catalogue administrative databases relevant for environmental monitoring and analysis. The results of these searches are published in two volumes, ***Databases for Environmental Analysis: Government of Canada*** (Statistics Canada Cat. No. 11-527E) and ***Databases for Environmental Analysis: Provincial and Territorial Governments*** (Statistics Canada Cat. No. 11-529E). These 'meta' databases contain characteristic information about each database: a description of the contents and purpose, the name and address of contact persons, the geographical coverage, the data acquisition method, the update frequency, the period for which data are available, the database hardware and software configuration, the output formats, the language(s) used, any restrictions on access and pricing information. These two 'databases of databases' are being maintained in electronic form, which facilitates rapid keyword searching, and they will be updated periodically in the future. They point to many rich lodes from which new statistical series can be developed.

Environmental accounts

About four years ago, Statistics Canada was asked by the Government of Canada to begin work on a new system of natural resource and environmental accounts, to be developed as a satellite to the existing Canadian national accounts. Funds were provided for the project as part of a broad government policy initiative, referred to as Canada's Green Plan.[3] Given the size and diversity of Canada and its resource base, the job of developing this new body of statistics is a very large one. It is anticipated that the work to develop the new accounts will take several years.

The project is moving ahead on schedule.[4] So far, particular effort has been concentrated on developing natural resource accounts, for both renewable and non-renewable resources. First priority has been given to oil and gas reserves and timber assets, two of Canada's most important natural resources. Some exploratory work also has been done on reserves of metal ores and other minerals, on land accounts and on wildlife accounts. Pollution and waste statistics and their linkage to economic activity have also received some attention, particularly in

1. The 'environmental industry' is actually a rather ill-defined mixture of industries from the Standard Industrial Classification (SIC), each of which produces goods or services having an environmental character. In this respect it is analogous to the 'tourism industry'. There is no 'environmental industry' as such in the SIC. However, at the time of the next SIC revision, planned for 1997, new and growing industries of particular interest from an environmental perspective will be more fully and carefully delineated.
2. Statistics Canada is required under the law to protect the confidentially of individual records vigilantly, by aggregating the information sufficiently.
3. See Government of Canada, 1990. The Green Plan is a comprehensive, multi-year government policy initiative involving actions in the areas of human health protection, water care and restoration, smog and other waste reduction, sustainable development of forest, agriculture and fishery resources, protection of unique ecological areas and wildlife, the reduction of global warming pressures, improved handling of environmental emergencies and provision of more complete public information about Canada's environment.
4. For a more detailed outline of the progress to date on the environmental accounting project, see Smith, 1994.

the area of greenhouse gas emissions. Resource use accounts for energy, water and some other materials are under development and a comprehensive set of environmental protection expenditure accounts is planned.

The environmental component will be a satellite[1] of the existing Canadian national accounts with four distinct components:

- *natural resource stock accounts*, recording the known size and composition of Canada's natural resource assets as they evolve over time, in both physical and monetary terms;
- *natural resource use accounts*, recorded in physical terms, showing when and how non-produced goods and services are brought into the economic sphere and used in production and consumption activities, and highlighting the role of selected produced goods that are important in analyses of certain environmental issues;
- *waste output accounts,* recorded in physical terms, reporting the types and quantities of waste products that are generated in the economy and relating these to the flow of output; and
- *environmental protection expenditure accounts* identifying current and capital expenditures, by business, government and households, that are intended to conserve or protect natural resources and the environment.

The broad structure of the environmental accounts and their relationship to the conventional Canadian national accounts are shown in Figure 1.2. The natural resource stock accounts, expressed in monetary terms, are an addition to the national balance sheet. The existing Canadian national balance sheet and flow accounts include only financial and produced assets. The plan is to develop physical and monetary natural resource stock and flow accounts according to the classification suggested in the revised SNA,[2] that is, for each of the asset categories shown in Text Box 1.2.

The natural resource use accounts will show the physical quantities of various natural resources that are used by industries to produce their outputs, and by consuming households. As such, these accounts provide additional detail for selected rows in the use matrix of the input-output tables

Text Box 1.2

SNA Asset Classification

- Tangible non-produced assets
  - Land
    - Land underlying buildings and structures
    - Land under cultivation
    - Recreational land and associated surface water
    - Other land and associated surface water
  - Subsoil assets
    - Coal, oil, natural gas and crude bitumen reserves
    - Metallic mineral reserves, notably copper, nickel, zinc, lead, gold, silver, molybdenum, iron and uranium ores
    - Non-metallic mineral reserves, notably gypsum, potash, asbestos, salt, limestone, sand and gravel
  - Non-cultivated biological resources
    - Forest timber
    - Wildlife, notably fish, moose, deer and caribou
  - Water resources

converted from monetary terms to physical units. For natural resource commodities, the total use is carried over to the 'other changes in volume of natural resource assets' statement, where it helps account for changes in natural resource reserves over time. For other environmental commodities such as air and water, there are no corresponding stock accounts, although associated environmental quality measures can be developed and, possibly, linked to the resource use and waste output accounts.

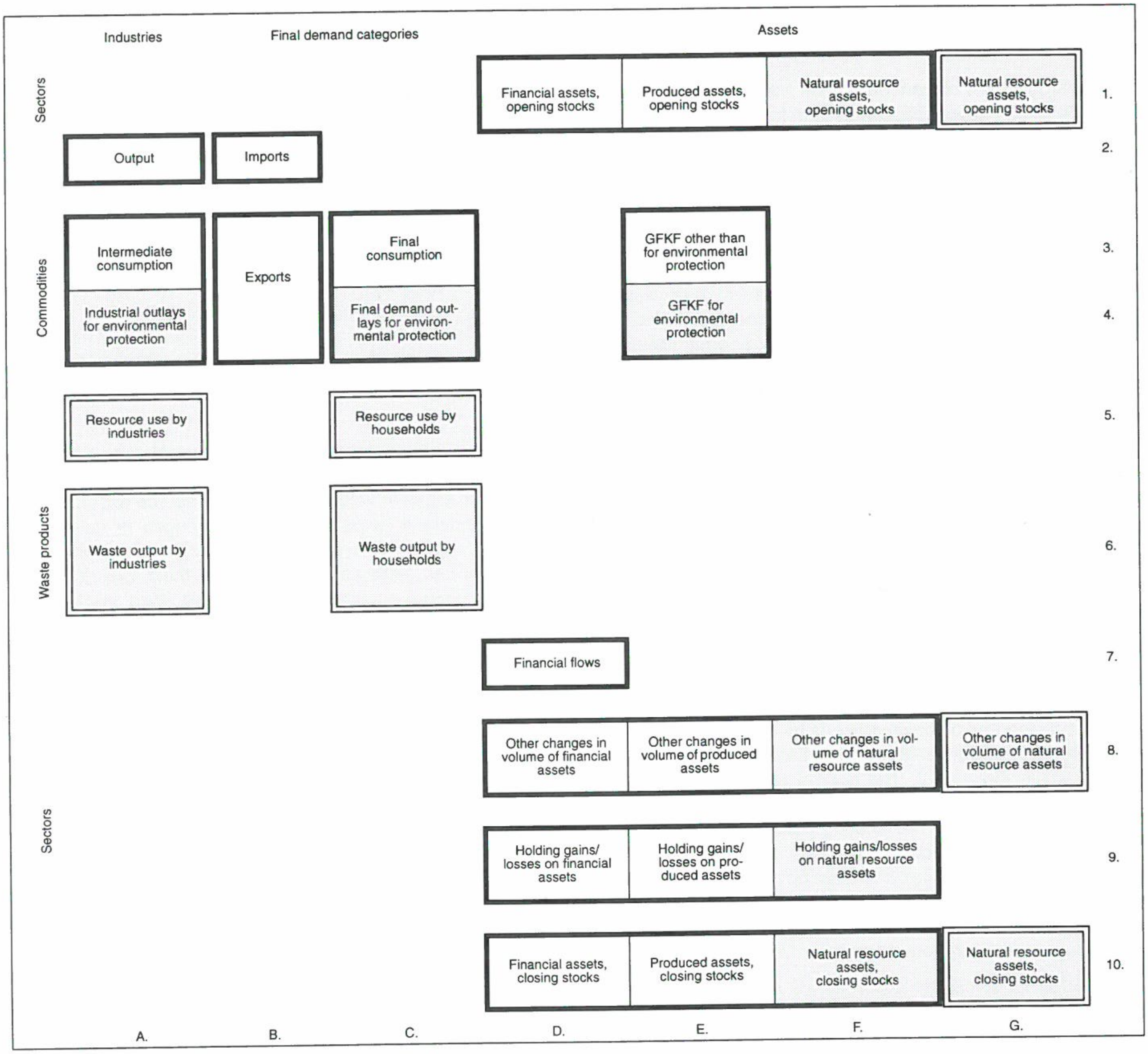
The waste output accounts will record emissions of waste products, whether solid, liquid or gaseous, generated by industries, governments and households. These accounts will be developed in physical terms only. They can be thought of as a counterpart of the resource use accounts, the two together providing an integrated description of natural resources flowing through and being transformed by the economic system. Sub-accounts may also be developed for international 'trade' in waste products and for accumulations of waste.[3]

Finally, the environmental protection expenditure accounts will disaggregate the existing gross output time series in the core national accounts to show 'defensive' or 'protective' outlays separately from other production. Initially these accounts will be restricted to 'end-of-pipe' type expenditures.[4]

This framework bears many similarities to the System of Integrated Environmental and Economic Accounting (SEEA), proposed by the Statistical Division of the United Nations.[5]

1. United Nations *et al.*,1993a, chapter XXI, contains a discussion of satellite accounts in general and environmental satellite accounts in particular: "Typically satellite accounts or systems allow for: (a) the provision of additional information on particular social concerns of a functional or cross-sector nature; (b) the use of complementary or alternative concepts, including the use of complementary and alternative classifications and accounting frameworks, when needed to introduce additional dimensions to the conceptual framework of national accounts; (c) extended coverage of costs and benefits of human activities; (d) further analysis of data by means of relevant indicators and aggregates; and (e) linkage of physical data sources and analysis to the monetary accounting system." (p. 489.)
2. See United Nations *et al.*,1993b, annex V, part D.
3. Garbage is routinely shipped for disposal between Canada and the United States, depending on where the tipping fees are lowest. It would be useful to identify these shipments within the satellite account, as well as any concentrated accumulations of garbage or hazardous waste products.
4. By 'end-of-pipe' expenditures is meant outlays for non-integrated equipment or facilities acquired specifically for the purpose of pollution abatement and control. It is often more difficult to distinguish PAC expenditures when pollution abatement is a built-in function of the associated equipment and facilities.
5. United Nations, 1993a.

Figure 1.2
Natural Resource and Environmental Accounts within the Canadian National Accounts*



* Shaded areas are part of the environmental satellite account. In some instances these parts are simply decompositions within the existing core national accounts (row 4). In others they represent additions to the core accounts in line with the new UN-SNA standard (column F). Finally, in some cases they represent enhancements for the purposes of the satellite account only (rows 5 and 6 and column G). Boxes with solid black borders represent accounts measured in monetary units; boxes with double-line borders represent accounts measured in physical units. GFKF signifies 'gross fixed capital formation'.

A major difference though is that in the SEEA, several items are moved up from the 'other changes in volume of natural resource assets' account and netted against gross fixed capital formation (GFKF) and gross value added, defining a new aggregate, 'environmentally-adjusted net domestic product' (EDP). The Canadian satellite accounts will not, at least not in their initial versions, redefine or supplement existing SNA aggregates such as gross or net domestic (or national) product, although the accounts will provide much of the information necessary for those who may wish to calculate such 'green aggregates'. It will take many years of data development, research and professional discussion before meaningful, reliable and credible aggregates of this kind are possible from a statistical perspective.

As has been noted, and as is recommended in the revised SNA, much of the statistical information in the satellite accounts will be measured in physical units rather than or as well as in monetary terms. In most cases, physical measurement of stocks and flows is a necessary first step even if the ultimate objective is monetary values. The measurement of physical stocks and flows is also less controversial. Some priority is being given to assessing monetary values for natural resource assets, but this effort is regarded as experimental at this stage. Like other countries, Canada is hoping a clearer international consensus on what valuation techniques are most appropriate will soon begin to emerge. The assignment of monetary values to natural resource assets will have the obvious benefit of facilitating aggregation and comparisons of diverse asset types.

In some areas the development work is moderately well advanced while in others little progress has been made so far beyond basic exploratory investigations. Canada's natural resources are vast and the task of building the satellite accounts is expected to take several years.

Conclusion

Canada's environmental statistics program has grown and matured considerably over the past two decades. Progress has been made on many fronts.

Four editions of the compendium ***Human Activity and the Environment*** have been published - in 1978, 1986, 1991 and 1994 - and each one has brought important extensions and improvements. The GIS-type environmental database upon which ***Human Activity and the Environment*** is built has grown larger and more comprehensive over time and this database is now available for use by the general public. The annual publication ***Environmental Perspectives: Studies and Statistics*** has been established to report on new developments in environmental statistics between the normally quinquennial issues of ***Human Activity and the Environment***.

Year by year, new environmental data sources have been developed. Some of these sources are the result of efforts to recast existing Statistics Canada survey data in ways that are more useful for environmental analysis. Others reflect the establishment of new household, business and government surveys designed to fill key data gaps. Still others arise from the identification and exploitation of administrative and regulatory data. And finally, in some cases new time series estimates are now being derived for the purposes of the environmental accounts by applying technical coefficients to economic data.[1]

Much headway has been made in developing an appropriate conceptual framework for environmental statistics, starting with the STRESS approach and evolving from there to the PEP system. Now, working with other countries and some international institutions, Canada is developing another framework, building upon the System of National Accounts structure that has proven so effective, for some fifty years, as a means for organizing economic statistics.

But the environmental statistics program still faces many important challenges as the demand for more and better statistics grows steadily. A great many data gaps remain and more new surveys are required. Despite the advances that have been made, there continues to be a vast potential for the better use of administrative and regulatory information for statistical purposes. The field of environmental accounting, while exciting and promising, is still in its infancy. Quite clearly, the future agenda for Canada's environmental statistics program is a full and challenging one.

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1. For example, annual time series estimates of industrial greenhouse gas emissions, by type of gas, have been developed by applying engineering coefficients to input-output statistics. See R. Smith, Statistics Canada, 1993a, p. 9-18.

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2 Environmental Change Around Waterton Lakes National Park

by Douglas Trant[1], Christine de Boer[1] and Kevin Van Tighem[2]

Introduction

Waterton Lakes National Park is part of the Crown of the Continent ecosystem. This ecosystem is centred around the Lewis, Clark and Livingston Ranges of the Rocky Mountains and covers 15 000 square kilometres of southwestern Alberta and southeastern British Columbia in Canada, and northwestern Montana in the United States. Map 2.1 indicates the location of the study area.

Map 2.1
Study Area Location

Waterton Lakes National Park is part of the protected core of the Crown and is known as the place "...where prairie grasslands meet the Rocky Mountains." In fact, the entire area is one of abrupt landscape transitions. Because of the exceptional biodiversity and cultural value of the area, the Man and the Biosphere Program, initiated by the United Nations Educational, Scientific and Cultural Organization (UNESCO), designated Waterton Lakes National Park as a "biosphere reserve" in 1976. This serves to encourage the protection and scientific study of this area for all the world's people.[3]

Waterton Lakes National Park has both intrinsic and scientific value. On the one hand, it is a Canadian national park, a place that has been set aside to be kept unimpaired and in a state of ecological integrity so as to benefit present and future generations of Canadians. On the other hand, as a biosphere reserve it is the protected core of a diverse and important regional ecosystem and serves as a benchmark for measuring the impacts of change in that broader area.

The present study was undertaken as part of a broad initiative to detect trends and emerging issues within the Crown of the Continent ecosystem. The scenic beauty, abundant wildlife and ecological diversity that most residents and visitors consider to characterize the Crown are all influenced by social and economic factors that lead to landscape modification or changing levels and intensities of human use. The purpose of this study is to measure changing socio-economic trends that are influencing the environment within the Crown of the Continent ecosystem.

Physiography of the study area

The study area is formed by four areas which can be described by the characteristics of the ecoregions which are contained within them. Demarchi and Lea (1993) describe these ecoregions, which are depicted in Map 2.2, in detail.

The Flathead Trench, the Rocky Mountains and higher portions of the Porcupine Hills are within the Northern Continental Divide ecoregion. For the purposes of this study, this ecoregion is divided into two areas between British Columbia and Alberta. This ecoregion is characterized by coniferous forest ranging from Douglas-fir and limber pine at lower elevations, through extensive lodgepole pine forests to high elevation forests of subalpine fir, Engelmann spruce and whitebark pine. The climate here is Cordilleran with mild summers (less than 80 frost-free days per year) and cold winters frequently moderated by mild chinook winds. Annual precipitation exceeds 400 mm with most falling between May and July.

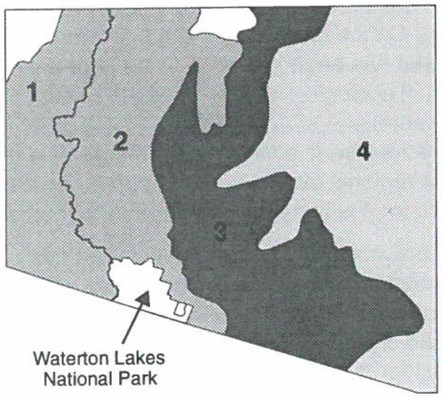
In the Chinook Upland ecoregion, the foothills and lower portions of the Porcupine Hills are found. This area is characterized by the prevalence of rough fescue/timer oatgrass grassland in a rolling upland landscape and some extensive stands of aspen. The climate is predominantly continental with warm summers (80 to 100 frost-free days per year) and cold winters frequently moderated by mild chinook winds. Annual levels of precipitation are between 450 and 600 mm, with peak rainfall between May and July.

The third ecoregion within the study area is the Southern Alberta Plains, which includes the western edge of the Great

1. Research Analysts, National Accounts and Environment Division, Statistics Canada, Ottawa, Ontario.
2. Ecosystem Management Specialist, Waterton Lakes National Park, Waterton Park, Alberta.

3. To date, six UNESCO biosphere reserves have been designated in Canada, while more than 300 other heritage sites have been chosen in the 198 bio-geographic provinces around the world.

Map 2.2
Ecoregion Study Area Reference Map - Province and Ecoregion Boundaries



Provincial Ecoregions:

BRITISH COLUMBIA

1 - Northern Continental Divide

ALBERTA

2 - Northern Continental Divide
3 - Chinook Upland
4 - Southern Alberta Plains

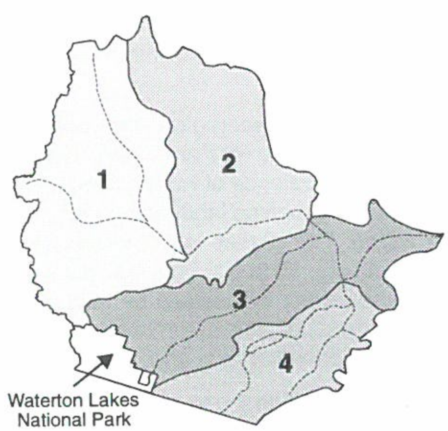
Source:
Demarchi, D.A. and E.C. Lea, 1993.

Plains and the downstream reaches of major rivers draining the east side of the Crown of the Continent ecosystem. This area is characterized by the prevalence of speargrass/wheatgrass grassland in an undulating plain with deeply incised river valleys. However much of the natural vegetation has been converted to agricultural uses. The climate here is continental with hot summers (100 to 120 frost-free days per year) and cold winters occasionally moderated by chinook winds. Annual precipitation averages from 350 to 500 mm, with most falling from May through July.

A second perspective for this study was to examine changing land use within watersheds surrounding Waterton Lakes National Park. There are four river basins which are studied, where the western edge of the Great Plains, incised by coulees and large river valleys, ranges in elevation from 3 000 to 4 500 feet. Map 2.3 defines this study area and indicates the park's location. Major drainage basins include the Upper Oldman River, Willow Creek, Belly, Waterton and St. Mary Rivers.

For the purposes of this study, socioeconomic and land data are stratified and analyzed by ecoregion, as defined by the ecoregion study area, and by watershed, as defined by the river basin study area.

Map 2.3
River Basin Study Area Reference Map - River Basin Boundaries



River Basins:

ALBERTA

1 - Upper Oldman River Basin
2 - Willow Creek Basin
3 - Belly and Waterton Rivers Basin
4 - St. Mary River Basin

——— river basin boundaries

-------- river

Note:
The solid lines represent river basin boundaries. Dashed lines indicate larger river channels only.
Source:
Water Resources Branch, Inland Waters Directorate, Environment Canada, 1986.

Employment and demographic trends

The Canadian portion of the Crown of the Continent ecosystem is sparsely populated, especially west of the Continental Divide. Population density increases eastward from the Rockies and land use is for the most part agricultural. The main agricultural activities include cattle/forage ranches and mixed barley and wheat farms.

Table 2.1 indicates that the population of the ecoregion study area increased by 34 percent between 1971 and 1991. The largest change occurred between 1971 and 1981 when population increased by 25 percent. In Table 2.2 rural population increased by 15 percent over the twenty year study period, and now exceeds a one-third share of the area's population. The largest fluctuations and changes in rural population occurred in the Northern Continental Divide ecoregion. In addition, the total population of this region more than doubled between 1971 and 1991.

Table 2.1

Population by Ecoregion, 1971 - 1991

Provincial ecoregion	Total population					Population change		
	1971	1976	1981	1986	1991	1971-1981	1981-1991	1971-1991
	number of people					percent		
British Columbia								
Northern Continental Divide	3 926	6 784	8 291	8 938	7 854	111.2	-5.3	100.1
Alberta								
Northern Continental Divide	7 807	8 650	8 879	8 368	8 022	13.7	-9.7	2.8
Chinook Upland	16 571	16 108	17 201	16 698	18 028	3.8	4.8	8.8
Southern Alberta Plains	72 428	82 254	91 856	97 210	100 806	26.8	9.7	39.2
Study area total	**100 732**	**113 796**	**126 227**	**131 214**	**134 710**	**25.3**	**6.7**	**33.7**

Sources:
Statistics Canada, National Accounts and Environment Division and Census of Population.

Table 2.2

Rural Population by Ecoregion, 1971 - 1991

Provincial ecoregion	Rural population					Population change			Rural share of total population		
	1971	1976	1981	1986	1991	1971-1981	1981-1991	1971-1991	1971	1981	1991
	number of people					percent			percent		
British Columbia											
Northern Continental Divide	1 773	1 796	1 898	3 233	2 455	7.1	29.3	38.5	45.2	22.9	31.3
Alberta											
Northern Continental Divide	2 994	3 600	4 287	5 064	4 773	43.2	11.3	59.4	38.4	48.3	59.5
Chinook Upland	10 659	9 617	10 177	9 401	10 888	-4.5	7.0	2.1	64.3	59.2	60.4
Southern Alberta Plains	17 000	19 550	19 576	19 788	19 271	15.2	-1.6	13.4	23.5	21.3	19.1
Study area total	**32 426**	**34 563**	**35 938**	**37 486**	**37 387**	**10.8**	**4.0**	**15.3**	**32.2**	**28.5**	**27.8**

Sources:
Statistics Canada, National Accounts and Environment Division and Census of Population.

In addition to population size, employment statistics provide valuable insight into the economy of the area. Table 2.3 provides counts of the number of people employed by industry within each ecoregion for the years 1981 and 1991.

The Southern Alberta Plains ecoregion employment profile dominated the employment distribution figures in the study area as it supported 75 percent of the total employment. For this region, the services and trade industries together accounted for close to one half of employed persons. By 1991 employment had decreased in the trade, manufacturing and construction industries, while increases in employment occurred in the services and public administration industries.

Within the ecoregions, the ranking of industries by relative contribution to employment varied slightly. In the British Columbia Northern Continental Divide, the mining industry dominated the employment distribution with over half of this region's employment. This industry also maintained strong employment in the Alberta portion of the Northern Continental Divide over the ten years. This high proportion of mining activity is due to the existence of eleven open pit mines and one crushing plant in the Canadian portion of the Crown of the Continent ecosystem. The services industry was consistently among the top two industries in all ecoregions.

Wholesale and retail trade were the third largest employer in the Northern Continental Divide and Chinook Upland regions. The agriculture industry dominated for both 1981 and 1991 in the Chinook Upland ecoregion, accounting for close to 30 percent of the area's employment. Although the manufacturing and agriculture industries alternated as the third largest employer in the Southern Alberta Plains between 1981 and 1991, both are still significant contributors to employment.

Despite consistent increases in the levels of employment between 1981 and 1991 in the Chinook Upland and Southern Alberta Plains ecoregions, the employment rate declined for the same period. The employment rates ranged from 91 percent to 95 percent in 1981, but by 1991 they had dropped to between 88 percent and 92 percent. During the same period, the size of the labour force grew by one quarter for the Chinook Upland ecoregion, while only small increases were felt in the Northern Continental Divide - an area which experienced both a decline in population and a reduction in labour force size between 1981 and 1991.

Table 2.3

Employment by Industry and Ecoregion, 1981 and 1991

	Ecoregion															
	B.C. - Northern Continental Divide				Alberta - Northern Continental Divide				Chinook Upland				Southern Alberta Plains			
	Employed persons		Employment distribution		Employed persons		Employment distribution		Employed persons		Employment distribution		Employed persons		Employment distribution	
Industry	1981	1991	1981	1991	1981	1991	1981	1991	1981	1991	1981	1991	1981	1991	1981	1991
	persons		percent		persons		percent		persons		percent		persons		percent	
Agriculture	25	40	0.6	1.2	350	340	9.4	9.3	1 925	2 660	28.7	32.6	4 320	4 555	10.1	9.9
Communication	45	35	1.1	1.0	50	45	1.3	1.3	65	35	1.0	0.5	850	825	2.0	1.8
Construction	250	105	6.5	2.8	255	190	6.8	5.3	550	515	8.2	6.3	3 610	2 595	8.5	5.7
Finance	60	125	1.6	3.4	120	105	3.1	2.9	160	170	2.4	2.1	1 810	1 715	4.2	3.7
Fishing and hunting	-	-	-	-	-	-	-	-	-	5	-	0.1	5	15	0.0	0.0
Forestry	40	10	1.0	0.4	70	80	2.0	2.1	20	25	0.2	0.3	5	40	0.0	0.1
Manufacturing	160	115	4.1	3.1	315	280	8.4	7.6	280	285	4.2	3.5	4 800	3 940	11.2	8.6
Mining	2 155	1 845	55.8	50.3	815	660	21.8	18.1	270	225	4.1	2.7	195	320	0.5	0.7
Public administration	90	130	2.4	3.5	210	225	5.6	6.1	450	550	6.7	6.7	3 305	3 765	7.7	8.2
Public utilities	-	25	-	0.7	20	30	-	0.8	55	45	0.9	0.5	530	520	1.2	1.1
Services	640	700	16.5	19.0	825	1 005	22.1	27.5	1 420	2 200	21.2	26.9	11 845	16 645	27.7	36.3
Transport and storage	140	95	3.6	2.5	70	100	1.9	2.7	175	215	2.6	2.6	1 715	1 950	4.0	4.2
Wholesale and retail trade	240	375	6.2	10.2	515	495	13.9	13.6	960	980	14.3	11.9	8 585	7 920	20.1	17.3
Undefined	40	75	1.0	2.0	120	100	3.3	2.7	385	260	5.7	3.2	1 185	1 075	2.8	2.3
Total employed	**3 870**	**3 665**	**100.0**	**100.0**	**3 740**	**3 645**	**100.0**	**100.0**	**6 705**	**8 170**	**100.0**	**100.0**	**42 740**	**45 895**	**100.0**	**100.0**
Total unemployed	**290**	**500**	...	...	**370**	**515**	...	...	**380**	**735**	...	...	**2 860**	**5 465**	...	...
Total labour force[1]	**4 165**	**4 175**	...	...	**4 105**	**4 165**	...	...	**7 095**	**8 905**	...	...	**45 600**	**51 370**	...	...

Notes:
Figures may not add due to rounding.
1. Total labour force data is the sum of employed and unemployed persons.
Sources:
Statistics Canada, National Accounts and Environment Division and Census of Population.

Land use characteristics

Agriculture is the dominant land use activity in the ecoregion study area. Throughout the study period (1971-1991) agriculture has occupied on average between 61 and 67 percent of the land area here. Farmland area increased by 8.8 percent over the 20 year period rising from 1.48 to 1.61 million hectares. Table 2.4 describes these changes in farmland area in absolute and relative terms.

The principal ecoregion undergoing change is the Northern Continental Divide. Here the amount of farmland area within the Alberta portion tripled by 1991, though farmland still accounts for less than 50 percent of the ecoregion area. The British Columbia portion of the Northern Continental Divide has experienced a 25 percent reduction in farmland. Little change has occurred in the Southern Alberta Plains and the Chinook Upland which consist mainly of farmland (90 percent).

Table 2.5 looks at farmland area in the river basin study area. Here farmland occupies an average of 61 percent of the land area, with only a marginal increase in area between 1971 and 1991. Moderate decreases in farmland area occurred in the Willow Creek and Belly/Waterton River basins.

Table 2.4
Farmland Area by Ecoregion, 1971 - 1991

Provincial ecoregion	Ecoregion area	Farmland area 1971	1976	1981	1986	1991	Proportion in agriculture 1971	1991	Change in area 1971-1981	1981-1991	1971-1991
	hectares						percent				
British Columbia											
Northern Continental Divide	339 991	3 995	3 922	3 510	3 871	2 973	1.2	0.9	-12.1	-15.3	-25.6
Alberta											
Northern Continental Divide	543 336	78 173	126 162	125 150	138 503	241 183	14.4	44.4	60.1	92.7	208.5
Chinook Upland	714 851	647 460	555 062	557 977	561 639	649 157	90.6	90.8	-13.8	16.3	0.3
Southern Alberta Plains	819 159	752 674	827 655	770 746	763 127	719 940	91.9	87.9	2.4	-6.6	-4.3
Study area total	**2 417 337**	**1 482 302**	**1 512 801**	**1 457 383**	**1 467 140**	**1 613 253**	**61.3**	**66.7**	**-1.7**	**10.7**	**8.8**

Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Table 2.5
Farmland Area by River Basin, 1971 - 1991

River basin	River basin area	Farmland area 1971	1976	1981	1986	1991	Proportion in agriculture 1971	1991	Change in area 1971-1981	1981-1991	1971-1991
	hectares						percent				
Willow Creek	416 210	270 621	262 601	250 952	253 931	239 244	65.0	57.5	-7.3	-4.7	-11.6
Upper Oldman River	494 237	179 285	218 225	212 280	207 286	262 757	36.3	53.2	18.4	23.8	46.6
Belly/Waterton Rivers	446 086	337 047	331 322	301 726	311 961	257 321	75.6	57.7	-10.5	-14.7	-23.7
St. Mary River	233 311	168 323	184 561	187 337	194 076	208 715	72.1	89.5	11.3	11.4	24.0
Total[1]	**1 589 844**	**955 276**	**996 709**	**952 295**	**967 254**	**968 037**	**60.1**	**60.9**	**-0.3**	**1.7**	**1.3**

Note:
1. This total is the sum of the four river basins and does not equal the total presented in the ecoregion summaries.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Over the twenty year period, the average farm size in the ecoregion study area increased by almost 10 percent to reach 460 hectares. This farm size was 26 percent larger than the Alberta average of 364 hectares in 1991.[1]

Table 2.6 shows that the greatest change in farm numbers and average size occurred in the Northern Continental Divide. Average farm size decreased within British Columbia's portion of this ecoregion as a result of a reduction in farmland area and an increase in farm numbers. In the Alberta portion, however, there was a greater farmland area and more farms by 1991, increasing the average farm size by 12 percent in Alberta's Northern Continental Divide. The only ecoregion to experience both a reduction in farmland area and farm numbers by 1991 was the Southern Alberta Plains, though steady increases in average farm size occurred throughout the study period.

In the river basin study area, farm numbers decreased by 9 percent and average farm size increased by close to 3 percent overall. Both the Willow Creek and Belly/Waterton River basins saw reductions in farmland area and the number of farms.

1. Statistics Canada, 1992, p. 53.

Table 2.6
Number of Farms and Farm Size by Ecoregion, 1971 - 1991

Provincial ecoregion	Number of farms					Change 1971-1991	Average farm size			Change 1971-1991
	1971	1976	1981	1986	1991		1971	1981	1991	
						percent	hectares per farm			percent
British Columbia										
Northern Continental Divide	21	28	37	38	35	66.7	190	95	85	-55.4
Alberta										
Northern Continental Divide	164	216	229	230	270	64.6	477	547	893	87.4
Chinook Upland	1 084	1 051	1 067	1 067	1 259	16.1	597	523	516	-13.7
Southern Alberta Plains	2 276	2 269	2 106	2 176	1 946	-14.5	331	366	370	11.9
Study area total	**3 545**	**3 564**	**3 439**	**3 511**	**3 510**	**-1.0**	**418**	**424**	**460**	**9.9**

Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Table 2.7
Number of Farms and Farm Size by River Basin, 1971 - 1991

River basin	Number of farms					Change 1971-1991	Average farm size			Change 1971-1991
	1971	1976	1981	1986	1991		1971	1981	1991	
						percent	hectares per farm			percent
Willow Creek	505	471	493	544	475	-5.9	536	533	485	-9.4
Upper Oldman River	330	337	349	359	336	1.8	543	630	753	38.6
Belly/Waterton Rivers	1 146	1 160	1 092	1 122	958	-16.4	294	260	236	-19.9
St. Mary River	437	430	455	483	424	-3.0	385	436	459	19.1
Total[1]	**2 418**	**2 398**	**2 389**	**2 508**	**2 193**	**-9.3**	**395**	**397**	**405**	**2.6**

Note:
1. This total is the sum of the four river basins and does not equal the total presented in the ecoregion summaries.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Tables 2.8 and 2.9 look at the "Improved farmland"[1] trends around the park. In the ecoregion study area cropland increased by 42 percent, with the largest change occurring in the Chinook Upland. In the river basin study area, an overall increase of 28 percent in cropland area occurred, with the St. Mary River basin almost doubling its share.

Large reductions in summerfallow were evident in all areas. Such reductions in summerfallow can be regarded as positive in that they reduce the risk of soil salinization.[2]

1. **Improved farmland** is defined here to include cropland, improved pasture and summerfallow. "Other" land categorized as improved farmland which have been omitted from this study include woodland, idle land, barnyards and laneways.
2. Dumanski, J. *et al.*, 1986, p. 206.

Improved pasture increased by 15 percent in the ecoregion study area, with the Northern Continental Divide more than tripling its share. Among the four river basins an overall reduction of 6 percent in improved pasture occurred, with the only increase occurring in the Upper Oldman River area.

New farmland area usually originates from land that was once natural habitat. In this region of Canada newly acquired lands are generally referred to as unimproved farmland and are primarily used for cattle grazing.

Table 2.8

Improved Farmland by Ecoregion, 1971-1991

	Cropland				Improved pasture				Summerfallow			
Provincial ecoregion	1971	1981	1991	Change 1971-1991	1971	1981	1991	Change 1971-1991	1971	1981	1991	Change 1971-1991
	hectares			percent	hectares			percent	hectares			percent
British Columbia												
Northern Continental Divide	663	918	735	10.9	32	420	489	1 428.1	x	x	x	x
Alberta												
Northern Continental Divide	14 623	20 487	22 525	54.0	2 942	7 407	10 553	258.7	3 003 [1]	1 604 [1]	2 058 [1]	-31.5
Chinook Upland	154 834	225 250	293 581	89.6	32 333	42 367	37 614	16.3	52 811	24 067	14 917	-71.8
Southern Alberta Plains	332 584	417 716	395 239	18.8	48 859	52 834	47 894	-2.0	178 824	111 671	108 681	-39.2
Study area total	**502 704**	**664 372**	**712 080**	**41.7**	**84 165**	**103 027**	**96 550**	**14.7**	**234 638**	**137 342**	**125 656**	**-46.5**

Notes:
Figures may not add due to rounding.
1. Data for the Alberta and British Columbia portions of the Northern Continental Divide have been combined to preserve confidentiality.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Table 2.9

Improved Farmland by River Basin, 1971-1991

	Cropland				Improved pasture				Summerfallow			
River basin	1971	1981	1991	Change 1971-1991	1971	1981	1991	Change 1971-1991	1971	1981	1991	Change 1971-1991
	hectares			percent	hectares			percent	hectares			percent
Willow Creek	67 054	102 191	85 551	27.6	19 817	24 544	18 974	-4.3	31 612	21 429	11 674	-63.1
Upper Oldman River	35 748	48 013	33 601	-6.0	5 998	13 053	10 633	77.3	10 785	3 843	2 252	-79.1
Belly/Waterton Rivers	126 567	151 184	124 821	-1.4	19 475	20 313	16 818	-13.6	47 835	23 497	10 044	-79.0
St. Mary River	76 384	119 270	145 939	91.1	14 889	15 033	10 264	-31.1	28 726	6 933	5 031	-82.5
Total[1]	**305 753**	**420 657**	**389 913**	**27.5**	**60 180**	**72 943**	**56 689**	**-5.8**	**118 957**	**55 702**	**29 001**	**-75.6**

Note:
1. This total is the sum of the four river basins and does not equal the total presented in the ecoregion summaries.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

In the ecoregion study area, the amount of unimproved farmland increased by 3 percent, increasing its proportion of the ecoregion area to 28 percent (see Table 2.10). Most of the increase occurred in the Northern Continental Divide where new areas of rangeland have been opened up. The greatest change was in the Alberta portion of this region, where the unimproved farmland area more than tripled.

In the river basin study area, there was a total increase of 5 percent in unimproved farmland area. The Upper Oldman River basin accounted for the majority of this change with an increase of 71 percent. The Willow Creek and Belly/Waterton River basins experienced moderate declines in unimproved area with 19 and 26 percent reductions respectively. These figures are listed in Table 2.11.

Agricultural practices and their effects

The Crown of the Continent ecosystem is subject to environmental modification from a number of sources. The sources measured in this study include pesticide use and irrigation.

In landscapes with high ecological integrity, nutrients are cycled internally within diverse natural ecosystems. A simple analogy might be to compare a suburban lawn with adjacent native prairie.

The suburban lawn is a simple ecosystem containing perhaps ten species of plants, and is consequently subject to constant invasion by weed species which are usually con-

Table 2.10

Unimproved Farmland by Ecoregion, 1971-1991

Provincial ecoregion	Ecoregion area	Unimproved farmland area 1971	Unimproved farmland area 1981	Unimproved farmland area 1991	Proportion of unimproved farmland 1971	Proportion of unimproved farmland 1991	Change in unimproved farmland area 1971-1981	Change in unimproved farmland area 1981-1991	Change in unimproved farmland area 1971-1991
	hectares				percent				
British Columbia									
Northern Continental Divide	339 991	3 269	2 078	1 749	1.0	0.5	-36.4	-15.9	-46.5
Alberta									
Northern Continental Divide	543 336	57 605	95 652	206 046	10.6	37.9	66.0	115.4	257.7
Chinook Upland	714 851	407 482	266 293	303 046	57.0	42.4	-34.6	13.8	-25.6
Southern Alberta Plains	819 158	192 407	188 525	168 126	23.5	20.5	-2.0	-10.8	-12.6
Study area total	**2 417 336**	**660 764**	**552 549**	**678 967**	**27.3**	**28.1**	**-16.4**	**22.9**	**2.8**

Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Table 2.11

Unimproved Farmland Around Waterton Lakes National Park by River Basin, 1971-1991

River basin	River basin area	Unimproved farmland area[1] 1971	Unimproved farmland area[1] 1981	Unimproved farmland area[1] 1991	Proportion of unimproved farmland 1971	Proportion of unimproved farmland 1991	Change in unimproved farmland area 1971-1981	Change in unimproved farmland area 1981-1991	Change in unimproved farmland area 1971-1991
	hectares				percent				
Willow Creek	416 210	152 139	102 789	123 045	36.6	29.6	-32.4	19.7	-19.1
Upper Oldman River	494 237	126 755	147 372	216 271	25.6	43.8	16.3	46.8	70.6
Belly/Waterton Rivers	446 086	143 170	106 733	105 638	32.1	23.7	-25.5	-1.0	-26.2
St. Mary River	233 311	48 324	46 101	47 481	20.7	20.4	-4.6	3.0	-1.7
Total[2]	**1 589 844**	**470 388**	**402 994**	**492 436**	**29.6**	**31.0**	**-14.3**	**22.2**	**4.7**

Notes:
1. Unimproved farmland areas are calculated using total farmland values and the sum of improved land variables listed in Table 9.
2. This total is the sum of the four river basins and does not equal the total represented in the ecoregion summaries.

Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

trolled by herbicides. It requires regular fertilization to replace lost nutrients, frequent watering because the species present are not adapted to the local climate, and lawn mowing substitutes for the cropping action of herbivores. Inputs of energy, pesticides and water are high.

The adjacent native prairie, on the other hand, is cropped by cattle or wild ungulates with the nutrients removed by cropping being recycled as dung. There may be more than 50 different plants, including weeds, interacting seasonally and continually replenishing the soil, and capable of thriving with the water that is available from rain and snow.

Based on this analogy, it can be seen that application rates of fertilizers, herbicides, insecticides and water can serve as one indicator of ecosystem function; the higher the quantities used, the more artificial inputs are substituting for the self-regenerative capabilities of healthy ecosystems. Fertilizers represent lost soil fertility, pesticides represent simplified and unstable ecosystems, and irrigation represents a de-coupling of plant communities from the regional climate.

The use of pesticides also can be seen as an indicator of environmental stress, since runoff of fertilizers and pesticides has been associated with water degradation, and since some pesticides are persistent and bioaccumulate in plants and animals.

Pesticide expenditures in the Waterton Lakes area more than tripled since 1970.[1] These values are shown in Tables 2.12 and 2.13. In the ecoregion study area, the rate of application per hectare of cultivated land[2] increased from $2.86 to $10.84 constant 1990 dollars. Though this is a large increase, the average value reached in 1990 was 46 percent below the national average of $15.80 per hectare.[3]

1. Value of pesticide applied is only a surrogate for actual change in pesticide toxicity.
2. Cultivated land includes cropland, improved pasture and summerfallow areas.
3. Statistics Canada, 1994, p. 20.

Table 2.12

Agricultural Chemical Expenditures and Application Rates by Ecoregion, 1970-1990

Provincial ecoregion	Agricultural chemical expenditures 1970	1980	1990	Change 1970-1990	Cultivated land area 1970	1980	1990	Change 1970-1990	Value of chemical per hectare of cultivated land 1970	1980	1990	Change 1970-1990
	1990 dollars			percent	hectares			percent	1990$/hectare			percent
Northern Continental Divide[1]	18 598	68 838	104 520	462.0	21 294	30 930	36 361	70.8	0.87	2.23	2.87	229.1
Chinook Upland	563 867	2 290 425	3 587 124	536.2	239 978	291 684	346 112	44.2	2.35	7.85	10.36	341.1
Southern Alberta Plains	1 764 684	4 722 156	6 434 354	264.6	560 267	582 221	551 814	-1.5	3.15	8.11	11.66	270.2
Study area total	**2 347 149**	**7 081 419**	**10 125 998**	**331.4**	**821 538**	**904 835**	**934 287**	**13.7**	**2.86**	**7.83**	**10.84**	**279.4**

Notes:
Chemical dollar values have been deflated by using farm input price indices for 1970-1990.
1. For the purposes of this table data for the Alberta and British Columbia portions of the Northern Continental Divide have been combined to preserve confidentiality.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Table 2.13

Agricultural Chemical Expenditures and Application Rates by River Basin, 1970-1990

River basin	Agricultural chemical expenditures 1970	1980	1990	Change 1970-1990	Cultivated land area 1970	1980	1990	Change 1970-1990	Value of chemical per hectare of cultivated land 1970	1980	1990	Change 1970-1990
	1990 dollars			percent	hectares			percent	1990$/hectare			percent
Willow Creek	319 763	925 007	1 034 557	223.5	118 483	148 163	116 199	-1.9	2.70	6.24	8.90	229.9
Upper Oldman River	72 839	355 169	270 896	271.9	52 531	64 909	46 486	-11.5	1.39	5.47	5.83	320.3
Belly/Waterton Rivers	646 679	1 798 309	1 883 949	191.3	193 877	194 994	151 683	-21.8	3.34	9.22	12.42	272.4
St. Mary River	400 531	1 520 257	2 255 449	463.1	119 999	141 236	161 234	34.4	3.34	10.76	13.99	319.1
Total[1]	**1 439 812**	**4 598 742**	**5 444 851**	**278.2**	**484 890**	**549 302**	**475 603**	**-1.9**	**2.97**	**8.37**	**11.45**	**285.5**

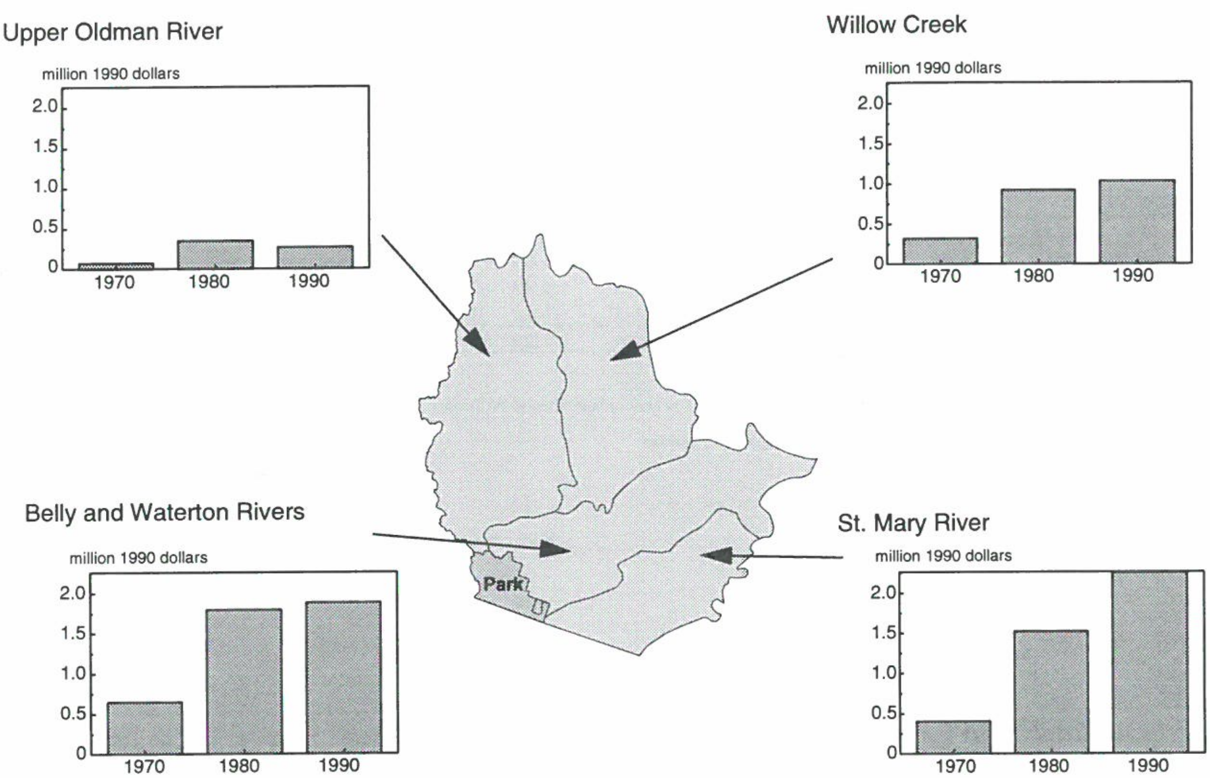
Notes:
Chemical dollar values have been deflated by using farm input price indices for 1970-1990.
1. This total is the sum of the four river basins and does not equal the total represented in the ecoregion summaries.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

In the river basin study area, the St. Mary River basin was the only area which incurred an increase in cultivated land area. The overall pesticide value per hectare reached $11.45 in 1990.

The bar graphs in Figure 2.1 indicate the trends in pesticide expenditures for each of the four river basins. Here we see a greater increase in the use of pesticides occurring between 1970 and 1980, with slight increases by 1990. In the Upper Oldman River Basin, however, pesticide expenditures actually declined between 1980 and 1990, though the final level reached was still more than three times the value of pesticides originally purchased in 1970.

Figure 2.1

Pesticide Expenditures by River Basin for 1970 - 1990



Sources:
Statistics Canada, National Accounts and Environment Division and Census of Agriculture.

The application of pesticides is needed to control both insects and weeds from invading cultivated land. As evident in Tables 2.14 and 2.15, the land area to which both insecticides and herbicides are being applied has increased dramatically since 1970.

Among the river basins, the greatest increases of cultivated land area treated with pesticides were in the St. Mary River basin. Here, more than a seven-fold increase occurred in the area sprayed for insects, while the area sprayed for weeds more than tripled.

Greater amounts of pesticide are being applied to the east of Waterton Lakes National Park, specifically within the Belly/Waterton Rivers and St. Mary River basins. These areas also support the bulk of irrigated agriculture in the study area and have by far the greatest acreage under cultivation in cropland (Table 2.9).

Table 2.14

Areas Sprayed With Insecticides and Herbicides by Ecoregion, 1970-1990

	Area sprayed for insects				Area sprayed for weeds			
Provincial ecoregion	1970	1980	1990	Change 1970-1990	1970	1980	1990	Change 1970-1990
	hectares			percent	hectares			percent
Northern Continental Divide[1]	69	20	245	255.9	2 216	6 317	5 348	141.3
Chinook Upland	2 891	1 838	26 113	803.1	57 838	157 612	199 294	244.6
Southern Alberta Plains	8 849	8 131	42 471	379.9	143 458	299 773	301 247	110.0
Study area total	**11 810**	**9 989**	**68 829**	**482.8**	**203 513**	**463 703**	**505 889**	**148.6**

Note:
1. For purposes of this table data for the Alberta and British Columbia portions of the Northern Continental Divide have been combined to preserve confidentiality.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

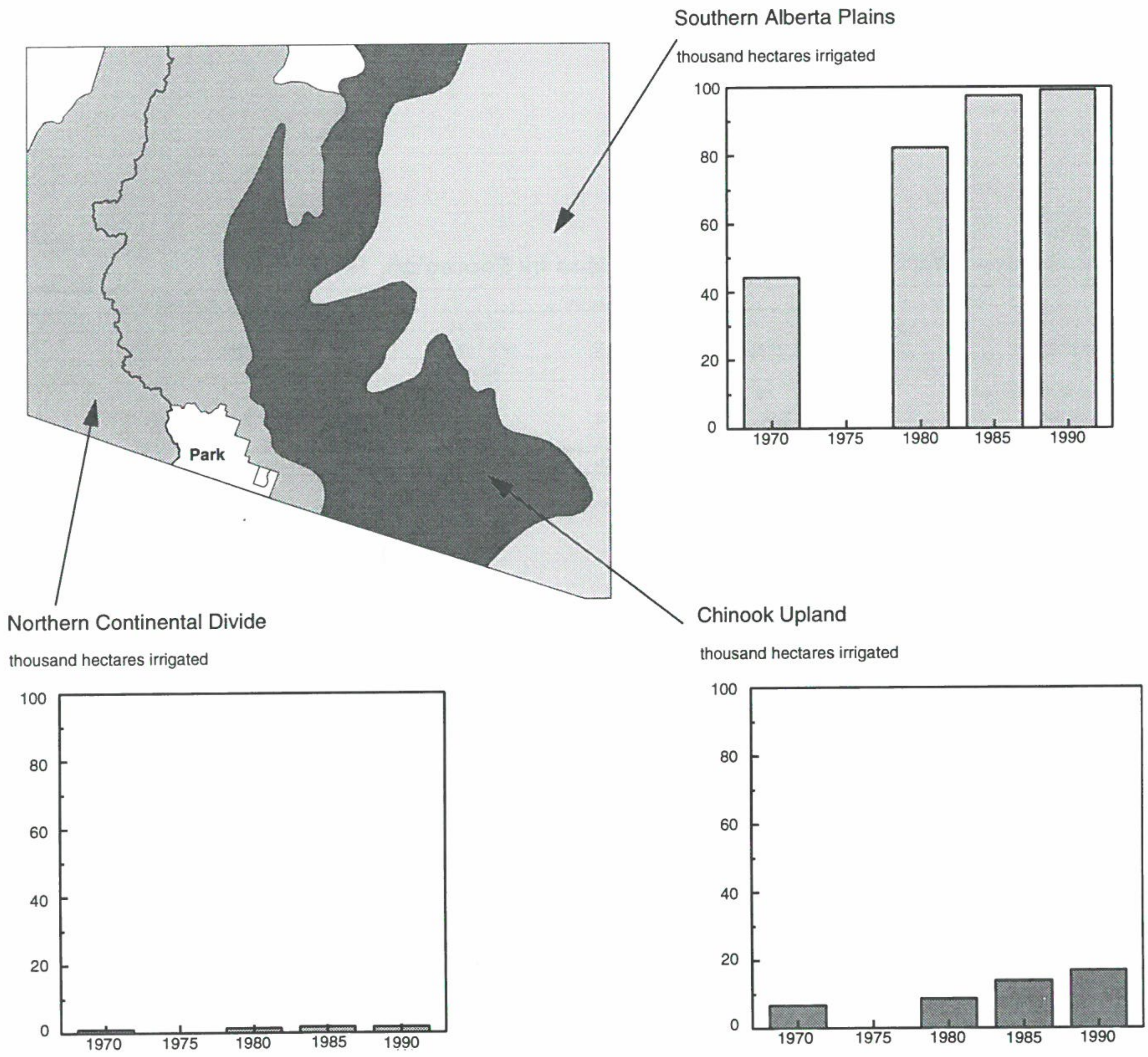
Table 2.15

Areas Sprayed With Insecticides and Herbicides by River Basin, 1970-1990

	Area sprayed for insects				Area sprayed for weeds			
River basin		1980	1990	Change 1970-1990	1970	1980	1990	Change 1970-1990
	hectares			percent	hectares			percent
Willow Creek	1 889	1 336	5 915	213.1	25 400	67 822	56 002	120.5
Upper Oldman River	184	75	639	246.8	10 756	26 327	12 305	14.4
Belly River	3 565	2 291	11 464	221.5	52 094	97 029	79 270	52.2
St. Mary River	2 085	670	15 482	642.5	34 167	94 308	110 864	224.5
Total[1]	**7 724**	**4 372**	**33 499**	**333.7**	**122 418**	**285 487**	**258 442**	**111.1**

Note:
1. This total is the sum of the four river basins and does not equal the total represented in the ecoregion summaries.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Figure 2.2
Irrigated Area by Ecoregion, 1970 - 1990



Source:
Demarchi, D.A. and E.C. Lea, 1993.

Irrigation is another agricultural practice with significant economic benefits and considerable environmental impact. The availability of irrigation water allows more intensive agriculture by stabilizing and maximizing yields and enabling farmers to grow a greater variety of crops than might otherwise be the case.

Irrigation development in the area surrounding Waterton Lakes National Park dates back to the late 1800's when Mormons began diverting water from Lee Creek, a tributary of the St. Mary River, to irrigate farmland in the Cardston area. Since then, all rivers in the Alberta portion of the study area have been developed for irrigation. Major projects have included the St. Mary Dam (1951), the Waterton River Dam (1964), the Oldman River Dam (1992) and three diversion weirs on the Belly River.

Irrigation can also have positive effects. It increases vegetation diversity by allowing the establishment of poplar, willow and other species along canals and in upland areas. At the same time it can be detrimental to ecosystem health if too much water is removed from streams during critical periods, or if on-stream dams interrupt hydrological processes that sustain downstream ecosystems. Rood (1987) documented a 25 percent decline in cottonwood forests - which rely on regular spring flooding and adequate summer water levels - downstream of the Waterton River Dam, and a 55 percent decline downstream from the St. Mary River Dam.

Ecological diversity is far higher in areas adjacent to water than elsewhere in the Southern Alberta Plains ecoregion (World Wildlife Fund Canada, 1989). In the prairie regions of Canada, forests located near water are important corridors that allow wildlife and plant populations to adjust to long-term climate change. In addition, many species of fish, such as whitefish, bull trout and walleye, are migratory. Dams and diversions that fail to provide for fish passage and the continued functioning of downstream ecosystems fragment populations and landscapes.

As shown in Table 2.16 and Figure 2.2, the total irrigated area within the ecoregion study area more than doubled between 1971 and 1991. The more significant increases occurred in the Chinook Upland and Southern Alberta Plains.

The river basin study area indicates an increase of 91 percent in irrigated area with significant increases in the Willow Creek and Belly/Waterton River basins. In addition, the river basin with the highest irrigation stress, with 11 percent of its land irrigated, is the Belly/Waterton River basin. This phenomenon is depicted in Figure 2.3.

Table 2.16

Irrigated Area by Ecoregion, 1970-1990

Ecoregion	Ecoregion area	Irrigated area 1970	1980	1985	1990	Proportion irrigated 1970	1990	Change in area 1970-1980	1980-1990	1970-1990
	hectares					percent				
Northern Continental Divide[1]	543 336	557	421	818	721	0.1	0.1	-24.5	71.4	29.5
Chinook Upland	714 851	6 690	8 708	13 973	16 918	0.9	2.4	30.2	94.3	152.9
Southern Alberta Plains	819 158	44 224	82 265	97 381	99 090	5.4	12.1	86.0	20.5	124.1
Study area total	**2 077 345**	**51 471**	**91 394**	**112 173**	**116 728**	**2.5**	**5.6**	**77.6**	**27.7**	**126.8**

Note:
1. For the purposes of this table data for the Alberta and British Columbia portions of the Northern Continental Divide have been combined to preserve confidentiality.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

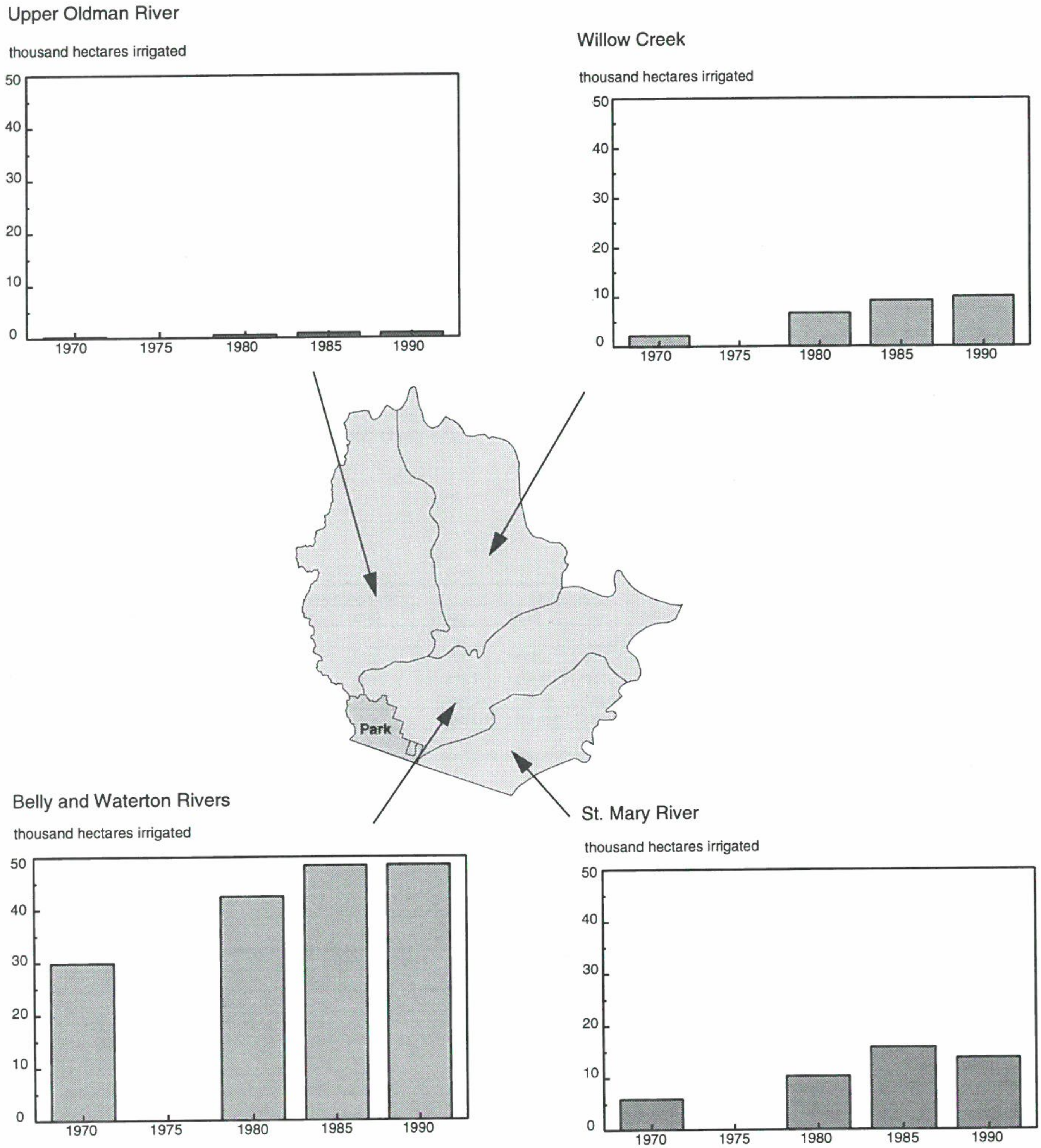
Table 2.17

Irrigated Area by River Basin, 1970-1990

River basin	River basin area	Irrigated area 1970	1980	1985	1990	Proportion irrigated 1970	1990	Change in area 1970-1980	1980-1990	1970-1990
	hectares					percent				
Willow Creek	416 210	2 164	6 719	9 266	10 009	0.5	2.4	210.5	49.0	362.5
Upper Oldman River	494 237	218	594	843	872	-	0.2	172.3	46.9	300.0
Belly/Waterton Rivers	446 086	29 849	42 472	48 368	48 446	6.7	10.9	42.3	14.1	62.3
St. Mary River	233 311	5 950	10 291	15 835	13 746	2.6	5.9	73.0	33.6	131.0
Total[1]	**1 589 844**	**38 181**	**60 076**	**74 312**	**73 073**	**2.4**	**4.6**	**57.3**	**21.6**	**91.4**

Note:
1. This total is the sum of the four river basins and does not equal the total presented in the ecoregion summaries.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Figure 2.3
Irrigated Area by River Basin, 1970 - 1990



Sources:
Statistics Canada, National Accounts and Environment Division and Census of Agriculture.

The use of pesticides to increase the availability of trace nutrients can improve crop yields where natural soil fertility has been depleted. Fertilizer use, however, is not only a symptom of declining soil health, it also has the potential to produce pollution problems.[1]

The total amount of fertilizer used in this area has more than doubled between 1970 and 1990, although this increase has been accompanied by more than a three-fold increase in the area being fertilized. These factors together have led to reductions in the rate of fertilizer application in the 1970-1990 period, as shown in Tables 2.18 and 2.19.

In the river basin study area, the lowest decrease in fertilizer application occurred in the Upper Oldman River basin. This area also experienced the highest increase in farmland and maintained the most consistent application rate of fertilizer between 1970 and 1990 at 139 kg per hectare.

Overall, the intensity of fertilizer application in the area surrounding Waterton Lakes National Park is lower than the national average of 180 kg per hectare.

1. Government of Canada, 1991, p. 9-21.

Table 2.18

Commercial Agricultural Fertilizer Application by Ecoregion, 1970-1990

	Commercial fertilizer tonnage				Area fertilized				Application rate			
Provincial ecoregion	1970	1980	1990	Change 1970-1990	1970	1980	1990	Change 1970-1990	1970	1980	1990	Change 1970-1990
	tonnes			percent	hectares			percent	kg/hectare			percent
Northern Continental Divide[1]	528	1 231	1 280	142.4	3 844	8 882	9 471	146.4	137.4	138.6	135.2	-1.6
Chinook Upland	8 669	25 081	29 389	239.0	57 511	187 186	249 611	334.0	150.7	134.0	117.7	-21.9
Southern Alberta Plains	14 738	41 503	37 102	151.7	79 693	304 887	295 501	270.8	184.9	136.1	125.5	-32.1
Study area total	**23 935**	**67 815**	**67 771**	**183.1**	**141 048**	**500 956**	**554 583**	**293.2**	**169.7**	**135.4**	**122.2**	**-28.0**

Note:
1. For purposes of this table data for the Alberta and British Columbia portions of the Northern Continental Divide have been combined to preserve confidentiality.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Table 2.19

Commercial Agricultural Fertilizer Application by River Basin, 1970-1990

	Commercial fertilizer tonnage				Area fertilized				Application rate			
River basin	1970	1980	1990	Change 1970-1990	1970	1980	1990	Change 1970-1990	1970	1980	1990	Change 1970-1990
	tonnes			percent	hectares			percent	kg/hectare			percent
Willow Creek	2 956	9 516	7 622	157.8	21 431	78 789	66 264	209.2	137.9	120.8	115.0	-16.6
Upper Oldman River	1 478	4 329	2 521	70.6	10 432	31 438	18 150	74.0	141.7	137.7	138.9	-2.0
Belly/Waterton Rivers	7 932	18 768	13 751	73.4	40 192	116 837	102 859	155.9	197.4	160.6	133.7	-32.3
St. Mary River	4 770	15 417	16 838	253.0	30 725	111 266	134 930	339.2	155.2	138.6	124.8	-19.6
Total[1]	**17 136**	**48 030**	**40 733**	**137.7**	**102 780**	**338 329**	**322 203**	**213.5**	**166.7**	**142.0**	**126.4**	**-24.2**

Note:
1. This total is the sum of the four river basins and does not equal the total represented in the ecoregion summaries.
Sources:
Statistics Canada, National Accounts and Environment Division and Agriculture Division.

Conclusion

The Canadian portion of the Crown of the Continent ecosystem contains extensive areas where natural processes continue to operate and where the area's original biological diversity survives. This is due, in part, to the presence of a protected core area, Waterton Lakes National Park. It is also due to the quality of stewardship accorded to the agricultural and public lands that make up most of the remaining area.

Within the Crown, Waterton Lakes National Park has been set aside for the people of Canada, to be kept unimpaired for all time. As a Man and Biosphere reserve, the park's ecological health serves as a benchmark for the larger area. By and large, the signs are good. Wolves, sandhill cranes and trumpeter swans, once exterminated, now breed in small numbers in the area. Grizzly bears still range the landscape, and populations of elk, deer, bighorn sheep and moose remain healthy.

However, some environmental stresses are becoming more evident in the Crown. Bull trout populations have declined dramatically due to dams, overfishing and habitat deterioration (Fitch, 1994). Cottonwood forests have declined by as much as 55 percent along the Waterton and St. Mary Rivers (Rood, 1987). Speculative interest in converting agricultural land to residential or recreational land has also been increasing (Pickell, 1994).

Data evaluated for this study indicate that the largest relative changes over the study period took place in the Northern Continental Divide ecoregion. Changes in this ecoregion have a particularly large impact because of the relatively pristine state of the region.

Within the Alberta portion of the study area, the Upper Oldman and St. Mary River basins experienced marked increases in farmland acreage (Table 2.5). As well, there were large increases in the use of agricultural pesticides throughout the study area, with increases greater than fourfold occurring in the Chinook Upland ecoregion and in the St. Mary River basin. Irrigated acreage quadrupled in the Willow Creek and Upper Oldman River basins (Table 2.17).

All of the above facts lead to important questions that will have to be answered if the relationship between the park and its surroundings is to remain stable in the long term. The balance between the Crown of the Continent's ecosystem integrity, and a viable socio-economy will have to be carefully monitored as we move into the 21st century.

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3 Household Waste Management in the '90s: Reduce, Reuse and Recycle

by Murray Cameron[1]

Introduction

Environment Canada estimates that over 32 million tonnes of solid wastes are generated each year in Canada[2]. Residential waste accounts for almost half of this amount[3].

Waste[4] presents one of the greatest challenges to the Canadian environment. Excessive solid wastes are creating problems for communities which have no more land available for landfill sites. Effective use of the 3Rs - reduction, reuse and recycling - helps to protect the environment by reducing pressure on communities for disposal lands through significant cuts in the waste stream.

This chapter highlights some of the results from the 1993 Local Government Waste Management Survey[5]. This national survey sampled 642 municipalities Canada-wide and included questions on garbage collection, recycling, composting and the handling of hazardous waste. The municipalities surveyed accounted for approximately 79 percent of the Canadian population in 1993.

The survey was the second of its kind conducted by Statistics Canada. As a follow-up to the original pilot study conducted in 1991 (see Text Box 3.1), it was intended to provide an overview of the structure and function of Canadian local government waste management activities. A number of definitional problems were identified in the pilot survey and were subsequently corrected for the 1993 survey. As a consequence, comparisons between years cannot readily be made.

1. The author would like to thank Marcia Santiago for her valuable assistance.
2. Environment Canada, Office of Waste Management.
3. Statistics Canada, 1993.
4. Waste is defined as any substance discarded for final disposal or recycling for which the owner or generator has no further use.
5. A complete survey report is available from National Accounts and Environment Division, Statistics Canada.

Text Box 3.1

Highlights of the 1991 Pilot Local Government Waste Management Practices Survey[1]

The survey, conducted in 1990/1991, contained a number of questions designed to profile the practices of local governments including the collection, transportation and disposal of garbage, as well as recycling and the handling of hazardous waste. As a pilot study, it was intended to obtain an overview of the structure and function of Canadian local government activities pertaining to waste management.

Some highlights[2] include:

Based upon the total annual quantities reported, 83 large municipalities collected, on average, about 1 tonne of residential garbage per dwelling per year or 2.5 kilograms per day. Seventy-three of these municipalities had a recycling program, through which approximately 9 percent (by weight) of the total municipal garbage was recycled.

Fifty-six of the municipalities had some form of residential hazardous waste program while only 10 had a program for non-residential hazardous wastes.

Thirty-six of the municipalities reported having arranged for waste composition studies, an important step towards effective waste management. In addition, 53 of the municipalities had some form of waste reduction program.

1. Statistics Canada, 1993.
2. The data presented in the article reflected 83 municipalities that had a population greater than 50 000 in 1991. These accounted for about half of the Canadian population.

Waste not ...

Whether we are aware of it or not, we pollute our environment daily in many ways. The very act of preparing food generates many by-products, such as residues from organic matter and packaging, that have to be disposed of. It is how we dispose of these wastes that has an impact on our environment.

Much of the material entering landfills can be recycled or composted. Although education programs help to inform households about recycling, composting and hazardous waste disposal, organized recycling and composting programs offer the best hope for protecting the environment against further degradation.

Waste collection[1]

Among the 642 municipalities surveyed, an average of 2.5 kilograms per day of residential waste was collected from each dwelling served (see Figure 3.1). Those municipalities with under 30 000 in population reported higher levels of garbage collected, averaging 2.8 kg/day/dwelling.

Overall, waste collection is primarily handled by contractors hired by municipalities. Overall 62 percent of municipalities reported using contractors only while 13 percent used their own employees for this task (Table 3.1). No waste collection programs were reported in 8 percent of the municipalities - many were communities of under 30 000.

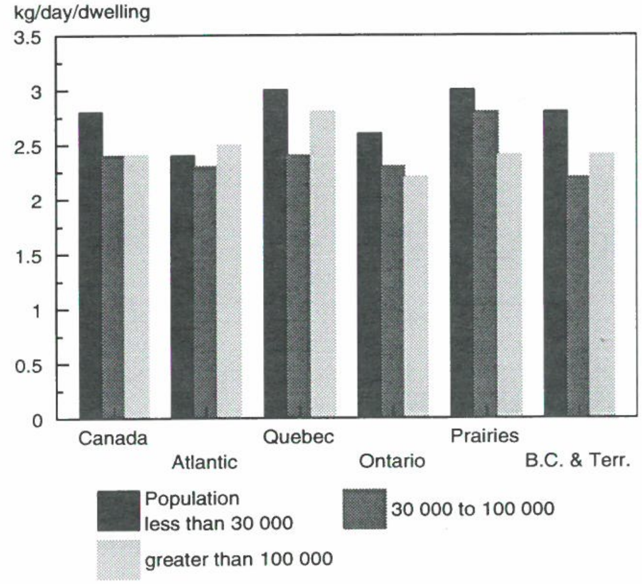
In Quebec, only 2 percent of the municipalities used only municipal employees for waste collection, while 84 percent of Quebec municipalities employed contractors only.

The Prairie region had the highest incidence of municipalities with no waste collection programs, 18 percent or 19 municipalities, while Quebec had the lowest incidence of municipalities with no waste collection, at 4 percent.

1. This section refers to waste collection for disposal, which is waste destined for landfill, incineration or export.

Figure 3.1

Residential Waste Collected for Disposal, per Dwelling, by Municipality Size, 1993



Note:
These are preliminary figures and do not include estimates for municipalities with a population less than 5 000, which were not sampled.
Source:
Statistics Canada, National Accounts and Environment Division.

Table 3.1

Waste Collection by Agent Responsible, Municipality Size and Region, 1993

	Municipal population				Region				
	Under 30 000	30 000 - 99 999	100 000 and over	**Canada**	Atlantic provinces	Quebec	Ontario	Prairie provinces	B.C., Yukon and N.W.T.
Number of municipalities reporting	508	97	37	**642**	64	189	218	104	67
Agent responsible for collection				percent of municipalities reporting					
Municipal employees only	12	15	19	**13**	19	2	13	19	30
Contractors only	64	60	38	**62**	48	84	67	40	33
Other	5	1	-	**4**	6	5	2	2	12
Municipal employees and other	2	8	5	**3**	3	-	2	8	12
Contractors and other	3	1	5	**3**	-	3	3	2	3
Municipal employees and contractors	4	7	32	**6**	11	2	6	10	4
Municipal employees, contractors and other	-	4	3	**1**	2	-	1	1	1
No program	9	3	-	**8**	11	4	6	18	4
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Notes:
Figures may not add due to rounding.
These are preliminary figures and do not include estimates for municipalities with a population less than 5 000, which were not sampled.
Source:
Statistics Canada, National Accounts and Environment Division.

Recycling

Across Canada, the majority of municipalities surveyed reported having a household recycling program in place in 1993 (Table 3.2), through which approximately 16 percent (by weight) of the total residential waste stream was recycled.

Regionally the incidence of recycling programs in municipalities surveyed varied from a high of 91 percent in Ontario to a low of 31 percent in the Atlantic Provinces.

Collection of recyclable materials was handled primarily by contractors to the municipalities as reported by 36 percent of the sample, as shown in Table 3.3. Other organizations accounted for the next largest collection mechanism, 23 percent of the municipalities. Municipal employees were used in fewer municipalities for recyclables collection (7 percent) as compared to general waste collection (13 percent) shown in Table 3.1.

All reporting municipalities relied primarily on contractors or private haulage (Table 3.3).

Of the recyclable materials collected in 1993 (see Table 3.4), newspaper, at 16.3 kg/person, ranked as the largest

Table 3.2

Recycling and Program Availability by Municipality Size and Region, 1993

	Municipal population				Region				
	Under 30 000	30 000 - 99 999	100 000 and over	**Canada**	Atlantic provinces	Quebec	Ontario	Prairie provinces	B.C., Yukon and N.W.T.
Number of municipalities reporting	508	97	37	**642**	64	189	218	104	67
					percent				
Municipalities with recycling program	68	93	100	**73**	31	70	91	60	87
Waste recycled as a proportion of total waste collected	23	16	13	**16**	40	9	20	13	17

Note:
These are preliminary figures and do not include estimates for municipalities with a population less than 5 000, which were not sampled.
Source:
Statistics Canada, National Accounts and Environment Division.

Table 3.3

Collection of Recyclable Materials by Agent Responsible, Municipality Size and Region, 1993

	Municipal population				Region				
	Under 30 000	30 000 - 99 999	100 000 and over	**Canada**	Atlantic provinces	Quebec	Ontario	Prairie provinces	B.C., Yukon and N.W.T.
Number of municipalities reporting	508	97	37	**642**	64	189	218	104	67
Agent responsible for collection				percent of municipalities reporting					
Municipal employees only	6	5	27	**7**	2	3	7	13	13
Contractors only	31	55	46	**36**	11	52	44	8	27
Other	25	18	11	**23**	14	12	30	25	40
Municipal employees and other	1	2	3	**2**	3	-	1	5	-
Contractors and other	1	5	3	**2**	-	2	2	2	3
Municipal employees and contractors	2	6	5	**3**	2	1	4	6	3
Municipal employees, contractors and other	--	2	5	**1**	2	-	2	1	-
No program	32	7	-	**27**	67	30	9	40	13
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Notes:
Figures may not add due to rounding.
These are preliminary figures and do not include estimates for municipalities with a population less than 5 000, which were not sampled.
Source:
Statistics Canada, National Accounts and Environment Division.

contributor to the recyclables stream (Figure 3.2). Paper products as a whole accounted for 23 kg/person, or 65 percent of all recyclables.

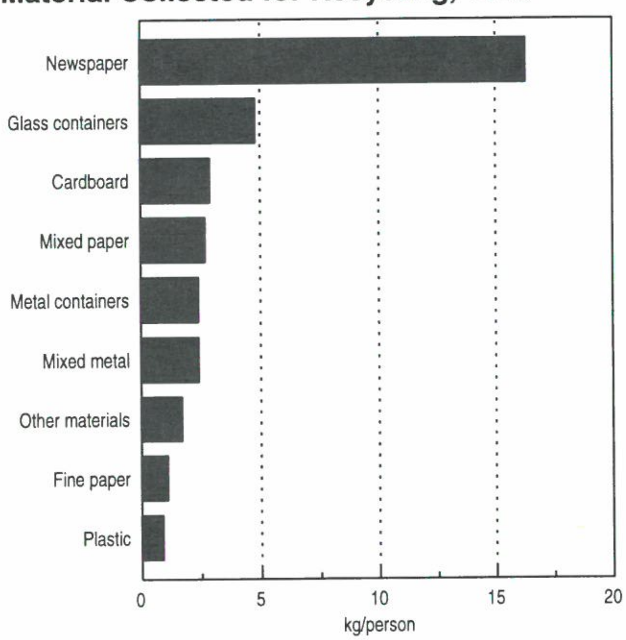
With respect to population served by recycling programs, the proportion of the total Canadian population served increased from 1990 to 1993 (see Table 3.5). Regionally most areas of the country reported an increase with Quebec making the largest gain.

Table 3.4
Material Collected for Recycling, 1993

Materials	Composition	Quantity
	percent	kilograms per person
Newspaper	46	16.3
Glass containers	14	4.8
Cardboard	8	2.9
Mixed paper	8	2.7
Metal containers	7	2.4
Mixed metal	7	2.4
Other materials	6	1.7
Fine paper	3	1.1
Plastic	3	0.9
Total	**100**	**35.1**
Municipalities reporting	451	451

Note:
These are preliminary figures and do not include estimates for municipalities with a population less than 5 000, which were not sampled, or municipalities that did not report the quantity of materials collected for recycling.
Source:
Statistics Canada, National Accounts and Environment Division.

Figure 3.2
Material Collected for Recycling, 1993



Note:
These are preliminary figures and do not include estimates for municipalities with a population less than 5 000, which were not sampled.
Source:
Statistics Canada, National Accounts and Environment Division.

Table 3.5
Proportion of Population with Access to Recycling Programs, 1990 and 1993

	1990	1993
Atlantic provinces	0.52	0.46
Quebec	0.61	0.85
Ontario	0.96	0.98
Prairie provinces	0.77	0.89
B.C., Yukon and N.W.T.	0.86	0.96
Canada	**0.80**	**0.91**

Note:
These are preliminary figures and do not include estimates for municipalities with a population less than 5 000, which were not sampled.
Source:
Statistics Canada, National Accounts and Environment Division.

Hazardous waste programs

Across Canada, hazardous waste programs were reported in 290 municipalities, or 45 percent of the 642 municipalities surveyed (Table 3.6). Of the 290 municipalities with hazardous waste programs, 210 (72 percent) had less than 30 000 in population.

Fifty-four communities between 30 000 and 100 000 in population reported a hazardous waste program, while 26 municipalities over 100 000 in population reported similar programs. The Prairies reported the highest regional rate with 61 percent of municipalities surveyed reporting some type of program (63 municipalities).

Of those communities reporting a hazardous waste program, 96 percent employ the depot system for collection while the remaining 3 percent used either a curbside pickup program or did not specify.

Composting and other programs

Composting of organic wastes is one way municipalities can reduce the amount of waste destined for landfills.

Table 3.7 shows that of the 642 municipalities surveyed, 216 (34 percent) reported a compostables collection program. These municipalities offer residents yard waste pickup during the spring and fall as well as Christmas tree collection in January. Ontario led the way in these types of programs with 51 percent of its municipalities (111) having participated[1].

Municipalities also actively encourage composting programs through sponsoring and distributing backyard composters. Across Canada 50 percent of municipalities surveyed reported such programs. Ontario reported the highest incidence with 87 percent of its municipalities distributing backyard composters (Table 3.7).

Many communities put a high priority on reducing the amount of garbage generated. As shown in Table 3.7, 27 percent of municipalities across Canada have undertak-

1. These figures do not include estimates for municipalities with a population less than 5 000, which were not sampled.

Table 3.6
Hazardous Waste Programs by Municipality Size and Region, 1993

	Municipal population				Region				
	Under 30 000	30 000 - 99 999	100 000 and over	Canada	Atlantic provinces	Quebec	Ontario	Prairie provinces	B.C., Yukon and N.W.T.
Number of municipalities reporting	210	54	26	**290**	8	84	127	63	8
	percent of municipalities reporting								
Curbside	2	-	15	**3**	12	2	4	1	-
Depot	95	100	96	**96**	75	93	99	97	100

Notes:
Figures do not add to 100 percent as municipalities may offer more than one type of program.
These are preliminary figures and do not include estimates for municipalities with a population less than 5 000, which were not sampled.
Source:
Statistics Canada, National Accounts and Environment Division.

Table 3.7
Other Municipal Waste Management Service Programs by Municipality Size and Region, 1993

	Municipal population				Region				
	Under 30 000	30 000 - 99 999	100 000 and over	Canada	Atlantic provinces	Quebec	Ontario	Prairie provinces	B.C., Yukon and N.W.T.
Number of municipalities reporting	508	97	37	**642**	64	189	218	104	67
	percent of municipalities reporting								
Compostables collection	27	51	76	**34**	20	25	51	25	28
Distribution of backyard composters	46	62	76	**50**	22	32	87	19	60
Waste composition studies	24	35	46	**27**	45	22	24	29	33
Public education programs	50	76	89	**56**	52	42	70	54	58

Note:
These are preliminary figures and do not include estimates for municipalities with a population less than 5 000, which were not sampled.
Source:
Statistics Canada, National Accounts and Environment Division.

en waste composition studies to determine how to reduce waste. More than half of the municipalities surveyed (56 percent) also provide public education programs designed to promote waste reduction at the residential level. Both of these initiatives are important steps towards effective waste management.

Conclusion

One of the most effective ways to limit the amount of waste being discarded is through the implementation of the 3Rs - reduce, reuse and recycle. Canadians appreciate that there are limits to how much garbage the environment can absorb, as well as how much of the environment they are willing to sacrifice for waste disposal purposes.

Nationally, the proportion of the Canadian population served by recycling programs increased from 1990 to 1993. This result underlines the importance of this kind of survey, since it provides a gauge to the progress being made with respect to residential waste management practices across Canada. Plans are underway to conduct this survey on a regular basis.

References

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4 Measuring Ontario's Timber Resource

by Rick Moll and Greg Lawrance

Introduction

The physical timber resource stock account described in this chapter is one of a number of resource stock accounts being developed by Statistics Canada. These accounts will form an environmental component of the Canadian System of National Accounts, the major statistical framework for the measurement of economic activity in Canada. The purpose of this component is the measurement of the effect and dependence of economic activity on the environment. Four groups of accounts are being developed to cover natural resource stocks, natural resource use, waste or pollutant output and environmental expenditure.

The development of timber resource stock accounts started with an Ontario pilot project, carried out with the assistance of the Ontario Ministry of Natural Resources (OMNR). The first phase of this project, construction of historical time series estimates for forest stock data, is complete.

Physical account

The physical accounts estimate a series of yearly stock data which show the area covered by accessible and potentially commercial forest land and describe the volume, age and species composition. The change in these stocks from year to year and the reasons for this change, such as growth, harvest, natural loss or change in land use, are also presented. The physical accounts are based on forest inventories produced by the province. These inventories are carried out periodically for different land bases so that stock data are not available as a time series. To obtain a time series for the accounts, missing years' data are estimated by using a model which starts with inventory data for a year and simulates the impact of growth, harvesting, natural loss and other changes.

The physical accounts show the evolution of forest land over an historical time period: 1953 to 1991. This type of simulation is similar to a wood supply analysis done by the provincial managers of the forest. The data in the physical accounts are not limited to a description of timber or the production forest, but could cover all forest land. Other information that could be included are details of ownership, use, or accessibility.

Timber resource accounting structure

The Ontario timber resource account involves the development of a simulation framework, **STCMacroForest**, which is conceptually similar to a population model (Moll, 1992); it evolves an age-distributed stock (area) of forest land over time and is classed as a positive linear systems model (Luenberger, 1979).

STCMacroForest for Ontario distinguishes twenty four districts that contain productive stocked and nonstocked nonreserved forest land. Stocked forest land (Haddon, 1988) is land supporting tree growth which in this context includes seedlings and saplings. Nonstocked forest land (Haddon, 1988) is productive forest land that lacks trees completely or that is so deficient in trees the residual stand of merchantable tree species will be insufficient to allow utilization in an economic operation. Within each district, the framework distinguishes three cover types (coniferous, mixedwood and hardwood) and 180 single year age classes.

STCMacroForest attempts to integrate the processes of fire, mortality, harvesting, aging, natural and artificial (planting) regeneration with the forest inventory data over a historical period 1953 to 1991. This period was originally chosen because the Ontario 1953 Forest Resources Inventory (Ontario FRI, 1953) provided the only initial condition for the simulation. However, this inventory did not provide a numerically defined age class distribution. A first attempt to calibrate the model used an assumed age class distribution derived from the aggregate maturity classes given in the 1953 FRI. However, using these initial conditions the 1991 target age class distribution was not met, therefore, a different approach was adopted. First, a 1953 inventory is estimated by running the simulation model backwards. Using the estimated 1953 age class distribution, as the initial condition, the model was ran forwards to meet the desired 1991 data points. This method will be described in more detail in the section entitled **model validation**.

The 1991 Ontario FRI was used as the end point of the simulation. The 24 districts used in the 1953 FRI were the basis of the geographic detail of the simulation model. These boundaries were maintained because most of the change data conforms with this spatial resolution.

The following are the main factors which give rise to changes in the simulated forest stock over time:

- growth and endemic mortality due to disease and insects are absorbed in the volume per hectare as a function of age (empirical yield curves);
- catastrophic stand mortality due to fire (fire rates);

- annual volume harvested given by cubic metres of softwood and hardwood roundwood;
- aging and natural regeneration after fire; and
- artificial and other natural regeneration.

These factors will be described in more detail in the following sections. First, the input and output variables are defined together with the structure of the calculation sequence during a year of the above mentioned processes.

Time loop structure

Figure 4.1 outlines an overview of the calculation sequence of **STCMacroForest**. The inputs and outputs associated with the processes of fire, mortality, adjustment for parks, harvesting, aging and regeneration are shown. These show the order in which the calculations are performed during one year of the accounting period. As can be seen from Figure 4.1 the stocked forest land at the start of a period is adjusted for loss due to fires and natural mortality. Forest land area which became parkland is also removed from the exploitable forest land base. The surviving stocked forest land is input to the harvesting calculation where the annual roundwood production (m^3 of timber) is translated into area harvested from the stocked forest land.

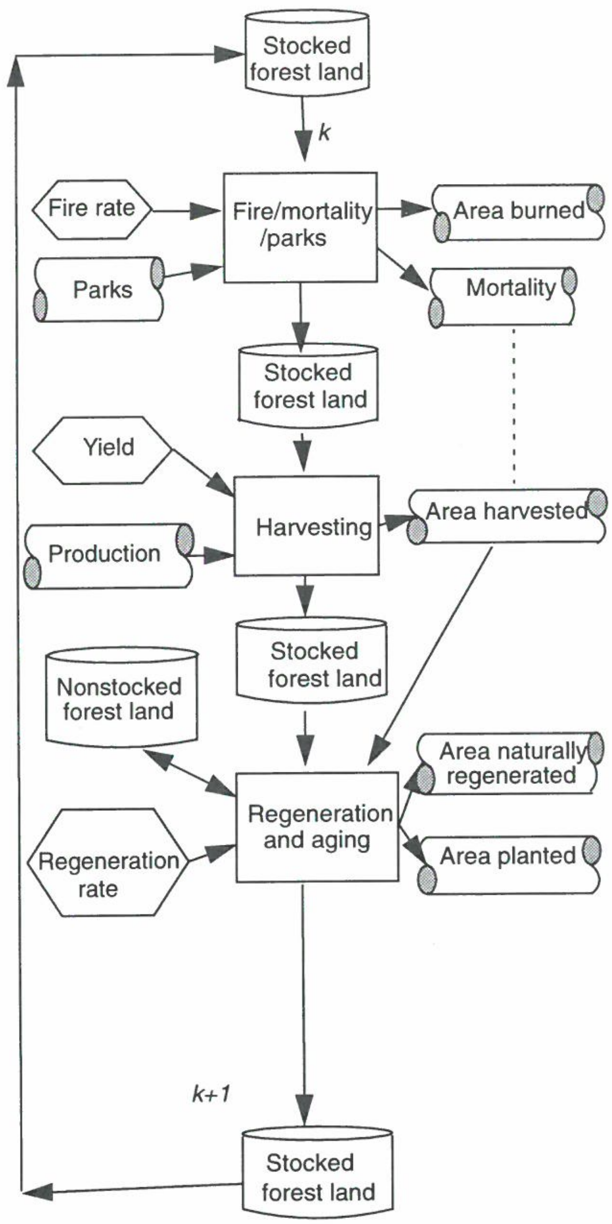
It is assumed that area burned regenerates as the same cover type. This is modeled by burned area regenerating in the first age class at the start of the subsequent year. Mortality is simulated by the disappearance of the area in the oldest age class each year. This area is spread equally over all other age classes to approximate the natural growth of an understorey. The harvesting algorithm assumes that the harvest area cut is met by proration of the cut according to the distribution of the potential volume of timber in the allowable age classes. Harvesting of two wood types: "softwood" and "hardwood" may be performed in three cover types.

In the last block newly harvested area regenerates either by planting or natural regeneration. Regeneration of nonstocked forest land also occurs at this stage. Finally, the stocked forest land is aged by shifting area from each age class to the next oldest age class. The year index is incremented and the calculations are repeated for as many years as there are in the simulation time horizon. In the next sections the processes of fire, mortality, harvesting, aging and regeneration will described in more detail.

Indices and Sets

The algebraic idiom of multi-dimensional arrays is used to represent the data objects which comprise the inputs and outputs of the accounting framework. First the stratification of each dimension is defined by describing the elements of each set as shown in Text Box 4.1. Sets are fundamental building blocks and allow a model to be succinctly stated. The sets describe the level of disaggregation while providing a notation for indexing. The elements in a set (titleset) are the labels.

Figure 4.1
Time Loop Structure



Forest fires, mortality and parks

In Figure 4.1, three adjustments to the forest land stock during a period of the simulation year are represented. In the first block these are reductions of stocked productive forest due to fire, natural mortality and newly created parks.

Text Box 4.1
Titleset Definitions

Index	Titleset elements	Titleset name	Dimension
k	1953-1991	years	39
i	1 to 180	age class180	180
s	coniferous mixedwood hardwood	cover types	3
d	North Bay Timiskaming Cochrane Kapuskasing Geraldton Thunder Bay Pembroke Parry Sound White River Sudbury Sault Ste. Marie Chapleau Gogama Fort Frances Kenora Sioux Lookout Kemptville Tweed Lindsay Lake Simcoe Lake Huron Lake Erie PEA East PEA West	districts	24
w	softwood hardwood	wood type	2

Forest land is updated for fire by decreasing the inventory according to historical fires. Fire rates are available for the years 1953 to 1991 and were obtained for each of the 24 districts. At the 'provincial level' the fire losses for 1953 to 1991 demonstrate considerable variability. The significance of 500 000 hectares of forest burned in one district (Sioux-Lookout) in one year by an unknown number of fires is not demonstrated. Fires of this size will have a considerable impact on the future age class distribution of the forest. Fire data are not available on a cover type- or age- specific basis. The fire rates were calculated for each year and district as a percentage of the area burned to the total forest land area for that district. These rates were then applied uniformly for each age class and cover type of the forest land stock. The area burned stratified by age, cover type and district is subtracted from the stock. The area burned is summarized by cover type and district and regenerated in the youngest age class at the start of the subsequent year.

The surviving stocked forest land is input to a mortality process where the area of forest which reaches the oldest age class (180 years) is assumed to die naturally. Then the forest land inventory is adjusted for transfers to park land. A historical time series of park land additions is known by district and this series is pro-rated according to the age class and cover type distribution of forest land for each year.

Harvesting

In Figure 4.1 the second process represents how the historical production of roundwood (softwood and hardwood) are translated into area harvested so that the forest land stock can be adjusted each year. The forest is cut according to historical data for roundwood production volume (cubic metres). Two types of roundwood volume were provided as input to the harvesting algorithm: softwood and hardwood. In this accounting framework, 75 percent of the softwood volume was harvested from "coniferous" and 25 percent from "mixedwood" stands. All the hardwood volume was met by harvesting from the "hardwood" cover type. First, the potential volume for softwood timber in the two cover types "coniferous" and "mixedwood" is calculated by multiplying the unit volume per hectare yield for softwood timber by the forest land area and summing over the selected allowable age classes. These are the ages from which harvesting may occur and are called the limits of operability. This is the period in the stand's development when there is sufficient volume so that they may be economically harvested. For softwood, the age class range from which harvesting can occur was 60-180 years.

Similarly, the potential hardwood volume was calculated by multiplying the forest land area in hardwood cover type by the unit volume per hectare for hardwood wood type in hardwood cover type and summing over the age classes 50 to 180. Harvesting of younger hardwood stands was allowed. Then the ratio of roundwood produced to the potential volume that could be harvested was calculated. This proportion (harvest ratio) was used to determine how much area of forest needed to be cut to satisfy the production in each year. In other words the harvest was allocated across age classes by the proportion of the wood produced to the total potential volume in each cover type.

An allowance of three percent of annual area harvested was made for the construction of roads in the forest. Stocked productive forest land is therefore reduced by three percent of the area harvested each year since newly created roads are not regenerated as stocked forest land.

After harvesting recently cut land is aggregated each year by district and cover type by summing the area cut over wood type and the age classes in which harvesting was permitted. This forest land is then passed to the final block which represents the regeneration process.

Aging and natural regeneration of burn and mortality

Aging of the forest, natural regeneration due to fire and natural mortality are represented in the last block of Figure 4.1. It is assumed that regeneration occurs immediately after both fire and natural mortality.

Natural regeneration of depletions due to fire are achieved by updating the first age class of stocked forest land at the start of the next simulation year. First the area burned is summarized by cover type and district in each year. Then the stocked forest land in age class 1 for year *k+1* is updated by the area burned during year *k*. It is assumed that the area regenerates to the same cover type after a burn.

Forest that died during year *k* is regenerated in the following way. Rather than regenerating this area in age class one at the start of the next year this area is distributed amongst the age classes 1 to 179 according to the current age class and cover type distribution. The reasoning behind this is that in a stand mortality is not an abrupt process. Trees do not die off as soon as they reach 180 years. There is mortality in the stand and regeneration in the form of an understorey is always present. In order to capture this natural evolution of the forest stand the 180 year old age class is allocated amongst the other age classes.

The remaining age classes of the stocked forest land are aged by one year. This simple process is due to the single year representation of the age class structure of the forest.

Artificial and natural regeneration of cut

Natural and artificial regeneration of recently harvested and previously nonstocked forest land is represented by the last block. Area which naturally regenerates is distinguished from artificial regeneration through planting by multiplying by the natural regeneration share. A 50 percent natural regeneration rate is assumed. The regeneration rates for both newly cut forest land and previously nonstocked forest land determine how fast these area types regenerate. The regeneration rate for newly cut land was 0.7 and that for nonstocked .01. In other words the nonstocked land slowly regenerates to stocked whereas the new cut land regenerates quickly.

Succession in regeneration is represented by distinguishing the probability of transition to different cover types after harvest and planting. Data on regeneration after harvest and planting were available (Hearnden, Wilson and Millson, 1992) and absorbed in two regeneration transition matrices; one for natural regeneration and one for planting. The regeneration transition matrices are dimensioned 3 cover types by 3 cover types indicating by row the propensity of regenerating from one cover type to another.

The nonstocked forest land for beginning of year *k+1* is updated by including the proportion of newly cut forest which will be nonstocked plus the surviving nonstocked forest land from the end of the previous year *k*.

Finally, stocked forest land is updated at the beginning of year *k+1* in age class 1 for natural and artificial regeneration of harvested and nonstocked forest land during year *k*.

Data preparation

The final results of the project depend on the quality of data used by the model. This section focuses on describing the origin and characteristics of the different data used by the project, and some of the processing necessary to prepare the data for model input. Considerable effort was necessary to recode and format data for input into the model structure. The principal difficulty encountered was obtaining input data for each of the model's input variables referenced to common geographic areas for the 40 years.

Geographical units

Selection of the appropriate levels of spatial, temporal and categorical resolution for model elements and data is difficult. Compromises in the form of aggregation are necessary because not all data are available for the same geographic areas, in the same format, over the entire time period.

Although provincial estimates are the objective of the project, the spatial dependencies of much of the data (e.g. yield, fire, harvest) suggested that modeling at the sub-provincial level and aggregating up to a provincial total would produce more accurate results than modeling at the provincial total level.

OMNR divides the province into a number of geographically defined management units for the purpose of preparing resource plans. These management units form the statistical frame for the collection and reporting of the majority of data pertaining to the resource.

Similarly, in order to efficiently coordinate forest resource management, the province aggregates management units into geographically defined regions, districts, and areas. Like the management unit, these administrative units are often used to define the frame for data collection and reporting. Neither the management unit nor administrative boundaries have remained stable over the entire period of the historic account.

The geographic boundaries with the most longevity during the 40 years of the account were those of the 22 districts of the Lands & Forest (L&F). These boundaries also coincided well with early forest inventory data which could be used as a test against the simulation model results.

1991 Canada Forest Inventory

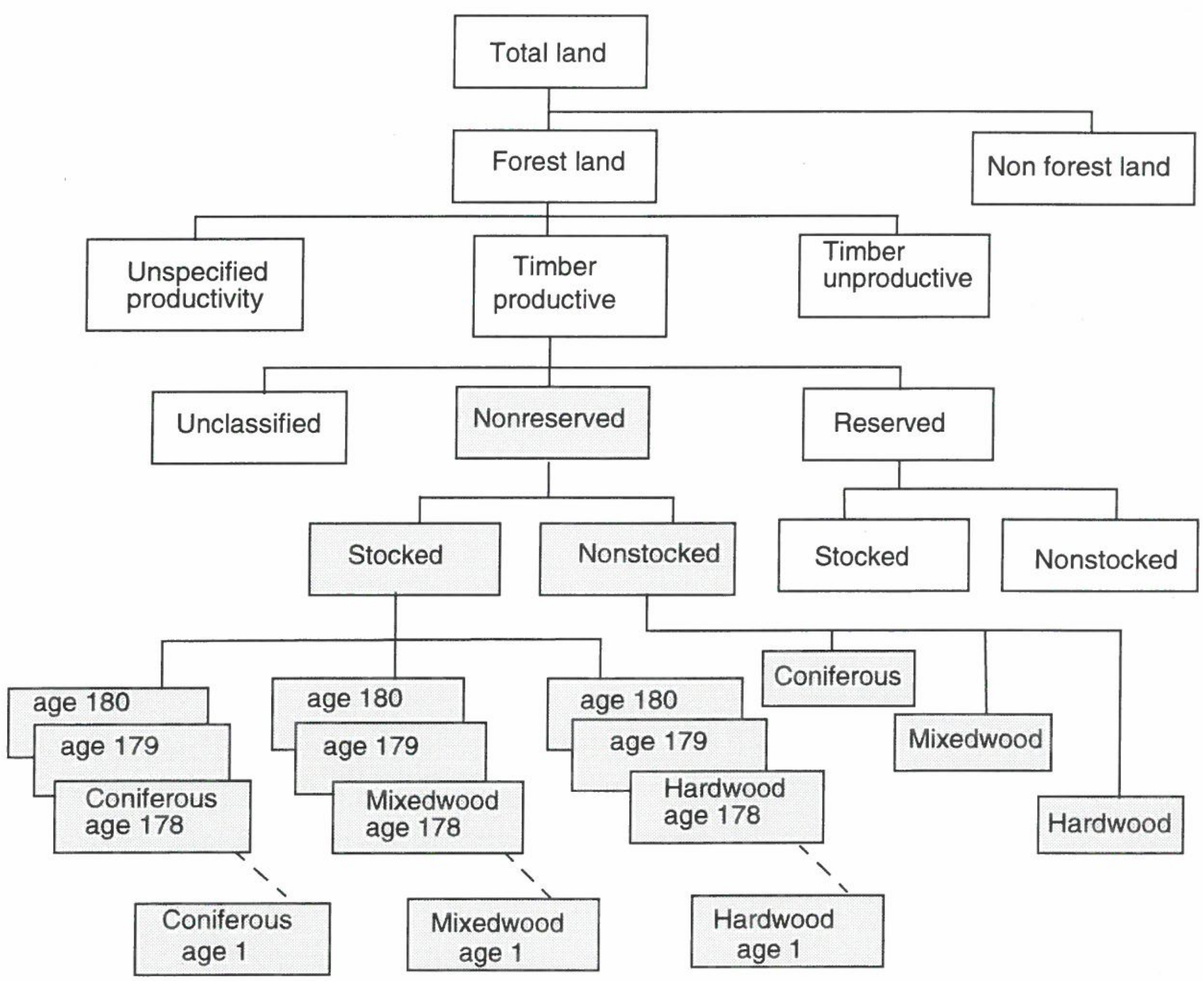
The original project plan was to use a composite 1953 inventory of the province as a starting point for the time series and evolve to the 1991 Canada Forest Inventory (CanFI) of Ontario.

The project now exclusively uses the Canada Forest Inventory (CanFI) for Ontario, maintained by the Canadian Forest Service. This inventory is a collection of over 100 inventories of different parts of Ontario, conducted by the provincial and federal governments over a time-span of 25 years.

The majority of the inventories which comprise the CanFI for Ontario were originally carried out to facilitate resource planning on geographically defined management units. These management unit inventories, known as forest resource inventories (FRI), are conducted at approximately 20-year intervals. This means that the average age of the inventories held in the CanFI is close to 10 years. Unfortunately, the names and boundaries of the management units are frequently changed so it is very difficult to track the state of the resource through time.

For the purposes of the account the CanFI recorded area, and softwood and hardwood net merchantable volume over 24 districts, 3 broad cover types (coniferous, mixedwood or hardwood) and nine 20-year age classes. The inventory area classification may be represented hierarchically as shown in Figure 4.2. Out of a total area of forest land of 57.4 million hectares 41.9 million were timber productive and 15.5 million timber unproductive. The timber productive forest land was further broken down into reserved (1.5 million hectares) and nonreserved (35.3 million hectares). The nonreserved stocked and nonstocked timber productive forest land areas were used in the simulation model. These area classifications are shaded in the hierarchy shown in Figure 4.2.

Figure 4.2
1991 Canada Forest Inventory



Digital map creation

Since district specific data were not available, a means to convert to and from this geographical level of detail was necessary. A digital map of the 22 districts was developed, supplemented by two additional northern districts (PEA[1] East & West), using various background coverages[2] and hard-copy inventory maps for guidance. CFI data is referenced to an irregular geographic grid which divides the province into approximately 4 500 cells. These data were aggregated to the 24 districts through a process of overlaying the boundaries of the districts on the centroids of the CFI cells. A cross-reference table linking the cells to the districts was then created and used to aggregate the cell level data up to a district level using a relational database.

Forest fire data

The simulation framework required estimates of area by cover type and age consumed by fire in each district/region during a year. The following notes detail the availability of data over the modeling period:

1953-55: Volume of standing timber burned (cu.ft), and its value, was recorded in the annual statistical reports, by each of the 22 districts. Using these volume loss estimates the provincial area burned was apportioned among districts. Provincial estimates (1951-1961) of the distribution of the area burned by cover types and land classes (e.g. non-forest, cutover, plantation) were used to reduce the area burned statistics by 6 percent (to account for non-forest area burned) and to estimate the portion of the area burned occurring in stocked forest (79%) versus nonstocked forest (21%).

1955-72: Area burned in each of the 22 L&F districts was recorded in the annual statistics. These statistics do not classify the area burned by cover type or land class, assumptions derived from 1951-61 data, were used as stated in the previous section.

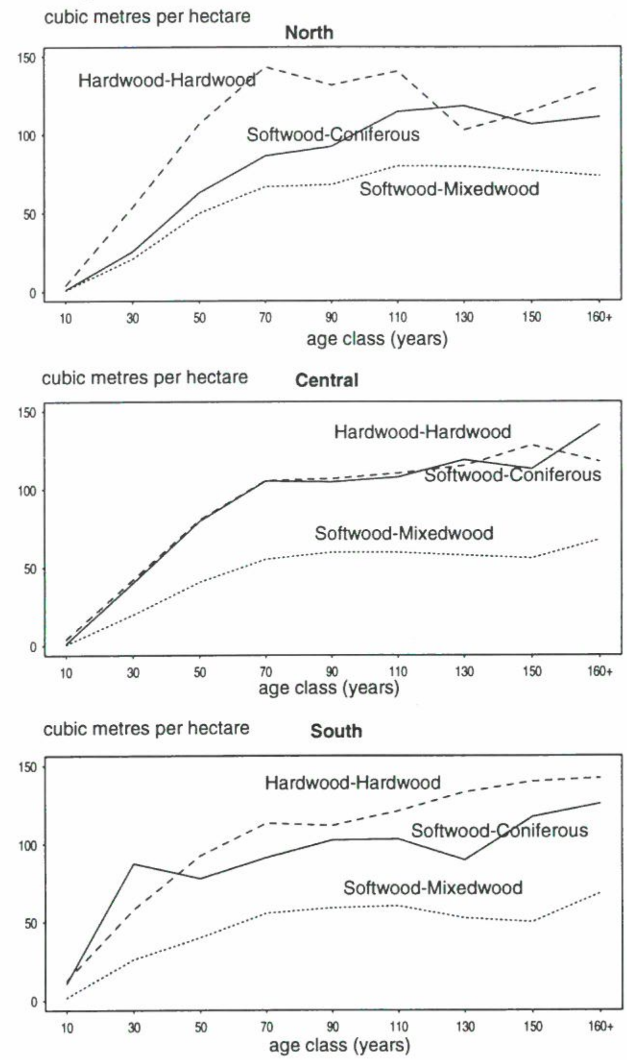
1973-91: Data for area burned in each of 8 regions were available. The area burned in the three northern regions were reduced because the extent of forest inventory used by the model is south of the northern boundaries of these regions. This was done by applying a factor to the area burned statistics equal to the total area burned in the intensive and measured zones relative to the regional total, based on a twelve year average (1976-88).

Yield tables

Yield tables establish the yield, usually in volume, which an area of forest normally provides at a given age. Yield tables were created using empirical methods to determine the average volume yield of softwood and hardwood woodtypes for three regions in Ontario (north, central and south) as shown in Figure 4.3. These tables provide the connection between the harvest volume (data) and the area harvested. Volume at individual ages was determined by interpolation of the 20 year age class data using a cubic spline function.

Figure 4.3

Average Volume Per Hectare



Harvesting data

It was difficult to obtain accurate, comprehensive harvest data. Problems included: incomplete time coverage, no coverage of private wood, non-convertible units, no geographic labelling or changing geographic framework, incorrect values from mis-reporting or poor measurement unit conversion, and no specification of method of harvest.

1. Potentially Exploitable Area
2. Coverage = digital map file used by a geographic information system (GIS).

The following principal sources of harvest data were explored: timber management planning annual reports, timber scaling and mill license returns.

Regeneration data

Post fire regeneration is represented by an immediate return of the stock affected to an age class of zero. Post harvest regeneration is predicted based on success rates found by a regeneration survey for the Ontario Independent Forestry Audit (Hearnden, Wilson and Millson, 1992). The regeneration transition matrices shown by tables 4.1 and 4.2 provide success rates for artificially assisted or naturally occurring regeneration. The accuracy of the regeneration-predictions are subject to the assumption that changes in harvesting methods, stock, regeneration method, sites and climatic condition have no effect on regeneration predictions.

Table 4.1
Planting Regeneration Transitions

	Coniferous	Mixedwood	Hardwood
Coniferous	0.440	0.397	0.163
Mixedwood	0.194	0.598	0.208
Hardwood	0.150	0.620	0.230

Table 4.2
Natural Regeneration Transitions

	Coniferous	Mixedwood	Hardwood
Coniferous	0.43	0.411	0.159
Mixedwood	0.21	0.580	0.210
Hardwood	0.07	0.360	0.570

Model validation

Traditional model validation involves devising a test that the model, if false, would fail to pass. If the model fails the test then it must be rejected. If it passes, then a more stringent test should be devised and so on until the degree of validation is satisfied . The model is accepted if it explains all the facts. In other words there is always a degree of subjectivity in model validation in deciding when to stop testing its validity.

In the next section the procedures used for validating the simulation framework are briefly described. A method of reconstructing the forest inventory by backward simulation of the 1991 inventory is outlined. A closeness criterion was determined by comparing the graphed age class distributions for the simulated and actual inventories.

Estimation of 1953 age class distribution by reverse calculation method

It was necessary to establish an initial condition from which to commence the simulation. It was originally intended that the initial condition would be based on the 1953 inventory. Unfortunately, it categorized the forest into broad maturity classes. While an attempt was made to convert the maturity classes into numerical age classes, an age class distribution which would provide an adequate initial condition could not be reached.

As an alternative, the model was rewritten to run in reverse and derive an initial condition from the 1991 inventory. The reconfiguration proved somewhat problematic since many of the processes in the model require a cover type, age class distribution to predict the changes which will take place in a period. For example, the fire losses in any one period are spread amongst the cover types and age classes according to their relative occurrence in a district. The cover type, age classes distribution at the end of year $k+1$ was shifted backwards one year and used as a substitute for the distribution for the beginning of a year k.

Another difference in the reverse-order model is the handling of the fire regeneration. When a fire occurs in the forward stepping model the area burned is placed in the first year age class at the start of the next period. The direct opposite would be to remove all of the area burned from this first age class and distribute it amongst the other ages. In the case of large fires this may not be feasible where there is inadequate area in the first year age class to cover the fire loss. To avoid this difficulty the reverse-order model takes area from all of the first 20 age classes. Since the areas in the single-year age classes were originally taken from an inventory which grouped them into 20 year classes, this is a reasonable solution. These slight differences in the forward and reverse models mean that there are some differences in the original 1991 and the predicted 1991 inventory.

Results

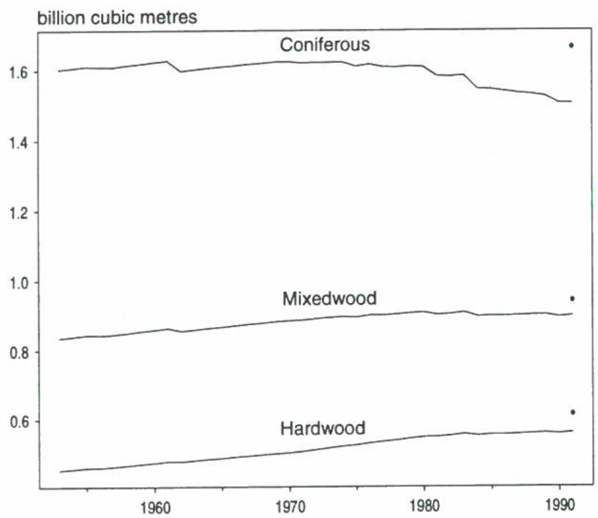
The physical accounts are a series of year end stock data showing the area and volume of forest land as provincial totals. The stock data, which include both the growing stock in cubic metres and the forest land area, are estimated by cover type. The changes to these stocks from year to year and the reasons for this change, such as growth, harvest, natural loss due to fire and mortality, change in land use due to area withdrawn for roads or parks are summarized in the next sections as provincial totals.

Growing stock

One indicator of forest development is total growing stock, calculated as the product of the area of forest and the yield, net merchantable volume per hectare. Yield tables are derived as a function of age for both softwood and hardwood woodtypes specific to the cover type defined. Figure 4.4 shows the total growing stock (cubic metres) by three cover types for the historical period 1953 to 1991. These derived data are the result of simulating the changes to the estimated 1953 inventory over the 38 years which constitute the simulation time horizon.

As can be seen from Figure 4.4 a shortfall of about 200 million cubic metres is predicted for 1991. This results from the prediction of a younger forest with lower volumes per hectare. Also, as discussed in the next paragraph, the predicted forest broken down by cover type is different from the 1991 inventory. More mixedwood cover type area is predicted which has a lower volume per hectare than the coniferous forest type.

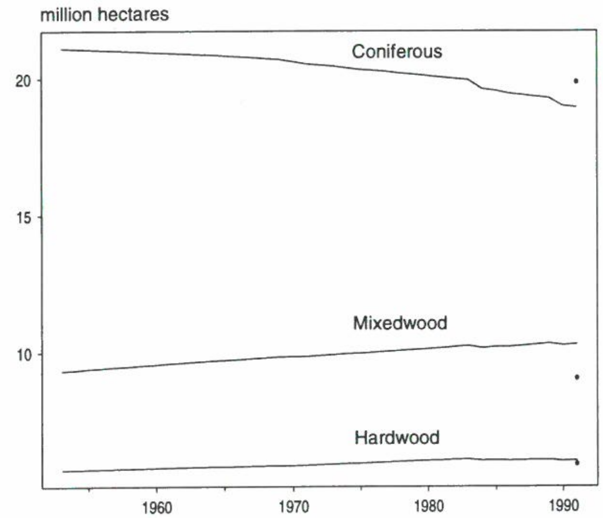
Figure 4.4
Growing Stock by Cover Type



Note:
The points are the 1991 Canada Forest Inventory, Canadian Forest Service.

The stocked forest land area over time, as depicted by Figure 4.5, reveals a discrepancy between the end point of the simulation (1991) with the actual data points for the 1991 inventory. However, the difference between the total 1991 inventory in area and that projected from the model is small. This discrepancy is a result of assuming that forest area burned or died regenerates to the same cover type and that the regeneration transition matrices are not defined on a district basis. These regeneration assumptions will introduce error over time in the distribution of forest land by cover type.

Figure 4.5
Stocked Forest Land Area



Note:
The points are the 1991 Canada Forest Inventory, Canadian Forest Service.

Fire loss

The randomness of forest fires from year to year is seen in Figure 4.6. Catastrophic fires occurred in 1961 and 1980. The variability of these disturbances becomes visible in the age class distribution of the forest originating as large regenerated areas in the first age class as shown by Figure 4.7.

Figure 4.6
Volume Burned

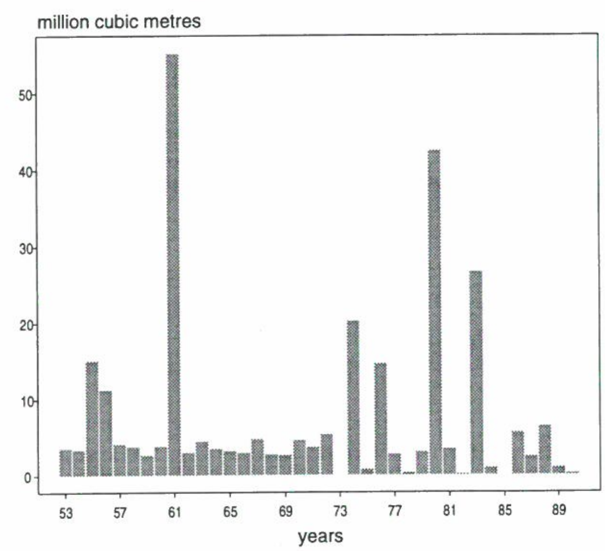


Figure 4.7
Age Class Structure of Forest, 1991

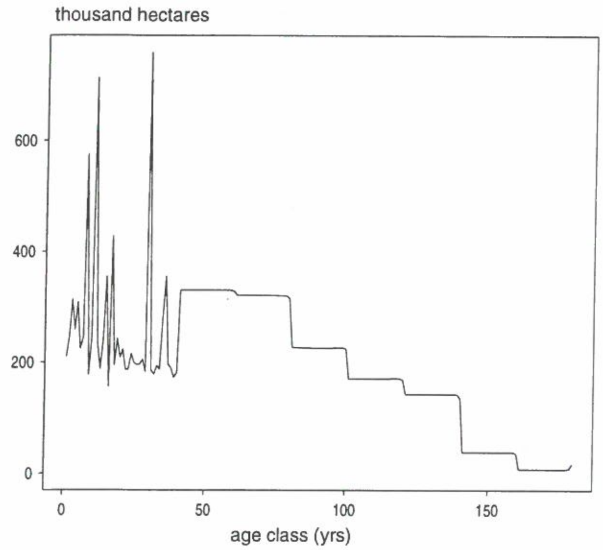
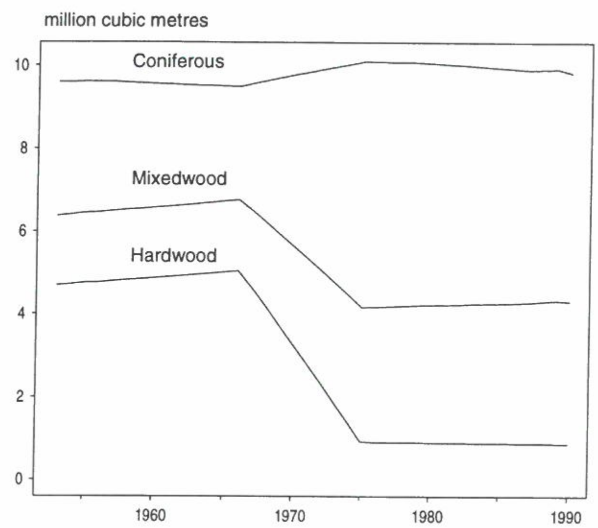


Figure 4.8
Volume Lost to Mortality



Mortality

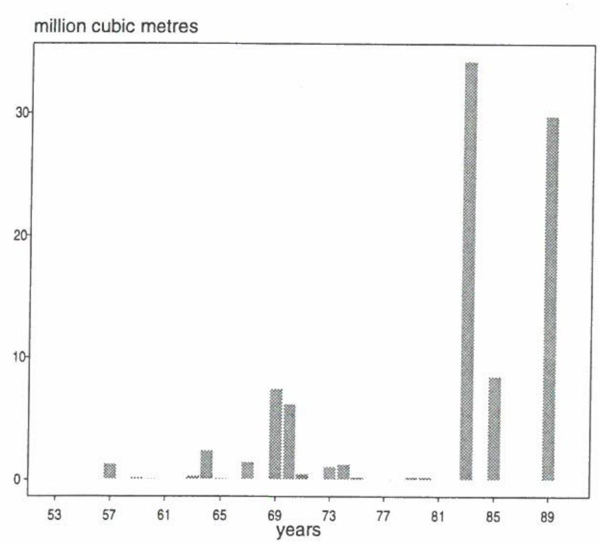
Natural mortality is represented by assuming that the area of the oldest single year age class (180 years) dies. The pattern of mortality seen in Figure 4.8 displays the volume of forest that is lost to mortality over the historical period 1953 to 1991. The drop in mortality for both mixed and hardwood cover types is explained as a result of the way in which the age class structure evolves over time. Since mortality is represented in the model as all area that reaches the oldest age class, discontinuities in the age class structure will be reflected in the shape of the mortality curve.

Discontinuities in the age class structure in this framework arose because a single year age class distribution was created from twenty year age classes. Therefore, these drops in mortality are in part an artefact of the model structure. The abruptness of this effect was smoothed by running the time series through a simple linear time invariant filter (a convolution filter).

Roads and parks

Each year a certain amount of stocked productive forest land is withdrawn from the exploitable landbase. The first withdrawal is the creation of new parks. The second withdrawal is the roads required for harvesting. Three percent of the area harvested was used as the proxy for logging roads. Figure 4.9 shows the volume of forest withdrawn for parks over time. The trend suggests that forest set aside for parks has increased considerably recently.

Figure 4.9
Volume Withdrawn for Parks



Harvesting

As mentioned in the data section of this report, harvesting volume time series for two wood types: softwood and hardwood were reconstructed for the 24 districts from several provincial sources. Figures 4.10 and 4.11 show the provincial total volume and area harvested respectively.

Figure 4.10
Volume Harvested by Woodtype

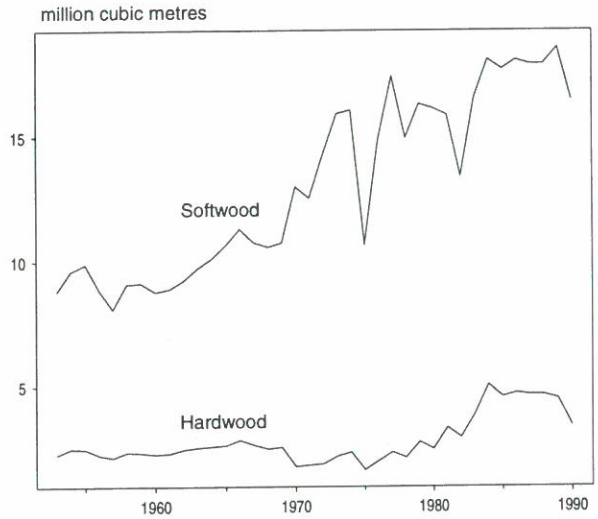
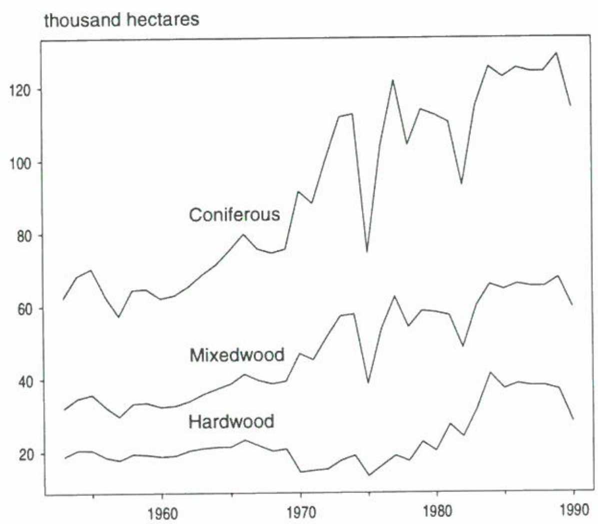


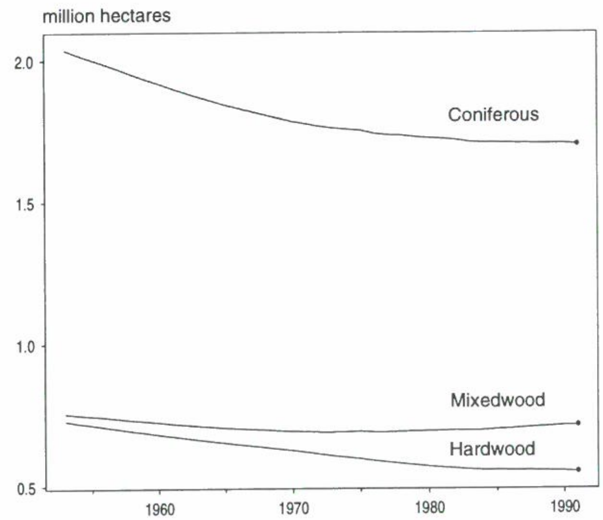
Figure 4.11
Forest Land Area Harvested



Nonstocked forest land

In Figure 4.12 the time path of nonstocked forest land by cover type is shown. A decline in overall nonstocked forest land is seen in Figure 4.12. The points signify the 1991 data points of total provincial nonstocked forest land by cover type. The plotted lines indicate the result of simulating this nonstocked variable over the period 1953 to 1991.

Figure 4.12
Nonstocked Forest Land Area



Timber volume and area account

The physical stock/flow accounting for Ontario net merchantable timber volume is shown in Table 4.3:

Closing Stock = Opening Stock - Volume Lost (due to harvest, fire, mortality and roads and parks withdrawals) + Net Growth.

Where net growth is imputed from the identity:

Net Growth [*k*] = Growing Stock [*k+1*] - Growing Stock [*k*] - Fire Volume Lost [*k*] - Mortality Volume Lost [*k*] - Volume Withdrawn for Roads/Parks [*k*] - Harvest Volume [*k*].

Table 4.3
Ontario Timber Resource Volume Account

Year	Opening stock	Harvest	Fire	Mortality	Parks	Roads	Growth	Closing stock
	thousand cubic metres							
1953	2 892 058	11 081	3 695	20 668	-	332	47 442	2 903 724
1954	2 903 724	12 099	3 464	20 632	-	363	47 509	2 914 675
1955	2 914 675	12 360	15 217	20 720	5	371	47 934	2 913 937
1956	2 913 937	11 083	11 308	20 730	-	332	48 307	2 918 791
1957	2 918 791	10 217	4 253	20 815	1 315	307	48 716	2 930 602
1958	2 930 602	11 434	3 937	20 837	49	343	48 729	2 942 732
1959	2 942 732	11 452	2 839	20 873	232	344	48 927	2 955 919
1960	2 955 919	11 049	3 975	20 909	165	331	49 201	2 968 691
1961	2 968 691	11 187	55 319	20 952	-	336	49 621	2 930 518
1962	2 930 518	11 698	3 096	21 002	-	351	49 523	2 943 895
1963	2 943 895	12 251	4 585	21 055	374	368	49 583	2 954 845
1964	2 954 845	12 684	3 659	21 108	2 465	381	49 612	2 964 160
1965	2 964 160	13 261	3 332	21 162	169	398	49 678	2 975 516
1966	2 975 516	14 127	3 076	21 221	70	424	49 645	2 986 244
1967	2 986 244	13 400	4 847	20 620	1 489	402	49 191	2 994 677
1968	2 994 677	13 059	2 891	19 967	66	392	48 625	3 006 927
1969	3 006 927	13 289	2 777	19 304	7 512	399	47 831	3 011 477
1970	3 011 477	14 759	4 753	18 636	6 260	443	46 666	3 013 292
1971	3 013 292	14 354	3 850	17 954	539	431	48 193	3 024 357
1972	3 024 357	16 169	5 466	17 266	38	485	47 201	3 032 134
1973	3 032 134	18 093	160	16 570	1 159	543	46 058	3 041 667
1974	3 041 667	18 384	20 291	15 868	1 315	552	45 287	3 030 544
1975	3 030 544	12 282	948	15 167	254	368	45 493	3 047 017
1976	3 047 017	16 830	14 766	15 145	131	505	44 491	3 044 131
1977	3 044 131	19 744	2 918	15 153	78	592	43 783	3 049 430
1978	3 049 430	17 064	470	15 165	-	512	44 111	3 060 330
1979	3 060 330	19 051	3 210	15 175	284	572	43 701	3 065 740
1980	3 065 740	18 598	42 588	15 164	280	558	43 706	3 032 258
1981	3 032 258	19 194	3 603	15 152	-	576	43 406	3 037 139
1982	3 037 139	16 323	253	15 140	16	490	43 721	3 048 639
1983	3 048 639	20 393	26 740	15 128	34 238	612	42 507	2 994 035
1984	2 994 035	23 116	1 123	15 112	-	693	41 965	2 995 956
1985	2 995 956	22 244	79	15 100	8 511	667	41 766	2 991 120
1986	2 991 120	22 769	5 771	15 087	-	683	41 541	2 988 350
1987	2 988 350	22 542	2 627	15 074	-	676	41 451	2 988 881
1988	2 988 881	22 542	6 508	15 115	-	676	41 415	2 985 455
1989	2 985 455	23 051	1 169	15 155	29 833	692	40 780	2 956 335
1990	2 956 335	19 872	340	15 032	-	596	41 047	2 961 543

Sources:
Statistics Canada, Canadian Forest Service and Ontario Ministry of Natural Resources.

Finally, the forest land area account is shown in Table 4.4 This states the opening stock in thousand hectares of non-reserved stocked timber productive forest land and the areas harvested, lost to fire and mortality together with area withdrawn from this landbase due to parks and construction of logging roads.

The next column gives the area regenerated due to planting or natural means and the closing stock for nonreserved stocked timber productive forest land. The closing stock of timber productive park land which is also nonreserved and timber productive is shown. The final column provides the closing stock for the nonreserved timber productive forest land which is nonstocked.

Discussion

Forest inventory and timber resource accounting

The primary purpose of the simulation modeling efforts in this project was to estimate a physical, historical time series of Ontario's forest estate. If the estate had been fully inventoried on a regular basis, and all of the changes from both natural events and human interventions were estimated and recorded, simulation would not have been necessary.

The past 30 years has seen the arrival of a number of key technologies for updating and maintaining forest inventories. These new technologies include: computerized databases, satellite imagery, geographic information systems, and global positioning systems. Through the application of these technologies, inventories are becoming more current and comprehensive every year. It is now easy to envision inventory information which is no more than a year or two out of date at anytime.

Original forest inventories in Ontario are currently updated at district and area offices on a five-year recurring basis for the purpose of management planning. Unfortunately, these updated inventories are rarely aggregated back to a provincial level due to differences in standards, computing environments and inventory boundaries. Work on provincial data management and information systems now underway should make provincial compilations simpler and easier.

The 1991 CanFI, used by this project, is compiled on a five year cycle from original provincial forest inventories which are anywhere from 1 to 20 years old. It should be possible to replace the entire Ontario 1991 inventory with a complete, updated inventory for the province on the five year CanFI cycle once the new data management systems are in place. By using CanFI data for resource accounting it will not be necessary to predict more than four years in advance to have annual inventory estimates. This will keep divergence between estimates from the model and the inventory to a minimum.

Change data

The other side of forest resource accounting is tracking the changes which occur to the forest. The compilation of harvest and artificial regeneration statistics is improving in Ontario, with documentation requirements for timber management plans and the environmental assessment driving the process. However, the aggregation of these statistics to a provincial level and the estimation of changes due to natural regeneration, growth, mortality, pest infestations and other natural disasters needs improvement.

The information now available at the provincial level within the National Forestry Database is similar to that required for resource accounting. It would make an excellent starting

Table 4.4
Ontario Timber Resource Area Account

Year	Nonreserved opening stock	Harvest	Fire	Mortality	Parks	Roads	Regeneration	Nonreserved closing stock	Parks closing stock	Nonstocked closing stock
	thousand hectares									
1953	36 144	113	49	169	-	3	361	36 170	915	3 489
1954	36 170	124	47	169	-	4	367	36 194	915	3 461
1955	36 194	127	191	170	-	4	514	36 217	915	3 435
1956	36 217	114	143	170	-	3	455	36 242	915	3 406
1957	36 242	105	57	170	16	3	362	36 253	932	3 376
1958	36 253	117	53	171	1	4	368	36 276	932	3 349
1959	36 276	117	40	171	3	4	355	36 296	935	3 322
1960	36 296	113	54	172	2	3	366	36 318	937	3 295
1961	36 318	115	672	172	-	3	985	36 341	937	3 268
1962	36 341	120	43	171	-	4	359	36 363	937	3 243
1963	36 363	126	62	171	5	4	383	36 378	942	3 219
1964	36 378	130	51	172	30	4	375	36 366	972	3 197
1965	36 366	135	47	172	2	4	375	36 381	974	3 176
1966	36 381	144	44	173	1	4	380	36 395	975	3 158
1967	36 395	137	66	174	19	4	397	36 392	994	3 138
1968	36 392	133	42	175	1	4	370	36 407	995	3 117
1969	36 407	136	40	175	93	4	371	36 330	1 088	3 098
1970	36 330	153	66	176	74	5	410	36 267	1 162	3 082
1971	36 267	148	53	130	7	4	348	36 273	1 168	3 065
1972	36 273	167	73	127	-	5	379	36 280	1 169	3 052
1973	36 280	187	2	127	13	6	324	36 269	1 182	3 044
1974	36 269	189	267	127	15	6	591	36 256	1 197	3 036
1975	36 256	126	11	127	3	4	285	36 269	1 200	3 016
1976	36 269	173	196	127	2	5	507	36 273	1 202	3 005
1977	36 273	203	35	127	1	6	370	36 271	1 203	3 001
1978	36 271	176	6	128	-	5	319	36 275	1 203	2 991
1979	36 275	195	42	128	3	6	371	36 272	1 206	2 985
1980	36 272	191	559	128	3	6	884	36 270	1 209	2 978
1981	36 270	195	49	127	-	6	377	36 270	1 209	2 973
1982	36 270	165	3	127	-	5	307	36 276	1 209	2 961
1983	36 276	206	376	127	447	6	712	35 826	1 657	2 958
1984	35 826	232	15	126	-	7	371	35 817	1 657	2 960
1985	35 817	224	1	126	101	7	350	35 709	1 758	2 960
1986	35 709	229	83	126	-	7	437	35 701	1 758	2 962
1987	35 701	227	34	126	-	7	387	35 693	1 758	2 963
1988	35 693	227	90	127	-	7	443	35 685	1 758	2 964
1989	35 685	233	13	127	390	7	371	35 285	2 148	2 966
1990	35 285	202	5	126	-	6	336	35 283	2 148	2 962

Sources:
Statistics Canada, Canadian Forest Service and Ontario Ministry of Natural Resources.

point and would provide the provinces with a means of making this information available to a wider audience with minimal effort.

Conclusion

The modeling methodology was successful in resolving a time series estimate of the physical stock of Ontario's forest estate over the 38 year historical period. Despite the flexibility of the modeling software considerable effort was required to transform and translate the raw data available into the structures necessary for simulation. In the opinion of the authors, the resolution of the model and its outputs represent the best compromise given the resources and data available.

It is difficult, to ascertain the accuracy and reliability of the estimates generated because of the complexity of the model, the number of assumptions required and the unavailability of additional independent data.

Over the 38 year period the total forest stock increased to 3.07 million cubic metres in 1980 and then declined to 2.98 million cubic metres in 1990. This change in stock level depends on several factors. Evolution of the age class distribution shows a decrease in volume in the older age classes. By 1990 the total growing stock is distributed such that most volume is centred around the 60-year old class.

This young forest has considerable potential for growth because the average volume per hectare is an increasing function with age as seen in Figure 4.3. Therefore the growth rates are greater in the younger age classes.

Glossary

Canada forest inventory. Through the Canadian Forest Inventory Committee, the Canadian Forest Service works in close cooperation with provincial and territorial forest management agencies to make recommendations on forest inventory procedures, and to acquire data for national area and volume summaries on topics such as ownership, status, productivity, site quality, stocking, disturbance, age, forest types and species groups. Data on forest inventories are available from the Forest Inventory and Analysis Project, Canadian Forest Service.

Coniferous cover type contains cone-bearing trees with needle or scale-like leaves belonging to the botanical group Gymnospermae.

Coverage in remote sensing terminology is the overall area covered by overlapping aerial photos or by maps.

Cover type is a group of forested areas or stands of similar composition which differentiates it from other groups.

Endemic mortality due to insects and diseases is mortality reflected in the empirical yield tables.

Empirical yield table is a summary table showing, for stands (usually even-aged) of one or more species on different site qualities the characteristics of the stand at different ages. The characteristics usually include average diameter and height and total basal area, number of trees, and volume per hectare. Empirical tables are prepared for actual average stand conditions.

Growing stock is the sum by number, basal area or volume of trees in a forest or specified part of it.

Hardwood cover type contains trees belonging to the botanical group Angiospermae with broad leaves usually all shed annually.

Limits of operability define the range of ages from which harvesting may occur.

Mixedwood cover type contains an approximately equal mixture of coniferous and hardwood trees.

Multi-dimensional array is the generalization of a matrix. Where matrices have two subscripts, arrays may have one, two, three or more subscripts.

Nonreserved forest land is forest land that, by law or policy, is available for the harvesting of forest crops.

Positive linear system is a linear system in which the state variables are always positive (or at least nonnegative) in value.

Production forest is productive forest land where harvesting may occur.

Productive forest land is forest land that is capable of producing a merchantable stand within a reasonable length of time.

Reserved forest land is not available for the harvesting of forest crops.

Roundwood is the section of tree stems, with or without bark.

Titleset is a collection of character labels which describe the elements in each array dimension.

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5 Valuing Ontario's Timber Resource Stock

by Gerry Gravel, Greg Lawrance and Susan Ecclestone

Introduction

This chapter discusses a method used to produce a time series of estimates of the value of Ontario's timber resource stock. The development of timber resource accounts started with an Ontario pilot project, carried out with the assistance of the Ontario Ministry of Natural Resources (OMNR). The pilot project will be extended to other provinces.

The value of resource stocks will be included in Canada's National Balance Sheet Accounts, a part of the Canadian System of National Accounts. Physical and monetary accounts of natural resource assets will show the importance of natural resources relative to the other assets which make up national wealth and the change in value or relative importance over time.

Forest assets in the System of National Accounts

The ***System of National Accounts 1993*** (SNA93), published jointly by the United Nations, the Organization for Economic Cooperation and Development, Eurostat, the International Monetary Fund and the World Bank, is the international standard guide for economic accounts. This recent version recommends that estimates of the value of natural resources be included along with the tangible assets such as buildings and equipment already shown in national balance sheet accounts. The Canadian System of National Accounts will be made compatible with this world standard by 1997. The SNA93 makes a distinction between natural resources and natural assets, where only the latter part is to be included in economic accounts. The natural assets to be included in economic accounts are those resources over which ownership rights have been established and which are commercially exploitable[1]. Remote or protected forests which are inaccessible or where there is no effective right of exploitation are excluded.

Additional information on natural assets is shown in an account called other changes in volume of assets. This account reconciles differences in the value of assets from one year to the next by showing the value of changes due to a number of causes, which, in the case of forests, include growth, depletion through harvest, changes in use or ownership, catastrophic loss and changes in price.

The ***system of integrated environmental and economic accounting*** (SEEA), (United Nations, 1993a), outlines a preliminary version of a more extensive set of environmental accounts that would be satellites to the existing accounts of the SNA. These accounts include physical balances in addition to monetary measures and are based on a definition of natural assets which extends beyond those which are commercially exploitable. Monetary accounts would, in effect, expand what is considered production to include natural growth. The value of timber which is harvested would be recorded as depletion, which would be netted against the value of growth to arrive at a measure of Eco Domestic Product (EDP). Stocks of assets which are not economic assets in the conventional SNA would not be valued in monetary terms, but recorded in physical terms only. Changes in the stocks of these assets, or uses of these assets that degrade their quality, would be valued. Suggested methods of valuation are based on the cost of prevention or of restoration of the degradation. These costs would also be included in the calculation of EDP.

The exact content and structure of the Canadian forest accounts has not been decided yet. The accounts will show the area and volume of the physical stock and changes due to growth and to harvest or other loss. The physical data can cover all forest land, not just what is commercially exploited. Some of the benefits of a forest that could be given a monetary value include the harvesting of timber and other forest products, recreational use, aesthetic benefits, flood protection, prevention of soil erosion, water purification and storage, effect on climate, wildlife habitat and biodiversity. There are currently no generally acceptable methods for valuing all of these benefits.

In this chapter, we consider only the commercially exploitable forest, which we value as a timber resource. The value is based on the net income obtained from harvesting the timber. Other uses of the timberland and remote or protected forest are not valued; estimates of these values would require a different method of valuation.

The physical timber asset

The part of the forest resource that we consider as a natural asset is the accessible land on which timber harvesting is allowed and on which trees of commercially valuable species grow to a merchantable size in a reasonable length of time. The period since 1961 has seen changes in Ontario's timber land base as a result of roadbuilding and changing land use. Technological change in harvesting and wood processing has meant that more of the standing volume could be harvested or used in forest products and that new uses were found for some species. Remote areas have

1. United Nations, 1993a, paragraph 13.53.

been made accessible with roadbuilding and part of the area has been restricted to maintain habitat or prevent erosion. Transportation costs mean that forest which is distant from a mill is not commercially viable until a mill is constructed in its vicinity.

Valuation

To be comparable to other assets in national balance sheet accounts, timber should ideally be shown at market value, the price that would be obtained if the asset were sold in a competitive public market. In the case of timber in Ontario, market transactions rarely take place.

The government of Ontario owns 86 percent of the productive forest land. Rather than selling cutting rights, the government enters into management agreements under which it sets maximum allowable harvest levels, known as the annual allowable cut, based on an assessment of long-run sustainable yield. The provincial government receives revenue in the form of area charges and stumpage fees in return for the wood supply and management services. Since stumpage fees are set by the province rather than determined by public auction, it is difficult to know how closely they reflect the market value of the timber. Many of the buyers of timber have monopsonistic markets (single buyer) due to the relatively high cost of transporting wood to the next nearest mill, so that even a market transaction might not represent a competitive market price.

Rent

The market value of timber determined by public auction is highest bid based on a buyer's calculation of stumpage value, the difference between the eventual selling price of the timber and the cost of bringing it to market. The term stumpage value means, literally, the value of timber 'on the stump' before industrial intervention. The term rent is used more generally to apply to all resources and also refers to the value of the resource itself.

Calculating the stumpage value of a province's timber asset for a long time series is impractical because of the lack of sufficiently detailed historical data. Data would be required for the numerous factors that determine the stumpage value, which include species, size, quality, location (distance from a market), accessibility and the costs of felling.

Instead of calculating a value based on the characteristics of the timber itself, we calculate a rent residual from historical data for annual production by the province's forest product industries. Capital and operating costs incurred by the industry in felling, transporting or processing timber are subtracted from the value of forest products produced. Payment of stumpage or other fees is not considered a cost; these fees are part of the residual. The residual rent estimate is based on harvesting which took place on the timber production land base of the period with available production capacity. The annual rent obtained is the basis for valuation of the timber stock asset.

Net price

A simple valuation technique, with physical data for the volume harvested and for the volume of the total timber asset, would be to use the annual rent to derive an average rent per unit of volume to apply to the total volume. This method, often called net price, is essentially an estimate of the rent that would be obtained if the whole forest were harvested immediately. A refinement of the method would exclude the volume of trees which are too small to be harvested but which are included in the volume data, so that what is calculated is exactly what would be harvested if it were possible to do so. The method is limited in that it ignores the value of trees which are currently small, but which will be harvested in the future when their volume has increased. The assumption that all harvestable timber will be harvested within a short period of time means that what will actually be future rent income is given an undiscounted present value, that is, there is no allowance for time preference.

Present value

Estimating the value of rent from future harvests would require knowledge about future prices, costs and harvest volumes. If the forest is being harvested at a sustainable rate, that is, if the annual allowable cut is determined accurately and is not exceeded, an indefinite number of equivalent future harvests is possible. If we assume that annual rent will be constant, the value of the timber asset as the source of future income can be calculated as the present value of an infinite series of annual rent equal to the current year's rent. Capitalizing a stream of future income by discounting it to a present value is a common method of valuing a financial asset such as a bond, which yields interest annually or semi-annually. The difference is that the bond's yield is known, but the rent actually to be obtained from the timber is not. Use of this method to value timber raises questions about the validity of assuming constant rent and about the choice of an appropriate discount rate.

The selling prices of forest products are cyclical and this is reflected in the rent residual. Rather than capitalizing each year's rent individually, we use a moving average to reduce cyclical volatility. In other words, we assume that future rent will be similar to current average experience. Discounting future income limits the effective length of time during which rent is assumed to be constant; a 5 percent discount rate gives a near zero present value to income earned after about fifty years (a 10 percent rate would reduce this time to twenty years).

The question of which discount rate to use is difficult to answer conclusively. It could be argued that the discount rate should reflect a social time preference because the rent is, to a great extent, potential revenue of the province which owns the resource. The rate used to discount future rent income should be seen as a real rate, that is, there is no inflation to discount since we assume constant future prices and costs. We use more than one rate to show the effect of the discount rate on asset values. One of the rates used, 4 percent, is an estimated average real provincial government borrowing rate for the period 1961 to 1991.

Timber and land

Both SNA93 and the SEEA classify timber separately from the land it grows on. While it is easy to distinguish between timberland and the timber on it in physical accounts, it is difficult to value them separately.

The value calculated on the basis of future harvest rent income is a return both to the timber resource and to the land it occupies, since the land must be devoted to growing timber. Use of the land for timber production does not necessarily or always exclude some other uses such as wildlife habitat or human recreation. These other uses of the land or timber could also have economic value which could be added to the value of the asset, although whether the asset is land or forest is again ambiguous. It is questionable whether much of the timberland really could have a different use. Some timberland is too remote to be sold as a building site and unsuitable for agriculture. We do not try to separate timber value from land value.

The question of land ownership and timber production is a further consideration in the value of the timber asset. The forest management expenses incurred by the government in maintaining the timber asset are considered a cost to be netted from the rent. An additional reason to consider public forest management expenditure is consistency among the eventual data series for all provinces. The share of total forest management expenditures borne by government varies among provinces and changes over time. For example, the responsibility for expenditure on reforestation in Ontario has recently shifted from government to industry. Both private and public forest management expenditures are considered.

The calculation of asset value

Industry surplus

The selling price and cost data required to calculate annual rent are available for the logging industry. However, a large number of the logging establishments which report the data are part of integrated firms. These establishments do not actually sell timber to their parent mills, so that the selling prices reported do not necessarily reflect market prices for timber. If the reported selling price were too low, part of the rent would, in effect, be shifted to the buyer of the timber, so that a rent calculation based on the logging industry alone would be understated. Similarly, a high reported price would overstate the actual rent. To avoid the problem, we calculate rent for an industry group consisting of both the logging establishments and the secondary wood processing industries which sell their output in public markets. These secondary industries are pulp and paper mills, veneer and plywood and sawmilling and planing.

The value of production is based on data for value of shipments and changes to inventory from the Statistics Canada publications ***Logging Industry*** (Cat. No. 25-201), ***Sawmilling and Planing*** (Cat. No. 35-204) and ***Pulp and Paper Mills*** (Cat. No. 36-204). The value of wood cut by consumers for own consumption (primarily firewood and some sawn wood) is not estimated.

Statistics on operating costs such as labour, fuel and electricity, materials and supplies (but excluding stumpage fees) for the logging industry were taken from ***Logging Industry*** (Statistics Canada, Cat. No. 25-201). Similar statistics for the sawmilling, pulp and paper and veneer and plywood industries were taken from ***Canadian Forestry Statistics*** (Statistics Canada, Cat. No. 25-202).

Capital costs include both a consumption allowance (depreciation) and the cost of financing the net capital investment. Capital consumption allowances and end-of-year net capital stock measures by industry are prepared by Statistics Canada's Investment and Capital Stock Division. Capital stock estimates are at replacement cost. Depreciation is straight line over a life of thirteen years. The cost of financing capital is a nominal average corporate long-term bond rate (data from Scotia McLeod published in the ***Bank of Canada Review***) applied to the value of the capital stock. No allowance is made for profit; the borrowing cost is applied to the total capital stock, whether financed by debt or by equity, so that there is some return to equity included.

The annual value of rent generated in the logging industry (SIC 0410) is shown in Table 5.1. The logging industry has consistently been profitable over the period studied, but this could reflect pricing of sales to cover costs by establishments which are integrated with mills. The cost of capital averages 3 percent of the industry's total costs.

The annual values of production for the wood industries (sawmilling, planing, veneer & plywood) are presented in Table 5.2. The sawmill and planing industry (SIC 2510) and veneer and plywood industry (SIC 2520) were aggregated to protect confidential data in the veneer and plywood industry. Capital costs averaged about 11 percent of total costs.

Table 5.1
Logging Industry Production Surplus

Year	Costs			Value of production	Surplus
	Operating	Capital	Total		
	millions of current dollars				
1961	104.5	10.9	115.4	135.3	19.9
1962	106.4	11.0	117.4	137.8	20.4
1963	111.1	11.3	122.4	143.9	21.5
1964	115.4	11.7	127.1	147.2	20.1
1965	129.1	12.7	141.8	164.3	22.5
1966	149.0	14.2	163.2	195.5	32.3
1967	168.1	15.8	183.9	211.0	27.1
1968	150.0	16.4	166.4	192.3	25.9
1969	169.1	18.1	187.2	215.2	28.0
1970	172.6	18.5	191.1	215.0	23.9
1971	163.7	18.7	182.4	205.3	22.9
1972	182.2	19.1	201.3	228.0	26.7
1973	208.3	22.0	230.3	266.1	35.8
1974	263.1	30.5	293.6	348.4	54.8
1975	253.6	36.8	290.4	334.0	43.6
1976	274.1	37.7	311.8	359.8	48.0
1977	332.7	41.2	373.9	430.2	56.3
1978	415.2	45.2	460.4	511.3	50.9
1979	491.6	52.6	544.2	599.8	55.6
1980	571.1	62.6	633.7	706.1	72.4
1981	612.4	78.7	691.1	731.1	40.0
1982	547.0	71.9	618.9	662.6	43.7
1983	633.5	68.1	701.6	786.9	85.3
1984	790.0	66.0	856.0	952.8	96.8
1985	764.3	61.8	826.1	937.8	111.7
1986	809.5	61.0	870.5	1 033.5	163.0
1987	771.1	61.0	832.1	987.2	155.1
1988	913.6	60.4	974.0	1 206.3	232.3
1989	1 006.8	59.5	1 066.3	1 300.1	233.8
1990	937.7	61.9	999.6	1 165.5	165.9
1991	854.3	55.7	910.0	1 065.0	155.0

Sources:
Statistics Canada, National Accounts and Environment Division, Industry Division and Investment and Capital Stock Division.

Table 5.2
Wood Industries Production Surplus

Year	Costs			Value of production	Surplus
	Operating	Capital	Total		
	millions of current dollars				
1961	64.2	6.5	70.7	79.2	8.5
1962	71.4	6.8	78.2	88.5	10.2
1963	78.3	7.1	85.4	98.9	13.5
1964	85.1	7.6	92.7	110.3	17.6
1965	89.1	8.8	97.9	120.7	22.8
1966	102.0	9.9	111.9	129.8	17.9
1967	105.0	10.7	115.7	131.0	15.3
1968	115.2	11.3	126.5	142.6	16.1
1969	121.0	14.1	135.1	151.8	16.7
1970	114.2	15.4	129.6	134.0	4.4
1971	120.7	15.9	136.6	147.6	11.0
1972	137.4	17.8	155.2	185.8	30.6
1973	173.5	22.9	196.4	260.8	64.4
1974	198.6	35.0	233.6	267.0	33.4
1975	204.8	41.4	246.2	240.4	-5.8
1976	235.1	41.6	276.7	277.8	1.1
1977	287.1	45.8	332.9	349.7	16.8
1978	363.8	52.7	416.5	486.5	70.0
1979	460.1	63.6	523.7	623.5	99.8
1980	521.2	77.2	598.4	620.6	22.2
1981	556.8	95.7	652.5	645.5	-7.0
1982	489.5	87.1	576.6	538.0	-38.6
1983	608.5	90.0	698.5	733.0	34.5
1984	709.2	90.9	800.1	827.2	27.1
1985	797.5	81.8	879.3	947.8	68.5
1986	854.2	80.4	934.6	1 019.2	84.6
1987	875.8	84.0	959.8	1 014.7	54.9
1988	967.9	90.4	1 058.3	1 116.7	58.4
1989	976.5	89.5	1 066.0	1 095.9	29.9
1990	893.4	90.2	983.6	969.5	-14.1
1991	793.6	77.2	870.8	864.9	-5.9

Sources:
Statistics Canada, National Accounts and Environment Division, Industry Division and Investment and Capital Stock Division.

The pulp and paper industry production surpluses are presented in Table 5.3. Capital costs are significantly higher than in the other forest industries, averaging more than 18 percent of total costs. The surpluses and deficits exhibited by the pulp and paper industry dominate the forest industries as a whole. The importance of its surplus or deficit relative to the rest of the industry raises some questions about just what is captured in the residual. For example, rent could be dissipated by inefficient producers.

Forest management expenditure

Forest management expenditures fund activities such as maintenance of a forest inventory, planning, access provision, fire protection and reforestation or other silvicultural activities. Data available for forest management expenditure by government apply to more than just the timber-producing part of the forest, so that an allocation must be estimated.

The Ontario Ministry of Natural Resources (OMNR) recently contracted an accounting firm to review the ministry's financial reporting and develop accounting methods which would determine the cost of protection and renewal to be recovered in the price of resources. The ***Forest Management Accounting Framework***, published in 1993 as the result of the study, indicates the part to be allocated to timber supply of expenditures made in the four broad categories administration, aviation and fire protection, resource access and forest management. These ratios were applied to historical data from ministry annual reports. Despite the broad categories, changes in reporting format result in a less than perfectly continuous series of estimates over time.

Table 5.3

Pulp, Paper and Allied Industries Production Surplus

Year	Costs: Operating	Costs: Capital	Costs: Total	Value of production	Surplus
	millions of current dollars				
1961	352.3	48.9	401.2	479.2	78.0
1962	365.7	49.7	415.4	509.8	94.4
1963	375.0	51.9	426.9	521.9	95.0
1964	398.5	58.2	456.7	555.9	99.2
1965	412.6	70.9	483.5	577.9	94.4
1966	457.8	82.9	540.7	631.7	91.0
1967	478.2	90.5	568.7	631.1	62.4
1968	505.4	91.7	597.1	648.7	51.6
1969	547.3	103.5	650.8	718.8	68.0
1970	583.5	109.4	692.9	736.2	43.3
1971	588.3	116.0	704.3	727.2	22.9
1972	627.6	124.1	751.7	780.3	28.6
1973	701.6	139.4	841.0	916.3	75.3
1974	906.1	186.5	1 092.6	1 383.6	291.0
1975	756.4	225.0	981.4	1 044.9	63.5
1976	1 026.6	251.3	1 277.9	1 251.8	-26.1
1977	1 305.2	280.7	1 585.9	1 612.2	26.3
1978	1 458.7	312.7	1 771.4	1 787.5	16.1
1979	1 723.7	378.3	2 102.0	2 260.3	158.3
1980	1 925.0	453.0	2 378.0	2 644.8	266.8
1981	2 155.5	628.4	2 783.9	2 890.4	106.5
1982	2 149.9	654.8	2 804.7	2 631.1	-173.6
1983	2 316.1	686.3	3 002.4	2 776.7	-225.7
1984	2 559.5	692.8	3 252.3	3 398.4	146.1
1985	2 619.9	671.0	3 290.9	3 388.4	97.5
1986	2 718.5	688.8	3 407.3	3 679.1	271.8
1987	2 934.7	722.7	3 657.4	4 288.6	631.2
1988	3 055.4	764.4	3 819.8	4 665.1	845.3
1989	3 185.6	853.1	4 038.7	4 672.1	633.4
1990	3 226.5	983.5	4 210.0	4 358.7	148.7
1991	2 926.6	912.3	3 838.9	3 441.1	-397.8

Sources:
Statistics Canada, National Accounts and Environment Division, Industry Division and Investment and Capital Stock Division.

Table 5.4

Government Timber Supply Expenditure

Year	Administration	Aviation and fire	Resource access	Forest management	Total
	millions of current dollars				
1961	1.5	2.6	-	6.0	10.1
1962	1.6	2.1	-	6.2	9.9
1963	2.1	2.2	-	7.4	11.7
1964	2.3	2.2	0.4	7.8	12.8
1965	2.5	2.2	0.4	8.2	13.3
1966	3.3	2.7	0.4	11.2	17.5
1967	3.4	3.1	0.8	12.8	20.1
1968	3.7	3.1	0.9	14.9	22.6
1969	3.6	3.3	0.6	13.6	21.1
1970	4.0	4.2	0.8	14.9	23.9
1971	3.9	4.2	0.7	19.3	28.1
1972	9.3	4.1	0.8	20.8	34.9
1973	10.1	3.6	3.3	29.8	46.8
1974	11.2	6.8	5.4	24.9	48.3
1975	13.5	6.7	5.7	31.0	56.9
1976	14.8	11.3	2.7	36.3	65.2
1977	15.7	8.8	2.6	43.2	70.4
1978	17.2	6.4	2.5	49.7	75.8
1979	18.6	8.5	2.9	56.8	86.8
1980	19.5	18.9	2.5	71.5	112.4
1981	26.5	17.1	2.3	80.4	126.3
1982	30.0	11.9	2.3	89.4	133.7
1983	32.6	16.2	2.3	112.6	163.7
1984	33.8	12.6	2.0	143.0	191.4
1985	33.7	13.2	2.1	157.3	206.3
1986	37.3	20.4	2.0	195.1	254.9
1987	40.8	22.6	2.1	192.1	257.6
1988	42.8	29.3	2.3	186.8	261.2
1989	44.5	21.9	2.3	197.4	266.2
1990	47.7	24.2	3.6	214.4	289.9
1991	33.9	33.8	3.6	214.4	285.6

Source:
Ontario Ministry of Natural Resources.

The timber supply expenditure estimates for the period 1961 to 1991 are presented in Table 5.4. While all categories increased over this period the forest management category has undergone the largest escalation, due in particular to regeneration efforts. Some of the expenditure in the early 1980s may be attributable to the treatment of a backlog of land left previously untreated. The cost of fire control is also variable and again, the variation is not closely related to current harvest volumes. No attempt is made to reassign costs by prorating reforestation or fire control expenditure based, for example, on the area harvested.

The category 'resource access' covers only the maintenance costs for logging roads; expenditure on their construction is included in the category of 'forest management'. Isolating the expenditure on permanent roads would be desirable, so that it could be treated as capital, that is, the cost could be amortized over the life of the asset rather than treated as an expenditure in the year it is purchased.

Aggregate surplus and resource rent

The value of the aggregate surplus for all industries is shown in Table 5.5. Negative values occur in 1982, 1983 and 1991. Subtracting the government's forest management expenditures gives negative rent in 1976, 1981 and 1990 as well. Rent should not be negative, since there would be no exploitation of a resource if the selling price did not cover the exploitation costs.

In part, the negative values are the result of the slightly myopic view imposed by an annual series. Averaged over a longer period of time, rent is positive. The effect of decreased prices and demand on rent can be exaggerated by the methodology used. Capital is depreciated annually, not according to the volume of production. The capital cost per unit increases if the amount produced decreases, that is, generally when demand and prices fall and the rent residual is already reduced. One of the effects of averaging is to amortize capital costs over a longer period, so that it applies to a more typical volume of production. Averaging can also

Table 5.5

Aggregate Industry Surplus and Rent

Year	Costs	Value of production	Surplus	Timber expenses	Rent Annual	Rent Deflated	Rent Averaged
	millions of dollars						
1961	587.3	693.7	106.4	10.1	96.3	398.1	455.8
1962	611.0	736.0	125.0	9.9	115.0	469.6	459.9
1963	634.7	764.7	130.0	11.7	118.2	472.9	457.4
1964	676.6	813.4	136.8	12.8	124.0	482.6	433.8
1965	723.3	862.9	139.6	13.3	126.2	476.4	410.7
1966	815.8	957.0	141.2	17.5	123.7	444.8	385.3
1967	868.3	973.1	104.8	20.1	84.7	292.1	338.5
1968	890.1	983.6	93.5	22.6	70.9	236.4	281.6
1969	973.1	1 085.8	112.7	21.1	91.6	291.8	233.9
1970	1 013.6	1 085.2	71.6	23.9	47.7	145.5	217.5
1971	1 023.4	1 080.1	56.7	28.1	28.7	84.6	281.8
1972	1 108.2	1 194.1	85.9	34.9	51.0	142.3	261.0
1973	1 267.7	1 443.2	175.5	46.8	128.6	329.9	208.0
1974	1 619.8	1 999.0	379.2	48.3	330.9	742.0	194.6
1975	1 517.9	1 619.3	101.4	56.9	44.5	90.8	197.0
1976	1 866.4	1 889.4	23.0	65.2	-42.2	-79.1	225.8
1977	2 292.6	2 392.1	99.5	70.4	29.1	51.4	227.4
1978	2 648.3	2 785.3	137.0	75.8	61.1	101.9	123.7
1979	3 170.0	3 483.6	313.6	86.8	226.8	343.6	61.6
1980	3 610.1	3 971.5	361.4	112.4	249.0	341.1	31.2
1981	4 127.5	4 267.0	139.5	126.3	13.1	16.2	35.7
1982	4 000.1	3 831.7	-168.4	133.7	-302.1	-343.7	31.6
1983	4 402.4	4 296.6	-105.8	163.7	-269.5	-292.0	20.3
1984	4 908.4	5 178.4	270.0	191.4	78.6	82.5	51.2
1985	4 996.3	5 274.0	277.7	206.3	71.4	73.1	162.9
1986	5 212.4	5 731.8	519.4	254.9	264.5	264.5	290.4
1987	5 449.3	6 290.5	841.2	257.6	583.6	557.4	333.4
1988	5 852.2	6 988.1	1 135.9	261.2	874.8	798.1	259.0
1989	6 170.9	7 068.1	897.2	266.2	631.0	549.2	290.0
1990	6 193.2	6 493.7	300.5	289.9	10.6	9.0	295.1
1991	5 619.8	5 371.0	-248.8	285.6	-534.4	-438.4	229.5

Sources:
Statistics Canada, National Accounts and Environment Division, Industry Division, Investment and Capital Stock Division and Ontario Ministry of Natural Resources.

help smooth some of the annual variation in other expenditures, such as fire control.

The rent series was averaged using a seven-year centred moving average after being converted to constant 1986 dollars using the GDP implicit price index. The seven year period is based on a study of residual timber value completed for the OMNR which estimated business cycle lengths of six or ten years for different forest industries (OMNR, 1993a). The averaged series is always positive, although the value is very low in the early eighties.

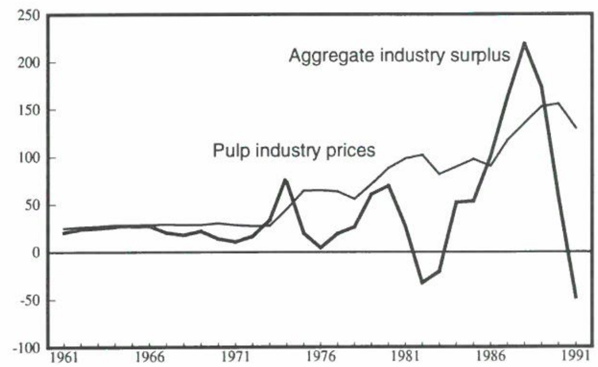
By 1991, in nominal value, current expenditure increased about nine times over its 1961 value, capital expenditure about ten times and government expenditure on timber supply almost twenty-five times. At the start of the series, timber supply expenditure was equivalent to about 2 percent of the forest products industries' total expenditure. It reached 5 percent by 1991.

Stock values

Table 5.6 presents a number of estimates of the value of the resource stock. Estimates are made in both constant 1986 dollars and in current dollars.

Figure 5.1

Indexes of Industry Surplus and Pulp Prices (1986 =100)



Sources:
Statistics Canada, National Accounts and Environment Division and Prices Division.

Two methods are used to calculate present value series of timber stock values in constant 1986 dollars. The columns labelled 'projected rent' are calculated by dividing the current average resource rent by the discount rate, based on the assumption that the current rent will be obtained for an indefinite number of years. The picture of the asset that this presents is its value based on the accessible timber and harvest and production technology of the era. Future harvest volumes, costs and prices do not change. Current experience is projected forward into a future limited by the value of the discount rate.

For comparison, the column labelled 'actual rent' is the sum of the discounted series of calculated future rents shown in the first column, labelled 'averaged deflated rent'. For example, the value calculated for 1961 under 'actual rent' is the sum of the values shown under 'averaged deflated rent' for 1962 onward, discounted to a 1961 value (the last year's averaged deflated rent is used to extend the series into the future to a time where its discounted value is insignificant).

The values for the two different methods converge as the series summation becomes more dependent on the extended value of the last year's rent. The change from actual to projected rent is inconsistent, so that the series cannot be used as the estimate of the value of the asset. However, using actual rent gives a 'perfect knowledge of the future' version of the value estimate, for at least part of the series, which can be compared to the estimate made by projecting current rent. The perfect knowledge series seems to indicate that the exceptionally gloomy outlook of the early

Table 5.6
Estimates of Timber Stock Value

	Averaged	NPV			Net price				NPV		Net price
	deflated	Projected rent		Actual rent	Harvest	Unit	Inventory	Inventory	Projected rent		Inventory
Year	rent	2 percent	4 percent	4 percent	volume	price	volume	value	2 percent	4 percent	value
	millions of 1986 dollars or millions of cubic metres								millions of current dollars		
1961	455.8	22 790	11 395	6 469	11.0	41.25	1 322	54 534	5 671	2 835	13 569
1962	459.9	22 996	11 498	6 272	11.2	41.11	1 301	53 485	5 799	2 899	13 487
1963	457.4	22 870	11 435	6 063	11.7	39.10	1 306	51 066	5 863	2 931	13 091
1964	433.8	21 689	10 845	5 848	12.3	35.41	1 310	46 386	5 630	2 815	12 041
1965	410.7	20 534	10 267	5 648	12.7	32.38	1 313	42 513	5 449	2 724	11 281
1966	385.3	19 264	9 632	5 463	13.3	29.05	1 316	38 235	5 281	2 641	10 482
1967	338.5	16 925	8 463	5 296	14.1	23.96	1 318	31 581	4 778	2 389	8 915
1968	281.6	14 082	7 041	5 170	13.4	21.02	1 319	27 722	4 097	2 048	8 065
1969	233.9	11 696	5 848	5 095	13.1	17.91	1 322	23 682	3 559	1 779	7 206
1970	217.5	10 875	5 438	5 065	13.3	16.37	1 321	21 621	3 595	1 797	7 146
1971	281.8	14 089	7 044	5 050	14.8	19.09	1 318	25 162	5 353	2 677	9 561
1972	261.0	13 049	6 524	4 970	14.4	18.18	1 322	24 036	5 164	2 582	9 513
1973	208.0	10 400	5 200	4 908	16.2	12.86	1 327	17 070	4 209	2 104	6 908
1974	194.6	9 728	4 864	4 896	18.1	10.75	1 332	14 323	4 076	2 038	6 001
1975	197.0	9 851	4 926	4 898	18.4	10.72	1 327	14 221	4 308	2 154	6 219
1976	225.8	11 289	5 644	4 897	12.3	18.38	1 337	24 577	5 564	2 782	12 113
1977	227.4	11 369	5 685	4 867	16.8	13.51	1 336	18 050	6 424	3 212	10 198
1978	123.7	6 185	3 093	4 834	19.7	6.27	1 337	8 377	4 154	2 077	5 625
1979	61.6	3 082	1 541	4 904	17.1	3.61	1 342	4 847	1 678	839	2 639
1980	31.2	1 561	781	5 038	19.1	1.64	1 342	2 200	54	27	76
1981	35.7	1 784	892	5 208	18.6	1.92	1 325	2 541	407	204	580
1982	31.6	1 578	789	5 381	19.2	1.64	1 329	2 185	481	240	666
1983	20.3	1 013	506	5 565	16.3	1.24	1 337	1 659	750	375	1 229
1984	51.2	2 558	1 279	5 767	20.4	2.51	1 312	3 291	3 140	1 570	4 040
1985	162.9	8 143	4 071	5 947	23.1	7.05	1 312	9 243	9 294	4 647	10 551
1986	290.4	14 520	7 260	6 022	22.2	13.06	1 308	17 077	15 960	7 980	18 769
1987	333.4	16 670	8 335	5 972	22.8	14.64	1 305	19 109	17 961	8 980	20 588
1988	259.0	12 949	6 475	5 877	22.5	11.49	1 302	14 959	13 582	6 791	15 690
1989	290.0	14 499	7 249	5 854	22.5	12.86	1 297	16 684	15 251	7 626	17 550
1990	295.1	14 753	7 376	5 798	23.1	12.80	1 281	16 397	15 656	7 828	17 401
1991	229.5	11 474	5 737	5 735	19.9	11.55	1 281	14 792	12 275	6 137	15 825

Source:
Statistics Canada, National Accounts and Environment Division.

1980s that results from the projection of current experience was unwarranted. But then, not all of the actual values are in yet.

The importance of the discount rate is evident in the difference in value obtained by using rates of 2 and 4 percent. Doubling the rate halves the present value.

Table 5.6 also presents the timber stock values estimated using a net price or per-unit rent. Rent per unit of volume is calculated by dividing the averaged annual rent by the annual harvest volume. This rent per unit is applied to the volume of mature timber in the forest inventory estimate for that year. The estimate of volume is obtained from the physical forest account described in chapter four.

As mentioned earlier, the net price method is not expected to give an approximation of market price because it equates present and future value and because it ignores the young part of the forest. The values it gives are nonetheless interesting, since they tell a similar story in a more dramatic way with a larger decline in value from the beginning to the end.

The change in value of the asset (the constant 1986 dollar series drops to one quarter of its starting value by the end of the series) is due entirely to a change in the rent per unit; the volume of mature timber is fairly constant. While the per-unit rent in 1991 is only one quarter of the 1961 rent, the harvest volume has doubled. As a result, the total rent actually generated in 1991 is about one half of that generated in 1961. The present value series based on projected rent end at about half of their 1961 starting values, since they are based on total rent.

Some factors which contribute to the decline in per-unit rent are competition from low-cost sources of pulp fiber and the increasing use of less valuable species as new products or technologies allow their use. The increase in government timber supply expenditure is a significant part of the rent residual. Part of the increase in the harvest volume is a reflection of the increased use of formerly unused species.

The three right-hand columns of Table 5.6 show the current dollar values of the timber stock that would actually appear on the balance sheet.

Conclusion

For use in balance sheet accounts, a present value method is preferable to a net price approach. The present value is an approximation of market value and provides a better measure of timber as an income producing asset.

If we consider other accounts, such as the other changes in volume of assets, the argument for using present value is perhaps even stronger. Change in volume or stock-flow reconciliation accounts measure the change in the value of an asset. For timber, an attempt would be made to value growth and loss due to harvest or fire independently. These changes and a revaluation of the remaining stock account for the change in the value of the stock from one year to another. While the two methods would give a similar value for timber harvested, there could be a large difference for the value of growth or of timber lost to fire. The volume increase of a tree nearing harvest age has a higher present value than an equivalent increase in younger trees. The age and location of trees lost to fire is significant. If the trees are very young, there may be no effect on the value of future harvests at all. While this argues for a present value approach, it is evident that detailed knowledge of the physical inventory of the forest is necessary to be able to estimate values of loss and growth. To some extent, this data problem is solved by forest management practice. Fire loss or insect damage, for example, are risks taken into consideration when calculating allowable cut. In this case, only an unusual fire would have any effect on harvest levels; that is the annual allowable cut would be changed.

The time series of timber asset values based on projected current rent cannot assess sustainability in the sense of providing information about the future. The future is assumed to be like the present. Comparing the value of growth with harvest and other loss is a frequently suggested indicator of sustainability. The quality of such an indicator is questionable unless, as we said above, the value of loss is based on detailed physical data. The mature volume of the forest is perhaps a better rough indicator of sustainability than a monetary indicator would be.

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6 Quantity and Value of Canada's Coal Reserves

by Alice Born, Marcia Santiago and Véronique Dumas

Introduction

The value of Canada's national wealth is measured in the National Balance Sheet Accounts. Wealth, as it is currently measured on the balance sheet, is the value of the economy's tangible assets such as buildings, residential and agricultural land and machinery and equipment.

However, our wealth is currently being understated since the available wealth statistics do not include the value of our natural assets such as mineral reserves, timber stocks, fish stocks, parkland, etc. These natural assets are being treated as "free gifts" of nature in the current System of National Accounts (SNA) since no entries are included in the asset accounts or production accounts. By excluding the value of natural resources in the SNA, there is no way of measuring how rapidly we are depleting our natural resource stocks or more generally, whether we are maintaining our *total* capital base, both produced and natural.

The new international SNA standard approved in 1993 recommends that the national balance sheet be expanded to include natural resources. Statistics Canada proposes to include the dollar value of Canada's natural resources in the National Balance Sheet Accounts by 1997. Towards that end, estimates of Canada's natural resources are being developed. This chapter provides preliminary estimates of Canada's coal reserves in physical and monetary terms.

Other accounts have been completed for Canada's oil and natural gas reserves and timber stock in Ontario (Born, 1992; Smith, 1995; Moll and Lawrance, 1995; and Gravel *et al.*, 1995). Work is in progress on accounts for metals and other minerals.

Coal in the Canadian economy

Coal is an important mineral to the Canadian economy. It is a fuel that is used in the production of electricity and it will be running many of Canada's power stations into the next century. Today, about 15 percent of Canada's electricity is generated from coal. Coal is also used in the production of steel, tars and chemicals, and in industrial processes such as cement and glass-making.

Canada's coal production and exports have increased steadily in the 1970s and 1980s. In 1991, Canada was the world's fourth largest exporter of coal and twelfth largest producer (Natural Resources Canada, 1994).

While coal is the only fossil fuel available in quantities that for practical purposes are inexhaustible, only one percent of the world's coal reserves are located in Canada. Yet, assuming constant extraction rates at current levels, there remain roughly 100 years of coal production from economically recoverable reserves in Canada. Table 6.1 compares coal reserves of Canada and United States. In 1993, the United States' coal stocks were about 30 times greater than Canada's, representing almost 25 percent of the world's total coal reserves.

Table 6.1
Coal Reserves in Canada and the United States, 1985-1993

Year	Canada			United States		
	Bituminous	Subbituminous and lignite	Total	Bituminous	Subbituminous and lignite	Total
	millions of tonnes					
1985	1 600	4 300	5 900	125 000	132 000	257 000
1986	3 548	3 298	6 846	131 971	131 872	263 843
1987	3 471	3 107	6 578	131 971	131 872	263 843
1988	3 433	3 075	6 508	130 787	131 359	262 146
1989	3 753	3 071	6 824	130 194	131 059	261 253
1990	3 716	3 044	6 760	129 543	130 752	260 295
1991	4 509	4 114	8 623	112 668	127 892	240 560
1992	4 509	4 114	8 623	112 668	127 892	240 560
1993	4 509	4 114	8 623	112 668	127 892	240 560

Source:
British Petroleum, various issues.

Physical accounts

In assessing Canada's endowment of coal, many aspects must be considered before the quantity of coal available for present as well as future generations can be determined. Estimates of the volume of coal present in the ground are obtained from exploration drilling, and from geological and seismological knowledge of the coal-bearing formations. Assumptions about prices, costs and technology determine whether resources can be considered as recoverable reserves and extracted profitably. The quantity of coal is determined from general criteria and more specifically, the classification of coal resources and coal reserves is based on three sets of criteria: resource feasibility, assurance of existence and technology, as shown in Figure 6.1. To qualify as a resource, coal must have potential for endowing wealth to the nation. Classifying coal from resources to reserves is a dynamic process that occurs on the basis of changing supply and demand (Smith, 1989).

The *feasibility class* distinguishes between resources of **immediate** and **future interest** (Figure 6.1). **Resources of immediate interest** are contained in coal seams that, because of favourable combination of thickness, depth, quality and location, are considered to be of immediate interest for possible exploitation. On the other hand, **resources of future interest** are contained in seams that, because of less favourable combination of thickness, depth, quality and location, may become exploitable in the foreseeable future with changes in economic factors and/or production technologies (Hughes *et al.*, 1989). Coal reserves are a subset of resources of immediate interest and are further sub-divided into those reserves in active or inactive mines.

The level of certainty with which resource quantities are known is the *assurance class* (Figure 6.1). Four categories are used to define the assurance class: **measured, indicated, inferred** and **speculative**. Measured and indicated resources have a high degree of geological certainty of existence whereas inferred resources have a relatively low degree of assurance. Speculative resources are based on few data points where coal exploration has been limited and are always classified as resources of future interest.

Although precise levels of uncertainty of these categories have not been calculated, experience with Canadian coal deposits suggests that measured resource quantities are normally known within 10 percent, indicated within 20 percent and inferred within 50 percent of estimates. Coal reserves form a portion of measured and indicated resources of immediate interest.

Coal quantities that are anticipated to be mineable based on feasibility studies, existing technology and current economic conditions are classified as **in-place** and **recoverable** resources in the *technology class*. In-place coal is that portion of coal in mineable seams with no recovery factors applied. Recoverable reserves refers to that portion of the coal in mineable seams that can be recovered with current technology and at current market prices (Hughes *et al.*, 1989).

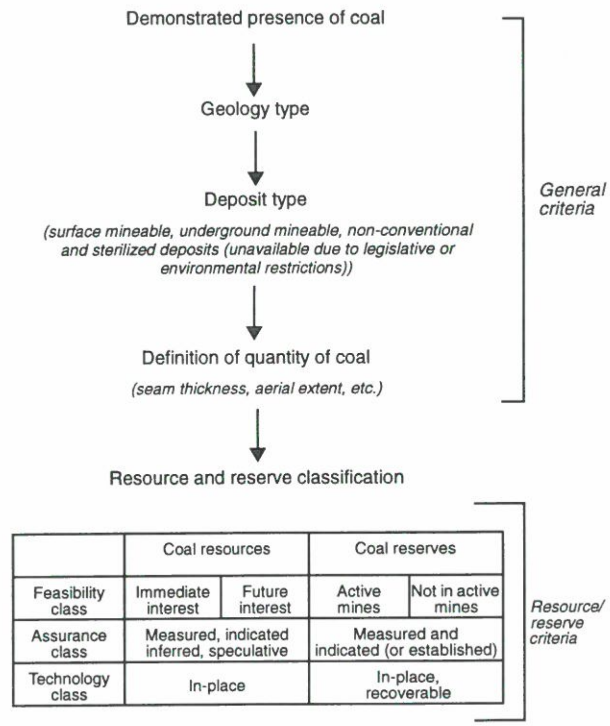
Portions of measured and indicated resources of immediate interest that are the most likely to be developed commercially are called **reserves**. Only those reserves that are recoverable in active mines are valued in the monetary accounts presented below since they have a high probability of being extracted in the foreseeable future.[1] Figure 6.2 shows the relationship between the total coal resource and recoverable reserves in active mines.

Quality

The quality of coal is another aspect to consider when developing physical resource accounts. The quality of Cana-

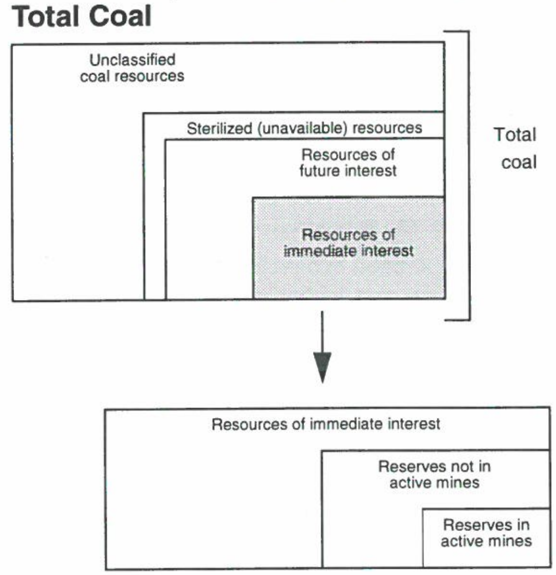
1. In Alberta, the reserve terminology differs. Coal reserves are called in-mine established reserves and are approximately the same as recoverable reserves in active mines. A detailed description of Alberta's terminology is presented in the following section "Provincial data".

Figure 6.1
Coal Resource and Reserve Classification



Source:
Hughes, J.D. *et al.*, 1989.

Figure 6.2
Relationship of Resources and Reserves to Total Coal



Source:
Hughes, J.D. *et al.*, 1989.

dian coal ranges from lower quality coal called lignite and subbituminous coal to higher quality bituminous and anthracitic coal. Table 6.2 shows the different types of coal and their uses. Although all classes of coal are present in Canada, anthracite is not being currently exploited.

As the quality of the coal increases, so does its energy content. Lignite and subbituminous coal are not economic to transport because of their low energy values and corresponding lower prices. These types of coal are used for thermal power generation close to the minesite. Lignite has half the heating value of bituminous coal which means that 5 billion tonnes of bituminous coal from Nova Scotia, for example, would have the heating value equivalent to 10 billion tonnes of lignite from Saskatchewan. Furthermore, lignite commands a much lower price than bituminous coal and to follow the above example, its extraction and transport methods must be low cost for a deposit to be considered economically recoverable.[1]

Table 6.2

Coal Quality and Use in Canada

Coal class	Potential use	Location	Percentage of total Canadian production in 1992
Anthracite	Thermal coal, source of carbon for chemical production.	Nova Scotia	No production in Canada
Bituminous coal	Metallurgical and thermal coal	British Columbia	26 percent
		Alberta	16 percent
		Nova Scotia	7 percent
		New Brunswick	1 percent
Subbituminous coal	Thermal coal	Alberta	35 percent
Lignite	Minesite thermal coal	Saskatchewan	15 percent

About 70 percent of bituminous coal mined in Canada is used as metallurgical coal. Metallurgical coal is used in the production of coke which is a reducing agent and heat source for the steel industry. The remaining 30 percent of bituminous coal is used as thermal coal to generate electricity mainly in Nova Scotia and New Brunswick.

Another important characteristic of coal is its sulphur content. Increasing concerns over sulphur dioxide (SO_2) emissions and acid rain have placed a premium value on western Canadian coal reserves which have less than one percent sulphur content. Atlantic coals generally contain about four percent sulphur.

To depict more accurately Canada's reserves, the physical accounts of coal reserves are presented by type of coal. Included in the bituminous class are all the sub-classes of high, medium and low volatile bituminous coal, while subbituminous coal and lignite are reported separately.

Provincial data

Energy, Mines and Resources (EMR, now known as Natural Resources Canada) evaluated coal reserves in 1976, 1977, 1982 and 1985. Table 6.3 presents a sample of the data from 1985 by province for recoverable reserves and coal resources of immediate interest.

With the exception of Alberta[2], provincial physical accounts are based on the recoverable reserve data published by EMR. Reassessments of the reserve stock were not available every year for each province, so estimates for missing years were calculated by reducing the previous years' stocks by recorded depletion. In order to obtain a more accurate estimate, one would have to take into account any evaluations of mining properties. The EMR estimates were chosen as the benchmarks since they form a consistent and complete data set.

Table 6.3

Remaining Recoverable Reserves and Resources of Coal in Canada, 1985

Province	Class of coal	Coal resources of immediate interest	Remaining recoverable reserves
		millions of tonnes	
British Columbia	Lignite	1 090	566
	Bituminous - thermal	1 610	433
	Bituminous - metallurgical	17 105	1 563
Alberta	Subbituminous coal	33 475	871
	Bituminous - thermal	815	800
	Bituminous - metallurgical	12 645	240
Saskatchewan	Lignite	7 595	1 670
New Brunswick	Bituminous - thermal	75	21
Nova Scotia	Bituminous - thermal	1405	300
	Bituminous - metallurgical	..	115
Yukon and N.W.T.	Lignite and subbituminous	2 290	..
	Bituminous - thermal	90	..
	Bituminous - metallurgical	500	..
Canada	Lignite	44 630	2 236
	Subbituminous		871
	Bituminous - thermal	2 515	1 553
	Bituminous - metallurgical	31 730	1 918
	Total	**78 875**	**6 578**
Canada	Metallurgical	31 730	4 660
	Thermal	47 145	1 918

Source:
National Energy Board, 1991.

1. In 1992, the average value of lignite was $10/tonne in Saskatchewan compared with $60/tonne for bituminous coal in Nova Scotia.

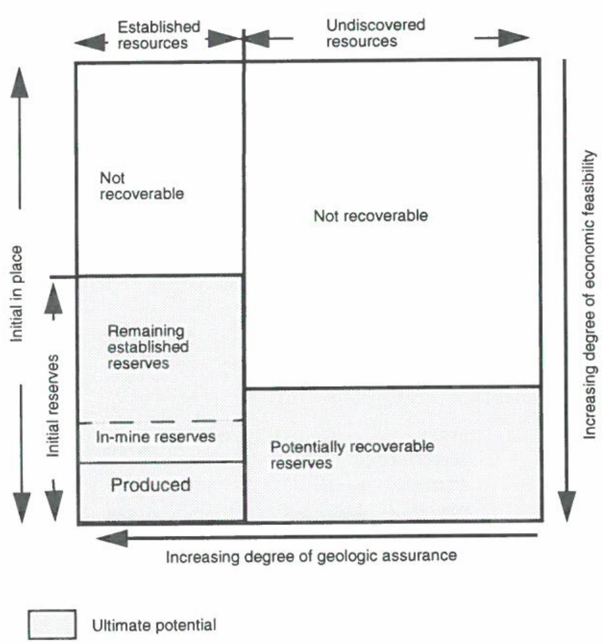
2. Data for Alberta are taken from the Alberta Energy Resources Conservation Board.

Gross mine output from Statistics Canada, published in ***Coal Mines***, Cat. No. 26-206, was used for the quantity of depletion in the physical accounts. The reserve addition column corrects for any discrepancies between opening and closing stocks that are not consistent with the simple depletion by production. Often adjustments of reserve additions can be related to opening or closing of certain coal mines or a re-evaluation of the resource/reserve base.

Alberta

Alberta has the largest share of coal reserves in Canada. The reserves are also the best documented and measured. They represent about 60 percent of Canada's total resource of immediate interest. The Alberta Energy Resources Conservation Board (ERCB) uses the term **established reserves** that is the same definition applied to oil and natural gas reserves. The quantities reported in this chapter are **remaining established reserves** defined as the reserves considered recoverable under current technology and present or anticipated future economic conditions. ERCB's terminology is applied to the McKelvey box to illustrate the relationship between the various classifications of coal resources and reserves specific to Alberta (Figure 6.3).

Figure 6.3
Alberta's Coal Resource Terminology



Source:
Alberta Energy Resources Conservation Board, 1988.

The ERCB reports remaining established reserves and distinguishes between reserves that are within mine boundary and those that are not (Figure 6.2). **In-mine reserves** represent about 8 percent of total recoverable reserves in Alberta (based on 1991 data). For the physical and monetary accounts, only in-mine established reserves are considered and this is consistent with the reserve definition used for the other provinces. Despite differences in reporting resources, EMR and ERCB do have comparable methods of calculating reserves. When comparing provincial reserve data with those of other provinces, EMR has used the in-mine established reserves calculated by ERCB for the Province of Alberta.

Alberta produces both bituminous and subbituminous coal. Physical accounts including additions and depletion were put together by combining reserves data and raw coal production from the ERCB for bituminous and subbituminous coal. The closing stock of bituminous reserves has almost tripled since 1976 (Table 6.4) and subbituminous coal reserves have increased 1.5 times since 1976 (Table 6.5). Assuming current extraction rates, the reserve life of bituminous coal is 95 years and for subbituminous coal 50 years from currently established reserves.

Alberta's coal of ultimate potential

Ultimate potential is an estimate of the initial reserves which will have become developed by the time all exploration and development of reserves has ceased. Geological prospects of the area and anticipated technological, economic and social conditions are considered when deriving the estimate. The ultimate potential includes cumulative production, remaining established reserves and presumed future reserve additions.

Although there is a large degree of uncertainty associated with estimating ultimate potential, the estimate provides a forecast of coal reserves that could be developed in the future. Table 6.6 shows the magnitude of coal reserves that could be extracted in the future.

Table 6.6
Established Reserves and Ultimate Potential in Alberta, 1991

	Remaining established reserves	Ultimate potential
	billions of tonnes	
Bituminous coal	1.4	183.6
Subbituminous coal	1.2	539.1

Source:
Alberta Energy Resources Conservation Board, 1992.

British Columbia

Unlike Alberta, British Columbia does not evaluate its reserves of coal every year. Data from EMR's reports were used to develop the physical accounts for British Columbia's reserves of bituminous coal (Table 6.4). Reserve data for the province include the quantities present in the produc-

Table 6.4

Canada's Recoverable Reserves of Bituminous Coal, 1976-1992

Year	Nova Scotia				New Brunswick				Alberta			
	Opening stock	Additions	Depletion	Closing stock	Opening stock	Additions	Depletion	Closing stock	Opening stock	Additions	Depletion	Closing stock
	thousands of tonnes											
1976	93 205	-	2 205	91 000	34 327	-	327	34 000	542 824	-	6 752	536 072
1977	91 000	387	2 387	89 000	34 000	-694	306	33 000	536 072	-	6 072	530 000
1978	89 000	-	2 921	86 079	33 000	-	348	32 652	530 000	-	7 308	522 692
1979	86 079	-	2 157	83 922	32 652	-	310	32 342	522 692	-44 929	7 763	470 000
1980	83 922	-	2 726	81 196	32 342	-	439	31 903	470 000	49 552	9 552	510 000
1981	81 196	-	2 539	78 657	31 903	-	524	31 379	510 000	-1 320	9 680	499 000
1982	78 657	369 394	3 051	445 000	31 379	-12 880	499	18 000	499 000	36 985	9 985	526 000
1983	445 000	-	2 986	442 014	18 000	-	565	17 435	526 000	330 174	10 174	846 000
1984	442 014	-	3 093	438 921	17 435	-	564	16 871	846 000	204 774	10 774	1 040 000
1985	438 921	-20 680	3 241	415 000	16 871	4 473	544	20 800	1 040 000	10 794	10 794	1 040 000
1986	415 000	-	3 275	411 725	20 800	-	480	20 320	1 040 000	380 136	10 136	1 410 000
1987	411 725	-	3 672	408 053	20 320	-	517	19 803	1 410 000	-49 722	10 278	1 350 000
1988	408 053	-	4 586	403 467	19 803	-	521	19 282	1 350 000	13 380	13 380	1 350 000
1989	403 467	-	3 147	400 320	19 282	-	495	18 787	1 350 000	4 019	14 019	1 340 000
1990	400 320	-	4 283	396 037	18 787	-	533	18 254	1 340 000	139 496	13 496	1 466 000
1991	396 037	-	4 894	391 143	18 254	-	497	17 757	1 466 000	-9 989	14 011	1 442 000
1992	391 143	-	4 502	386 641	17 757	-	354	17 403	1 442 000	-	15 069	1 426 931

Year	British Columbia				Canada			
	Opening stock	Additions	Depletion	Closing stock	Opening stock	Additions	Depletion	Closing stock
	thousands of tonnes							
1976	972 741	-	8 278	964 463	1 643 097	-	17 562	1 625 535
1977	964 463	-	9 463	955 000	1 625 535	-307	18 228	1 607 000
1978	955 000	-	9 988	945 012	1 607 000	-	20 565	1 586 435
1979	945 012	-	10 616	934 396	1 586 435	-44 929	20 846	1 520 660
1980	934 396	-	10 156	924 240	1 520 660	49 552	22 873	1 547 339
1981	924 240	-	11 781	912 459	1 547 339	-1 320	24 524	1 521 495
1982	912 459	1 197 309	11 768	2 098 000	1 521 495	1 590 808	25 303	3 087 000
1983	2 098 000	-	11 687	2 086 313	3 087 000	330 174	25 412	3 391 762
1984	2 086 313	-	20 775	2 065 538	3 391 762	204 774	35 206	3 561 330
1985	2 065 538	-34 033	35 505	1 996 000	3 561 330	-39 446	50 084	3 471 800
1986	1 996 000	-	32 360	1 963 640	3 471 800	380 136	46 251	3 805 685
1987	1 963 640	-	34 407	1 929 233	3 805 685	-49 722	48 874	3 707 089
1988	1 929 233	-	38 508	1 890 725	3 707 089	13 380	56 995	3 663 474
1989	1 890 725	-	38 152	1 852 573	3 663 474	4 019	55 813	3 611 680
1990	1 852 573	-	40 003	1 812 570	3 611 680	139 496	58 315	3 692 861
1991	1 812 570	-	39 596	1 772 974	3 692 861	-9 989	58 998	3 623 874
1992	1 772 974	-	25 987	1 746 987	3 623 874	-	45 912	3 577 962

Sources:
Energy, Mines and Resources Canada, 1976.
CANMET, 1984.
Energy, Mines and Resources Canada, 1987.
Alberta Energy Resources Conservation Board, various issues.
Statistics Canada, 1992.

ing coalfields. The large increase in reserves in 1982/1983 is attributable to the opening of 4 surface mines in the province. Since 1976, reserves of bituminous coal have increased over 80 percent while physical depletion has more than tripled.

Reserves of lignite are also located in British Columbia, however they are not being exploited. From 1976 to 1981, the quantity of recoverable reserves totalled 397 tonnes. This increased to 566 tonnes at the end of 1982 and has remained at this level to present day.

Saskatchewan

The only source of consistent data on reserves is EMR reports. The only type of coal being exploited is lignite which is located in the southern part of the province. The low quality of the coal requires extraction by surface mining methods to minimize the extraction cost. Reserves are therefore limited to that portion of the coal that lies within 45 metres of the surface and in seams exceeding 1.5 metres in thickness.

Once more the physical accounts are simply the opening stocks of reserves reduced by annual production as reported by Statistics Canada as gross mine output (Table 6.5).

Table 6.5
Canada's Recoverable Reserves of Subbituminous Coal and Lignite, 1976-1992

	Saskatchewan				Alberta				Canada			
Year	Opening stock	Gross additions	Depletion	Closing stocks	Opening stocks	Gross additions	Depletion	Closing stocks	Opening stocks	Gross additions	Depletion	Closing stocks
	thousands of tonnes											
1976	1 896 000	5 156	5 156	1 896 000	790 000	6 419	6 419	790 000	2 686 000	11 575	11 575	2 686 000
1977	1 896 000	-169 961	6 039	1 720 000	790 000	7 847	7 847	790 000	2 686 000	-162 114	13 886	2 510 000
1978	1 720 000	-	5 575	1 714 425	790 000	8 279	8 279	790 000	2 510 000	8 279	13 854	2 504 425
1979	1 714 425	-	5 013	1 709 412	790 000	9 580	9 580	790 000	2 504 425	9 580	14 593	2 499 412
1980	1 709 412	-	5 971	1 703 441	790 000	160 500	10 500	940 000	2 499 412	160 500	16 471	2 643 441
1981	1 703 441	-	6 798	1 696 643	940 000	11 500	11 500	940 000	2 643 441	11 500	18 298	2 636 643
1982	1 696 643	7 851	7 494	1 697 000	940 000	-7 000	13 000	920 000	2 636 643	851	20 494	2 617 000
1983	1 697 000	-	7 760	1 689 240	920 000	-5 500	14 500	900 000	2 617 000	-5 500	22 260	2 589 240
1984	1 689 240	-	9 917	1 679 323	900 000	-4 600	15 400	880 000	2 589 240	-4 600	25 317	2 559 323
1985	1 679 323	349	9 672	1 670 000	880 000	6 800	16 800	870 000	2 559 323	7 149	26 472	2 540 000
1986	1 670 000	-	8 280	1 661 720	870 000	7 500	17 500	860 000	2 540 000	7 500	25 780	2 521 720
1987	1 661 720	-	10 020	1 651 700	860 000	358 500	18 500	1 200 000	2 521 720	358 500	28 520	2 851 700
1988	1 651 700	-	12 148	1 639 552	1 200 000	20 000	20 000	1 200 000	2 851 700	20 000	32 148	2 839 552
1989	1 639 552	-	10 816	1 628 736	1 200 000	900	20 900	1 180 000	2 839 552	900	31 716	2 808 736
1990	1 628 736	-	9 407	1 619 329	1 180 000	41 700	21 700	1 200 000	2 808 736	41 700	31 107	2 819 329
1991	1 619 329	-	8 981	1 610 348	1 200 000	22 300	22 300	1 200 000	2 819 329	22 300	31 281	2 810 348
1992	1 610 348	-	10 027	1 600 321	1 200 000	23 020	23 020	1 200 000	2 810 348	23 020	33 047	2 800 321

Note:
Reserve data before 1979 are estimated.
Sources:
Energy, Mines and Resources Canada, 1976.
CANMET, 1984.
Energy, Mines and Resources Canada, 1987.
Alberta Energy Resources Conservation Board, various issues.
Statistics Canada, 1992.

Reserves of lignite have declined from 1 896 million tonnes in 1976 to 1 600 million tonnes in 1992 with annual depletion almost doubling over that period. At current extraction rates, there is sufficient coal for 160 years of exploitation.

Nova Scotia

The Sydney coalfield contains more than 98 percent of the reserves of bituminous coal. Coal reserves have declined since 1982 from 445 million tonnes to 387 million tonnes in 1992. There remain an estimated 85 years worth of coal production in Nova Scotia.

New Brunswick

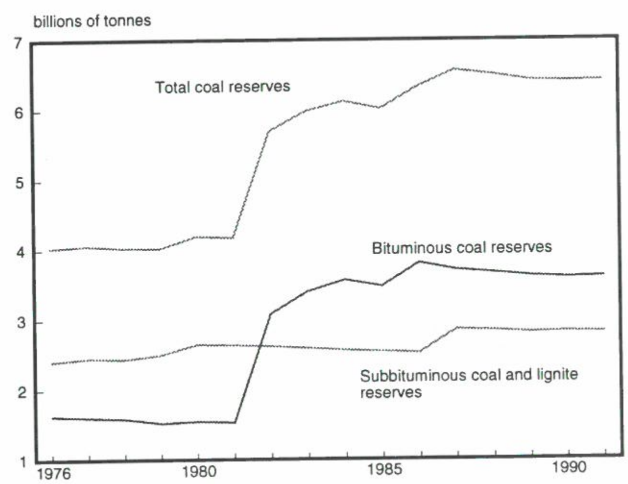
New Brunswick can claim to have the oldest site of coal mining in North America. Exploitation of coal outcrops started as early as 1639 although no major coalfield has ever been discovered in the province's numerous seams. Coalfields are steadily being depleted as extraction is not being replaced by additions to reserves.

All of the high sulphur (6-8 percent) bituminous coal being mined is used as thermal coal for the province's power plants.

Canada

Reserves of bituminous coal have more than doubled since 1976 and have remained at the same level since 1985 (Figure 6.4). The level of reserves of lignite and subbituminous coal have been relatively constant since 1976 ranging from 2.6 billion tonnes to 2.9 billion tonnes. Total coal reserves in Canada reflect the same trend for bituminous coal with marked increases in coal reserves in British Columbia and Nova Scotia at the end of 1982. Generally, the stock of coal reserves as defined here is being maintained in Canada at about 6.4 billion tonnes remaining.

Figure 6.4
Remaining Recoverable Coal Reserves of Canada, 1976-1991



Remaining recoverable reserves as reported in the physical accounts above are only a small portion of the total reserve and resource base of coal. Remaining recoverable reserves of total coal represent only 8 percent of coal resources of immediate interest (Table 6.3).

Monetary accounts

Monetary valuation of natural capital is at the heart of integrated economic and environmental accounting (Bartelmus, 1994). Without such valuation, comparison of different economic and environmental activities is often exceedingly difficult. Valuation means assigning prices to what are now treated as "free goods" in the conventional national accounts.

Reserves of depletable natural resource assets "in the ground" such as coal generally do not have a market price since they are rarely bought and sold. In Canada, these assets are typically owned by government. Therefore, several methods of valuation are used to estimate or impute the market value of the reserves. Text Box 6.1 presents the algebraic description of the three methods used to value coal reserves: net price method I, net price method II and present value. A more formal description of the methodology is presented in Born (1992 and 1995).

Net price

The net price method is based on the Hotelling model which assumes that in a perfectly competitive market, the price of the marginal unit of a non-renewable resource net of extraction costs should rise over time at a rate equal to the nominal rate of interest. In other words, the price of the resource should increase at the rate of interest and there is no need for discounting. If this assumption is true, the value of the stock of the resource is equal to the net price per unit of the resource times the quantity of reserve stock.

All three methods are in fact based on the net price method. The first two variations of the net price method are presented in this paper to show the range in values of the coal stock using different assumptions about the treatment of the return to capital used to find and extract the reserves. Also, the net price is presented in order to do international comparisons of natural asset accounts. However, the net price can also be rationalized as zero time preference or a present value using a zero discount rate.

Net price method I

The first method, net price method I, imputes the value of the rent or the return to the natural capital by netting out the extraction costs and the return to invested produced capital of the coal mining industry. The return to capital is calculated as a "normal" rate of return on produced capital (using an average yield on industrial bonds) times the net capital stock of the coal industry plus the depreciation of the capital stock. A per unit rent is calculated by dividing the net rent by the quantity extracted. The resource rent per unit is then multiplied by the quantity of the remaining recoverable reserves that have been estimated in the physical accounts of coal.

In theory the net price should be net of all costs including capital costs so that it can accurately represent the value added associated with the natural resource. However, there is some uncertainty regarding the estimation of the return to the invested produced capital in the calculation of the net price, particularly when the net operating surplus is already small (United Nations, 1993). In the case of coal, in some instances, the net price becomes negative after the deduction of the return to the produced capital. This result suggests that (world market) price of the coal is so low that a

Text Box 6.1

Alternative Methods of Valuing Coal Reserves

Net price method I (based on return to capital):

$$GR = TR - C$$
$$RR = GR - (rK + \delta)$$
$$V = (RR/Q)\,S$$

Net price method II (based on the value of capital stock):

$$V = (GR/Q)S - K$$

Present value method:

$$\phi = \sum_{t=1}^{T} \frac{1/T}{(1+r)^t}$$

$$PV = \phi\,[(GR/Q)S - K]$$

TR = *total revenue from extraction*
C = *extraction costs including fuel and electricity, material and supplies and wages*
GR = *gross rent*
RR = *resource rent*
r = *long-term industrial or provincial bond rate*
K = *net capital stock valued at replacement cost*
δ = *depreciation of the capital stock*
V = *net price value of the reserve stock*
Q = *quantity of the resource extracted*
S = *stock of remaining recoverable or established reserves*
PV = *present value net price*
ϕ = *discount factor*
T = *life of the reserve*
t = *current year*

Table 6.7

Value of Coal Reserves in Canada: Net Price Method I and Method II, and Present Value, 1975-1993

	Alberta						British Columbia			Saskatchewan		
	Bituminous coal			Sub-bituminous coal			Bituminous coal			Lignite		
	Net price		Present	Net price		Present	Net price		Present	Net price		Present
Year	Method I	Method II	value	Method I	Method II	value	Method I	Method II	value	Method I	Method II	value
	millions of dollars											
1975	13 533	15 683	2 364	675	2 265	341	6 446	21 313	4 169	...[1]	3 480	130
1976	11 141	13 470	2 295	...[1]	1 580	256	3 450	24 456	3 801	70	3 589	177
1977	7 923	11 168	1 803	...[1]	1 137	221	4 137	24 700	4 320	40	2 979	190
1978	9 031	12 071	2 346	...[1]	1 695	352	4 325	25 132	4 790	...[1]	3 005	177
1979	4 732	7 834	1 814	...[1]	2 362	562	5 234	25 601	5 738	37	3 822	224
1980	5 664	9 013	2 358	288	3 222	713	...[1]	16 765	3 641	1 306	4 516	317
1981	2 792	6 533	1 719	663	4 054	978	...[1]	17 692	4 464	1 905	4 944	396
1982	6 679	10 858	2 837	677	4 981	1 365	...[1]	46 641	5 231	3 838	7 606	672
1983	14 523	22 889	3 926	570	4 914	1 504	...[1]	49 972	5 606	5 568	9 799	900
1984	11 409	25 582	3 749	1 027	5 236	1 722	...[1]	52 066	10 392	8 300	11 710	1 383
1985	4 906	19 476	2 863	1 087	5 019	1 806	...[1]	42 666	9 559	5 775	9 052	1 048
1986	6 842	26 019	2 812	282	4 004	1 470	...[1]	39 671	8 450	3 665	7 338	731
1987	5 645	23 582	2 516	1 084	5 910	1 748	...[1]	33 057	7 432	4 874	7 740	939
1988	8 832	21 392	3 026	726	5 177	1 627	...[1]	35 542	9 145	5 465	8 080	1 196
1989	9 454	20 912	3 104	1 588	5 601	1 859	...[1]	21 546	5 618	9 695	12 919	1 715
1990	11 020	23 063	3 102	2 065	6 079	2 016	...[1]	29 274	7 715	7 707	11 246	1 306
1991	15 956	25 934	3 843	2 499	5 733	2 083	...[1]	22 536	6 148	7 288	10 675	1 191
1992	16 748	25 605	3 865	2 992	5 840	2 178	...[1]	20 457	3 994	4 792	7 732	969
1993	18 354	26 277	4 023	3 301	5 836	2 222	...[1]	31 582	7 421	5 217	8 421	1 063

Notes:
Although the physical reserve data are not available for 1993, the closing stock of reserves for 1993 was calculated by subtracting the quantity extracted from 1992 closing stock.
1. The calculated value was negative, resulting from a negative resource rent. In the Canada total, these values are treated as zero.
Source:
Statistics Canada, National Accounts and Environment Division.

normal return to invested capital is not achieved (Born, 1995).

The main disadvantage of this net price method is that the assumption made regarding the rate of return to invested capital may be inappropriate. By presetting the rate of return to invested capital, no allowance is made for relatively low or high rates of return observed in the coal industry. Further, it could be argued that produced capital rather than the resource should be the residual claimant on the gross revenues.

In the case of British Columbia, negative values using net price method I have existed since 1980. Negative returns on total capital employed have been reported for 1989 to 1991 (Coopers & Lybrand, 1992). The value of coal reserves is also negative for several years for bituminous coal in Nova Scotia[1], subbituminous coal in Alberta and lignite in Saskatchewan when net price method I is used (Table 6.7).

1. The net price value of coal in Nova Scotia also includes subsidies in the total revenue of extraction. This is consistent with the definition of industry value added in national accounting calculations. Subsidies for Nova Scotia coal range from $26.7 million in 1970 to none in 1992 and the value of production ranged from $55.1 million to $203.3 million during the same time period.

Net price method II

An alternative method, net price method II calculates the resource rent by subtracting out the replacement cost of the net capital stock from the value of the reserve stock (Text Box 6.1). The advantage of this method is that it does not require an explicit assumption about the return to the produced capital associated with the coal. The values are positive when no return to capital is assumed.

Since coal is used as an input in the generation of electricity, it is assumed that the returns to capital may be captured from the returns or value added from electricity generation. The effect of this transfer pricing is assumed to have a major impact on upstream resource revenues and resource rents. By not making an explicit assumption about a "normal" return to capital, the effect of transfer pricing is reduced.

Present value

In the case of natural resource assets for which the returns are spread over a lengthy period of time, as with coal assets, a rate of discount should be used to compute the present value of the expected future returns. This flow of expected economic rents is the same as the rent calculation

Table 6.7

Value of Coal Reserves in Canada: Net Price Method I and Method II, and Present Value, 1975-1993 (Concluded)

Year	Nova Scotia Bituminous coal Net price Method I	Nova Scotia Bituminous coal Net price Method II	Nova Scotia Bituminous coal Present value	New Brunswick Bituminous coal Net price Method I	New Brunswick Bituminous coal Net price Method II	New Brunswick Bituminous coal Present value	Canada Total Net price Method I	Canada Total Net price Method II	Canada Total Present value
	millions of dollars								
1975	768	1 287	428	180	220	52	21 602	44 249	7 485
1976	607	1 070	419	113	180	31	15 381	44 344	6 980
1977	1 181	1 631	687	45	123	21	13 326	41 738	7 241
1978	666	1 044	511	285	360	69	14 308	43 306	8 245
1979	1 080	1 626	711	343	428	81	11 425	41 673	9 131
1980	900	1 362	701	467	531	142	8 626	35 408	7 871
1981	197	804	405	506	563	178	6 063	34 592	8 139
1982	754	5 347	733	320	358	164	12 268	75 790	11 002
1983	1 815	7 081	1 001	383	419	210	22 859	95 074	13 147
1984	5 607	12 041	1 695	340	379	194	26 684	107 014	19 135
1985	4 336	12 408	1 679	474	530	238	16 578	89 153	17 194
1986	... [1]	9 334	1 338	469	539	224	11 259	86 905	15 026
1987	3 042	14 104	2 023	457	520	234	15 103	84 914	14 892
1988	... [1]	7 491	1 311	493	558	258	15 517	78 239	16 563
1989	... [1]	7 516	1 314	521	592	271	21 258	69 086	13 881
1990	3 540	13 498	2 320	493	576	278	24 824	83 737	16 738
1991	2 587	10 965	2 297	544	692	320	28 875	76 536	15 881
1992	... [1]	7 355	1 681	222	462	187	24 753	67 450	12 874
1993	... [1]	8 213	1 555	349	594	239	27 221	80 923	16 523

Notes:
Although the physical reserve data are not available for 1993, the closing stock of reserves for 1993 was calculated by subtracting the quantity extracted from 1992 closing stock.
1. The calculated value was negative, resulting from a negative resource rent. In the Canada total, these values are treated as zero.
Source:
Statistics Canada, National Accounts and Environment Division.

used in the net price methods and is based on the value added of the natural resource.

As observed in calculating the net price, negative operating surpluses were obtained when a "normal return to capital" was assumed. However, since coal is an input into thermal power plants, returns to capital from upstream operations (i.e. coal extraction) may be captured from returns from electrical power generation. With low coal prices, a "normal return" to capital is not achieved under the assumptions used in net price method I. Since net price method I produced negative values in some years, the present value calculation is based on the second net price method in order to yield positive results throughout the time series.

The choice of an appropriate discount rate should reflect certain aspects of the resource being valued. There are several things to consider: a private versus a social discount rate, time preference, intergenerational equity and ownership of the resource.

The present value is calculated by using a discount rate that reflects the rate of return to the owners of the coal reserves, namely the provincial governments. A rate of 5 percent was used which is roughly equally to the average real provincial government borrowing rate for the period 1975 to 1993.

A discount factor was derived using the reserve life and assuming a real discount rate of 5 percent. The present value of the stock equals the discount factor times the net price value II (Text Box 6.1; BEA, 1994).

Comparison of the estimates

The two methods of net price valuation and the present value provide a range of the value of coal reserves in Canada. The asset value of coal reserves based on the second net price method produces positive values for all types of coal in all provinces which is not the case for net price method I. The present value is simply the discounted value derived from the second net price method.

Only the stock of recoverable reserves of coal is used in estimating the value of Canada's reserves. This is consistent with the other natural resource stock accounts already developed. For Canada, the net price value ranges from $27.2 billion to $80.9 billion in 1993. The stock of coal reserves would add between 1.0 percent and 3.0 percent to Canada's national wealth of $2 630 billion.[1] Over time, the value of coal reserves as a share of an expanded estimate of wealth has decreased; in 1975, coal reserves added from 3.1 to 6.2 percent to national wealth.

1. National wealth is the sum of tangible or non-financial assets across all domestic sectors.

The present value estimates ranged from $7.5 billion in 1975 to $16.5 billion in 1993. These estimates would add 1.1 percent to national wealth in 1975 and 0.6 percent in 1993.

Conclusion

Recoverable reserves of coal as presented in the physical accounts, represent only a small portion of Canada' s total coal resource. Recoverable reserves in active mines represent approximately 8 percent of coal resources of immediate interest. Although Canada has only one percent of the world's coal reserves, there remain 78 years of bituminous coal and 85 years worth of subbituminous coal and lignite assuming current depletion rates.

Results from the physical accounts indicate that Canada's stock of coal reserves has been maintained since the 1980s. Coal will remain an important primary energy source, particularly in Nova Scotia, Ontario, Saskatchewan and Alberta. In 1993 coal-fired electric power plants generated 15 percent of electricity production, up 5 percent from the 1970s.

In order to treat coal reserves and other natural resources as part of Canada's national wealth, monetary accounts had to be developed also. For inclusion in the National Balance Sheet Accounts, the present value is preferred as an estimate of the market value. Estimates of coal values using the net price method I resulted in some negative values. Negative asset values present empirical problems with regards to balance sheet entries. However, positive values were obtained when no return to invested capital was allowed for. Further work will be needed before deciding on an appropriate valuation method.

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7 Water Use in Economic and Domestic Activity

by Tony Johnson[1]

Introduction

Compared with much of the world, Canada is well endowed with available fresh water and has one of the world's longest coastlines. Indeed, the industrial structure of its economy and the lifestyle of its people have been heavily influenced by the abundance of water and other natural resources. It should be noted however, that 90 percent of Canada's population lives within a narrow band along its southern boundary, while 60 percent of its water supply flows north towards the Arctic Ocean (Environment Canada, 1992, p. 2). There has been ample evidence that growth in urbanisation and economic activity has stressed the ability of aquatic systems to cope with the demands placed on them.

The need for the enhancement and maintenance of Canada's water resources has been the focus of initiatives at all levels of government. The 1987 Federal Water Policy sets out a national strategy for the protection and enhancement of the quality of water resources and promotes the wise and efficient use of water. This goal has been reaffirmed in Canada's Green Plan (Government of Canada, 1990).

Statistics Canada is committed to the provision and promotion of statistical information on the environment as an important aid to informed decision making. A major facet of this work is aimed at developing satellite accounts to integrate, as far as possible, environmental and natural resource concerns with the traditional national accounting framework.

Two major accounts within this satellite system, the natural resource use accounts and the waste output accounts, are cast within an input-output industry framework[2]. They enable analysts to relate natural resource use (or waste output), measured in physical terms, to the production and consumption activities (measured in monetary terms) of industries, government and households.

This chapter reports on work in progress towards the development of resource use accounts for water. It presents data for one year (1991) at the national level only. Future work will extend the data set to cover a time series and individual provinces. There is also a longer term prospect of incorporating water-use micro data into Statistics Canada's Geographic Information System. Water-use issues are of course more effectively studied on a provincial or small area basis.

A framework for water use statistics

The hydrologic cycle describes the natural recirculation of the world's water supply. From its various repositories on earth (oceans, rivers, lakes, streams, groundwater, snow, ice and plants), water gravitates towards the seas, is evaporated and transpired to the atmosphere as water vapour, and is returned as precipitation. There is a strong interaction between the hydrosphere, the atmosphere and the land. For instance, the oceans and groundwater contain dissolved minerals from geological formations and water is oxygenated through contact with the atmosphere. These are natural processes. Humans, through economic processes and other activity, also profoundly affect water systems, often in ways that are deleterious to their quality. This can be directly through the withdrawal of water, the discharge of wastes, or the creation of water diversions, and, indirectly, through the transfer of land-based and airborne wastes to water systems through the hydrological cycle.

Water use accounts

Water use accounts can only hope to shed light on a small (albeit important) component of these interactions. Figure 7.1 is a schematic representation of water use in economic and other human activity. Broadly, two major uses of water are defined: withdrawal use, and non-withdrawal ("in-stream") use.

Withdrawal use involves the diversion of water from source and its transport to the place of use. Its return to source may be delayed or it may not be returned at all, thereby impacting on water flow available "downstream" for the maintenance of natural ecosystems and other competing uses. The use of withdrawn water in industrial processes (for example for mixing and transporting raw materials, cleaning, cooling and heating) and for human sanitation almost always involves a systematic degradation of its quality, notwithstanding pollution abatement practices.

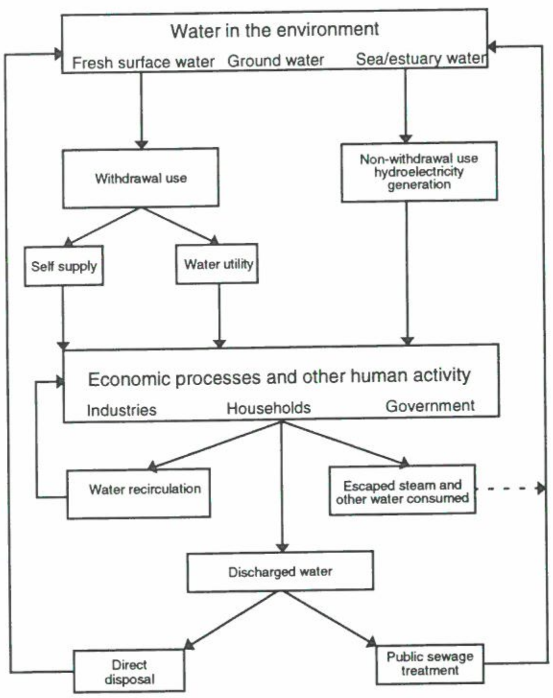
Non-withdrawal use includes sea and river transport, hydro electricity generation, fish culture, and water and snow sports. Except for hydro electricity generation, non-withdrawal use does not diminish supply and water quality degradation tends to be incidental, although it can be no less devastating for the environment (for example, crude oil spills and transfers of exotic aquatic species in ballast water).

1. The author acknowledges the help provided by Debbie MacDonald in the preparation of this article.

2. Waste output accounts for greenhouse gas emissions and resource use accounts for energy have already been developed at Statistics Canada (see Canadian Carbon Dioxide Emissions, 1981-1990, included in this publication).

Although water use in hydroelectricity generation is essentially a non-withdrawal use (because the activity occurs "in-stream"), it also has elements which are more characteristic of withdrawal use. Dams and diversions modify stream flow for year round electricity generation. Furthermore, dams involve the flooding of terrestrial ecosystems upstream, with resultant changes in water quality that are not incidental (for example, increased oxygen demands of decomposing organic matter). Because of its hybrid nature, and its prominence as a major water-use issue in Canada, it warrants separate identification in Figure 7.1.

Figure 7.1
Water Use in Economic and Other Human Activity



Note:
The flows shown for non-withdrawal use represent flows of services, not water, from the environment. The dashed arrow signifes that a substantial portion may be lost to the local environment, but not to the environment at large.

Although the non-withdrawal use of water contributes enormously to economic and other human activity, the water use account presented here is defined to include only the withdrawal use of water. The interaction between the environment and the former category is perhaps best measured using a variety of indicators such as accidental spills data and the area of resevoirs associated with hydroelectricity generation.

The water use account focuses on the following:

- the users of water (industries, households and government);
- the source of supply (fresh surface water, ground water and sea/estuary water), and whether it is drawn directly by the user (self-supplied) or supplied by a municipal water utility;
- the use to which the water is put (for example domestic use, cooling, industrial processes, sanitation);
- the incidence of water recirculation;
- water "consumption";[1] and,
- the quantity and quality of waste water discharged by each sector into the environment.

This is not a complete list of water-use variables that could be of interest for analysis. For example, studies of price elasticities of demand for water require information on the cost of obtaining and discharging water. However, the water-use variables listed above capture the important water resource interactions with economic and household activity. The factors driving this interaction are subjects for separate analysis (see for example Tate, Renzetti and Shaw, 1992).

Input-output analysis

The Canadian System of National Accounts (CSNA) provides an integrated and comprehensive picture of economic activity, both within Canada and between Canada and the rest of the world. Gross Domestic Product (GDP), the overall measure of production in the economy, is probably the most widely used and publicised summary aggregate from the CSNA. The input-output tables present the most detailed elaboration of GDP, focusing in particular on the production and intermediate consumption activity of industries and the distribution of goods and services to final consumers. Because of this focus on industry use and production of commodities, input-output tables (suitably augmented) can provide a useful framework in which to study the interaction between the environment (including natural resource use) and economic activity.[2]

The national accounts are of course key to macroeconomic analysis and policy advising. Input-output analysis is an established technique for use in macroeconomic forecasting and simulation models. Therefore, the presentation of natural resource use (and waste) data according to the concepts and classifications used in the input-output framework provides economic analysts with a convenient data set to for-

1. Includes water lost as steam or evaporated in cooling and heating processes, irrigation water lost by evaporation and transpiration, water embodied in products (for example beverages), and reticulation system leakages. In concept, it is a measure of the quantity of water not returned to point of source.
2. The potential for using input-output analysis for the study of environmental issues has been recognised for many years. Victor (1972), provided a generalised framework for the incorporation of environmental commodities into the Canadian input-output tables. This work forms much of the conceptual basis for the input-output studies currently underway at Statistics Canada.

mally integrate environmental commodities into economic model building generally.

A detailed technical description of input-output tables and their augmentation for the study of environmental commodities (greenhouse gas emissions) has already been published by Statistics Canada in a discussion paper (Smith, 1991). As the techniques presented in that paper can be readily generalised to other environmental commodities, including water use, only a brief non-technical description of input-output analysis is presented here to aid the readers interpretation of the data presented in Tables 7.2 and 7.4.

A basic identity in both economic theory and national accounting is that the supply of commodities (defined broadly to include services), equals demand. Commodities produced by an industry are either purchased by another industry for input to its production (intermediate consumption) or sold to final consumers (final consumption). Input-output tables are a fully balanced series of matrices showing commodity flows between industries and to final consumers. They are compiled at a very detailed level (627 commodities, 216 industries and 136 categories of final demand), but are published at a more aggregated level mainly for reasons of confidentiality under the provisions of the *Statistics Act*.

Three basic input-output tables are compiled for each year: the make matrix, showing the value of each commodity produced by each industry; the use matrix, showing the requirement of each industry for commodity and primary inputs; and the final demand matrix, showing the value of each commodity supplied to final demand. These tables are, of course, in value (dollar) terms. In the augmented input-output model employed in this study, an additional table relating to water use by each industry is also included (but measured in physical terms).

Using the information contained in each of these tables, and given the identity that the supply of commodities equals demand, quite powerful input-output models can be formulated. For example, the water requirements of industries given various economic growth scenarios can be simulated and forecast (see for example Tate, 1985). Input-output derivations are shown in Tables 7.2 and 7.4.

Sources of estimates and data quality

Estimates of water use for the major water-using industries contained in Tables 7.1 and 7.3 are derived from Environment Canada surveys. However estimates for the relatively small water using industries (the majority of industries), have been prepared by Statistics Canada from various sources in order to approximate all-of-Canada coverage, and to provide estimates for all industries and final demand sectors enumerated in the input-output tables (although they are published at a more aggregated level here). Important comments about data quality are contained in the following paragraphs.

Environment Canada, in co-operation with Statistics Canada and the provinces, has been collecting water-use data from industries and municipalities for many years. Industrial Water Use Surveys were conducted for 1972, 1976, 1981, 1986 and 1991[1], while municipal surveys were conducted for 1983, 1986, 1989 and 1991. Agriculture water-use estimates are prepared by Environment Canada using data for livestock numbers and land-area under irrigation together with water-use coefficients.

Industrial Water Use Survey

The Industrial Water Use Survey collects water use data for the mining, manufacturing and thermal electric power systems industries. In order to keep collection costs to acceptable levels, only business establishments classified by Statistics Canada as "large businesses" are surveyed. Also, manufacturing industries that are considered relatively small water users are not surveyed except where their industrial processes are known to result in high emissions of pollutants, despite their low water use. The 48 manufacturing industries surveyed (out of 100 manufacturing industries in the more detailed input-output industry classification) are expected to account for approximately 95 percent of water use by manufacturers.

Because of the predominance of low-cost self-supply in major water-using industries, and because municipal authorities often charge without (or with only partial) metering, some businesses may not keep accurate, if any, records of the volume of water used. Therefore, there is often a degree of approximation in survey responses and the incidence of non-response is fairly high, necessitating imputations. Despite these shortcomings, it is believed that the Industrial Water Use Survey provides data of acceptable quality.

Special mention should be made of some factors affecting the accuracy of estimates for the mining industries. The quarries and sand pits industry (6) and the services related to mineral extraction industry (7) are not surveyed for water use. Estimates contained in Table 7.1 are approximations developed at Statistics Canada from other sources. Also, for the 1991 water use survey, coverage of the oil and natural gas industry was not sufficient to produce reliable estimates. The estimates contained in Table 7.1 for this industry are based on 1986 water-use data adjusted for the changed level of oil and natural gas production in 1991. However, because of uncertainties in accounting for major shifts in mining technology, the estimates should be regarded as indicative only.

The existence of minewater in water discharge data introduces some problems of interpretation. Although minewater is used as a source of water in mining operations, substantial amounts are simply pumped from the mine in order to prevent flooding. Conceptually, in these estimates all mine-

1. A full description of the survey methodology, data items collected and a summary of results is contained in Tate and Scharf (1995, pending) and in earlier issues by the same authors.

water discharged is regarded as water use although it may not be used directly in mining processes. This is because it involves diversion of groundwater and the discharge of effluents. For the mining industry, water intake is set to equal water discharged (the mine water component of water discharge is not known), with the consequence that water consumed is artificially shown as zero.[1]

Municipal data and sector and industry allocations

Municipal surveys[2] collect information on water supplied by public water utilities from all municipalities with a population of 1 000 or more. They are asked to classify water supplied to four user classes: "residential", "industrial", "commercial" and "other". No further industry detail is available from the survey.

Water included in "other" was a substantial 15 percent of total municipal water supplied in 1991, and reflects a number of factors including the incidence of respondents who could not provide or estimate adequate customer data for water volume because water metering is not used (or is only partially used). It also includes system leakages and some public uses such as for street cleaning and fire fighting. As the estimates in this paper are presented by sector and industry, water included in "other" had to be reallocated. For municipalities that included all water supplied in that category, those amounts were reallocated according to provincial averages for the four user classes. As the remainder was in the order of engineering estimates of system leakages, it was included in the government sector in Table 7.1. This approach attributes the leakage to water use by the municipal water utility (as owner of the supply infrastructure) rather than the customer.

Municipal water classified as "domestic" formed the basis of the personal sector estimates contained in Table 7.1. However, domestic water use by over six million Canadians is not captured in the survey because they either reside outside the municipalities in the survey or they do not draw water from a municipal water utility. The figures shown in Table 7.1 include an estimate for this missing domestic water use, based on water use per person in the surveyed sector adjusted for the affect of lifestyle differences, based on U.S. studies (U.S. Geological Survey, 1987, p. 71).

A variety of sources were used to allocate the "industrial" and "commercial" user classes to industry. As the Industrial Water Use Survey asks respondents to supply information on their source of water, municipal supply for those respondents can be taken from that source. Estimation techniques were used to allocate the remainder of municipal supply to individual industries and the government sector.

1. In practice, water consumption is calculated by subtracting water discharged from water intake.
2. Environment Canada, Municipal Water Use Data (MUD).

The approach used in deriving the estimates was first to take employment data for the government sector and the remaining industries and combine with other person-based indicators including school enrollment, hospital and care-facility bed days, persons in correctional institutions, passengers through airports, and overnight stays in hotels. This result was multiplied by a water-use coefficient (water use per person). Differences between the aggregate all-industry first estimate derived in this way and the benchmark provided an indication of the suitability of assumptions. Any differences after further adjustments were allocated on a *pro rata* basis.

Where available, water-use coefficients for estimated manufacturing and mining industries were based on comparable U.S. data (U.S. Bureau of the Census, 1982).[3] Coefficients for the remaining industries and the government sector were chosen individually after considering a variety of indicators. These included a micro-data analysis of water use per employed person by industries included in the Industrial Water Use Survey, an analysis of water audit studies undertaken by Public Works Canada for a variety of government buildings, and domestic water use per person.

As the methods are indirect, the resulting estimates should be regarded more as "approximations" or "allowances" for the purpose of input-output analysis of aggregate water use, and are not regarded as reliable in their own right. Nevertheless, it was considered important that estimates be made for these industries, as analysis of municipal water demand is an important area of economic and environmental study, particularly as the provision and maintenance of water utility and sewage treatment infrastructure is a large public cost. Table 7.1 contains a column signifying whether estimates are derived substantially from 1991 survey data or from the various indirect sources.

Because of lack of data, it is assumed that these relatively small water using industries and the government sector draw water only from municipal supplies, (water withdrawals from other sources are shown as zero in Tables 7.1 and 7.2). There will be cases where this assumption does not hold. For example, accommodation and recreation facilities such as golf courses that are close to rivers and lakes typically supply their own water.

Analysis of water use estimates

Canadian industries, households and governments withdrew 45 billion cubic metres of water from the environment in 1991, approximately 90 percent of which was returned at

3. Water use in U.S. mining and manufacturing establishments for 1983 was collected as a follow up to the 1982 U.S. Census of Mining and Manufacturing and is the latest year for which detailed industry data are available. Use of these data to provide water use per employed person co-efficients for the derivation of estimates in this paper rests on the assumption that manufacturing technology in respect of water use and capital intensity has not changed in almost a decade and that U.S. results are transferrable to Canada.

Table 7.1
Water Use by Sector, 1991

	Self supplied			Municipal	Total	Water	Gross	Water	Water	Data
	Surface	Ground[1]	Sea/estuary		intake	recirculated	water use	consumed	discharged	reliability[2]
	millions of cubic metres									
Business sector										
1 Agricultural and related services	3 472.0	519.0	-	-	3 991.0	-	3 991.0	3 089.0	902.0	E
2 Fishing and trapping	-	-	-	-	-	-	-	-	-	E
3 Logging and forestry	-	-	-	-	-	-	-	-	-	E
4 Mining	280.9	181.7	5.7	20.2	488.5	1 220.7	1 709.2	-	488.5	S
5 Crude petroleum and natural gas	102.1	6.0	-	0.3	108.4	735.6	844.0	56.0	52.4	E
6 Quarries and sand pits	65.0	-	-	-	65.0	-	65.0	13.0	52.0	E
7 Services related to mineral extraction	5.0	-	-	-	5.0	-	5.0	2.5	2.5	E
Sub-total, primary resource industries (1-7)	**3 925.0**	**706.7**	**5.7**	**20.5**	**4 657.9**	**1 956.3**	**6 614.2**	**3 160.5**	**1 497.4**	
8 Food products	72.9	45.1	65.1	179.5	362.6	201.1	563.8	29.6	333.0	S
9 Beverages	18.8	12.2	-	44.3	75.3	16.7	92.0	12.2	63.1	S
10 Tobacco products	-	-	-	1.8	1.8	1.8	3.6	0.4	1.4	E
11 Rubber products	4.7	8.7	-	8.5	21.9	56.3	78.1	2.1	19.8	S
12 Plastic products	2.4	0.9	-	53.9	57.2	261.0	318.2	3.7	53.5	S
13 Leather and allied products	-	-	-	2.3	2.3	0.2	2.5	0.1	2.2	E
14 Primary textile and textile products	249.3	1.1	-	29.4	279.9	192.3	472.2	36.6	243.3	S
15 Clothing	-	-	-	9.3	9.3	0.9	10.3	0.5	8.9	E
16 Wood products	39.8	2.3	7.3	24.2	73.7	6.1	79.8	15.9	57.7	S
17 Furniture and fixtures	-	-	-	5.9	5.9	0.6	6.5	0.3	5.6	E
18 Paper and allied products	2 718.0	31.1	2.9	154.3	2 906.2	2 242.6	5 148.8	184.8	2 721.4	S
19 Printing, publishing and allied products	-	-	-	13.4	13.4	1.3	14.7	1.2	12.1	E
20 Primary metal products	1 487.9	1.6	4.2	89.5	1 583.1	1 715.3	3 298.4	91.6	1 491.5	S
21 Fabricated metal products	7.2	0.9	-	50.9	59.0	32.7	91.7	3.4	55.6	E
22 Machinery	-	-	-	23.1	23.1	2.3	25.4	4.1	19.0	E
23 Transportation equipment	3.6	0.4	--	107.8	111.8	39.0	150.8	9.1	102.7	E
24 Electrical and electronic products	-	-	-	28.2	28.2	2.8	31.0	2.9	25.3	E
25 Non-metallic mineral products	43.4	32.5	0.3	74.4	150.5	172.8	323.3	52.8	97.8	S
26 Refined petroleum and coal products	323.8	1.6	93.1	21.0	439.4	1 018.1	1 457.5	34.6	404.8	S
27 Chemical and chemical products	1 223.4	2.1	0.6	72.2	1 298.3	1 006.3	2 304.6	95.2	1 203.1	S
28 Other manufacturing industries	-	-	-	7.3	7.3	0.7	8.0	0.4	6.9	E
Sub-total, manufacturing industries (8-28)	**6 195.1**	**140.3**	**173.5**	**1 001.3**	**7 510.3**	**6 971.0**	**14 481.3**	**581.7**	**6 928.6**	
29 Construction	0.3	-	-	3.5	3.9	-	3.9	3.9	-	E
30 Transportation	-	-	-	8.5	8.5	-	8.5	2.0	6.5	E
31 Pipeline transport	-	-	-	0.1	0.1	-	0.1	0.1	-	E
32 Storage and warehousing	-	-	-	0.5	0.5	-	0.5	0.1	0.4	E
33 Communications	-	-	-	5.1	5.1	-	5.1	0.5	4.6	E
34 Thermal electric power and other utilities	26 124.8	8.8	2 148.4	6.7	28 288.7	3 374.3	31 663.0	105.2	28 183.6	S
35 Wholesale trade	-	-	-	15.8	15.8	-	15.8	1.6	14.2	E
36 Retail trade	-	-	-	37.4	37.4	-	37.4	11.2	26.2	E
37 Finance and real estate	-	-	-	15.1	15.1	-	15.1	1.5	13.6	E
38 Insurance	-	-	-	2.2	2.2	-	2.2	0.2	2.0	E
41 Business services	-	-	-	17.6	17.6	-	17.6	1.8	15.8	E
42 Educational services[3]	-	-	-	0.9	0.9	-	0.9	0.1	0.8	E
43 Health services[3]	-	-	-	32.0	32.0	-	32.0	3.2	28.8	E
44 Accommodation and food services	-	-	-	135.4	135.4	-	135.4	27.1	108.3	E
45 Amusement and recreational services	-	-	-	46.1	46.1	-	46.1	9.2	36.9	E
46 Personal and household service	-	-	-	42.5	42.5	-	42.5	4.3	38.3	E
47 Other services	-	-	-	7.9	7.9	-	7.9	0.8	7.1	E
Sub-total, service industries (30-33,35-47)	**-**	**-**	**-**	**367.1**	**367.1**	**-**	**367.1**	**63.6**	**303.5**	
Sub-total, business sector (1-47)	**36 245.3**	**855.8**	**2 327.6**	**1 399.2**	**40 827.9**	**12 301.6**	**53 129.5**	**3 914.8**	**36 913.1**	
Personal sector	..	..	..	**2 777.0**	**3 334.0**	-	**3 334.0**	..	..	S
Government sector[4]	-	-	-	**949.0**	**949.0**	-	**949.0**	..	..	E
Sub-total, personal and government sectors	..	..	..	**3 726.0**	**4 283.0**	..	**4 283.0**	..	..	
Total, whole economy	..	..	..	**5 125.2**	**45 110.9**	**12 301.6**	**57 412.5**	..	..	

Notes:
1. Includes mine water discharged.
2. "S" denotes an estimate which is predominantly based on survey data available for 1991. "E" denotes an estimate which is predominantly based on indirect methods or survey sources that are significantly out of date. These latter estimates should be interpreted as "approximations".
3. Includes services provided by private sector only. Public education and health are included in estimate for the government sector.
4. Includes 598 million cubic metres of water unaccounted for or lost as leakage in municipal water systems.

Source:
Statistics Canada, National Accounts and Environment Division.

Table 7.2

Derived Water Use Statistics for Industries, 1991

		Self supplied	Municipal	Total intake	Gross use	Water consumed	Water discharged	Use rate[1]	Consumption rate[2]
		thousands of cubic metres per million dollars of output							
1	Agricultural and related services	167.5	-	167.5	167.5	129.6	37.9	1.0	77.4
2	Fishing and trapping	-	-	-	-	-	-	-	-
3	Logging and forestry	-	-	-	-	-	-	-	-
4	Mining	38.7	1.7	40.4	141.2	-	40.4	3.5	-
5	Crude petroleum and natural gas	5.8	--	5.8	45.1	3.0	2.8	7.8	51.7
6	Quarries and sand pits	59.1	-	59.1	59.1	11.8	47.3	1.0	20.0
7	Services related to mineral extraction	1.2	-	1.2	1.2	0.6	0.6	1.0	50.0
8	Food products	4.6	4.5	9.1	14.1	0.7	8.3	1.6	8.2
9	Beverages	5.2	7.4	12.7	15.5	2.0	10.6	1.2	16.1
10	Tobacco products	-	0.9	0.9	1.9	0.2	0.7	2.0	24.5
11	Rubber products	5.0	3.1	8.1	28.9	0.8	7.3	3.6	9.7
12	Plastic products	0.6	9.4	9.9	55.3	0.6	9.3	5.6	6.4
13	Leather and allied products	-	2.4	2.4	2.6	0.1	2.3	1.1	5.8
14	Primary textile and textile products	43.4	5.1	48.5	81.8	6.3	42.1	1.7	13.1
15	Clothing	-	1.5	1.5	1.6	0.1	1.4	1.1	5.0
16	Wood products	3.7	1.8	5.5	6.0	1.2	4.3	1.1	21.6
17	Furniture and fixtures	-	1.5	1.5	1.6	0.1	1.4	1.1	5.0
18	Paper and allied products	128.0	7.2	135.2	239.5	8.6	126.6	1.8	6.4
19	Printing, publishing and allied products	-	1.0	1.0	1.1	0.1	0.9	1.1	9.4
20	Primary metal products	69.3	4.2	73.5	153.0	4.3	69.2	2.1	5.8
21	Fabricated metal products	0.5	3.2	3.7	5.7	0.2	3.5	1.6	5.7
22	Machinery	-	2.5	2.5	2.8	0.5	2.1	1.1	17.8
23	Transportation equipment	0.1	2.1	2.2	3.0	0.2	2.0	1.3	8.1
24	Electrical and electronic products	-	1.4	1.4	1.5	0.1	1.2	1.1	10.4
25	Non-metallic mineral products	11.7	11.5	23.2	49.8	8.1	15.1	2.1	35.0
26	Refined petroleum and coal products	23.9	1.2	25.1	83.2	2.0	23.1	3.3	7.9
27	Chemical and chemical products	54.7	3.2	57.9	102.7	4.2	53.6	1.8	7.3
28	Other manufacturing industries	-	1.1	1.1	1.2	0.1	1.1	1.1	5.9
29	Construction	--	--	--	--	--	-	1.0	100.0
30	Transportation[3]	-	0.2	0.2	0.2	--	0.2	1.0	23.4
31	Pipeline transport	-	--	--	--	--	-	1.0	100.0
32	Storage and warehousing	-	0.4	0.4	0.4	0.1	0.3	1.0	20.0
33	Communications	-	0.2	0.2	0.2	--	0.2	1.0	10.0
34	Electric power	1 056.9	0.2	1 057.1	1 183.2	3.9	1 053.2	1.1	0.4
35	Wholesale trade[3]	-	0.3	0.3	0.3	--	0.3	1.0	10.0
36	Retail trade[3]	-	0.7	0.7	0.7	0.2	0.5	1.0	30.0
37	Finance and real estate	-	0.2	0.2	0.2	--	0.2	1.0	10.0
38	Insurance	-	0.2	0.2	0.2	--	0.2	1.0	10.0
41	Business services	-	0.4	0.4	0.4	--	0.4	1.0	10.0
42	Educational services	-	0.4	0.4	0.4	--	0.4	1.0	10.0
43	Health services	-	1.7	1.7	1.7	0.2	1.6	1.0	10.0
44	Accommodation and food services	-	5.1	5.1	5.1	1.0	4.1	1.0	20.0
45	Amusement and recreational services	-	4.7	4.7	4.7	0.9	3.8	1.0	20.0
46	Personal and household service	-	4.9	4.9	4.9	0.5	4.4	1.0	10.0
47	Other services	-	0.6	0.6	0.6	0.1	0.6	1.0	10.0

Notes:
1. Calculated as gross use divided by total intake.
2. Calculated as water consumed divided by total intake times 100.
3. Output for the transport, retail and wholesale trade industries is defined as the margin after deducting the value of commodity inputs from the transaction value of output.

Source:
Statistics Canada, National Accounts and Environment Division.

or close to point of source after use. Total intake represented 1.5 percent of estimated precipitation for the year (2 905 cubic kilometres). Precipitation measures the amount of water renewed annually through the hydrological cycle.

The agriculture, manufacturing and thermal electric power industries together accounted for 88 percent of total water withdrawals in 1991, with domestic use accounting for only 7 percent. Thermal electric power was by far the largest user, accounting for 63 percent. Because of its large contribution to water use totals, it is often useful to isolate data for thermal power when analysing water use. Three of the 21 manufacturing industries represented in Table 7.1 (paper and allied products (18), primary metals (20) and chemical and chemical products (21)) accounted for 77 percent of manufacturing water use.

When viewed in terms of direct water-use coefficients (water withdrawals per dollar unit of output) in Table 7.2, the above mentioned industries also ranked high among all industries, with the electric power industry using more water per unit of output than any of the others, again by a large factor.

Comparisons of the magnitude of water withdrawals in isolation can be misleading, as ultimately the environmental impact of water use is a consequence of the discharge of water-borne pollutants and water consumption or diversion. Therefore, the use to which water is put in economic and human processes and the pollution abatement practices in-place within an establishment are also important elements to consider. Only limited information on these aspects of water use is available from the water use survey (see below).[1]

Only 11 percent of water was drawn from municipal sources in 1991, the remainder being self supplied. However, if the thermal electric power industry is excluded, the municipal proportion was a more substantial 30 percent. Of course, municipal water is also drawn from (and returned to) the environment. If municipal and rural water was withdrawn from source in the same proportions as in 1981 (Statistics Canada, 1994, p. 279), 91 percent of all water withdrawals in Canada would have been taken from fresh surface waters, 4 percent from ground water and 5 percent from sea/estuary sources.

Agriculture was by far the largest consumptive user of water, accounting for 79 percent of water consumed by industries. Water consumption refers to water that is not returned (discharged) at or close to point of source after use. Of water used for irrigation and livestock watering, 23 percent is estimated to be discharged back to source. The concept of discharge for the agriculture industry is defined to include waste irrigation water that drains through the soil to the water table, thereby returning more or less to nearby surface waters. Consumption rates for each industry are shown in Table 7.2. Estimates are not available for household and government water consumption.

Gross water use measures an industry's technical requirement for water in production processes (given current technology and water cost and supply conditions).This requirement for water can be met using withdrawals from the environment, or by a combination of withdrawals and recirculation. Obviously, the higher the rate of recirculation, the less impact economic processes have on the environment. Table 7.2 shows the use rate for each industry, calculated by dividing gross use by intake. It measures the number of times intake water is recirculated. All manufacturing industries recirculated water to some extent, although only six of the 21 industries in the manufacturing group recirculated intake water two or more times. Within this group, the plastic products industry showed the highest recirculation rate at 5.6 times. Considering all industries, the crude petroleum and natural gas industry had the highest recirculation rate of any industry (7.8).

Purpose of water use

Table 7.3 shows the use of water by purpose in selected industries. Process and sanitary water comes in direct contact with unfinished products, raw materials or wastes and therefore may contain chemical or solid residues on discharge. It includes water which is embodied in products. Cooling, condensing and steam water includes pass-through water used for cooling and condensing, air conditioning, and the creation of steam. It does not come in direct contact with process materials but, of course, is subject to temperature change (increased temperatures in water bodies can harm aquatic species and increase rates of evaporation). Even though it has a cooling function, quenching water is included in the former category because it comes in direct contact with the process materials. As mentioned previously, the extent to which pollutants (including waste heat) are discharged to the environment in waste water depends on pollution abatement practices.

Domestic use

Of water used within the home, around 75 percent is for bathroom and toilet use, 20 percent for laundry, and 5 percent for cooking/drinking (Environment Canada, 1992, p. 8). Lawn watering and other outdoor uses can be significant in summer. Pollutants contained in domestic waste water include organic materials (oxygen-demanding substances), viruses, refractory organics, detergents, phosphates, grease and oil, salts and solids (Manahan, 1984, p. 166). To the extent that sewage is inadequately treated (or not treated at all), these pollutants enter the aquatic environment. Of the 75 percent of the population served by sewage collection systems in 1991, 84 percent had some form of sewage treatment, while the remainder discharged wastewater di-

1. Statistical studies on waste emissions and pollution abatement expenditures are underway at Statistics Canada and will be reported on in the future.

rectly to receiving water bodies (Environment Canada, 1994, p. 3).

Agriculture

Except for thermal power, agriculture withdraws more water than any other industry and is by far the largest consumptive user of water. Water is used in agriculture for irrigation and for livestock production (drinking water, sanitation and waste disposal). Data for 1981 (the latest available Environment Canada estimates by purpose of use), show irrigation use to be 88 percent of total water use in agriculture. Irrigation, by nature, is concentrated in areas that experience dry seasonal conditions, a factor which heightens its impact on aquatic environments. Irrigation and its associated dam construction and diversion works affects stream flows and return water contains dissolved fertilizers, pesticides, salts and sulphates (Government of Canada, 1991, p. 3-10).

Thermal electricity industry

Although water use by purpose data are not available for this industry, nearly all water use is for condenser cooling, with relatively smaller amounts being used for boiler feed and purposes such as ash control and sanitation. As thermal power stations often employ once-through cooling systems, water is returned to the environment at a higher temperature than it is withdrawn, with consequential environmental impacts. Although the consumption rate is only 0.4 percent, it is relatively substantial in volume terms. The consumption rate would be higher if the increased evaporation from warmer receiving waters was taken into account.

Table 7.3
Water Use by Purpose for Selected Industries

	Process and sanitary use	Cooling, condensing and steam use	Total
	millions of cubic metres		
4 Mining	300.2	59.1	359.3
8 Food products	219.5	143.1	362.6
14 Primary textile and textile products	70.0	209.8	279.8
18 Paper and allied products	2 281.2	625.0	2 906.2
20 Primary metal products	674.4	908.7	1 583.1
26 Refined petroleum and coal products	53.0	386.4	439.4
27 Chemical and chemical products	201.5	1 096.9	1 298.4
All other manufacturing	358.5	282.3	640.8
Total manufacturing	**3 858.1**	**3 652.2**	**7 510.3**

Source:
Statistics Canada, National Accounts and Environment Division.

Mining

The predominant use of water in the mining industry (4) is process and sanitary use (84 percent). The composition of minewater effluent varies with the composition of the ore, but it is commonly acidic. Mineral concentration activity is a heavy user of water. Although process water is generally held in tailings ponds before release, the discharged water typically contains residues of ore and other waste minerals as well as small quantities of chemicals which can be highly toxic (Government of Canada, 1991, p. 3-12). The crude petroleum and natural gas industry (excluded from Table 7.3 because reliable estimates are not available for 1991) uses large amounts of water for condensing of natural gas, for heat extraction of crude from oil sands and for injection into wells to enhance oil recovery.

Paper and allied products industry

The paper and allied products industry (18) is a large water user and its impact on aquatic systems has been an increasing focus of attention in recent years. Water use is predominately for process purposes (76 percent). Water is used in cleaning and steaming wood chips and for adding to pulp to make a slurry from which paper is made. Effluent from mills include solid waste and chlorinated organic chemicals such as dioxins and furans, which are of particular concern as they have the propensity to bioaccumulate (Government of Canada, 1991, p. 3-12).

Primary metals industry

The primary metal products industry (20) is the second largest user of water in the manufacturing sector (after the paper and allied products industry), with the primary steel industries and non-ferrous smelting and refining industries accounting for over 90 percent of the water use. As an indication of water use in this industry, U.S. sources state that blast furnaces typically use around 42 cubic meters of water to produce one ton of iron, with additional amounts required to convert iron to steel (U.S. Geological Survey, 1987, p. 88). Cooling accounts for 57 percent of water use, the remainder being for process, sanitary and other purposes. Process use includes quenching, sintering, scale removal, and cleaning of blast furnaces. Wastewater can include contaminants such as suspended solids, metals, oil and grease, cyanide, ammonia, acids and phenols (Environment Ontario, 1991).

Refined petroleum and coal products industry

As petroleum refining uses heat to separate the various products from crude oil, the predominant use of water in this industry (26) is for cooling (the cooling, condensing and steam water use category represents 88 percent of total water use). However in volume terms, large amounts of process water is also used. Largely in response to federal effluent regulations and guidelines, the industry has dramatically reduced its liquid discharge of sulphides, ammo-

Table 7.4
Total Water Intensity of Commodities, 1991

		Self supplied	Municipal	Total intake	Gross use	Water consumed	Water discharged
		thousands of cubic metres per million dollars of output					
1,2	Grains and live animals	258.1	1.3	259.4	275.5	165.1	94.3
3	Other agricultural products	257.6	1.3	258.9	275.0	164.8	94.1
4	Forestry products	27.0	0.7	27.8	35.3	6.4	21.3
5	Fish landings	15.2	0.7	15.9	23.0	1.7	14.2
6	Hunting & trapping products	20.5	1.1	21.6	30.0	5.4	16.2
7	Iron ores & concentrates	100.7	2.2	103.0	217.0	1.0	102.0
8	Other metal ores & concentrates	106.1	2.7	108.8	221.9	1.6	107.2
9	Coal	100.7	2.2	103.0	216.9	1.0	102.0
10	Crude mineral oils	43.0	0.5	43.5	90.2	3.8	39.7
11	Natural gas	43.0	0.5	43.5	90.1	3.8	39.7
12	Non-metallic minerals	88.2	1.7	89.9	142.2	6.9	83.0
13	Services incidental to mining	38.0	0.9	38.9	52.5	1.9	37.0
14	Meat products	103.0	6.1	109.2	127.7	49.3	59.8
15	Dairy products	100.0	6.2	106.3	124.6	47.3	59.0
16	Fish products	99.5	6.2	105.7	123.9	47.0	58.7
17	Fruit & vegetable preparations	97.5	6.2	103.7	121.8	45.7	58.0
18	Feeds	97.2	6.1	103.3	121.2	45.7	57.7
19	Flour, wheat, meal & other cereals	100.1	6.2	106.4	124.7	47.3	59.0
20	Breakfast cereal & bakery products	93.7	5.7	99.5	116.6	42.8	56.7
21	Sugar	100.1	6.2	106.4	124.7	47.3	59.0
22	Miscellaneous food products	99.3	6.0	105.2	123.4	46.8	58.4
23	Soft drinks	41.3	9.3	50.6	65.7	8.1	42.5
24	Alcoholic beverages	39.1	9.4	48.5	63.4	6.6	41.9
25,26	Tobacco and cigarettes	58.0	2.1	60.2	73.1	24.1	36.0
27	Tires & tubes	45.9	4.1	50.0	83.4	2.2	47.8
28	Other rubber products	48.7	4.5	53.2	88.0	2.7	50.6
29	Plastic fabricated products	57.8	10.4	68.2	133.3	2.8	65.4
30	Leather & leather products	28.1	3.5	31.7	41.4	3.2	28.4
31	Yarns & man made fibres	91.3	6.7	98.0	148.8	8.5	89.5
32	Fabrics	90.0	6.7	96.6	146.7	8.4	88.2
33	Other textile products	87.7	6.5	94.2	143.1	8.1	86.1
34	Hosiery & knitted wear	27.8	2.9	30.7	42.4	1.9	28.8
35	Clothing & accessories	28.7	3.0	31.7	44.0	2.0	29.7
36	Lumber & timber	44.1	2.8	46.9	57.4	3.9	43.0
37	Veneer & plywood	43.8	2.8	46.6	57.0	3.9	42.7
38	Other wood fabricated materials	43.8	2.8	46.6	57.5	3.8	42.8
39	Furniture and fixtures	36.7	3.1	39.8	55.2	1.7	38.0
40	Pulp	244.0	9.1	253.1	390.0	11.9	241.3
41	Newsprint and other paper stock	243.0	9.1	252.1	388.4	11.8	240.3
42	Paper products	196.1	8.5	204.6	318.4	9.6	195.0
43	Printing & publishing	50.4	2.7	53.2	77.4	2.3	50.9
44	Advertising and print media	48.4	2.7	51.1	74.1	2.2	48.9
45	Iron & steel products	143.6	5.5	149.1	260.5	5.5	143.7
46	Aluminum products	151.2	5.6	156.8	274.8	5.8	151.0
47	Copper & copper alloy products	149.5	5.6	155.1	271.7	5.7	149.4
48	Nickel products	153.1	5.6	158.8	278.5	5.8	152.9
49	Other non ferrous metal products	140.7	5.5	146.2	255.0	5.5	140.7
50	Boilers, tanks & plates	45.8	4.6	50.4	77.0	1.7	48.7
51	Fabricated structural metal products	56.6	4.8	61.4	97.0	2.2	59.3
52	Other metal fabricated products	56.6	4.9	61.5	98.2	2.2	59.3
53	Agricultural machinery	29.1	3.6	32.7	47.2	1.5	31.2
54	Other industrial machinery	33.8	3.4	37.2	55.6	1.6	35.5
55	Motor vehicles	20.8	3.2	23.9	34.2	0.9	23.0
56	Motor vehicle parts	22.4	3.2	25.6	37.1	1.0	24.7
57	Other transport equipment	21.0	3.0	24.0	34.3	0.9	23.1
58	Household appliances & receivers	24.2	2.5	26.7	38.2	1.0	25.7
59	Other electrical products	22.4	2.4	24.8	35.1	1.0	23.8
60	Cement & concrete products	75.9	13.5	89.4	136.2	10.5	78.8

Table 7.4
Total Water Intensity of Commodities, 1991 (Concluded)

		Self supplied	Municipal	Total intake	Gross use	Water consumed	Water discharged
		thousands of cubic metres per million dollars of output					
61	Other non-metallic mineral products	71.6	12.5	84.1	128.1	9.7	74.4
62	Gasoline & fuel oil	60.8	1.7	62.5	143.8	3.9	58.6
63	Other petroleum & coal products	65.0	1.8	66.8	138.5	4.2	62.6
64	Industrial chemicals	116.6	4.5	121.1	188.2	7.0	114.1
65	Fertilizers	133.3	2.6	135.9	220.7	32.3	103.6
66	Pharmaceuticals	117.8	4.5	122.2	188.4	8.1	114.1
67	Other chemical products	113.1	4.6	117.7	180.5	8.6	109.1
68	Scientific equipment	30.3	2.5	32.8	47.4	1.3	31.5
69	Other manufactured products	40.5	3.4	43.9	68.6	2.1	41.9
70-72	Construction	21.2	1.5	22.8	33.7	1.7	21.0
73	Pipeline transportation	102.3	0.3	102.6	116.6	0.7	101.9
74	Transportation & storage	21.2	0.9	22.1	31.2	0.9	21.2
75-77	Radio, television, telephone and postal services	9.4	0.6	10.0	12.4	0.3	9.7
78	Electric power	1 069.7	0.5	1 070.2	1 202.3	4.3	1 066.0
79	Other utilities	1 070.0	0.5	1 070.5	1 202.5	4.3	1 066.2
80	Wholesale margins	24.0	1.4	25.4	33.8	2.3	23.1
81	Retail margins	41.0	1.1	42.1	49.7	1.0	41.1
82	Imputed rent, owner occupied dwellings	1.2	0.1	1.3	1.8	0.1	1.2
83	Other finance, insurance & real estate	31.2	0.5	31.7	37.2	0.6	31.1
84	Business services	10.4	0.8	11.2	14.0	0.4	10.8
85	Education services	39.0	0.9	39.9	47.2	0.8	39.1
86	Health services	10.5	2.0	12.5	15.2	0.5	12.0
87	Amusement & recreation services	29.7	5.6	35.3	41.0	1.8	33.5
88	Accommodation & food services	45.0	6.3	51.3	59.8	9.9	41.4
89	Other personal & miscellaneous services	32.9	2.2	35.2	42.8	1.1	34.1
90	Transportation margins	18.9	0.8	19.7	27.9	0.8	18.9
91	Operating, office, lab. & food supplies	38.4	2.2	40.7	58.7	4.6	36.1
92	Travel, advertising & promotion	26.5	2.1	28.7	38.8	2.6	26.1

Source:
Statistics Canada, National Accounts and Environment Division.

nia, nitrogen, oil and grease and total suspended solids since 1972 (Government of Canada, 1991, p. 3-12). Intake water is recirculated on average 3.3 times.

Chemical and chemical products industry

The chemical industry (27) is diverse and includes industrial organic and inorganic chemicals, plastics, pharmaceuticals, paints, soap and cleaning compounds, and toilet preparations. Eighty-four percent of water use is for cooling, condensing and steam. However in volume terms, the industry uses large amounts of process water for the production of chemicals, residues of which can be discharged in waste water. Process waste water could include acids, bases, suspended solids, oil and grease, organic carbons, and toxic pollutants such as metals, phenols, and chlorinated hydrocarbons (Environment Ontario, 1991). Intake water is recirculated 1.8 times.

Water requirements of commodities

Table 7.4 utilizes one of the main features of input-output modelling to show the total quantity of water required to produce a unit value of a commodity for delivery to final demand. This is referred to as an "impact" or "total requirements" table and includes both direct and indirect water requirements, the meaning of which can best be illustrated by an example. The direct water requirement for the production of a motor vehicle is the water used by the motor vehicle manufacturer per dollar of motor vehicle output. However the motor vehicle industry also has requirements for commodities as inputs, for example steel, electricity, components, and tires, all of which have their own direct water requirements. The steel manufacturer has requirements for water to produce the steel sold to the car manufacturer and so on. Therefore, the total water required to produce a motor vehicle is the sum of direct and indirect water requirements.

As expected, Table 7.4 shows that commodities which are primary to large water using industries also tend to have high water-use intensities per dollar unit of output. For example, electric power requires 1.1 million cubic metres per million dollars produced and is by far the most water intensive commodity. In one sense, this actually understates the true water intensity of thermal electricity as the dollar value of output includes hydroelectricity (which does not "withdraw" water) in addition to thermal electricity. Agricultural commodities (1-3) and pulp (40), newsprint and other paper stock (41) all have a similar water intensity of approximately 250 thousand cubic metres per million dollars of output.

Total water intensity estimates are more interesting for higher order commodities that contribute substantially to final demand. For instance, motor vehicles (55) require 24 thousand cubic metres of water per million dollars of output. This is almost eleven times the amount of water used directly by the transportation equipment industry in the manufacture of its output. An extreme example of this multiplier affect is construction commodities (70-72), where water requirements are close to six hundred times the small amount of water used directly by the construction industry. High but less extreme multipliers are also evident for wholesale and retail trade margins (80-81), reflecting the high direct and indirect water use of inputs such as paper and energy (but excluding water use in the production of goods sold as they are excluded from the concept of margins).

Other commodities that make a substantial entry into final demand, and have a relatively high water intensity, include the various food categories (14-22) and pharmaceuticals (66). It is interesting to note that food products are over twice as water intensive as soft drinks and alcoholic beverages, despite the fact that the latter consist almost entirely of water.

A word of caution is necessary. Because of the way input-output tables are constructed, total water intensities derived for some commodities are not realistic. Where an industry produces more than one commodity, the water intensity of those commodities will be virtually the same and reflect the intensity of the industry's total output. For example, the water intensites shown for grains (1), live animals (2) and other agricultural commodities (3) should be viewed more as agricultural industry averages than as accurate measures of the water intensity of each commodity taken separately.

If the water-use intensities shown in Table 7.4 were multiplied by the value of final demand for each commodity, the result summed for all commodities would equal the total amount of water used by the business sector (as shown in Table 7.1). If a different set of final demands were postulated, the water requirements of that new level of production could be simulated, given certain standard assumptions required for input-output analysis. Similarly, a time series of total water intensity coefficients could be used to study the impact of changes in industry technologies on the water requirements of different commodities (for example, see Tate, 1986).

Domestic and government direct water use is not determined within the total water intensity model used to derive the estimates in Table 7.4 because both water supply and use for those sectors is contained within final demand. To the extent that water use is related to final expenditures, for example personal expenditure on gross imputed rent and various categories of government consumption expenditures (for example on hospitals, education and defence), these components could be internalised as direct co-efficients (water use per dollar of final expenditure). Alternatively, if analysis shows water use by these sectors to be more dependent on other variables, such as population or employment, it should best be determined outside the input-output model. This is the approach adopted in these estimates.

Conclusion

The state of Canada's water resources has been a key issue in the environmental debate for many years. Water use accounts provide a structured set of statistics at the national and provincial level that provide information on who is withdrawing water and how much, where it is coming from, what it is being used for, and the incidence of recirculation. The use of an input-output framework for the presentation of statistics is particularly suited for highlighting and analysing the interaction between economic activity and the environment. Work to extend the data set within this framework for earlier years (using Environment Canada and other sources) is underway. When that work is complete, it should be possible to draw some useful conclusions about trends in economy-environment (water use) interactions over time. Work planned for compiling waste accounts (including waste discharged in water) and pollution abatement statistics will add further to the information available within a consistent environmental accounting framework.

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8 Canadian Carbon Dioxide Emissions

by Robert Smith

Introduction

This chapter is an update of the greenhouse gas emissions study that was published in the previous edition of ***Environmental Perspectives: Studies and Statistics*** (Smith, 1993). While the earlier study presented emissions data for a number of greenhouse gases, but covered the year 1985 only, this paper focuses on carbon dioxide emissions only, but covers the entire period from 1981 to 1990. Data on other greenhouse gases were not sufficiently developed at the time of publication to be included here. Future work at Statistics Canada will include the development of time-series data for the other greenhouse gases, as well as for a range of other wastes.

The development of greenhouse gas emissions data at Statistics Canada has been undertaken as part of the development of a broader waste output account. This account will contain quantitative information on a wide range of waste materials generated by Canadian businesses, governments and households. The information will be organised into an accounting framework that will allow the linkage of the waste output data with the detailed economic information held by Statistics Canada. This linkage will allow the calculation of indicators of the waste intensity of Canadian economic activity, which, when compared over time, will provide useful insight into the development of the Canadian economy with respect to its demands on the environment as a sink for waste materials.

Before moving on to present the carbon dioxide emissions estimates for 1981 to 1990, it is useful as background information to discuss the relationship between carbon dioxide emissions and the greenhouse effect.

Carbon dioxide emissions and the greenhouse effect

The greenhouse effect is a naturally occuring phenomenon in which certain trace atmospheric gases, carbon dioxide being the most important, trap some of the sun's heat between the earth's surface and atmosphere before it can be reflected from the surface back into outer space. In this way, these gases act just like the glass covering on a greenhouse.

The current concern about the greenhouse effect is not that it is, in itself, an environmental threat. Indeed, it is largely as a result of this phenomenon that surface temperatures on the planet are kept within the range suitable for life. Rather, the concern about the greenhouse effect stems from the fact that human activities are significantly increasing the atmospheric concentrations of greenhouse gases, particularly carbon dioxide. Scientists believe that these increased concentrations will significantly enhance the naturally occurring greenhouse effect during the coming decades.[1] If this expected enhancement does occur there may be significant environmental consequences. Among the possible effects of an enhanced greenhouse effect are an increase of up to 3-4°C in the average global temperature; sea level rise of 0.5-1 metres, causing inundation of coastal regions; disruption of climatic patterns, with increased frequency of droughts and severe storms in some regions; and changes in habitat conditions so rapid that plant and animal species will be unable to adapt (Government of Canada, 1991). Alongside these predictions of negative consequences, some individuals note also that there may be economic benefits from an enhanced greenhouse effect, particularly from increased productivity of agriculture in some areas. Although the ultimate consequences of an enhanced greenhouse effect are still under debate, there is no doubt among scientists that carbon dioxide will be the most important gas in contributing to whatever changes do occur.

A colourless, odourless gas, carbon dioxide is the weakest of the greenhouse gases emitted from human activities in terms of its ability to absorb heat.[2] Nevertheless, it is the most significant in terms of its total contribution to the greenhouse effect. The International Energy Agency reports that 61 percent of the enhancement to the greenhouse effect predicted to take place over the next 100 years can be attributed to carbon dioxide emissions from global human activities. The contributions of the other major greenhouse gases are as follows: methane: 15 percent; chlorofluorocarbons: 11.5 percent; nitrous oxide: 4 percent; and others: 8.5 percent. Carbon dioxide's importance as a contributor to the greenhouse effect stems from its relatively high atmospheric concentration and long lifetime in comparison to the other greenhouse gases. One molecule of carbon dioxide will persist in the atmosphere for 50 to 200 years[3] and the average concentration of the gas was estimated to be 357 ppmv[4] in 1990. The latter has steadily increased from a pre-1800 value of approximately 280 ppmv and was in-

1. Although some evidence of the enhanced greenhouse gas effect has already been noted, an unequivocal demonstration of it is not expected for at least another decade (Intergovernmental Panel on Climate Change, 1992).
2. The family of chemicals known as the chlorofluorocarbons are the strongest gases in this regard.
3. The atmospheric lifetime of carbon dioxide is defined as the time required for carbon dioxide concentrations to equilibrate after a one-time surge in emissions. The large range in the reported lifetime is due to imperfect understanding of the carbon cycle (Houghton, *et al.*, 1990, p. 7).
4. ppmv = parts per million by volume.

creasing in 1990 at a rate of about 0.5 percent, or 1.8 ppmv, annually (International Energy Agency, 1991, p. 14-15).

Carbon dioxide is produced in very large quantities by human activities, principally from two sources. The combustion of fossil fuels (coal, oil and natural gas) is the most important source. The use of biomass associated with the production and consumption of wood, paper and agricultural products is the other main source. Production of cement, ammonia and natural gas, as well as the use of lubricants and petroleum feedstocks, contribute a few percent of the total carbon dioxide releases from human activities.

The annual release of carbon dioxide from global fossil fuel combustion and cement manufacturing has increased from less than 0.37 Gt in 1860 to 118 Gt in 1987.[1] The cumulative release of carbon dioxide from these sources during this period is estimated to have been 732 Gt ± 10 percent.

Ninety five percent of fossil fuel-related carbon dioxide emissions originate in the northern hemisphere, mainly in the industrialised nations. While per capita carbon dioxide emissions from fossil fuel combustion in the developing nations are substantially below those in industrialised nations (2.2 t versus 18.3 t), the rate of increase is much larger in the developing countries. During the 1970s and 1980s, per capita emission rates increased annually at a rate of approximately 6 percent in developing countries versus 1 to 3 percent in industrial economies (Houghton, *et al.*, 1990, p. 10).

Carbon dioxide emissions from biomass use are associated with a number of activities: forest burning during land clearing (mainly in tropical areas); decay of wastes from logging activities; decay of wood and paper products; and oxidation of organic matter found in soil resulting from agriculture and forestry activities. As the regrowth of forests and the redevelopment of organic matter in soil both remove carbon dioxide from the atmosphere, biomass represents both a source of carbon dioxide emissions as well as a store (sink) into which the gas is absorbed out of the atmosphere. The total release of carbon dioxide to the atmosphere from biomass sources between 1850 and 1985 is estimated to have been 421 Gt ± 30 percent. In the nineteenth and early twentieth centuries, most of the biomass-related carbon dioxide emissions were a result of forest harvesting in temperate regions, including Canada. Since the middle part of this century, however, the major source has been deforestation in the tropics. Over the entire period, the release of carbon dioxide from tropical regions is estimated to have been two to three times that from temperate regions (Houghton, *et al.*, 1990, p. 10-11).

Canada is responsible for approximately 2 percent of current annual global carbon dioxide emissions (excluding biomass sources, which are very difficult to estimate). Fossil fuel production and consumption[2] accounts for 97 percent of these emissions, with the remainder coming from the production of cement, lime, ammonia and natural gas, and the use of lubricants and petroleum feedstocks (Jaques, 1992, p. *xviii*).

1. Gt = gigatonnes
2. Consumption includes the use of fossil fuels for non-energy purposes.

Fossil fuels and carbon dioxide emissions

As just noted, fossil fuel use is responsible for nearly all of Canada's carbon dioxide emissions. Not all fossil fuels are created equal in terms of their contribution to these emissions. Text Box 8.1 below shows that there is significant variation among the fossil fuels in terms of carbon dioxide emissions. At the low end of the scale is natural gas, which emits approximately 50 tonnes of carbon dioxide per terajoule burned.[3] The various forms of coal and coke are found at the high end of the scale, with emission factors in the range of approximately 82 t/TJ to 100 t/TJ. The impact of this variability in unit carbon dioxide emissions on total Canadian emissions from fossil fuel combustion will become clear in the discussion that follows.

Carbon dioxide emission estimates, 1981-1990

Estimates are presented in Table 8.1 for the combined Canadian emissions of carbon dioxide from the combustion of fossil fuels and from the production of cement, lime, ammonia and natural gas, plus non-energy uses of petroleum products.[4] The data show that total carbon dioxide emissions in the economy varied during the period 1981-1990 from a low of 387 megatonnes in 1983 to a high of 490 meg-

3. The joule (J) is the basic unit of energy measure; a terajoule (TJ) is 10^{12}, or one thousand billion, joules. A 40 litre tank of gasoline contains approximately 1.36 billion joules.
4. The estimates do not include biomass emissions because of the high degree of uncertainty associated with their estimation.

Text Box 8.1
Carbon Dioxide Emission Factors for Fossil Fuel Combustion

Fuel type	Carbon dioxide emission factor (tonnes/terajoule)
Natural gas	49.68
Still gas	49.68
Automobile gasoline	67.98
Kerosene	67.65
Aviation gasoline	69.37
Liquified petroleum gases	59.84 - 61.38
Diesel oil	70.69
Light fuel oil	73.11
Heavy fuel oil	74.00
Aviation turbo fuel	70.84
Petroleum coke	100.10
Coal coke	86.00
Anthracite coal	86.20
U.S. bituminous coal	81.60 - 85.90
Canadian bituminous coal	83.00 - 94.30
Sub-bituminous coal	94.30
Lignite coal	93.80 - 95.00

Source:
Jaques, 1992, p. *xx*.

Table 8.1
Carbon Dioxide Emissions by Sector, 1981-1990

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
	kilotonnes									
Business sector										
1 Agricultural and related services	11 130	9 705	14 381	8 934	9 555	9 934	9 646	10 497	11 949	12 440
2 Fishing and trapping	1 240	1 239	1 027	1 103	1 121	1 145	1 031	1 119	1 307	1 263
3 Logging and forestry	2 040	1 453	1 668	1 575	1 985	2 521	2 303	2 341	2 026	2 700
4 Mining	7 438	4 820	5 673	6 233	6 508	6 289	7 905	9 027	8 684	6 964
5 Crude petroleum and natural gas	18 880	21 387	21 759	23 712	25 798	28 224	31 075	32 754	35 928	35 241
6 Quarries and sand pits	463	513	415	408	456	593	707	908	818	534
7 Services related to mineral extraction	2 349	2 065	1 751	1 969	2 225	1 667	1 527	2 195	1 483	1 344
Sub-total, primary resource industries (1-7)	**43 540**	**41 182**	**46 674**	**43 934**	**47 648**	**50 373**	**54 194**	**58 841**	**62 195**	**60 486**
8 Food products	4 220	4 119	3 834	3 650	3 902	4 169	4 777	4 418	4 252	3 949
9 Beverages	1 069	983	843	826	848	853	858	832	812	728
10 Tobacco products	59	58	45	46	50	51	42	49	52	51
11 Rubber products	480	292	412	393	412	419	454	401	419	364
12 Plastic products	298	285	252	252	279	311	379	501	521	476
13 Leather and allied products	88	73	79	86	99	88	83	84	65	57
14 Primary textile and textile products	1 528	1 216	1 244	1 146	1 003	1 071	1 239	1 408	1 332	1 228
15 Clothing	167	150	161	160	189	221	242	300	206	223
16 Wood products	1 751	1 489	1 627	1 662	1 672	1 527	2 150	2 038	2 072	1 485
17 Furniture and fixtures	219	213	199	209	282	290	365	384	416	355
18 Paper and allied products	15 031	10 265	12 110	11 461	10 650	10 734	10 412	10 940	12 753	14 322
19 Printing, publishing and allied	278	268	273	276	369	393	454	531	543	478
20 Primary metal products	26 454	21 299	22 468	25 565	26 180	26 902	26 979	27 323	27 210	21 570
21 Fabricated metal products	1 466	1 363	1 271	1 452	1 613	1 640	1 901	2 175	2 184	1 861
22 Machinery	630	600	492	517	616	583	701	788	719	699
23 Transportation equipment	1 862	1 773	1 842	1 919	2 387	2 348	2 596	3 039	3 202	2 344
24 Electrical and electronic products	1 138	874	800	1 436	1 091	1 623	1 370	1 160	1 143	1 019
25 Non-metallic mineral products	13 367	11 066	10 321	11 010	11 423	12 848	14 790	15 507	15 655	14 015
26 Refined petroleum and coal products	21 401	18 347	17 172	18 777	19 693	17 918	22 800	21 673	22 094	22 624
27 Chemical and chemical products	17 682	17 789	18 843	20 394	20 256	18 181	19 166	21 129	18 701	17 510
28 Other manufacturing industries	345	310	279	297	362	397	420	478	447	433
Sub-total, manufacturing industries (8-28)	**109 533**	**92 832**	**94 567**	**101 534**	**103 376**	**102 567**	**112 178**	**115 158**	**114 798**	**105 791**
29 Construction	8 192	7 265	6 152	6 514	7 392	6 911	7 914	8 005	7 823	6 545
30 Transportation	32 565	27 723	28 984	30 134	32 952	33 580	33 873	39 161	40 592	37 827
31 Pipeline transport	4 059	3 652	2 410	3 322	4 464	3 938	4 694	6 230	6 699	6 693
32 Storage and warehousing	265	286	225	375	390	349	403	370	415	408
33 Communications	1 190	1 220	1 063	1 173	1 344	1 195	1 136	1 219	1 160	1 052
34 Electric power and other utilities	70 634	77 130	76 672	83 017	84 334	77 710	88 720	98 068	110 103	95 627
35 Wholesale trade	7 216	6 537	6 008	6 674	6 997	6 595	6 754	7 321	7 342	7 381
36 Retail Trade	7 930	7 528	6 937	7 498	7 766	7 551	7 309	7 575	7 476	7 756
37 Finance and Real Estate	8 121	9 038	8 967	8 295	9 620	10 665	9 068	9 110	9 301	10 797
38 Insurance	303	250	220	151	150	168	163	208	188	180
41 Business services	1 151	1 124	1 011	1 096	1 328	1 511	1 446	1 544	1 578	1 612
42 Educational services	202	214	197	229	272	229	239	241	290	324
43 Health services	1 157	1 164	1 009	1 187	1 193	1 191	1 262	1 095	1 163	1 298
44 Accommodation and food services	3 814	3 627	3 276	3 583	3 702	3 361	2 639	2 687	2 843	3 096
45 Amusement and recreational services	401	395	327	356	392	457	390	383	443	576
46 Personal and household service	1 043	1 031	867	908	939	1 029	867	808	856	1 080
47 Other service	1 481	1 401	1 313	1 428	1 605	1 689	1 712	1 788	1 857	1 794
48 Operating, office, cafeteria and laboratory supplies	65	67	76	48	46	41	33	40	37	45
49 Travel, advertising and promotion	5 458	4 651	4 300	4 807	4 534	4 698	3 592	3 687	3 201	3 755
Sub-total, service industries (32,33,35-49)	**39 797**	**38 533**	**35 796**	**37 808**	**40 278**	**40 729**	**37 013**	**38 076**	**38 150**	**41 154**
Sub-total, business sector (1-49)	**308 320**	**288 317**	**291 255**	**306 263**	**320 444**	**315 808**	**338 586**	**363 539**	**380 360**	**354 123**
Personal sector										
Home heating	45 366	47 973	37 063	38 434	39 265	38 705	33 867	37 891	41 013	38 557
Motor fuels and lubricants	46 940	44 326	41 083	40 576	42 954	43 034	45 949	49 343	52 519	51 209
Other personal sector activities	2 686	2 741	2 511	2 702	2 642	2 901	3 010	2 752	3 377	3 554
Government sector										
Hospitals	1 671	1 712	1 474	1 323	1 262	1 252	940	610	697	1 048
Education	4 771	4 681	3 871	3 723	3 368	3 205	3 174	2 767	3 201	3 818

Table 8.1
Carbon Dioxide Emissions by Sector, 1981-1990 (Concluded)

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
					kilotonnes					
Defence	3 640	3 376	2 585	2 888	2 662	2 596	1 994	2 361	2 574	2 530
Other government activities	8 073	8 037	7 048	7 632	7 920	7 988	6 824	7 132	6 424	5 612
Sub-total, personal and government sectors	**113 147**	**112 846**	**95 635**	**97 278**	**100 073**	**99 681**	**95 758**	**102 856**	**109 805**	**106 328**
Total, whole economy	**421 466**	**401 165**	**386 892**	**403 539**	**420 519**	**415 490**	**434 348**	**466 396**	**490 169**	**460 450**

Note:
The total carbon dioxide emission estimate for 1985 reported here is higher than the figure published in the previous edition of ***Environmental Perspectives: Studies and Statistics*** (Smith, 1993). This is due to revisions in the energy data that were used to derive the estimates. In particular, producer consumption of natural gas by the crude petroleum and natural gas industry is included in the current study, whereas it had been improperly excluded in the earlier study.
Source:
Statistics Canada, National Accounts and Environment Division.

atonnes in 1989. On average during this period, the business sector accounted for 76 percent of total carbon dioxide emissions. Household emissions represented 21 percent of the total on average, and government activities accounted for the remaining 3 percent.

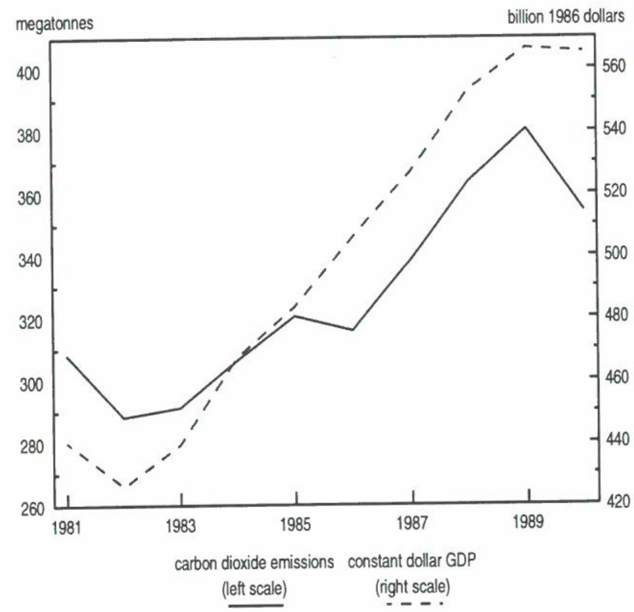
Within the business sector, the manufacturing industries (industries 8 to 28 in Table 8.1) accounted for the largest portion of carbon dioxide emissions in all years. Despite maintaining this leading position, over the period in question the manufacturing industries' share of business sector carbon dioxide emissions actually fell from 36 percent to 30 percent. The next largest contributor to business sector emissions, the electric power and other utilities industry (34), saw its share of emissions increase from 23 percent to 27 percent between 1981 and 1990. The carbon dioxide emissions from this industry are mainly the result of the use of fossil fuels, principally coal, to generate electricity in many parts of the country. The primary resource industries (1 through 7) accounted for 14 percent of emissions in 1981; this share had increased to 17 percent by 1990. The service industries (32, 33 and 35 to 49) made up 13 percent of emissions in 1981 and 12 percent in 1990. Finally, the for-hire transportation industries (truck, rail, marine, air, urban and pipeline transport) accounted for 12 and 13 percent of emissions in 1981 and 1990 respectively.[1]

Household sector[2] emissions were split fairly evenly between home heating and private transportation activities during the first half of the 1980s. In later years, however, transportation emissions dominated, as home heating emissions fell by 15 percent from 1981 to 1990. This decline was the result of decreased use of oil for home heating purposes in favour of both electricity and natural gas (Statistics Canada, 1992). Household transportation emissions fell from 1981 to 1986 by over 8 percent, but rose again by nearly 19 percent by 1990.

1. The for-hire transportation industries do not represent all transportation that takes place in the business sector. There is also transportation undertaken by businesses on their own account (private truck fleets for example). Thus, as an activity, transportation accounts for more carbon dioxide emissions than the 12-13 percent that are attributable to the for-hire industries alone.
2. The household sector includes non-profit organisations and unincorporated businesses as well as private households.

Business sector carbon dioxide emissions are plotted along with business sector constant dollar Gross Domestic Product (GDP)[3] in Figure 8.1. The figure shows a direct relationship between carbon dioxide emissions and GDP in most years. The year 1986 differs in this regard however, with carbon dioxide emissions falling while GDP was rising rapidly.

Figure 8.1
Business Sector Carbon Dioxide Emissions and Gross Domestic Product, 1981-1990



Source:
Statistics Canada, National Accounts and Environment Division.

The decline in business sector carbon dioxide emissions witnessed in 1986 was due in part to a continual shift by many industries away from petroleum and coal products to-

3. Business sector GDP is the portion of domestic production accounted for by activity in the business sector. On average, during the 1980s this portion was about 80 percent of total GDP.

Table 8.2

Business Sector Fossil Fuel Consumption, 1981-1990

Industry group	Fossil fuel type	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
		percent of total (unless otherwise noted)									
Primary resource	Coal and coke	1.0	0.9	0.9	1.0	1.3	1.6	3.8	3.8	3.4	1.8
	Petroleum products	49.1	40.0	45.8	37.2	37.3	35.0	30.3	31.9	29.7	33.8
	Natural gas	49.9	59.1	53.3	61.8	61.4	63.4	65.9	64.4	66.9	64.4
	Total fossil fuel consumption (TJ)	**644**	**628**	**733**	**701**	**721**	**772**	**831**	**890**	**937**	**923**
Manufacturing	Coal and coke	13.0	14.1	14.6	13.9	15.1	14.5	14.3	14.7	14.4	13.9
	Petroleum products	41.8	37.5	35.7	34.9	30.2	31.1	33.1	30.2	31.0	32.6
	Natural gas	45.2	48.4	49.7	51.2	54.7	54.5	52.7	55.1	54.6	53.5
	Total fossil fuel consumption (TJ)	**1 416**	**1 229**	**1 255**	**1 288**	**1 315**	**1 265**	**1 429**	**1 474**	**1 493**	**1 387**
Construction	Coal and coke	1.9	2.3	2.2	2.2	2.2	2.2	0.6	0.5	0.7	-
	Petroleum products	97.1	96.7	96.7	96.7	96.8	96.9	98.3	97.8	97.7	98.2
	Natural gas	1.0	1.0	1.1	1.1	1.0	0.9	1.1	1.6	1.6	1.8
	Total fossil fuel consumption (TJ)	**120**	**107**	**93**	**99**	**107**	**99**	**114**	**116**	**111**	**95**
For-hire transportation	Coal and coke	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
	Petroleum products	81.6	80.7	85.9	83.1	80.5	82.5	80.6	79.4	77.9	76.7
	Natural gas	18.4	19.2	14.0	16.9	19.4	17.5	19.4	20.6	22.1	23.3
	Total fossil fuel consumption (TJ)	**554**	**481**	**483**	**523**	**563**	**557**	**575**	**679**	**700**	**681**
Services	Coal and coke	-	-	-	0.1	0.1	0.1	-	-	-	-
	Petroleum products	69.0	66.4	63.4	66.3	63.0	64.0	62.5	60.5	60.5	61.8
	Natural gas	31.0	33.5	36.5	33.6	36.9	35.9	37.5	39.4	39.5	38.1
	Total fossil fuel consumption (TJ)	**661**	**645**	**621**	**656**	**676**	**675**	**623**	**646**	**657**	**714**
Electric power	Coal and coke	84.1	85.6	90.2	92.3	91.5	91.8	88.3	86.9	77.6	81.4
	Petroleum products	9.9	9.8	6.1	5.3	6.1	6.2	9.2	9.7	13.7	13.9
	Natural gas	6.1	4.6	3.7	2.4	2.4	2.0	2.5	3.4	8.7	4.7
	Total fossil fuel consumption (TJ)	**835**	**906**	**915**	**988**	**953**	**866**	**990**	**1 099**	**1 244**	**1 074**
Total business sector	Coal and coke	21.2	24.0	24.8	25.9	25.0	23.5	24.4	24.6	23.6	22.3
	Petroleum products	47.6	43.1	42.4	40.6	39.4	40.3	39.0	38.3	38.1	40.4
	Natural gas	31.2	33.0	32.8	33.5	35.6	36.3	36.6	37.1	38.3	37.3
	Total fossil fuel consumption (TJ)	**4 230**	**3 996**	**4 100**	**4 255**	**4 335**	**4 234**	**4 562**	**4 904**	**5 142**	**4 873**
Business sector GDP (billion 1986 dollars)		320	304	312	336	356	367	382	407	415	410
Fossil fuel consumption per unit of GDP (TJ per billion 1986 dollars)		13.22	13.16	13.12	12.67	12.19	11.55	11.93	12.06	12.40	11.88

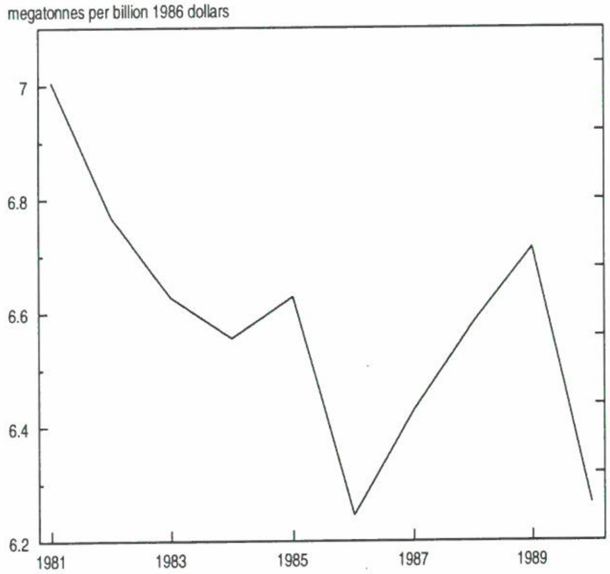
Source:
Statistics Canada, National Accounts and Environment Division.

ward natural gas between 1981 and 1986 (Table 8.2). In 1981, coal, coke and petroleum products taken together represented 68.8 percent of total business sector fossil fuel consumption; by 1986 this figure had fallen to 63.8 percent. In contrast, natural gas rose from 31.2 percent of fossil fuel consumption in 1981 to 36.3 percent in 1986. Since natural gas emits considerably less carbon dioxide per unit of energy than petroleum and coal products (Text Box 8.1), this shift in the composition of energy use exerted a downward force on carbon dioxide emissions. In 1986 this compositional shift was coupled with negative growth in total fossil fuel consumption. The result was the reduction in total carbon dioxide emissions seen for that year in Figure 8.1.

The shift away from petroleum to natural gas and the general low growth in fossil fuel demand in the middle 1980s were at least partly the results of substantial increases in the price of domestic crude oil that occurred from 1981 to 1986 (Hamilton, 1993). The move away from petroleum to natural gas actually began coincidently with a 40 percent increase in the average wellhead price of western Canadian crude oil in 1982. This price increase occurred just at the time when the economy was entering the economic recession of 1982. The combined result of these events was a fall in business sector fossil fuel consumption of 5.8 percent between 1981 and 1982 and the corresponding drop in carbon dioxide emissions shown in Figure 8.1. The recession ended in 1983, but crude oil prices continued to rise, reaching an all-time high in 1985 only to fall again by almost one half the next year. This major price reduction was responsible - along with strong economic growth - for a 21.9 percent increase in fossil fuel consumption by businesses between 1986 and 1989. As seen in Figure 8.1, business sector carbon dioxide emissions also rose very substantially between 1986 and 1989.

Figure 8.2 shows a plot of business sector carbon dioxide emissions per unit of constant dollar GDP. This ratio can be interpreted as an overall carbon dioxide intensity measure for business sector production. The figure shows a distinct contrast between the period 1981-1986, when this intensity fell by nearly 11 percent, and the period 1986-1989, when it rose again by over 7 percent. Data in the last row of Table 8.2 show that fossil fuel use per unit of GDP in the business sector followed this same trend. The fact that the fossil fuel (and carbon dioxide) intensity of overall production fell during the early years of the 1980s, when petroleum prices were rising rapidly, implies that businesses were in general able to reduce their fossil fuel consumption in order to reduce their fuel costs, while at the same time increasing their

Figure 8.2
Business Sector Carbon Dioxide Emissions per Unit of Gross Domestic Product, 1981-1990



Source:
Statistics Canada, National Accounts and Environment Division.

output. However, these reductions appear not to have been entirely maintained after the 1986 fall in petroleum prices, as the fossil fuel intensity (as well as carbon dioxide intensity) of production began to climb again after 1986. It is significant, however, that neither fossil fuel intensity nor carbon dioxide intensity had regained its level of the early 1980s by 1989. 1990 saw a fall in both of these intensities as a result of the recession that began in that year.

Carbon dioxide intensity of commodity production, 1981-1990

Table 8.3 presents carbon dioxide intensity estimates for 92 commodities or commodity groups representing the entire range of goods and services offered in the Canadian economy. Table 8.4 presents energy intensity estimates for the same group of commodities.[1,2]

The intensities shown in these two tables are measures of the *direct* and *indirect* carbon dioxide emissions (energy use) associated with one thousand dollars of production for each commodity. Direct emissions (energy use) in this context are those associated with the production of the commodity itself, while indirect emissions (energy use) are those associated with the production of the goods and services used as inputs by the commodity-producing industry. Text Box 8.2 presents a simple example to help clarify this distinction.

There are a number of factors that will influence the intensity measures for a given commodity. Most obviously, total fossil fuel consumption per unit of production has a major impact on both energy intensity and on carbon dioxide intensity. The most important factor affecting the quantity of fuel consumed per unit of production is the technology employed in making the commodity. There are two relevant aspects of a given technology in this regard. First, there is the efficiency of the energy-using equipment employed in the process. As this efficiency changes, all other things equal, so too will the carbon dioxide/energy intensity of production. Second, there is the relative importance of energy versus other inputs (labour, capital, materials) in the process. A giv-

Text Box 8.2
Direct Versus Indirect Waste Emissions

In the production of any product a certain amount of waste is created by the producing industry; this is what is referred to here as a *direct* waste output. For example, the carbon dioxide emissions from chemical plants are "direct" emissions associated with the production of industrial chemicals. The waste associated with chemical production is not just that which comes directly from chemical plants however. In order to make their products, chemical manufacturers must first purchase machinery, fuel, feedstocks and a variety of other inputs from suppliers. All of these products have waste emissions associated with their production that can be *indirectly* attributed to the chemical industry in proportion to its purchases of the products. If, for example, the chemical industry purchases 2 percent of the electric power industry's production, then 2 percent of the carbon dioxide emissions associated with electric power can be indirectly attributed to the chemical industry. Consideration of both types of emissions - direct and indirect - gives a complete picture of the waste emissions embodied in the production of products. The same distinction can be applied to energy use, or the use of any resource input for that matter (for a discussion of the water intensity of production of Canadian industries, see Chapter 7). Direct energy use is that by the industry producing a commodity; indirect energy use is that by the industries producing the inputs used by the producing industry.

1. A note of caution is in order in interpreting the data presented in Tables 8.3 and 8.4. In many instances, a given industry produces more than one commodity. For example, both grains and live animals are produced by the agriculture industry. In these cases, the intensity of the co-produced commodities will be identical (or nearly so), and will reflect the average intensity of one unit of "production" from the industry regardless of the proportion in which each of the commodities is represented in this production. In these cases, the commodities have been reported together in Tables 8.3 and 8.4.
2. The energy intensity estimates include both fossil fuel and electricity use.

Table 8.3

Carbon Dioxide Intensity of Commodity Production, 1981-1990

	Commodity	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
		tonnes per thousand 1986 dollars									
1,2	Grains and live animals	1.0957	1.0094	1.2585	0.9530	1.0068	0.9570	0.9950	1.0693	1.1250	1.0411
3	Other agricultural products	1.0933	1.0087	1.2535	0.9517	1.0057	0.9574	0.9911	1.0597	1.1130	1.0342
4	Forestry products	0.8783	0.7665	0.7192	0.6642	0.7574	0.8487	0.7645	0.7492	0.7171	0.8100
5	Fish landings	1.2608	1.2419	1.1135	1.2507	1.0762	1.0514	1.0410	1.0376	1.0805	1.0154
6	Hunting and trapping products	1.2618	1.2419	1.1134	1.2507	1.0762	1.0514	1.0410	1.0364	1.0805	1.0155
7	Iron ores and concentrates	1.3517	1.1702	1.2413	1.0813	1.0969	1.1154	1.2179	1.2662	1.2459	1.0553
8	Other metal ores and concentrates	1.4286	1.3203	1.3632	1.1895	1.2287	1.2704	1.3528	1.3322	1.3031	1.1191
9	Coal	1.3497	1.1674	1.2392	1.0782	1.0966	1.1154	1.2179	1.2665	1.2429	1.0561
10	Crude mineral oils	1.4469	1.5794	1.5138	1.5662	1.5760	1.7763	1.8481	1.7835	1.9410	1.8799
11	Natural gas	1.4473	1.5842	1.5206	1.5726	1.5837	1.7802	1.8475	1.7830	1.9401	1.8790
12	Non-metallic minerals	1.3108	1.3593	1.2837	1.2190	1.2034	1.2633	1.3310	1.3733	1.3816	1.2351
13	Services incidental to mining	0.9718	0.9366	0.8885	0.8597	0.8656	0.8597	0.9082	0.9964	0.9063	0.8038
14	Meat products	0.7832	0.7503	0.8124	0.6949	0.7032	0.6984	0.7240	0.7464	0.7768	0.7210
15	Dairy products	0.7852	0.7476	0.8139	0.6942	0.6998	0.6992	0.7252	0.7480	0.7793	0.7224
16	Fish products	0.7867	0.7494	0.8163	0.6968	0.7019	0.7010	0.7274	0.7503	0.7818	0.7246
17	Fruit and vegetable preparations	0.7803	0.7438	0.8064	0.6893	0.6941	0.6926	0.7180	0.7412	0.7691	0.7129
18	Feeds	0.7896	0.7566	0.8127	0.6947	0.6986	0.6955	0.7173	0.7379	0.7706	0.7117
19	Flour, wheat, meal and other cereals	0.7849	0.7468	0.8142	0.6943	0.7000	0.6995	0.7255	0.7481	0.7801	0.7231
20	Breakfast cereal and bakery products	0.7666	0.7248	0.7812	0.6708	0.6828	0.6806	0.6995	0.7122	0.7404	0.6897
21	Sugar	0.7849	0.7468	0.8142	0.6943	0.7000	0.6995	0.7255	0.7486	0.7798	0.7226
22	Miscellaneous food products	0.7844	0.7458	0.8092	0.6925	0.7006	0.6961	0.7197	0.7459	0.7777	0.7220
23	Soft drinks	0.6267	0.6217	0.6000	0.5759	0.5729	0.5893	0.5861	0.5711	0.5599	0.5234
24	Alcoholic beverages	0.6263	0.6209	0.5993	0.5756	0.5726	0.5891	0.5858	0.5646	0.5514	0.5155
25, 26	Tobacco and cigarettes	0.4992	0.4643	0.4852	0.4594	0.4239	0.4727	0.3901	0.3993	0.4516	0.4395
27	Tires and tubes	0.7480	0.7051	0.7081	0.6371	0.6081	0.6091	0.6178	0.5871	0.5787	0.5217
28	Other rubber products	0.7109	0.7008	0.6681	0.5971	0.5964	0.5762	0.5974	0.5704	0.5666	0.5159
29	Plastic fabricated products	0.7793	0.8066	0.7614	0.7319	0.6893	0.6649	0.6729	0.6852	0.6780	0.6155
30	Leather and leather products	0.4269	0.4045	0.3947	0.3687	0.3819	0.3514	0.3566	0.3606	0.3379	0.3135
31	Yarns and man made fibres	0.7337	0.7309	0.6767	0.6611	0.6009	0.5680	0.5892	0.6456	0.6226	0.6067
32	Fabrics	0.7245	0.7208	0.6537	0.6315	0.5754	0.5411	0.5600	0.6164	0.6076	0.5929
33	Other textile products	0.7281	0.7294	0.6609	0.6392	0.5859	0.5515	0.5717	0.6232	0.6146	0.5932
34	Hosiery and knitted wear	0.3097	0.3023	0.2990	0.2763	0.2604	0.2564	0.2558	0.2790	0.2609	0.2552
35	Clothing and accessories	0.3209	0.3126	0.3123	0.2884	0.2702	0.2662	0.2659	0.2908	0.2732	0.2641
36	Lumber and timber	0.7329	0.7067	0.6691	0.6260	0.6276	0.6323	0.6413	0.6304	0.6350	0.5945
37	Veneer and plywood	0.7217	0.6994	0.6601	0.6210	0.6236	0.6254	0.6333	0.6250	0.6234	0.5922
38	Other wood fabricated materials	0.7192	0.7060	0.6630	0.6233	0.6264	0.6316	0.6399	0.6273	0.6252	0.5941
39	Furniture and fixtures	0.4865	0.5134	0.4940	0.4642	0.4503	0.4437	0.4742	0.5044	0.5080	0.4552
40	Pulp	1.5599	1.3444	1.3915	1.3269	1.2833	1.2213	1.1893	1.2302	1.3532	1.4123
41	Newsprint and other paper stock	1.5563	1.3433	1.3873	1.3228	1.2796	1.2190	1.1873	1.2268	1.3488	1.4076
42	Paper products	1.3652	1.1851	1.2077	1.1647	1.1315	1.0896	1.0603	1.0825	1.1699	1.1965
43	Printing and publishing	0.4618	0.4330	0.4322	0.4184	0.4143	0.4096	0.4202	0.4465	0.4585	0.4355
44	Advertising and print media	0.4421	0.4187	0.4193	0.4069	0.4050	0.4034	0.4144	0.4372	0.4496	0.4261
45	Iron and steel products	2.0116	1.9941	1.9673	1.9272	1.8795	1.9219	1.8827	1.8100	1.7732	1.5551
46	Aluminum products	2.0765	2.0730	2.0669	2.0184	1.9730	2.0240	1.9813	1.9322	1.9088	1.6274
47	Copper and copper alloy products	2.0707	2.0543	2.0572	2.0062	1.9622	2.0103	1.9707	1.9336	1.9087	1.6143
48	Nickel products	2.1019	2.0725	2.0885	2.0377	1.9919	2.0395	2.0027	1.9482	1.9284	1.6521
49	Other non ferrous metal products	1.8783	1.9141	1.9351	1.8746	1.8528	1.8734	1.8360	1.7677	1.7157	1.5230
50	Boilers, tanks and plates	0.7161	0.6974	0.7331	0.7209	0.6900	0.6896	0.7243	0.7176	0.6891	0.5772
51	Fabricated structural metal products	0.9525	0.8730	0.9506	0.9651	0.9278	0.9144	0.9255	0.8918	0.8519	0.7139
52	Other metal fabricated products	0.7857	0.7751	0.8088	0.8005	0.7413	0.7629	0.8037	0.8187	0.7965	0.6693
53	Agricultural machinery	0.4509	0.4924	0.4733	0.4267	0.4225	0.4068	0.4352	0.4262	0.4231	0.3744
54	Other industrial machinery	0.5864	0.5965	0.5752	0.5538	0.5415	0.5210	0.5217	0.4756	0.4588	0.3909
55	Motor vehicles	0.3443	0.3320	0.3349	0.3254	0.3234	0.3170	0.3356	0.3135	0.3147	0.2622
56	Motor vehicle parts	0.3797	0.3797	0.3703	0.3422	0.3358	0.3330	0.3527	0.3337	0.3340	0.2811
57	Other transport equipment	0.4404	0.4230	0.4675	0.4281	0.4225	0.4107	0.4372	0.4030	0.4073	0.3492
58	Household appliances and receivers	0.5053	0.4758	0.4699	0.4686	0.4309	0.4439	0.4235	0.3776	0.3478	0.2950
59	Other electrical products	0.4824	0.4494	0.4378	0.4461	0.4043	0.4263	0.3993	0.3552	0.3187	0.2636
60	Cement and concrete products	2.8748	2.9433	2.6338	2.5744	2.4735	2.5769	2.7137	2.8027	2.8505	2.7705
61	Other non-metallic mineral products	2.7039	2.7472	2.4826	2.3878	2.2600	2.4207	2.5118	2.6189	2.6455	2.5378

Table 8.3
Carbon Dioxide Intensity of Commodity Production, 1981-1990 (Concluded)

	Commodity	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
		tonnes per thousand 1986 dollars									
62	Gasoline and fuel oil	1.8917	2.0285	2.0326	2.1526	2.1923	2.2690	2.4746	2.3925	2.4431	2.3646
63	Other petroleum and coal products	1.7981	1.9229	1.9022	1.9799	1.9827	2.0478	2.2019	2.1448	2.1855	2.1131
64	Industrial chemicals	1.8109	1.9324	1.8698	1.8814	1.8065	1.6484	1.6601	1.6920	1.5650	1.4618
65	Fertilizers	1.3141	1.1938	1.3270	1.1327	1.1558	1.1383	1.1773	1.2814	1.3127	1.1753
66	Pharmaceuticals	1.8257	1.9527	1.8865	1.8921	1.8079	1.6420	1.6565	1.7127	1.5785	1.4707
67	Other chemical products	1.7669	1.8767	1.8277	1.8237	1.7447	1.5976	1.6111	1.6548	1.5301	1.4240
68	Scientific equipment	0.5011	0.4783	0.4776	0.4586	0.4526	0.4527	0.4408	0.4220	0.4103	0.3743
69	Other manufactured products	0.6049	0.5952	0.5940	0.5853	0.5958	0.6048	0.6173	0.6312	0.6393	0.5774
70-72	Construction	0.5901	0.5436	0.5179	0.5325	0.5373	0.5167	0.5379	0.5311	0.5165	0.4591
73	Pipeline transportation	1.9041	1.8054	1.3008	1.5751	1.9082	1.7873	1.9345	2.2071	2.3779	2.2435
74	Transportation and storage	1.5603	1.4595	1.4522	1.3872	1.4420	1.4122	1.3726	1.4620	1.4945	1.4137
75-77	Radio, television, telephone and postal services	0.2155	0.2161	0.1981	0.2025	0.2086	0.1950	0.1853	0.1834	0.1685	0.1483
78	Electric power	4.5548	5.0424	4.7581	4.8571	4.6837	4.2801	4.6488	4.9916	5.4810	4.9464
79	Other utilities	4.5611	5.0397	4.7541	4.8526	4.6821	4.2803	4.6482	4.9914	5.4795	4.9468
80	Wholesale margins	0.5547	0.5531	0.5122	0.5168	0.4941	0.4599	0.4495	0.4511	0.4368	0.4220
81	Retail margins	0.4987	0.5050	0.4675	0.4695	0.4589	0.4365	0.4304	0.4381	0.4352	0.4339
82	Imputed rent, owner occupied dwellings	0.0379	0.0358	0.0323	0.0342	0.0339	0.0334	0.0362	0.0357	0.0335	0.0282
83	Other finance, insurance and real estate	0.3749	0.4274	0.4149	0.3905	0.3972	0.3905	0.3699	0.3736	0.3771	0.3893
84	Business services	0.2233	0.2214	0.2155	0.2025	0.2125	0.2100	0.1903	0.1865	0.1798	0.1789
85	Education services	0.4757	0.4632	0.4289	0.4697	0.4928	0.4552	0.4940	0.5097	0.5434	0.5235
86	Health services	0.2274	0.2303	0.2042	0.2178	0.2114	0.2062	0.2184	0.2074	0.2008	0.1962
87	Amusement and recreation services	0.3355	0.3447	0.3253	0.3110	0.3109	0.3047	0.2910	0.3047	0.3214	0.3285
88	Accommodation and food services	0.5117	0.5201	0.5126	0.5082	0.5107	0.4824	0.4551	0.4699	0.4848	0.4687
89	Other personal and miscellaneous services	0.4991	0.5010	0.4731	0.4720	0.4665	0.4567	0.4413	0.4354	0.4311	0.4236
90	Transportation margins	1.5150	1.4022	1.3906	1.3391	1.4006	1.3685	1.3249	1.4160	1.4492	1.3701
91	Operating, office, laboratory and food supplies	0.5438	0.5341	0.5265	0.5031	0.4723	0.4429	0.4449	0.4389	0.4156	0.4017
92	Travel, advertising and promotion	0.9492	0.8904	0.8595	0.8587	0.8365	0.8164	0.7311	0.7337	0.6264	0.6994

Source:
Statistics Canada, National Accounts and Environment Division.

en process can be altered within certain limits to use more or less energy to produce a given commodity. Replacing humans with robots on an automobile assembly line will change the quantity of energy consumed (and carbon dioxide released) per car produced, for example.

Not only does the absolute quantity of fuel consumed influence the carbon dioxide intensity of production but, as discussed above, so does the composition of this consumption. Thus, the declining carbon dioxide intensity of some commodities' production seen in Table 8.3 is due to switches from refined petroleum products to natural gas during the early 1980s when oil prices were very high. It is worth noting that price effects such as this will tend to shift the composition of fuel consumption toward the least-cost mixture, which is not always the least-carbon dioxide intensive mixture. It just so happened that the price of crude oil was high relative to that of natural gas during the first half of the 1980s, and, since natural gas produces less carbon dioxide per unit of energy than petroleum products, businesses shifted toward a less carbon dioxide intensive mix of energy commodities. If the reverse had been true with respect to relative energy prices, then businesses would have just as quickly moved toward a more carbon dioxide intensive mix of commodities.

It is not possible here to discuss the trends in carbon dioxide intensity for each commodity listed in Table 8.3. Much can be learned, however, from looking in detail at the data for some important semi-processed commodities that are used as inputs into a large number of finished goods. These include agricultural products (commodities 1-3 in Table 8.3), fossil fuels (9-11), wood products (36-38), pulp and paper (40-41), primary metals (45-49), cement and concrete (60), petroleum products (62-63), and electric power (78).

The carbon dioxide intensity of agricultural products moved downward from 1981 until 1986, after which it increased until 1989; a slight decrease in intensity occurred in 1990. This same pattern was seen in the production of cement and concrete, pulp and paper, and electricity. The increase in carbon dioxide intensity for these commodities subsequent to 1986 is explained by the fact that their producers stopped switching away from petroleum products after the fall in oil prices in 1986, while increasing their total consumption of fossil fuels rapidly at the same time (Statistics Canada, 1992). This resulted in an increase in the carbon dioxide intensities of production for these commodities from 1986 to 1989, although not to the levels reached in the early 1980s.

The carbon dioxide intensity of crude oil and natural gas production increased significantly over the period, due largely to increased consumption of natural gas by the

Table 8.4

Energy Intensity of Commodity Production, 1981-1990

Commodity		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
		gigajoules per thousand 1986 dollars									
1,2	Grains and live animals	18.0631	17.2113	21.2099	16.6118	16.9643	16.1801	16.5575	17.8408	18.6188	16.8603
3	Other agricultural products	18.0172	17.1799	21.1150	16.5741	16.9287	16.1684	16.4660	17.6425	18.3805	16.7204
4	Forestry products	13.4421	11.9596	11.4366	10.6177	11.5760	12.8501	11.7228	11.4594	10.8897	12.3070
5	Fish landings	18.5033	18.3388	16.8957	19.0715	15.7429	15.3098	15.3828	15.2289	15.6470	14.9649
6	Hunting and trapping products	18.5137	18.3388	16.8954	19.0715	15.7429	15.3098	15.3829	15.2208	15.6462	14.9658
7	Iron ores and concentrates	26.3168	24.2631	25.5969	22.6160	22.1662	22.6302	22.3403	23.5191	23.5105	21.2346
8	Other metal ores and concentrates	27.4283	26.5840	27.3973	23.8890	23.9769	24.4272	24.6061	24.5562	24.3151	22.5179
9	Coal	26.2875	24.2250	25.5685	22.5847	22.1680	22.6313	22.3411	23.5213	23.4507	21.2424
10	Crude mineral oils	22.4778	25.4941	25.6377	26.4715	25.4406	29.2639	31.1218	29.6138	31.9300	30.7748
11	Natural gas	22.4822	25.5556	25.7203	26.5565	25.5416	29.3084	31.1126	29.6051	31.9157	30.7606
12	Non-metallic minerals	21.8210	23.1931	22.5055	21.3979	20.3739	21.4785	22.3253	23.0472	23.3987	20.9424
13	Services incidental to mining	15.8470	15.7434	15.2458	14.7603	14.1581	14.1820	15.6928	16.9373	15.7922	13.6203
14	Meat products	13.4580	13.1245	14.4608	12.5968	12.4000	12.3493	12.7447	13.0991	13.4442	12.5220
15	Dairy products	13.5138	13.1008	14.4967	12.6028	12.3616	12.3767	12.7779	13.1359	13.4899	12.5574
16	Fish products	13.5295	13.1190	14.5185	12.6325	12.3799	12.3943	12.7991	13.1555	13.5104	12.5786
17	Fruit and vegetable preparations	13.4321	13.0372	14.3644	12.5089	12.2560	12.2519	12.6469	13.0129	13.3110	12.3946
18	Feeds	13.5318	13.1759	14.4419	12.5639	12.2975	12.2754	12.6083	12.9516	13.3258	12.3654
19	Flour, wheat, meal and other cereals	13.5102	13.0919	14.5015	12.6062	12.3656	12.3816	12.7832	13.1396	13.5024	12.5679
20	Breakfast cereal and bakery products	13.2361	12.7735	13.9768	12.2410	12.0742	12.0608	12.3606	12.6012	12.9111	12.0800
21	Sugar	13.5102	13.0919	14.5017	12.6062	12.3656	12.3816	12.7832	13.1458	13.4978	12.5624
22	Miscellaneous food products	13.4811	13.0566	14.3865	12.5235	12.3182	12.2815	12.6513	13.0548	13.4251	12.4993
23	Soft drinks	10.9299	10.8933	10.9436	10.3795	10.0440	10.2179	10.1574	9.9678	9.6822	9.2952
24	Alcoholic beverages	10.9247	10.8795	10.9314	10.3736	10.0381	10.2137	10.1504	9.8514	9.5349	9.1653
25,26	Tobacco, and cigarettes	8.8911	8.3327	9.2963	8.7618	7.9733	8.7921	7.3506	7.4329	8.1960	8.1692
27	Tires and tubes	12.9877	11.9270	12.7864	11.4752	10.5625	10.8183	11.2496	10.4724	10.3932	9.5176
28	Other rubber products	12.3649	11.8206	11.9552	10.6387	10.2867	10.2224	10.8163	10.2520	10.2388	9.4730
29	Plastic fabricated products	13.2544	13.4939	13.3700	12.4610	11.5759	11.4790	11.8984	11.8681	12.0547	10.9985
30	Leather and leather products	7.5727	7.1938	7.3533	6.8245	6.8954	6.4616	6.6062	6.6754	6.2159	5.8166
31	Yarns and man made fibres	13.3809	13.3593	12.8223	12.5718	11.0555	10.5328	11.0229	12.0067	11.6232	11.5040
32	Fabrics	13.2476	13.1778	12.5118	12.2618	10.7521	10.2044	10.6501	11.6637	11.4300	11.3698
33	Other textile products	13.2455	13.2563	12.5745	12.2775	10.8360	10.3127	10.7775	11.6881	11.4865	11.2811
34	Hosiery and knitted wear	5.6641	5.5685	5.7073	5.3166	4.9343	4.8780	4.9261	5.2907	4.9047	4.9260
35	Clothing and accessories	5.8673	5.7431	5.9516	5.5333	5.0994	5.0527	5.1084	5.4956	5.1208	5.0824
36	Lumber and timber	13.2235	13.0563	12.6651	11.8825	11.3816	11.3914	12.4584	12.0836	11.9596	10.7384
37	Veneer and plywood	12.9669	12.8991	12.3781	11.7252	11.2455	11.1476	12.2281	11.9264	11.7010	10.6954
38	Other wood fabricated materials	12.8861	12.9203	12.3729	11.6913	11.2099	11.1778	12.2024	11.8762	11.6568	10.7047
39	Furniture and fixtures	8.7861	9.4230	9.3671	8.5884	8.2470	8.0374	8.8382	9.4165	9.4048	8.7274
40	Pulp	32.5132	26.8978	34.8291	31.0289	30.1581	29.1764	27.5529	27.8303	28.8233	31.5137
41	Newsprint and other paper stock	32.3935	26.8310	34.6939	30.9184	30.0560	29.1110	27.4987	27.7412	28.7211	31.3981
42	Paper products	27.9489	23.3165	29.2933	26.5315	25.8673	25.3601	23.9650	23.8806	24.5149	26.2334
43	Printing and publishing	9.0055	8.2027	9.4986	8.7312	8.5938	8.6053	8.7674	9.1417	9.1263	9.0247
44	Advertising and print media	8.5925	7.9116	9.1644	8.4677	8.3754	8.4593	8.6353	8.9242	8.9322	8.8115
45	Iron and steel products	36.7927	37.5993	36.8900	33.5633	33.3517	32.3160	33.4957	32.2640	31.2872	31.4067
46	Aluminum products	37.9993	39.1129	38.7874	35.1514	35.0673	34.0691	35.2883	34.4358	33.6655	32.9149
47	Copper and copper alloy products	37.8707	38.7392	38.5701	34.9081	34.8124	33.7705	35.0477	34.4653	33.6631	32.6452
48	Nickel products	38.4483	39.0772	39.1563	35.4557	35.3383	34.2664	35.6194	34.7225	34.0063	33.4235
49	Other non ferrous metal products	34.0125	35.6710	35.9430	32.3368	32.6096	31.3030	32.3886	31.1749	29.8541	30.0880
50	Boilers, tanks and plates	13.1670	13.1589	13.9516	13.2652	12.5925	12.1944	13.2378	13.1146	12.5036	11.3227
51	Fabricated structural metal products	17.1510	15.9795	17.4210	16.8269	16.0718	15.2932	16.1892	15.9456	15.2096	13.8997
52	Other metal fabricated products	14.3384	14.4838	15.2497	14.4532	13.3667	13.2399	14.5055	14.8095	14.3312	13.1372
53	Agricultural machinery	8.2499	9.2986	9.0485	7.9069	7.7527	7.2397	8.0548	7.8383	7.7085	7.2907
54	Other industrial machinery	10.6671	11.1612	10.9204	10.0242	9.8280	9.1369	9.4342	8.6217	8.2722	7.5003
55	Motor vehicles	6.1228	6.0684	6.1983	5.8134	5.6514	5.4904	6.0690	5.6178	5.5979	4.9348
56	Motor vehicle parts	6.7511	6.9522	6.8562	6.1083	5.8751	5.7472	6.3713	5.9841	5.9492	5.3076
57	Other transport equipment	7.5020	7.3923	8.1589	7.3780	7.0880	6.8395	7.5126	6.8870	6.8969	6.1707
58	Household appliances and receivers	8.6617	8.7113	8.5002	7.6136	7.4568	7.0181	7.2818	6.5950	6.0750	5.4570
59	Other electrical products	8.2275	8.2250	7.9103	7.1521	6.9585	6.6127	6.7669	6.1582	5.5395	4.8722
60	Cement and concrete products	30.4005	31.0541	28.9025	28.2347	24.9045	25.8912	27.5896	28.7569	28.9673	27.1460
61	Other non-metallic mineral products	29.1256	29.6459	27.7238	26.6299	23.2462	24.6418	25.9226	27.1521	27.1229	25.1511

Table 8.4

Energy Intensity of Commodity Production, 1981-1990 (Concluded)

	Commodity	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
		gigajoules per thousand 1986 dollars									
62	Gasoline and fuel oil	28.0024	31.1210	31.8874	34.1154	33.5294	34.9465	38.4017	36.6338	37.8890	36.3380
63	Other petroleum and coal products	26.9434	29.5680	30.0617	31.1230	30.1698	31.7415	34.7341	33.3962	34.4610	32.9507
64	Industrial chemicals	25.9090	27.1812	27.3452	25.3588	24.1900	23.3039	24.0676	23.8442	23.7726	21.1792
65	Fertilizers	23.2300	21.4343	23.9571	20.8442	20.5012	19.8212	19.7958	21.2815	22.3104	20.1672
66	Pharmaceuticals	25.8679	27.1461	27.2544	25.1044	23.8345	22.9845	23.8056	23.8850	23.8068	20.9955
67	Other chemical products	25.0894	26.2099	26.4960	24.3412	23.0957	22.4186	23.1844	23.1777	23.0663	20.3645
68	Scientific equipment	8.9223	8.6455	8.9126	8.2568	8.0036	7.9324	7.9995	7.5997	7.3444	7.0027
69	Other manufactured products	10.5471	10.6928	11.0773	10.5853	10.5228	10.5638	10.9977	11.0181	11.1473	10.4074
70-72	Construction	8.9946	8.4105	8.2408	8.3571	8.1576	7.7036	8.1772	8.0527	7.7798	7.0171
73	Pipeline transportation	39.1705	36.6325	26.6888	32.5636	38.0046	35.0871	38.3954	42.9730	44.9944	43.2699
74	Transportation and storage	23.5228	22.3525	22.6480	21.7632	21.7303	21.1976	20.7311	21.8939	22.1807	21.2832
75-77	Radio, television, telephone and postal services	3.6923	3.7962	3.5209	3.6088	3.6133	3.3660	3.2555	3.2292	2.9656	2.6388
78	Electric power	62.7527	69.2618	66.4360	66.9626	62.2955	56.8966	60.7683	65.2628	72.4596	65.1867
79	Other utilities	62.8224	69.2260	66.3978	66.9098	62.2761	56.8960	60.7606	65.2493	72.4338	65.1777
80	Wholesale margins	9.0563	9.1986	8.7406	8.6865	8.1208	7.5662	7.4346	7.4300	7.1850	6.9832
81	Retail margins	9.1843	9.5542	8.9322	9.0654	8.7323	8.3260	8.2797	8.4220	8.2971	8.2696
82	Imputed rent, owner occupied dwellings	0.5914	0.5703	0.5288	0.5532	0.5308	0.5210	0.5731	0.5641	0.5278	0.4513
83	Other finance, insurance and real estate	7.0150	8.1740	7.9425	7.5762	7.5652	7.3663	7.1496	7.2413	7.1894	7.3550
84	Business services	3.7259	3.7525	3.7286	3.5248	3.6383	3.5709	3.3133	3.2507	3.1213	3.1201
85	Education services	8.9739	9.0584	8.3967	9.2885	9.5723	8.8914	9.6658	10.0867	10.6060	10.1595
86	Health services	3.7705	3.8617	3.5179	3.7579	3.5568	3.4715	3.7463	3.6177	3.4932	3.4021
87	Amusement and recreation services	6.4601	6.8029	6.4921	6.2623	6.1298	5.9885	5.9318	6.2097	6.5219	6.6183
88	Accommodation and food services	9.3554	9.7119	9.7313	9.8114	9.6612	9.1919	8.7894	9.0125	9.1577	8.8399
89	Other personal and miscellaneous services	8.4558	8.6737	8.3105	8.3091	8.0305	7.8373	7.7091	7.6176	7.4730	7.3172
90	Transportation margins	22.8394	21.4750	21.6860	21.0080	21.1065	20.5411	20.0109	21.2056	21.5087	20.6262
91	Operating, office, laboratory and food supplies	9.1934	8.9572	9.3529	8.6748	8.0766	7.6180	7.7516	7.6029	7.2375	7.1451
92	Travel, advertising and promotion	15.1523	14.3779	14.4023	14.3767	13.5518	13.2157	11.9787	11.9426	9.9739	11.4172

Source:
Statistics Canada, National Accounts and Environment Division.

crude petroleum and natural gas industry.[1] This increase was in turn a result of the nearly 69 percent increase in natural gas production that occurred during the 1980s.

Wood products experienced a decline in carbon dioxide intensity over the period in question. This was a result both of a shift away from petroleum products toward natural gas by the wood products industry and an overall decline in the energy intensiveness of wood products (Table 8.4).

The carbon dioxide intensities of the primary metal products fell steadily from 1981 to 1990. The same result was seen for the energy intensities of these commodities (Table 8.4), although the declines in carbon dioxide intensities were greater than those for the energy intensities (21 percent on average versus 14 percent on average respectively from 1981 to 1990). Part of the reduction in carbon dioxide intensity for these commodities was the result of the overall reduction in their energy intensity seen in Table 8.4; the remainder was due to shifts in the composition of energy consumption by this industry toward a less carbon dioxide intensive mix.

1. Natural gas consumption by this industry includes gas that is flared in the field and at processing plants, gas used for energy purposes in the gathering system and at processing plants, and gas otherwise used in the production processes of this industry.

Carbon dioxide intensity of final consumption

Since the production of goods and services takes place to meet demand for final consumption, it is reasonable to ask what portion of industrial carbon dioxide emissions are attributable to the production required to meet the demand from different final consumption categories.[2] Table 8.5 shows such a breakdown of industrial carbon dioxide emissions.[3] The first line in Table 8.5, for example, presents the carbon dioxide emissions from the business sector that are due to the production of commodities to meet the demand from households and non-profit organisations (personal consumption). Given that personal consumption makes up the largest category of final consumption, it is not surprising to see that it was responsible for the greatest portion of industrial carbon dioxide emissions in each year between 1981 and 1990.

2. Final consumption includes the current expenditures of households, governments and non-profit institutions, as well as investment in fixed capital formation, additions to inventories of goods, and exports.
3. It must be emphasized that the figures shown in Table 8.5 are the emissions associated with the production activity required to meet the demand for commodities from final consumption categories. They do not represent the emissions associated with the consumption of these commodities once they have been purchased. The latter were shown in Table 8.1 under household and government headings.

Table 8.5
Industrial Carbon Dioxide Emissions by Final Demand Category, 1981-1990

Final demand category	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
					kilotonnes					
Personal expenditure	122 525	122 774	122 945	124 460	129 477	132 494	138 505	150 086	156 781	151 059
Government current expenditure	21 089	21 859	21 292	21 120	21 932	22 308	23 560	25 340	26 217	25 130
Fixed capital formation	50 656	43 509	40 001	40 726	44 014	42 594	47 993	50 565	51 553	45 132
Exports	108 449	98 057	103 956	115 394	121 682	114 717	124 620	130 639	139 906	125 062
Other	5 602	2 117	3 063	4 562	3 339	3 695	3 912	6 908	5 905	7 738
Total business sector emissions	**308 320**	**288 317**	**291 255**	**306 263**	**320 444**	**315 808**	**338 586**	**363 538**	**380 360**	**354 123**
Imports	79 308	63 693	67 180	76 856	81 626	83 581	91 430	103 718	116 406	99 021

Source:
Statistics Canada, National Accounts and Environment Division.

Some explanation is required for the row labelled "imports" in Table 8.5. The emissions reported in this row are not the actual emissions that occurred in other countries during the production of Canada's imported commodities. Rather, they represent the emissions that would have occurred in Canada had we produced domestically this group of commodities. The assumption implicit in these estimates is that foreign industries emit the same quantity of carbon dioxide in producing one unit of a particular commodity as do Canadian industries.[1] The results reported in Table 8.5 indicate that Canada exported a more carbon dioxide intensive set of goods and services than it imported in all years considered in this study.

Table 8.6 reports the same data as Table 8.5, but per unit of expenditure rather than in absolute terms. When considered from this perspective, the export category of final consumption was the most carbon dioxide intensive in all years. This means that we emitted more carbon dioxide in producing one dollar's worth of our exports than was the case for any other category of final demand. Over the period considered, there were steady declines in the carbon dioxide intensity of all categories of final demand, from 6 percent for government current expenditure to nearly 27 percent for fixed capital formation. There are a number of possible reasons for this decline, several of which have been discussed above with respect to the carbon dioxide intensity of production activity. Aside from the reasons mentioned above, the carbon dioxide intensity of expenditure can also fall as a result of shifts in expenditure away from commodities that are relatively carbon dioxide intensive toward those that are less so. Another phenomenon that is certain to have contributed to the declines shown in Table 8.6 was the increase between 1981 and 1990 in the percentage of our domestic consumption met by imported goods and services. During this period imports rose steadily from 23.6 percent to 30.3 percent of domestic consumption. Since the production of our imported goods does not result in any domestic carbon dioxide emissions, increasing import levels led to declining carbon dioxide intensity of domestic consumption.

1. This assumption is reasonable given that most Canadian external trade is with the United States where the technological structure is very similar to that in Canada.

Conclusion

The data presented in this chapter indicate that the carbon dioxide emissions are closely tied to the overall level of economic activity (as measured by GDP) and are substantially affected by the prices of energy commodities. While petroleum prices were high during the first half of the 1980s, the carbon dioxide intensiveness of the business sector overall, as well as that of many individual commodities, declined significantly. With the fall of oil prices in 1986, carbon dioxide intensities began to rise again for the business sector, and for many commodities, although they did not regain the

Table 8.6
Carbon Dioxide Intensity of Final Demand, 1981-1990

Final demand category	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
					kilotonnes					
Personal expenditure	0.5079	0.5038	0.4848	0.4694	0.4653	0.4454	0.4453	0.4620	0.4657	0.4447
Government current expenditure	0.2081	0.2108	0.2031	0.1988	0.2001	0.1976	0.2044	0.2109	0.2113	0.1965
Fixed capital formation	0.4911	0.4792	0.4469	0.4487	0.4435	0.4194	0.4261	0.4075	0.3926	0.3564
Exports	1.0238	0.9536	0.9506	0.8964	0.8932	0.8544	0.8942	0.8656	0.9228	0.8095
Other	0.6212	0.4074	0.5209	0.4453	0.3480	0.3511	0.4342	0.5420	0.4964	0.5234
Imports	0.7422	0.7015	0.6843	0.6739	0.6659	0.6267	0.6410	0.6375	0.6828	0.5668

Source:
Statistics Canada, National Accounts and Environment Division.

levels seen in the early 1980s. The latter point means that the Canadian economy became more efficient in its use of the environment to absorb carbon dioxide emissions over the decade of the 1980s. However, the fact that there was an upward trend in intensiveness in the late 1980s suggests that some of these efficiency gains may have been temporary. Future energy consumption and carbon dioxide emission data developed at Statistics Canada will make it possible to determine if this was the case.

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9 Government Expenditures on Environmental Protection

by Anik Lacroix

Introduction

In the four years since the Green Plan[1] was launched by the Government of Canada in 1991, Statistics Canada has been involved in developing a system of environmental and natural resource accounts[2] that will be satellite components of the Canadian System of National Accounts. One of these accounts is aimed at highlighting the costs related specifically to environmental protection for each economic sector; governments, businesses and households.

This chapter presents the results of the first detailed analysis of environmental protection expenditures by federal, provincial/territorial and local governments during the 1965-1994 period. Such expenditures include, on the one hand, those aimed specifically at preventing or reducing the emission of wastes and pollutants generated by economic activity (pollution abatement and control expenditures (PAC)) and, on the other, expenditures aimed at protecting land (e.g. expenditures for parks), sub-soil resources, forests, water resources, fauna and fish.

The classification system of public government expenditures in Canada does not permit a breakdown between natural resource conservation activities and those aimed at developing the resources. As a result available conservation expenditure data relate to both natural resource conservation and development. Also, at the time of writing, park expenditure data were only available for provincial/territorial governments. Federal government data on park expenditures exist but have not been reconciled with the conceptual framework of environmental protection expenditures. Therefore, these limitations should be borne in mind when interpreting the results. The data presented in this article are collected by Statistics Canada from administrative sources and from surveys. The appendix provides a list of concepts used and a description of existing data.

1. The Canadian Green Plan is a government initiative over many years that comprises a number of actions aimed at protecting health and the environment, ensuring sustainable development of forestry, agricultural, fishing and water resources, and at protecting wildlife and its habitat, as well as providing comprehensive statistics on the environment in Canada.
2. This system of satellite accounts will consist of a Natural Resource Stock Account, a Natural Resource Use Account, a Waste Output Account and an Environmental Protection Expenditure Account.

Consolidated government expenditures on environmental protection[3]

In fiscal year 1991/92[4], consolidated capital and current expenditures of federal, provincial/territorial and local governments on environmental protection were estimated at $18 billion or 3 percent of gross domestic product (GDP), compared with $15 billion in 1988[5] (2.5 percent of GDP). From this total, $4.75 billion were spent to finance PAC activities in 1991; $13.3 billion were spent to finance natural resource conservation and development activities (see Table 9.2). These figures exclude expenditures for parks.

Government investment in pollution abatement and control, 1985-1992

Of all government capital expenditures on environmental protection and resource development made in 1992 (calendar year), $1.4 billion or 11 percent were in PAC activities, waste disposal facilities, sewage systems and sanitation equipment, according to the results of the Capital and Repair Expenditure Survey. These results are summarized in Table 9.1 (see the Appendix for a list of the categories). Between 1985 and 1992 investment in environmental protection increased at an average annual rate of 6 percent, which is more than double that of all government investment combined. Eighty-five percent of the investment related to PAC in 1992 was made by local governments and was for the installation of sewage systems. Investment in sewage system construction represented almost 9 percent of total government investment in 1992. In comparison, investment in waste disposal facilities accounted for close to one percent of total government investment between 1986 and 1992.

3. These expenditures exclude transfer payments between governments *for pollution abatement and control (PAC) and natural resource conservation and development.*
4. Unless otherwise indicated, years referred to here are fiscal years.
5. Data on consolidated expenditures for PAC and natural resource conservation and development are only available for 1988-1991 fiscal years. Historical data exist at the consolidated level however they include water supply expenditures, tourism, trade and industrial development expenditures as well as expenditures for water power. See Appendix.

Table 9.1

Consolidated Capital and Repair Expenditures by Governments on Environmental Protection, 1985-1992 (Calendar Year)

	1985[1]	1986	1987	1988	1989	1990	1991	1992
	thousand dollars							
Pollution abatement & control - Construction	x	40 182	26 901	42 973	68 175	134 261	137 514	141 792
Waste disposal facilities	x	81 457	85 217	90 698	96 439	134 026	100 638	140 543
Sewage systems								
Sewage treatment & disposal plants	666 098	240 154	431 732	378 508	587 117	668 391	555 576	530 034
Sanitary & storm sewers	302 567	676 466	520 995	627 583	560 745	721 959	564 282	578 313
Other sewage system construction[2]	4 369	6 180	12 228	11 049	25 363	7 116	12 840	3 277
Total sewage system construction	973 034	922 800	964 955	1 017 140	1 173 225	1 397 466	1 132 698	1 111 624
Pollution abatement & control equipment	5 728	x	x	x	x	x	43 680	23 408
Sanitation equipment[3]	1 817	19 882	15 694	15 925	27 964	61 210	5 286	7 928
Total government investment in environmental protection	**999 903**	**1 064 321**	**1 092 767**	**1 166 736**	**1 365 803**	**1 726 963**	**1 419 816**	**1 425 295**
Federal government	29 501	40 819	54 424	48 902	61 867	55 288	72 307	99 782
Provincial governments	67 331	56 715	32 213	45 094	38 700	60 314	60 723	79 239
Local governments	903 071	966 787	1 006 130	1 072 740	1 265 236	1 611 361	1 286 786	1 246 274
Total government investment in environmental protection	**999 903**	**1 064 321**	**1 092 767**	**1 166 736**	**1 365 803**	**1 726 963**	**1 419 816**	**1 425 295**
	As a percentage of total government investment							
Total government investment in environmental protection	9	10	11	10	11	12	11	11

Notes:
1. In 1985 local government expenditures for machinery and equipment were excluded.
2. Also includes investment in lagoon construction; in 1992 data on investments in lagoons and other sewage construction were available separately (respectively $2,905,000 and $372,000).
3. Combined PAC equipment and sanitation equipment expenditures from 1986 to 1990, because of confidentiality.

Sources:
Statistics Canada, Investment and Capital Stock Division and Public Institutions Division (local government expenditures).

Consolidated provincial/territorial and local government expenditures in 1991[1]

Consolidated capital and current expenditures by provincial/territorial and local governments related to PAC, natural resource conservation and development and the development of parks were $12.6 billion in 1991 and accounted for 6 percent of total consolidated expenditures by these governments in Canada[2].

Pollution abatement and control expenditures[3]

As shown in Table 9.2 consolidated expenditures of provincial/territorial and local governments on PAC, the bulk of government expenditures on PAC in Canada, were $4 billion in 1991; this represented 2 percent of total consolidated expenditures of the two levels of government. The main targets were sewage disposal (48 percent of PAC expenditures) and waste treatment (32.5 percent of PAC expenditures). However, expenditures on sewage treatment declined significantly in importance since 1988 when they accounted for more than half of PAC expenditures, in favour of expenditures on other environmental services.

Natural resource conservation and development expenditures[4] and expenditures for parks

Consolidated capital and current expenditures for natural resource conservation and development represented 4 percent of total consolidated expenditures by provincial/territorial and local governments in 1991, twice as much as PAC expenditures. Development and conservation of agriculture consumed $4.2 billion or 50 percent of the expenditures allocated for resource conservation and development. The development and conservation of forests and mines and other activities such as energy conservation or management of Crown land, accounted for expenditures of over $1 billion each. Expenditures on game and fish accounted for approximately $300 million. In Newfoundland and the Northwest Territories, most conservation and development expenditures were on mines, oil and gas, while in British Columbia and Nova Scotia forestry expenditures were dominant.

The development and operation of parks accounted for the smallest share of total consolidated expenditures by provincial/territorial governments in 1991 as well as in 1988.

1. Includes consolidated provincial/territorial government expenditures for parks.
2. Total consolidated government expenditure data are available through the Public Institutions Division and in Statistics Canada, ***Public Finance, Historical Data 1965/66-1991/92 Financial Management System***, Cat. No. 68-512, May 1992.
3. These are expenditures earmarked for the following activities: sewage treatment, waste treatment, other activities to abate and control air, soil and groundwater pollution (pollution control category) and other environmental services such as administration of an environment department. See Appendix for more detail.
4. These are expenditures associated with the development and conservation of the following resources: agriculture, fish and game, forests, mines, oil and gas and other activities such as the administration of Crown land and energy conservation. See Appendix for more detail.

Table 9.2

Consolidated Capital and Current Expenditures Made by Governments for Environmental Protection by Province, 1991 (Fiscal Year)

	Canada	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Yukon	N.W.T.
	thousand dollars												
Consolidated federal/provincial/local government expenditures[1]													
Pollution abatement and control	4 747 032	...	...	...	...	...	...	...	...	...	...	...	...
Natural resource conservation & development[2]	13 305 830	...	...	...	...	...	...	...	...	...	...	...	...
Consolidated provincial/local government expenditures													
Pollution abatement and control													
Sewage collection and disposal	1 955 541	19 420	2 580	63 210	42 898	537 628	838 006	55 495	37 426	146 430	192 799	5 329	14 320
Waste collection and disposal	1 321 232	14 444	3 808	53 844	20 732	267 306	635 900	29 608	18 001	107 937	164 894	864	3 893
Pollution control	265 261	2 956	348	6 103	3 420	-	179 066	746	29 730	42 131	-	-	759
Other environmental services[3]	517 544	1 826	1 490	5 575	19 468	169 533	73 024	10 984	119 213	11 785	103 934	590	122
Total pollution abatement and control	4 059 578	38 646	8 226	128 732	86 519	974 467	1 725 997	96 833	204 368	308 283	461 627	6 784	19 094
Natural resource conservation & development													
Agriculture	4 215 937	15 108	42 418	35 782	39 284	814 655	489 258	459 687	1 144 993	1 073 133	101 006	491	121
Fish and game	335 781	34 140	4 062	7 628	21 611	96 462	85 151	8 538	10 819	31 457	21 921	5 796	8 197
Forests	1 537 011	26 602	6 722	50 064	30 629	310 061	293 912	12 483	81 156	126 184	571 995	848	26 356
Mines, oil and gas	1 167 788	42 329	-	11 567	2 871	78 486	41 690	10 950	316 613	531 617	81 028	1 331	49 308
Other	1 080 652	4 622	5 562	10 429	34 282	150 055	433 042	42 326	30 233	222 741	120 116	6 701	20 544
Total conservation & development	8 337 169	122 801	58 763	115 469	128 676	1 449 719	1 343 053	533 984	1 583 813	1 985 131	896 066	15 167	104 526
Parks[4]	204 624	6 644	3 654	6 838	9 450	32 569	57 214	16 285	15 449	27 559	28 550	412	-

Notes:
Figures may not add due to rounding.
Data provided for fiscal years.
1. Excludes expenditures for parks because data are not available.
2. Estimates from the National Accounts and Environment Division.
3. Local government expenditures for other pollution abatement and control may include expenditures for both pollution control and other environmental services.
4. Include only expenditures for parks by provincial/territorial governments.

Source:
Statistics Canada, Public Institutions Division.

Expenditures by level of government, 1965-1994

PAC expenditures

As Table 9.4 reveals, local governments[1] are responsible for most government PAC expenditures in Canada. In 1991, they spent $3.2 billion on PAC and a total of $3.7 billion was earmarked for 1993. By comparison, consolidated PAC expenditures made by federal and provincial/territorial governments were each less than one billion dollars in 1991.

Local governments devote a larger portion of their budgets to PAC than the other levels of governments. In the early 1990s, however, the portion of their budgets devoted to PAC was no larger than that of the 1960s (5 percent). In contrast, federal and provincial/territorial governments devoted less than one percent of their budgets to PAC.

Between 1965 and 1983, local government PAC expenditures in constant dollars[2] (see Table 9.3) increased at the average annual rate of 2.5 percent. The growth rate more than doubled between 1983 and 1993 to 6 percent a year on average (this rate is higher than the rate of increase of total local government expenditures).

In general provincial/territorial government PAC expenditures in constant dollars increased markedly from 1970 to 1991, with growth rates often exceeding15 percent. In comparison, total expenditures by these governments increased less during these years.

Federal government PAC expenditures in 1986 dollars also increased markedly from 1970 to 1994, at an average annual rate of 26 percent. This rate was much higher than the 4 percent registered for federal government expenditures as a whole for that period.

Local governments

Table 9.4 shows that local governments are mainly responsible for sewage treatment ($2.2 billion in 1993) and for waste disposal ($1.4 billion in 1993). These activities are partly financed by provincial/territorial government transfers as will be seen later on. The portion of sewage treatment in PAC expenditures declined from 73 percent to 60 percent

1. Local government expenditures exclude inter-municipal transfers.

2. Growth rates of the various categories of expenditures in constant dollars are calculated from estimations at 1986 prices, which are made by applying the implicit price index of total government expenditures. The index for Canada is presented in Table 9.9 from 1965 to 1994. Provincial estimates in constant 1986 dollars are available since 1971 (since 1977 for the territories).

Table 9.3

Expenditures for Pollution Abatement and Control by Level of Government, 1965-1994 (Fiscal Years)

Year	Federal	Provincial/territorial	Local
	thousand 1986 dollars		
1965-66	..	..	1 164 119
1966-67	..	..	1 192 934
1967-68	..	..	1 296 202
1968-69	..	..	1 332 146
1969-70	..	..	1 218 960
1970-71	30 136	50 545	1 180 471
1971-72	73 907	114 576	1 311 940
1972-73	317 110	243 484	1 428 832
1973-74	725 179	318 573	1 651 180
1974-75	693 397	..	1 730 002
1975-76	659 679	299 504	1 858 026
1976-77	627 785	290 250	2 107 822
1977-78	600 053	277 096	2 086 988
1978-79	715 338	263 974	1 919 721
1979-80	580 257	332 487	1 865 530
1980-81	502 859	469 290	1 963 645
1981-82	454 807	544 576	1 852 088
1982-83	544 977	378 703	1 681 456
1983-84	538 697	379 072	1 746 082
1984-85	523 586	569 983	1 625 214
1985-86	433 644	..	1 671 661
1986-87	445 727	..	1 842 685
1987-88	481 242	..	1 942 980
1988-89	493 656	486 966	2 147 721
1989-90	546 502	599 540	2 465 506
1990-91	588 406	747 579	2 736 272
1991-92	582 512	885 214	2 703 442
1992-93[1]	579 549	..	2 928 412
1993-94[2]	602 090	..	2 997 882
1994-95[3]	745 226	..	..

Notes:
Figures represent non consolidated current and capital expenditures.
Expenditures in 1986 dollars have been estimated using the implicit price index of total government expenditures.
Figures may not add due to rounding.
1. In 1992-93 local government data are estimates.
2. In 1993-94 federal government data are revised estimates while local government data are preliminary estimates.
3. In 1994-95 federal government data are estimates.
Sources:
Statistics Canada, National Accounts and Environment Division and Public Institutions Division.

between 1965 and 1993, while the portion of expenditures on waste collection and disposal increased. Expenditures on waste collection and disposal represented close to 40 percent of local government PAC expenditures in 1993 compared to 25 percent in 1965. Expenditures for other environmental services[1] made up 3 percent of local government PAC expenditures in 1993 and were financed mainly by provincial/territorial transfers.

The most recent data from the Survey of Local Government Waste Management Practices[2] show that, in 1993, waste collection was mainly contracted out. Also, part of local government waste treatment expenditures was used to purchase recycling services, since almost 70 percent of the municipalities surveyed declared having such programmes. In British Columbia for instance, an integrated solid waste management strategy was adopted ("Reduce, Re-use and Recycle") to finance assistance programmes destined for municipalities. Other waste management activities financed by municipalities in Canada in 1993 included hazardous waste, compost collection and public education programmes and studies on waste composition.

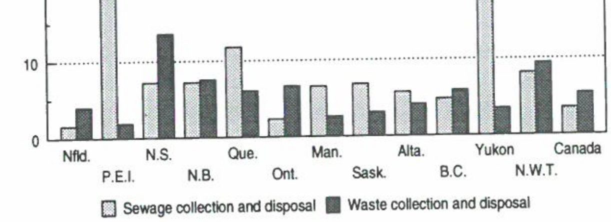
Waste disposal expenditures by local governments in 1986 dollars had an average annual growth rate of 5 percent between 1971 and 1993, as shown in Figure 9.1. This rate was higher than the rate of increase of total local government expenditures in Canada (3 percent). Expenditures on sewage disposal increased at an average annual rate of 3.5 percent since 1971. This translated into more municipal sewage facilities, particularly tertiary treatment facilities[3]. The Canadian population serviced by municipal wastewater treatment facilities increased from 72 percent to 84 percent between 1983 and 1991. In Prince Edward Island the average annual growth rate was over 40 percent since 1971 as shown in Figure 9.1.The real growth of waste and sewage collection

1. Local government expenditures for other environmental services may also include expenditures specific to pollution control.
2. See article by M. Cameron, in this issue, Chapter 3.

3. Figures obtained from ***Human Activity and the Environment 1994***, Cat. No. 11-509E, Table 4.2.2, p. 191.

Figure 9.1

Average Annual Rate of Growth of Local Government Expenditures for Sewage and Waste Collection and Disposal in 1986 Dollars, by Province, 1971-1993.



Notes:
Estimates in 1986 dollars were calculated from implicit price indices of total government expenditures (current and capital), for each province and for Canada as a whole.
In P.E.I. changes in local government expenditures for sewage collection and disposal were highly irregular.
Sources:
Statistics Canada, National Accounts and Environment Division and Public Institutions Division.

Table 9.4

Expenditures for Pollution Abatement and Control by Level of Government, 1965-1994 (Fiscal Years)

Year	Federal				Provincial/territorial					Local			
	Sewage disposal[4]	Pollution control	Other environmental services	Total PAC	Sewage disposal[4]	Waste disposal[4]	Pollution control	Other environmental services	Total PAC	Sewage disposal[4]	Waste disposal[4]	Other environmental services[5]	Total PAC
	thousand dollars												
1965-66	..	..	..	..	..	..	..	..	..	176 115	60 931	2 783	239 829
1966-67	..	..	..	..	..	..	..	..	..	193 563	66 894	3 096	263 553
1967-68	..	..	..	..	..	..	..	..	..	221 624	75 794	3 744	301 162
1968-69	..	..	..	..	..	..	..	..	..	238 156	81 667	4 021	323 844
1969-70	..	..	..	..	..	..	..	..	..	235 598	79 164	3 654	318 416
1970-71	8 297	-	-	8 297	-	-	10 227	3 689	13 916	240 072	81 272	3 664	325 008
1971-72	15 135	-	6 487	21 622	-	-	25 543	7 977	33 520	270 755	108 357	4 704	383 816
1972-73	27 097	-	72 296	99 393	-	-	62 455	13 861	76 316	325 260	117 707	4 877	447 844
1973-74	39 239	18 452	186 724	244 415	-	-	77 192	30 180	107 372	418 857	131 498	6 160	556 515
1974-75	32 049	23 273	213 472	268 794	..	..	..	..	..	490 109	169 751	10 772	670 632
1975-76	52 678	25 307	211 446	289 431	-	-	72 591	58 815	131 406	569 483	229 544	16 173	815 200
1976-77	73 734	28 596	204 468	306 798	-	-	87 080	54 765	141 845	763 087	245 144	21 859	1 030 090
1977-78	48 552	33 263	235 096	316 911	-	-	69 293	77 052	146 345	792 146	282 594	27 478	1 102 218
1978-79	113 914	36 258	254 949	405 121	-	-	69 916	79 582	149 498	725 503	315 782	45 921	1 087 206
1979-80	84 006	30 162	245 503	359 671	-	-	80 011	126 080	206 091	772 367	329 051	54 926	1 156 344
1980-81	69 378	35 474	238 001	342 853	-	-	102 991	216 974	319 965	890 198	390 894	57 735	1 338 827
1981-82	38 446	40 190	271 318	349 954	-	-	300 329	118 698	419 027	965 935	408 923	50 241	1 425 099
1982-83	50 421	44 742	370 909	466 072	-	-	193 034	130 838	323 872	938 213	456 641	43 150	1 438 004
1983-84	16 661	56 249	413 285	486 195	-	-	157 938	184 189	342 127	996 524	528 306	51 076	1 575 906
1984-85	12 986	58 649	419 697	491 332	-	-	148 832	386 039	534 871	967 211	514 442	43 445	1 525 098
1985-86	2 284	55 941	363 908	422 133	..	..	..	..	..	992 875	564 362	70 051	1 627 288
1986-87	-	61 983	383 744	445 727	..	..	..	..	..	1 138 023	627 753	76 909	1 842 685
1987-88	-	67 297	430 794	498 091	..	..	..	..	..	1 208 602	714 493	87 911	2 011 006
1988-89	-	87 142	442 869	530 011	77 526	54 022	226 639	164 641	522 828	1 413 609	817 079	75 200	2 305 888
1989-90	-	113 085	497 185	610 270	72 412	114 495	280 066	202 524	669 496	1 734 756	935 818	82 615	2 753 189
1990-91	-	118 855	571 471	690 326	75 327	125 943	296 300	379 501	877 071	2 001 997	1 125 905	82 331	3 210 233
1991-92	-	20 221	682 955	703 176	100 597	160 863	341 901	465 220	1 068 580	1 954 272	1 228 222	80 949	3 263 443
1992-93[1]	150	4 329	709 679	714 158	..	..	..	..	..	2 126 725	1 389 774	92 083	3 608 582
1993-94[2]	275	1 004	749 906	751 185	..	..	..	..	..	2 236 357	1 406 330	97 558	3 740 245
1994-95[3]	-	5 870	929 389	935 259	..	..	..	..	..	..	..	..	..

Notes:
Figures represent non consolidated current and capital expenditures.
Figures may not add due to rounding.
Data are expressed on a Financial Management System basis.
For a breakdown of provincial and local government expenditures see Annex, Table 13.
1. In 1992-93 local government data are estimates.
2. In 1993-94 federal government data are revised estimates while local government data are preliminary estimates.
3. In 1994-95 federal government data are estimates.
4. Includes collection expenditures as well.
5. May also include expenditures specific to pollution control.

Sources:
Statistics Canada, ***Federal Government Finance***, Cat. No. 68-211; ***Provincial Government Finance - Revenue and Expenditure***, Cat. No. 68-207 and Public Institutions Division.

and disposal expenditures accelerated between 1983 and 1993 compared with the growth over the 1971-1983 period. The average annual growth rate of sewage expenditures increased from 2 to 5 percent between the two periods while the average annual growth rate of waste expenditures increased from 4 to 7 percent. Expenditures on other environmental services saw their average annual growth rate decline from 14 to 5 percent between the 1971-1983 and 1983-1993 periods. This attests to an increasing focus of local government activities on waste disposal and sewage treatment.

Between 1983 and 1993, local governments were allocating more for the maintenance of PAC infrastructure and equipment than for PAC investment. Since the beginning of the 1990s current expenditures of local governments were twice as high as capital expenditures (see Table 9.5). However, most sewage treatment expenditures were for capital. Capital expenditures on PAC represented 14 percent of total municipal investment in Canada in 1993. Current expenditures on PAC represented less than 4 percent of total current expenditures.

Federal government

As shown in Table 9.4, federal government PAC expenditures made at the beginning of the 1990s were almost entirely on other environmental services such as Environment Canada's administrative services, environmental assessments and in 1994, elements of the federal government's infrastructure programme. A much lower amount was allotted specifically for pollution control. In earlier years the federal government was also involved in financing sewage treatment systems. Federal transfers to provincial/territorial and local governments have declined considerably since the 1970s relative to other types of PAC expenditures. In 1970-71, these transfers were the only means of financing PAC expenditures while in 1991-92, they accounted for less than 3 percent of all federal PAC expenditures.

Federal government PAC expenditures are mostly directed to implementing and applying environmental protection legislation (e.g. Canadian Environmental Protection Act, Fisheries Act). Environment Canada shares the responsibility of most federal PAC programmes. Some of these include the St. Lawrence River Action Plan, the Great Lakes Action Plan, the National Contaminated Sites programme, research on global change (e.g., research on the greenhouse effect), etc.

Provincial and territorial governments

From 1970 to the mid 1980s, provincial/ territorial PAC expenditures were only made for specific pollution control activities and for other environmental services. The relative importance of both activities varies from year to year but, in general, the share of expenditures on other environmental services increased considerably, from 26.5 percent in 1970 to 72 percent in 1984. This was at the expense of specific pollution control expenditures which saw their share of total PAC expenditures decline in the same proportions. Therefore, it seems that between 1970 and 1984, provincial/territorial governments gradually turned away from specific pollution control programmes toward more general activities such as environmental assessments, the administration of the environment departments, etc.

Statistics on expenditures for waste treatment and sewage disposal activities were first available in 1988 as shown in Table 9.4. However, expenditures for sewage disposal saw their share of PAC expenditures decrease between 1988 and 1991 (from 15 percent to 9 percent) and only British Columbia, New Brunswick, Nova Scotia and the Yukon have spent money on sewage treatment for the past three or four years.[1] The governments of Quebec, Saskatchewan and the Northwest Territories had no expenditures for waste

Table 9.5

Detail of Total Provincial/Territorial and Local Government Expenditures for Pollution Abatement and Control, 1991-92

	Sewage collection and disposal		Waste collection and disposal		Pollution control		Other PAC		Total PAC	
	thousand dollars	share of total (%)	thousand dollars	share of total (%)	thousand dollars	share of total (%)	thousand dollars	share of total (%)	thousand dollars	share of total (%)
PROVINCIAL/TERRITORIAL										
Current expenditures on goods & services	234	0.2	27 798	17.3	221 542	64.8	241 683	52.0	491 256	46.0
Capital expenditures	573	0.6	2 376	1.5	7 390	2.2	12 312	2.6	22 651	2.1
Other expenditures on goods & services	-	-	26 616	16.5	1 051	0.3	64 094	13.8	91 762	8.6
Transfer payments to persons	463	0.5	1 911	1.2	5 582	1.6	19 966	4.3	27 922	2.6
Transfer payments to business	-	-	3 862	2.4	7 358	2.2	31 531	6.8	42 751	4.0
Transfer payments to municipalities	99 328	98.7	66 274	41.2	76 640	22.4	28 625	6.2	270 867	25.3
Transfer payments to schools	-	-	638	0.4	-	-	-	-	638	0.1
Transfer payments to hospitals	-	-	940	0.6	-	-	-	-	940	0.1
Expenditure reconciliation and integration	-	-	27 434	17.1	-	-	5 840	1.3	33 274	3.1
Revenue/receipts offset against expenditure	-	-	-	-	-102	-	-662	-0.1	-765	-0.1
Adjustments[1]	-	-	3 013	1.9	22 440	6.6	61 829	13.3	87 282	8.2
Total provincial/territorial	**100 597**	**100.0**	**160 863**	**100.0**	**341 901**	**100.0**	**465 220**	**100.0**	**1 068 580**	**100.0**
LOCAL										
Current expenditures on goods & services	892 546	45.7	1 068 407	87.0	-	-	66 222	81.8	2 027 180	62.1
Capital expenditures	1 061 726	54.3	159 815	13.0	-	-	14 727	18.2	1 236 270	37.9
Total local	**1 954 272**	**100.0**	**1 228 222**	**100.0**	**-**	**-**	**80 949**	**100.0**	**3 263 440**	**100.0**

Notes:
Figures may not add due to rounding.
1. Adjustments are made in order to reconcile data from the System of National Accounts classification and data from the Financial Management System classification.
2. Local government expenditures specific to pollution control and for other environmental services are included in other pollution abatement and control expenditures.
Source:
Statistics Canada, Public Institutions Division.

treatment, leaving waste management responsibilities to local governments. At the other extreme, waste treatment accounted for the highest PAC expenditures by the Government of Prince Edward Island (see Annex, Table 13).

In 1991, other environmental services, worth over $465 million, were still the highest items of PAC expenditures for provincial and territorial governments. A considerable part of this expenditure was for administration of the ministries of the environment. Specific pollution control expenditures had their share of PAC expenditures increase between 1984 and 1988 before declining from 43 percent to 32 percent between 1988 and 1991 in spite of an increase in size. Some of the major government PAC expenditures partly managed or financed by the provinces include: the Municipal-Industrial Strategy for Abatement (MISA) in Ontario which aims at reducing water pollution, Ontario's participation in the Great Lakes Action Plan, Quebec's participation in the St. Lawrence River Action Plan, and British Columbia's contribution to the Fraser River Basin Action Plan (particularly the provincial Fraser River Estuary Management programme).

More detailed data on the composition of provincial/territorial expenditures exist. As shown in Table 9.5 for 1991, the size of transfers to municipalities and schools and hospitals for PAC purposes varies considerably by type of expenditure category. The largest transfer payments were made to finance sewage treatment ($99.3 million in 1991); they were followed by specific pollution control transfers (distributed among the different categories of municipal PAC expenditures), transfers for waste treatment and other transfers. In the case of British Columbia, all provincial government expenditures on sewage treatment made between 1988 and 1991 were in the form of transfers to municipalities. Only the Government of Newfoundland did not make transfer payments for PAC.

The financing of PAC expenditures through transfers to municipalities was not the only form of financing by provincial/territorial governments. As Table 9.5 reveals, over half of all expenditures specific to pollution control and on other environmental services were made for current purchases of goods and services in 1991. Expenditures on other environmental services consisted partly of purchase of unspecified goods and services and transfer payments to businesses. Almost 20 percent of waste treatment expenditures were current expenditures on goods and services.

Expenditures on natural resource conservation and development

Federal and provincial/territorial governments support various activities which encourage sustainable development and natural resource conservation as shown in Table 9.7.

1. It is possible that in other provinces, particularly in Quebec and Ontario, sewage disposal expenditures were included in the water supply category, due to the nature of certain provincial programmes for financing sewage systems and aqueducts.

Provincial/territorial governments spent $8 billion in 1991 for natural resource conservation and development. Throughout the 1988-1991 period, few transfers were paid to other governments for resource conservation and development. Conservation and development expenditures accounted for close to 5 percent of total expenditures by provincial/territorial governments in 1991. This ratio increased compared with the 1970 ratio of 3 percent but has been declining since the peak of 6 percent in 1982.

Table 9.6

Expenditures for Natural Resource Conservation and Development by Level of Government, 1965-1994 (Fiscal Years)

Year	Federal	Provincial/territorial	Local
	thousand 1986 dollars		
1965-66	..	..	55 311
1966-67	..	..	187 038
1967-68	..	..	111 685
1968-69	..	..	92 061
1969-70	..	..	129 267
1970-71	2 427 388	1 727 491	73 442
1971-72	2 587 840	1 887 666	34 547
1972-73	2 892 979	1 868 396	156 126
1973-74	3 776 026	2 096 909	165 716
1974-75	6 547 176	..	167 758
1975-76	7 373 301	3 061 520	157 880
1976-77	5 633 326	3 443 366	172 311
1977-78	5 206 971	3 487 097	184 698
1978-79	4 423 174	3 663 245	209 328
1979-80	6 740 367	3 988 179	278 814
1980-81	8 952 678	4 432 080	288 002
1981-82	9 040 159	4 851 356	240 483
1982-83	9 816 259	6 106 317	315 134
1983-84	8 201 312	5 523 942	300 220
1984-85	10 171 587	5 528 891	276 578
1985-86	6 885 778	..	288 669
1986-87	5 649 440	..	338 145
1987-88	6 829 863	..	353 897
1988-89	5 397 005	5 674 324	326 218
1989-90	4 319 564	6 064 719	372 884
1990-91	3 739 675	5 472 295	402 680
1991-92	5 186 693	6 642 873	411 926
1992-93[1]	4 146 417	..	368 948
1993-94[2]	3 927 788	..	341 539
1994-95[3]	3 448 337	..	..

Notes:

Figures represent non consolidated current and capital expenditures.

Expenditures in 1986 dollars have been estimated using the implicit price index of total government expenditures.

Figures may not add due to rounding.

1. In 1992-93 local government data are estimates.
2. In 1993-94 federal government data are revised estimates while local government data are preliminary estimates.
3. In 1994-95 federal government data are estimates.

Sources:

Statistics Canada, National Accounts and Environment Division and Public Institutions Division.

Federal government expenditures on conservation and development amounted to $6.3 billion in 1991, and then decreased to $4.3 billion in 1994. Federal expenditures on resource conservation and development accounted for approximately 3 percent of total federal government expenditures at the start of the 1990s.

In general, provincial/territorial government expenditures on resource conservation and development have increased sharply in real terms since 1970 as shown in Table 9.6. The average annual growth rate exceeded 6 percent since 1970. Federal government expenditures increased in real terms at an average rate of 4.5 percent per year between 1970 and 1994.

Federal government

As shown in Table 9.7, in the area of natural resource conservation and development, the federal government is primarily involved in programmes to develop agriculture. They accounted for over half of all federal conservation and development expenditures since the mid 1980s, although expenditures for agriculture decreased from $4.6 billion in 1991 to $2.4 billion in 1994. These programmes are mainly aimed at stabilizing prices and providing subsidies to farmers although part of the expenditures on agriculture also went to the National Soil Conservation programme and to research on global change. Expenditures on fish and game, the second highest expenditures also have declined since 1991. The North American Wildfowl Management Plan and the Environmental Effects Monitoring programme (monitoring of the effects of industrial activity on fish resource and its habitat) are examples of fish and game conservation programmes. Expenditures on mines, oil and gas declined significantly between 1984 and 1994, from $6 billion to $569 million. Several expenditures though were subsidies to Crown corporations designed to encourage mining exploration rather than conservation *per se*.

Table 9.7

Expenditures for Natural Resource Conservation & Development by Level of Government, Canada, 1965-1994 (Fiscal Years)

	Federal						Provincial/territorial						Local		
	Agriculture	Fish & game	Forests	Mines, oil and gas	Other	Total	Agriculture	Fish & game	Forests	Mines, oil and gas	Other	Total	Agriculture	Other	Total
	thousand dollars														
1965-66	..	..	..	..	..	..	..	..	..	..	..	..	770	10 625	11 395
1966-67	..	..	..	..	..	..	..	..	..	..	..	..	1 006	40 316	41 322
1967-68	..	..	..	..	..	..	..	..	..	..	..	..	1 187	24 762	25 949
1968-69	..	..	..	..	..	..	..	..	..	..	..	..	1 044	21 336	22 380
1969-70	..	..	..	..	..	..	..	..	..	..	..	..	898	32 869	33 767
1970-71	447 213	71 241	22 998	70 305	56 553	668 310	211 596	27 328	136 748	30 943	68 999	475 614	1 161	19 059	20 220
1971-72	540 633	73 182	23 559	48 606	71 108	757 088	229 339	39 852	174 252	37 593	71 212	552 248	461	9 646	10 107
1972-73	635 986	120 248	30 091	38 428	82 004	906 757	272 780	43 363	157 765	41 428	70 282	585 618	810	48 125	48 935
1973-74	710 302	110 241	1 241	319 843	131 048	1 272 675	321 265	61 091	177 347	51 305	95 736	706 744	1 042	54 811	55 853
1974-75	963 000	141 000	1 000	1 295 000	138 000	2 538 000	..	..	..	..	..	..	1 918	63 113	65 031
1975-76	1 262 000	181 000	1 000	1 629 000	162 000	3 235 000	635 598	104 166	290 304	169 592	143 567	1 343 227	9 320	59 949	69 269
1976-77	1 335 000	206 000	2 000	993 000	217 000	2 753 000	691 199	103 996	317 983	426 931	142 660	1 682 769	36 562	47 646	84 208
1977-78	1 287 000	217 000	2 000	977 000	267 000	2 750 000	738 299	122 042	369 138	408 672	203 518	1 841 669	46 335	51 211	97 546
1978-79	1 274 000	251 000	2 000	720 000	258 000	2 505 000	677 979	137 321	427 373	556 224	275 728	2 074 625	55 882	62 668	118 550
1979-80	1 564 000	252 000	4 000	2 104 000	254 000	4 178 000	908 494	154 777	510 187	579 410	319 195	2 472 063	76 736	96 086	172 822
1980-81	1 316 000	292 000	59 000	4 125 000	312 000	6 104 000	1 136 035	167 746	711 757	621 797	384 489	3 021 824	91 690	104 672	196 362
1981-82	1 681 000	356 000	75 000	4 382 000	462 000	6 956 000	1 459 124	184 363	803 015	706 539	579 861	3 732 902	77 023	108 018	185 041
1982-83	1 679 000	386 000	97 000	5 489 000	744 000	8 395 000	1 509 956	211 670	824 805	1 933 967	741 809	5 222 207	114 735	154 772	269 507
1983-84	1 819 000	502 000	117 000	4 429 000	535 000	7 402 000	1 527 207	209 810	837 733	1 584 565	826 255	4 985 570	139 809	131 151	270 960
1984-85	2 226 000	595 000	164 000	5 947 000	613 000	9 545 000	1 825 725	230 214	903 486	1 379 276	849 601	5 188 302	141 630	117 910	259 540
1985-86	2 427 000	510 000	200 000	2 943 000	623 000	6 703 000	..	..	..	..	..	..	145 000	136 006	281 006
1986-87	3 238 424	388 334	224 701	1 094 982	702 999	5 649 440	..	..	..	..	..	..	184 946	153 199	338 145
1987-88	4 720 872	328 401	660 250	708 981	650 481	7 068 985	..	..	..	..	..	..	170 102	196 185	366 287
1988-89	3 614 209	393 464	311 776	767 246	707 769	5 794 464	2 726 916	302 864	1 247 665	977 089	837 672	6 092 206	124 297	225 945	350 242
1989-90	3 011 498	402 070	284 463	365 551	760 003	4 823 585	2 834 386	342 942	1 394 897	1 340 073	860 072	6 772 370	163 413	252 980	416 393
1990-91	2 592 673	470 382	215 421	383 426	725 538	4 387 440	2 901 736	349 733	1 413 677	990 898	764 131	6 420 174	156 099	316 331	472 430
1991-92	4 622 131	483 973	206 653	325 310	623 016	6 261 083	4 168 575	338 934	1 537 011	1 167 788	806 594	8 018 902	168 376	328 878	497 254
1992-93[1]	3 237 913	693 646	236 048	321 573	620 308	5 109 488	..	..	..	..	..	..	146 683	307 959	454 642
1993-94[2]	2 881 503	692 158	237 655	497 388	591 718	4 900 422	..	..	..	..	..	..	139 388	286 726	426 114
1994-95[3]	2 436 523	573 942	225 869	568 992	522 337	4 327 663	..	..	..	..	..	..	..	..	..

Notes:

Figures represent non consolidated current and capital expenditures.

Figures may not add due to rounding.

Data are expressed on a Financial Management System basis.

For a breakdown of provincial and local government expenditures, see Annex, Table 13.

1. In 1992-93 local government data are estimates.
2. In 1993-94 federal government data are revised estimates while local government data are preliminary estimates.
3. In 1994-95 federal government data are estimates.

Sources:

Statistics Canada, ***Federal Government Finance***, Cat. No. 68-211; ***Provincial Government Finance - Revenue and Expenditure***, Cat. No. 68-207; Public Institutions Division.

Table 9.8

Detail of Provincial/Territorial Government Expenditures for Natural Resource Conservation and Development and for Parks, Canada, 1991-92

	Agriculture		Fish and game		Forests		Mines, oil and gas		Other natural resource conservation & development		Total natural resource conservation & development		Parks	
	thousand dollars	share of total (%)	thousand dollars	share of total (%)	thousand dollars	share of total (%)	thousand dollars	share of total (%)	thousand dollars	share of total (%)	thousand dollars	share of total (%)	thousand dollars	share of total (%)
Current expenditures on goods & services	754 753	18.1	177 221	52.3	1 088 391	70.8	269 916	23.1	781 528	96.9	3 071 810	38.3	185 116	90.4
Capital expenditures	23 816	0.6	8 427	2.5	57 532	3.7	6 524	0.6	19 452	2.4	115 750	1.4	13 652	6.7
Other expenditures on goods & services	86 263	2.1	29 845	8.8	181 849	11.8	15 251	1.3	38 238	4.7	351 445	4.4	11 755	5.7
Transfer payments to persons	71 584	1.7	6 686	2.0	6 319	0.4	15 831	1.4	7 112	0.9	107 532	1.3	513	0.3
Transfer payments to business	3 078 903	73.9	23 332	6.9	61 176	4.0	191 310	16.4	177 019	21.9	3 531 740	44.0	123	0.1
Transfer payments from provincial to federal governments	43 851	1.1	-	-	-	-	-	-	-	-	43 851	0.5	-	-
Transfer payments to municipalities	77 163	1.9	3 153	0.9	-	-	-	-	54 820	6.8	135 137	1.7	89	-
Interest on public debt	1	-	-	-	-	-	-	-	-	-	1	-	-	-
Expenditure reconciliation and integration	47 526	1.1	6 431	1.9	4 823	0.3	44 015	3.8	3 528	0.4	106 323	1.3	60	-
Direct taxes	-	-	-	-	-	-	43 452	3.7	-	-	43 452	0.5	-	-
Indirect taxes	-	-	-	-	-7 000	-0.5	-	-	-	-	-7 000	-0.1	-	-
Revenue/receipts offset against expenditure	-11 559	-0.3	-150	-	-1 309	-0.1	-180	-	-1 853	-0.2	-15 053	-0.2	-	-
Intra subsectorial transfers	-	-	-	-	-	-	-	-	-4 191	-0.5	-4 191	-0.1	-	-
Adjustments[1]	-3 725	-0.1	83 989	24.8	145 230	9.4	581 671	49.8	-269 059	-33.4	538 105	6.7	-6 596	-3.2
Total	**4 168 575**	**100.0**	**338 934**	**100.0**	**1 537 011**	**100.0**	**1 167 788**	**100.0**	**806 594**	**100.0**	**8 018 902**	**100.0**	**204 713**	**100.0**

Note:
1. Adjustments are made in order to reconcile data from the System of National Accounts classification and data from the Financial Management System classification.
Source:
Statistics Canada, Public Institutions Division.

Most of federal government transfer payments to provinces, territories and municipalities for natural resource conservation and development ($1 billion in 1991) went to agriculture. This constitutes a significant change compared with the 1970s and 1980s when transfers to mines, oil and gas represented more than half of all federal transfers for resource conservation and development.

Provincial/territorial governments

As shown in Table 9.7, agriculture also accounted for close to half of all provincial/territorial resource conservation and development expenditures since 1989. In fact since 1970 agriculture has represented a growing share of conservation and development expenditures. One of the programmes, in this regard, Ontario's Land Management Programme, is aimed at ensuring improved conservation of the province's agricultural land. Forest conservation and development accounted for the second highest group of expenditures, representing 19 percent of total provincial/territorial expenditures for conservation and development in 1991, although this ratio declined since 1971. Expenditures on mines, oil and gas accounted for almost 15 percent of conservation and development expenditures in 1991; this ratio has also declined since 1980. The other resource conservation and development expenditures accounted for 10 percent of the 1991 total. This ratio is also on the decline since the beginning of the 1980s.

As shown in Table 9.8, transfer payments to the other levels of government accounted for just 2 percent of resource conservation and development expenditures by provincial/territorial governments in 1991.

Transfer payments to business accounted for 44 percent of total natural resource conservation and development expenditures, and mainly consisted of payments in agriculture. Current expenditures accounted for 38 percent of total resource conservation and development expenditures, and were shared mainly among agriculture, forests and other natural resource and development activities.

Local governments

Local governments spent $139.4 million in 1993 on the conservation and development of agricultural resources and these expenditures grew at an average annual rate of 27 percent between 1965 and 1993. Local governments also spent $286.7 million in 1993 on other natural resources such as energy, and these expenditures increased at an average annual rate of 20.5 percent between 1965 and 1993.

Parks

The final category of environmental protection expenditure under review is the development and operation of parks. The Green Plan actually stressed the need to protect 12 percent of the land and to complete the national parks system by the year 2000. Provincial/territorial governments spent $204.7 million in 1991 for the development and operation of parks, an increase from $192.3 million in 1988. Almost all consisted of current expenditures on goods and services (90 percent in 1991), and the rest were mostly investments and other expenditures on goods and services (see Table 9.8).

Conclusion

Consolidated government environmental protection expenditures in Canada, estimated at $18 billion in 1991, are broken down between PAC expenditures ($4.7 billion) and natural resource conservation and development expenditures ($13.3 billion). Expenditures for parks should also be included but for the moment only data on provincial/territorial government expenditures are available since federal government data have yet to be reconciled with the conceptual framework of environmental protection expenditures. PAC expenditures represent one percent of total consolidated government expenditures in Canada and for more than thirty years have been mostly made by local governments. Local governments are mainly responsible for sewage treatment and waste disposal. Expenditures for other environmental services are made mostly by federal and provincial/territorial governments while specific expenditures for pollution control are almost exclusively made by provincial/territorial governments.

Expenditures on natural resource conservation and development are almost exclusively made by provincial/territorial governments and by the federal government. The largest expenditures in this respect are classified under the conservation and development of agriculture, although these expenditures are mostly subsidies to farmers. Indeed, data on the various categories of resource conservation and development expenditures do not separate the specific amounts related to the conservation of soils, forests, waters, mineral resources and the protection of fauna. There is an ongoing project to collect more information on government environmental protection expenditures through detailed analysis of the different sources of administrative data on expenditures by federal and provincial/territorial government departments. Eventually this work should provide more detail on the nature of resource conservation and development activities and more data on park expenditures. Other activities which relate to environmental protection such as regional planning and development might also be included.

Appendix: Definitions and data quality

Environmental protection expenditures by governments in Canada are defined as expenditures by federal, provincial/territorial and local governments that are undertaken with the sole aim of preventing, reducing and abating degradation of the natural environment or to preserve the environment. The following activities are included in this definition:

1. Pollution abatement and control (PAC)
   - protection of ambient air and climate
   - protection of surface water
   - waste collection and treatment
   - protection of soil and groundwater
   - protection against noise, vibration and radiation
   - research and development on PAC
   - other environmental services (e.g education, administration of the ministry of environment)
2. Conservation
   - wildlife and habitat
   - soil
   - mineral resources
   - forests
   - waters

Classification of expenditures according to the financial management system

In practice, data on government expenditures available at Statistics Canada are classified by function based on the Financial Management System (FMS) of government revenues and expenditures.

1. **PAC expenditures** are included in the 'environment' function of the FMS under the following categories:

- Sewage collection and disposal (sewage treatment): expenditures on the construction and maintenance of sewage removal and treatment facilities (including sanitary sewers and combined sanitary-storm sewers), expenditures related to inspection and cleaning of sewers, and subsidies related to assistance and research in this area.
- Waste collection and disposal (waste treatment or waste management): expenditures on construction and maintenance of garbage and waste collection and disposal (including landfill sites, incineration, recycling and landfill site cleanup), and on managing waste collection and disposal programmes.
- Pollution control: all expenditures to prevent or reduce air, water, soil or groundwater pollution.
- Other environmental services (not elsewhere specified): expenditures for such services as general administration of the ministry of environment, education, environmental assessments, contributions to environmental agencies, etc.

The 'environment' classification includes expenditures for water supply and distribution. However these expenditures are excluded from environmental protection expenditures because they relate to human health protection rather than to environmental protection. Data on government expenditures for the 'environment' function are published on a regular basis, by level of government, both at the consolidated and non consolidated levels.

2. **Natural resource conservation and development**

These expenditures are classified under the 'Natural Resource Conservation and Industrial Development' function of the FMS but exclude the categories 'tourism', 'trade and industrial development' as well as the category 'water power'. Water power includes control of damage due to floods and the installation of dams. Natural resource conservation and development activities include the following expenditures:

- Agriculture: expenditures for research, price stabilisation, soil conservation and protection against soil erosion, farm subsidies, drainage expenditures, etc.
- Fish and game: expenditures for research and management of fish and wildlife including expenditures for aquaculture as well as wildlife habitat protection expenditures, etc.
- Forests: expenditures for research, pest control, control of fires, expenditures for construction of logging roads, reforestation, etc.
- Mines, oil and gas: expenditures related to research, exploitation and conservation of mining resources.
- Other: expenditures related to the management of Crown land, energy conservation, subsidies to conservation agencies for energy related R&D, etc.

Data on government expenditures for the 'natural resource conservation and industrial development' function are published on a regular basis, by level of government, both at the consolidated and non consolidated levels.

3. **Parks**

Park expenditures are a component of the 'Recreation and Culture' function of the FMS. They comprise all expenditures associated with implementing and maintaining national, regional, provincial and municipal parks. Only data on expenditures by provincial/ territorial governments from 1988-89 to 1991-92 provide this amount of detail.

Available detail

Data on expenditures by provincial/territorial governments from 1988 to 1991 are produced using both an FMS classification and an economic classification (System of National Accounts). In order to reconcile the data from the two classifications, it is necessary to take account of differences in the methodologies.

The System of National Accounts classification is made up of the following elements:

- current expenditures on goods and services
- capital expenditures
- expenditures on non-specified goods and services
- transfers to individuals
- transfers to businesses
- transfers to local governments and to other levels of government
- interest payments on public debt
- expenditure reconciliation and integration (expenditures not specified above)
- direct and indirect taxes
- revenues/receipts offset against expenditures

Assets of the Capital and Repair Expenditure Survey

Statistics Canada's Capital Repair and Expenditure Survey provides figures on capital expenditures for PAC construction and machinery and equipment, and construction and equipment used for waste and sewage disposal from 1985 to 1992 (calendar years). These assets include the following:

- construction related to PAC
- waste disposal facilities
- construction of sewage networks: sewage treatment and disposal plants including pumping stations; sanitary and storm sewers, trunk and collection lines, open storm ditches and laterals; lagoons, and any other sewage system construction.
- PAC equipment
- sanitation equipment

Table 9.9
Implicit Price Index, Total Government Expenditure, 1986=100.0

Year	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Index	20.6	22.1	23.2	24.3	26.1	27.5	29.3	31.3	33.7	38.8	43.9	48.9	52.8	56.6	62.0

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Index	68.2	76.9	85.5	90.3	93.8	97.3	100.0	103.5	107.4	111.7	117.3	120.7	123.2	124.8	125.5

Source:
Statistics Canada, National Accounts and Environment Division.

Method of deflation

Estimates in constant dollars were produced from implicit price indexes of total government expenditures obtained from the national accounts with 1986 as the base year (see Table 9.9). A similar price index was calculated for each province and territory for the 1971-1993 period (1977-1993 period for the territories). These indices are crude approximations. Specific price indices for PAC and other environmental protection expenditures are not available.

References

Statistics Canada, 1992, ***Public Finance, Historical Data 1965/66-1991/92 Financial Management System***, Cat. No. 68-512.

_____, 1994, ***Human Activity and the Environment 1994***, Cat. No. 11-509E, Ottawa.

_____, ***Federal Government Finance***, Cat. No. 68-211 (discontinued).

_____, ***Provincial Government Finance - Revenue and Expenditure***, Cat. No. 68-207 (discontinued).

Annex: Environment and Natural Resource Statistics

Table 1

Selected Environmental Quality Statistics, 1961-1994

	Source	1961	1966	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
AIR QUALITY														
Urban ground level[1]														
Average station exceedances for SO_2, NO_x and CO	a	..	..	..	..	..	..	..	..	..	..	..	9.8	6.6
Average station exceedances for ozone	a	..	..	..	..	..	..	..	..	..	..	..	25.4	23.7
Average station exceedances for particulates	a	..	..	..	..	..	..	..	..	..	..	..	8.2	8.0
Ozone layer[2] (Dobson units[3])														
Toronto	b	346	354	353	353	351	348	349	351	352	350	347	349	350
Edmonton	b	338	353	344	342	341	342	344	343	343	343	341	342	343
Resolute	b	371	377	399	399	388	384	383	374	371	378	384	384	381
Production of CFCs (kt)	b	..	..	..	..	..	..	..	..	..	..	..	17.3	14.0
Production of other ozone depleting substances (kt)	b	..	..	..	..	..	..	..	..	..	..	..	3.4	2.8
Air emissions (thousand tonnes)														
Nitrogen dioxide	c	..	..	1 364	..	..	..	..	1 756	..	..	..	..	1 959
Sulphur dioxide	c	..	..	6 677	..	..	..	..	5 319	..	..	..	..	4 643
Carbon monoxide	c	..	..	10 057	..	..	..	..	10 594	..	..	..	..	10 273
Carbon dioxide from fossil fuel combustion	d	204	278	351	357	375	392	400	393	411	403	409	425	429
Particulates	c	..	..	1 850	..	..	..	..	1 787	..	..	..	..	1 907
LAND														
Agricultural land use (million hectares)														
Cropland	e,f	25.3	27.9	..	27.8	..	..	..	..	28.3	..	..	..	..
Improved pasture	e,f	4.1	4.4	..	4.1	..	..	..	..	4.1	..	..	..	..
Summerfallow	e,f	11.4	10.4	..	10.8	..	..	..	..	10.9	..	..	..	..
Other land	e,f	1.0	1.0	..	1.0	..	..	..	..	0.9	..	..	..	..
Unimproved farmland	e,f	28.0	26.7	..	25.0	..	..	..	..	24.2	..	..	..	..
Total farmland	e,f	69.8	70.5	..	68.7	..	..	..	..	68.4	..	..	..	..
Proportion of Canada's land area in agriculture (%)	d	7.6	7.6	..	7.5	..	..	..	..	7.4	..	..	..	..
Grain crop production (all types) (thousand tonnes)	f	15 961	36 784	25 863	35 892	32 938	33 799	28 205	33 441	40 931	37 947	37 342	30 643	35 564
Total cattle inventory (thousands)[4]	f	11 934	12 879	12 826	13 271	13 644	14 128	15 101	15 260	14 384	13 619	12 807	12 650	12 764
Agricultural fertilizer use (thousand tonnes)														
Nitrogen	g	73	218	268	323	334	410	513	531	586	599	755	831	831
Phosphate	g	161	333	281	326	341	415	494	502	503	503	594	630	628
Potash	g	93	142	175	184	189	191	202	207	242	234	273	330	349
Total fertilizer sold (thousand tonnes)[5]	g	709	1 811	1 694	1 915	1 972	2 261	2 608	2 676	2 780	2 829	3 267	3 671	3 572
Value of agricultural pesticides applied (million $1986)	e	..	..	169	..	..	..	..	..	..	..	..	..	398
Proportion of Canada's land area in forests (%)	d,h	..	..	..	..	..	..	..	..	..	..	..	..	47
Forest harvested (thousand cubic metres)	c	..	..	121 400	..	..	..	..	..	..	..	..	..	156 500
Natural loss of forests (thousand cubic metres)	c	..	..	..	..	..	..	..	..	..	..	..	..	24 600
Total forest depletion (thousand cubic metres)	c	..	..	...	..	..	..	..	..	..	..	..	..	181 100
Rural to urban land conversion (hectares)[6]	i	..	..	..	86 090	..	..	..	..	61 164	..	..	..	..
ATLANTIC FISH CATCH[7] (thousand tonnes)														
Groundfish	j	1 365	1 743	1 738	1 701	1 627	1 646	1 359	1 195	998	820	848	934	930
Pelagics	j	85	285	784	824	787	935	871	916	829	533	326	236	242
Salmon	j	2	4	4	5	4	5	4	5	4	4	3	3	4
Total finfish	j	1 452	2 032	2 526	2 530	2 418	2 586	2 234	2 116	1 831	1 357	1 177	1 173	1 176
ENERGY USE (petajoules)														
Coal	k,d	548	635	708	673	635	654	665	658	709	773	789	876	928
Oil	d	1 803	2 328	2 860	3 119	3 425	3 771	3 931	3 806	3 770	4 004	4 011	4 297	4 196
Natural gas	d	566	938	1 370	1 462	1 644	1 749	1 767	1 800	1 841	1 643	1 664	1 734	1 785
Natural gas liquids	d	13	43	49	56	66	69	83	74	71	56	48	69	86
Total primary fuels	d	3 294	4 408	5 545	5 890	6 411	6 937	7 209	7 081	7 183	7 296	7 389	7 864	7 929
Nuclear	d,e	...	1	4	15	26	54	53	45	63	95	112	127	137
Total non-renewable energy	d	6 224	8 353	10 536	11 215	12 208	13 235	13 708	13 463	13 637	13 866	14 013	14 967	15 062
Hydroelectricity	d,e	364	463	555	564	615	641	709	699	729	725	766	761	797
Wood	k	178	107	106	342	353	377	391	326	346	346	357	374	405
Total renewable energy	d	542	570	661	906	968	1 018	1 100	1 025	1 075	1 071	1 123	1 135	1 202
Total energy	d	6 766	8 923	11 197	12 121	13 176	14 252	14 808	14 487	14 712	14 937	15 136	16 102	16 264
Energy per capita (gigajoules per capita)	d	180	220	260	267	288	308	315	305	305	307	307	324	322
Energy per $ of real GDP (megajoules per 1986 $)	d	19.5	19.0	20.4	20.5	21.1	21.2	21.1	20.2	19.3	18.9	18.3	18.8	18.7

Notes:
1. This information provides a measure of the number of times the oxides, ozone or particulates exceeded maximum acceptable levels each year.
2. From 1961 to 1992 figures are averaged from six readings per year while 1993 figures are averaged from three readings.
3. Dobson unit: a unit measure used to estimate the thickness of the ozone layer. 100 Dobson units represents a quantity equivalent to a 1mm thick layer of ozone at sea level.
4. Changes in surveying dates and methods between 1975 and 1976 may cause some inconsistencies.
5. Total fertilizer sold includes all nutrients as well as fertilizer filler materials.
6. These figures represent rural to urban land use conversion over the preceding five years. Data were not collected after 1986.
7. Includes surveillance estimates of catches in the NAFO regulatory area and foreign catches made outside the 200-mile zone on straddling stocks and the Flemish Cap.

Sources:

a. Environment Canada, State of the Environment Directorate, ***Technical Supplement to the Environmental Indicator Bulletin on Urban Air Quality***, Ottawa, 1994.
b. Environment Canada, State of the Environment Directorate, ***Technical Supplement to the Environmental Indicator Bulletin on Stratospheric Ozone Depletion***, Ottawa, 1993.
c. Organisation for Economic Cooperation and Development, ***OECD Environmental Data Compendium 1993***, Paris, 1993.
d. Statistics Canada, National Accounts and Environment Division.
e. Statistics Canada, ***Human Activity and the Environment 1994***, Cat. No. 11-509, Ottawa, 1994.
f. Statistics Canada, Agriculture Division.
g. Statistics Canada, ***Fertilizer Trade***, Cat. No. 46-207, Ottawa, various issues, and Agriculture Canada, Farm Policy Development Branch.
h. Natural Resources Canada, Canadian Forest Service, Canada's Forest Inventory 1981, 1986, 1991.
i. Environment Canada, State of Environment Directorate, ***Technical Supplement to a Report on Canada's Progress Towards a National Set of Environmental Indicators***, Ottawa, 1991.
j. Department of Fisheries and Oceans Canada, Biological Sciences Directorate.
k. Environment Canada, State of the Environment Directorate, ***Technical Supplement to the Environmental Indicator Bulletin on Energy Consumption***, Ottawa, 1994.

Table 1

Selected Environmental Quality Statistics, 1961-1994 (Concluded)

	Source	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
AIR QUALITY															
Urban ground level[1]															
Average station exceedances for SO_2, NO_x and CO	a	10.3	6.8	5.4	2.2	2.6	4.4	1.8	2.5	1.3	3.3	1.0	0.2	..	..
Average station exceedances for ozone	a	23.8	13.8	35.6	17.9	11.6	10.0	15.8	57.8	19.8	10.6	19.0	6.7	..	..
Average station exceedances for particulates	a	5.8	4.4	2.7	3.1	2.0	2.0	2.5	2.4	1.9	0.9	1.1	0.8	..	..
Ozone layer[2] (Dobson units[3])															
Toronto	b	347	341	337	337	338	339	341	341	338	337	335	332	326	..
Edmonton	b	342	341	338	336	335	335	335	333	332	332	330	324	319	..
Resolute	b	376	372	367	370	375	366	357	354	350	349	349	345	337	..
Production of CFCs (kt)	b	15.2	14.2	15.6	16.9	18.5	19.9	21.2	21.0	18.8	13.1	8.8	10.7	..	..
Production of other ozone depleting substances (kt)	b	2.8	3.2	3.7	4.7	4.6	5.0	6.6	6.6	5.4	4.1	3.5	2.5	..	..
Air emissions (thousand tonnes)															
Nitrogen dioxide	c	1 907	1 897	1 884	1 871	1 958	..	..	..	..	1 923	..	..	..	..
Sulphur dioxide	c	4 291	3 612	3 625	3 955	3 692	3 627	3 762	3 838	3 695	3 323	3 306	..	..	..
Carbon monoxide	c	..	..	..	..	10 781	..	..	..	..	..	..	..	..	..
Carbon dioxide from fossil fuel combustion	d	410	390	381	396	412	404	419	450	465	445	437	452	453	..
Particulates	c	..	..	..	..	1 709	..	..	..	..	..	..	..	..	..
LAND															
Agricultural land use (million hectares)															
Cropland	e,f	30.9	..	..	..	..	33.2	..	..	..	..	33.5	..	..	..
Improved pasture	e,f	4.1	..	..	..	..	3.6	..	..	..	..	4.1	..	..	..
Summerfallow	e,f	9.7	..	..	..	..	8.5	..	..	..	..	7.9	..	..	..
Other land	e,f	1.4	..	..	..	..	0.7	..	..	..	..	..	..	..	..
Unimproved farmland	e,f	19.8	..	..	..	..	21.8	..	..	..	..	..	..	..	..
Total farmland	e,f	65.9	..	..	..	..	67.8	..	..	..	..	67.8	..	..	..
Proportion of Canada's land area in agriculture (%)	d	7.2	..	..	..	..	7.4	..	..	..	..	7.4	..	..	..
Grain crop production (all types) (thousand tonnes)	f	44 096	46 728	41 415	35 933	41 209	50 870	44 477	30 250	41 881	49 530	46 314	44 605	45 802	..
Total cattle inventory (thousands)[4]	f	12 764	12 591	12 290	12 031	11 651	11 299	11 264	11 512	11 780	11 907	12 172	12 473	12 715	13 263
Agricultural fertilizer use (thousand tonnes)															
Nitrogen	g	916	966	1 002	1 157	1 254	1 221	1 145	1 188	1 160	1 196	1 158	1 253	1 306	1 406
Phosphate	g	635	636	652	713	724	695	626	634	614	614	578	592	637	616
Potash	g	363	344	338	377	400	370	370	404	356	360	338	310	328	316
Total fertilizer sold (thousand tonnes)[5]	g	3 758	3 742	3 842	4 243	4 435	4 300	4 069	4 241	4 048	4 105	3 922	4 071	4 218	4 501
Value of agricultural pesticides applied (million $1986)	e	..	..	..	..	694	..	..	..	..	705	..	..	..	..
Proportion of Canada's land area in forests (%)	d,h	..	..	..	..	48	..	..	..	..	..	45	..	..	..
Forest harvested (thousand cubic metres)	c	..	..	..	..	143 700	..	..	..	..	188 000	..	..	..	..
Natural loss of forests (thousand cubic metres)	c	..	..	..	..	143 800	..	..	..	..	217 000	..	..	..	..
Total forest depletion (thousand cubic metres)	c	..	..	..	..	287 500	..	..	..	..	405 000	..	..	..	..
Rural to urban land conversion (hectares)[6]	i	98 976	..	..	..	..	55 210	..	..	..	..	..	..	..	..
ATLANTIC FISH CATCH[7] (thousand tonnes)															
Groundfish	j	980	1 032	949	983	1 062	1 157	1 120	1 031	1 026	998	886	659 p	455 p	192 p
Pelagics	j	255	217	231	270	302	379	412	493	423	516	331	286 p	258 p	203 p
Salmon	j	4	3	2	1	2	3	3	2	1	1	1	1 p	- p	- p
Total finfish	j	1 239	1 252	1 182	1 254	1 366	1 539	1 535	1 526	1 450	1 515	1 218	946 p	713 p	395 p
ENERGY USE (petajoules)															
Coal	k,d	946	1 002	1 048	1 167	1 122	1 040	1 118	1 200	1 198	1 077	1 104	1 137	1 044	..
Oil	d	3 990	3 332	3 183	3 170	3 077	3 038	3 155	3 339	3 402	3 463	3 249	3 175	3 462	..
Natural gas	d	1 710	1 718	1 754	1 880	2 361	2 317	2 358	2 593	2 790	2 676	2 705	2 863	2 439	..
Natural gas liquids	d	104	73	93	136	172	164	216	217	236	217	232	262	275	..
Total primary fuels	d	7 713	7 062	7 061	7 412	7 876	7 789	8 082	8 627	8 902	8 738	8 612	8 748	8 873	..
Nuclear	d,e	136	130	166	177	206	242	262	281	271	248	288	274	319	..
Total non-renewable energy	d	14 599	13 317	13 305	13 942	14 813	14 590	15 191	16 257	16 798	16 419	16 191	16 458	16 412	..
Hydroelectricity	d,e	826	806	817	881	939	989	972	996	1 005	1 057	1 033	1 038	1 055	..
Wood	k	393	421	459	391	473	498	503	503	483	473	485	491	493	..
Total renewable energy	d	1 219	1 227	1 276	1 272	1 412	1 487	1 475	1 499	1 488	1 530	1 518	1 529	1 548	..
Total energy	d	15 818	14 544	14 581	15 214	16 225	16 077	16 666	17 756	18 286	17 949	17 709	17 987	17 960	..
Energy per capita (gigajoules per capita)	d	310	280	277	288	304	297	304	321	325	314	306	308	314	..
Energy per $ of real GDP (megajoules per 1986 $)	d	17.5	16.6	16.1	15.9	16.1	15.4	15.4	15.7	15.7	15.4	15.5	15.6	15.9	..

Notes:
1. This information provides a measure of the number of times the oxides, ozone or particulates exceeded maximum acceptable levels each year.
2. From 1961 to 1992 figures are averaged from six readings per year while 1993 figures are averaged from three readings.
3. Dobson unit: a unit measure used to estimate the thickness of the ozone layer. 100 Dobson units represents a quantity equivalent to a 1mm thick layer of ozone at sea level.
4. Changes in surveying dates and methods between 1975 and 1976 may cause some inconsistencies.
5. Total fertilizer sold includes all nutrients as well as fertilizer filler materials.
6. These figures represent rural to urban land use conversion over the preceding five years. Data were not collected after 1986.
7. Includes surveillance estimates of catches in the NAFO regulatory area and foreign catches made outside the 200-mile zone on straddling stocks and the Flemish Cap.

Sources:
a. Environment Canada, State of the Environment Directorate, ***Technical Supplement to the Environmental Indicator Bulletin on Urban Air Quality***, Ottawa, 1994.
b. Environment Canada, State of the Environment Directorate, ***Technical Supplement to the Environmental Indicator Bulletin on Stratospheric Ozone Depletion***, Ottawa, 1993.
c. Organisation for Economic Cooperation and Development, ***OECD Environmental Data Compendium 1993***, Paris, 1993.
d. Statistics Canada, National Accounts and Environment Division.
e. Statistics Canada, ***Human Activity and the Environment 1994***, Cat. No. 11-509, Ottawa, 1994.
f. Statistics Canada, Agriculture Division.
g. Statistics Canada, ***Fertilizer Trade***, Cat. No. 46-207, Ottawa, various issues, and Agriculture Canada, Farm Policy Development Branch.
h. Natural Resources Canada, Canadian Forest Service, Canada's Forest Inventory 1981, 1986, 1991.
i. Environment Canada, State of Environment Directorate, ***Technical Supplement to a Report on Canada's Progress Towards a National Set of Environmental Indicators***, Ottawa, 1991.
j. Department of Fisheries and Oceans Canada, Biological Sciences Directorate.
k. Environment Canada, State of the Environment Directorate, ***Technical Supplement to the Environmental Indicator Bulletin on Energy Consumption***, Ottawa, 1994.

Table 2

Selected Water Quality Statistics, 1970-1992

	Source	1970	1975	1980	1983	1985	1986	1989	1991	1992
Surface water quality										
Nitrate(mg/litre)										
St. Lawrence River	a	0.193	0.230	0.160	..	0.200	..	0.420	..	..
Saskatchewan River	a	..	0.150	0.100	..	0.160	..	0.120	..	..
Phosphorus(mg/litre)										
St. Lawrence River	a	0.018	0.010	0.025	..	0.018	..	..	0.020	..
Saskatchewan River	a	..	0.049	0.064	..	0.070	..	..	0.032	..
Dissolved oxygen(mg/litre)										
St. Lawrence River	a	8.100	10.000	..	..	9.400	..	..	..	..
Saskatchewan River	a	..	10.000	10.800	..	10.400	..	..	10.000	..
Population served by municipal wastewater treatment (% of total population)										
No treatment	b	..	..	..	28	..	28	19	..	16
Some treatment	b	..	..	..	72	..	72	80	..	84
Primary treatment	b	..	..	..	16	..	15	20	..	20
Secondary treatment	b	..	..	..	28	..	26	28	..	27
Tertiary treatment	b	..	..	..	28	..	31	32	..	37

Note:
Figures may not add due to rounding.
Sources:
a. National Center for Economic Alternatives, ***Index of Environmental Trends***, Washington, 1995.
b. Environment Canada, Municipal Water Use Database (MUD).

Table 3

Selected Statistics on Land by Province and Territory, 1986-1993

	Year	Source	Canada	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Yukon	N.W.T.
Total area (km^2)		a	9 970 610	405 720	5 660	55 490	73 440	1 540 680	1 068 580	649 950	652 330	661 190	947 800	483 450	3 426 320
Water area (km^2)		a	755 180	34 030	--	2 650	1 350	183 890	177 390	101 590	81 630	16 800	18 070	4 480	133 300
Land area (km^2)		a	9 215 430	371 690	5 660	52 840	72 090	1 356 790	891 190	548 360	570 700	644 390	929 730	478 970	3 293 020
Area of farms (km^2)	1986	a	678 258	366	2 724	4 165	4 089	36 388	56 466	77 402	265 994	206 553	24 111	-	-
	1991	a	677 537	474	2 589	3 970	3 756	34 296	54 514	77 250	268 655	208 110	23 923	-	-
Forest land[1] (km^2)	1986	c	4 533 200	224 800	2 900	40 400	63 400	940 000	807 000	349 200	237 100	377 500	603 100	273 700	616 000
	1991	d	4 161 770	225 250	2 950	39 230	61 060	824 860	579 950	262 770	288 060	382 140	605 640	275 500	614 360
Other land (km^2)	1986	c	4 003 972	146 524	36	8 275	4 601	380 402	27 724	121 758	67 606	60 337	302 519	205 270	2 677 020
	1991	d	4 376 123	145 966	121	9 640	7 274	497 634	256 726	208 340	13 985	54 140	300 167	203 470	2 678 660
Use of farmland															
Cropland (km^2)	1986	a	331 812	49	1 565	1 095	1 295	17 444	34 580	45 193	133 258	91 625	5 708	-	-
	1991	a	335 078	63	1 541	1 062	1 222	16 385	34 117	47 610	134 589	92 920	5 568	-	-
Improved pasture (km^2)	1986	a	35 592	38	226	362	272	3 011	4 313	2 749	8 787	13 768	2 064	-	-
	1991	a	41 412	46	193	307	250	2 709	3 902	3 413	10 757	17 425	2 410	-	-
Summerfallow (km^2)	1986	a	84 990	4	26	39	43	318	803	5 092	56 583	21 270	812	-	-
	1991	a	79 209	1	10	12	16	147	637	2 970	57 128	17 714	575	-	-
Cropland tilled[2] (percent)	1991	b	80.9	97.7	99.4	98.9	98.7	99.1	98.2	94.1	70.2	84.0	90.6	-	-
Protected area (km^2)	1993	e	774 451	7 617	333	3 187	3 935	164 909	77 008	48 957	17 030	66 519	103 140	49 452	232 364
Road network															
Two-lane equivalent length[3] (km)	1990-91	f	874 155	12 290	4 935	25 779	20 670	119 321	167 500	84 965	193 923	173 473	62 158	5 238	3 903
Density (km/thousand km^2)	1990-91	f	95	33	872	488	287	88	188	155	340	269	67	11	1

Notes:
Figures may not add due to rounding.
1. Values in 1986 include estimates of non-inventoried forest land.
2. Cropland in this definition excludes no-till and permanent cropland areas such as tree fruit orchards.
3. Canada figures includes 14 743 km under federal jurisdiction.

Sources:
a. Statistics Canada, ***Canada Year Book 1994***, Cat. No. 11-402, Ottawa, 1994.
b. Statistics Canada, National Accounts and Environment Division.
c. Natural Resources Canada, ***Canada's Forest Inventory, 1986***, Ottawa, 1987.
d. Natural Resources Canada, Canadian Forest Service, Canadian Council of Forest Ministers, ***Compendium of Canadian Forestry Statistics 1993***, Ottawa, 1994.
e. ***Environment Canada, State of the Environment Directorate, National Conservation Areas Database, 1993.***
f. ***Transportation Association of Canada.***

Table 4

Selected Statistics on Forestry by Province and Territory, 1986-1992

Year	Canada	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Yukon[1]	N.W.T.[1]
Total production[2] (million $)													
1986	5 775.5	95.4	0.6	147.2	365.3	1 096.4	1 015.0	53.7	91.4	114.2	2 796.2	--	..
1987	7 538.3	107.7	--	173.5	439.1	1 441.4	1 146.9	74.7	107.3	138.8	3 907.3	--	..
1988	8 061.9	122.1	1.5	203.9	546.8	1 540.3	1 201.0	68.7	119.1	152.7	4 105.5	0.6	..
1989	8 696.8	132.0	2.0	203.9	603.4	1 732.9	1 290.5	72.9	122.4	183.9	4 351.7	1.4	..
1990	8 113.8	135.9	2.6	196.2	557.9	1 649.3	1 168.4	78.9	102.6	203.4	4 017.7	0.9	..
1991	7 702.0	132.6	3.3	198.2	492.2	1 520.6	1 092.6	61.7	78.3	273.4	3 848.5	0.6	..
1992	8 358.5	128.4	1.7	220.1	475.1	1 580.7	1 188.3	76.3	99.3	293.9	4 294.3	0.6	..
Total roundwood harvested (thousand cubic metres)													
1986	177 190	2 408	424	4 004	8 720	38 127	30 186	1 703	3 529	10 387	77 503	199	..
1987	191 684	2 524	479	4 789	7 869	39 503	29 692	1 887	3 666	10 496	90 591	188	..
1988	190 615	2 513	475	5 039	9 199	39 381	29 338	1 883	3 818	11 990	86 807	172	..
1989	188 254	2 535	416	4 772	9 281	36 192	29 642	1 848	3 685	12 293	87 414	176	..
1990	162 947	2 876	448	4 639	8 824	30 524	25 421	1 563	2 758	11 911	73 861	82	40
1991	161 511	2 680	452	4 322	8 643	29 595	23 828	1 278	2 957	12 926	74 706	79	47
1992	170 306	2 821	510	4 248	9 205	31 171	24 287	1 598	3 081	14 594	78 579	162	50
Area harvested (hectares)[3]													
1986	971 813	17 440	2 350	34 121	86 898	297 616	223 517	11 128	19 356	38 811	239 877	299	400
1987	1 050 850	18 940	2 725	42 266	88 976	329 300	228 464	12 362	25 742	40 248	259 982	1 172	672
1988	1 086 100	19 628	2 731	41 421	99 192	337 668	237 188	12 378	22 089	42 538	270 401	465	399
1989	1 017 820	19 449	2 421	36 733	90 144	342 231	230 308	12 205	22 281	41 688	218 384	1 554	450
1990	920 827	22 100	2 317	39 310	80 109	282 470	238 213	10 349	16 538	47 200	181 530	366	325
1991	857 162	20 584	2 091	37 566	91 916	236 815	199 719	8 518	17 522	47 960	192 654	350	467
1992	933 177	18 931	2 550	33 932	103 355	283 124	190 677	11 414	18 471	48 100	221 599	639	405
Area burned - stocked timber-productive forest land[3] (hectares)													
1986	311 367	23 511	85	268	37 216	173 296	50 598	5 495	4 031	1 587	9 474	3 132	11
1987	306 516	10 622	16	312	895	27 849	5 461	84 266	129 332	24 295	22 308	1 150	10
1988	639 777	7	2	89	1 778	273 066	35 994	295 930	24 187	5 149	3 284	288	3
1989	3 877 390	2 651	2	159	280	2 108 210	4 990	1 539 180	137 404	2 994	11 089	70 439	..
1990	281 831	2 601	4	477	5 198	76 825	3 200	6 727	71 198	21 281	52 575	16 704	..
1991	375 131	9 576	23	1 022	2 732	101 306	5 025	55 266	118 849	2 222	16 658	61 228	..
1992	..	1 015	8	805	4 668	24 298	10 331	187 890	12 798	1 006	..	3 785	..
Area seeded and planted (hectares)													
1986	334 918	802	863	9 160	20 517	64 888	94 782	4 146	4 482	19 539	115 739	-	-
1987	430 456	5 604	1 092	9 880	18 916	92 437	101 468	5 721	3 110	23 226	169 002	-	-
1988	459 865	4 468	1 077	11 655	19 123	99 880	111 251	7 061	7 020	28 845	169 485	-	-
1989	476 440	4 691	744	9 760	20 272	103 230	118 256	8 264	6 106	30 807	174 310	-	-
1990	508 608	3 548	833	11 255	22 148	104 369	107 861	6 282	6 012	37 052	209 168	80	..
1991	505 689	2 891	1 032	8 198	19 529	99 590	120 627	8 041	6 545	39 775	199 422	39	..
1992	463 364	3 531	1 161	7 502	16 526	96 897	96 259	7 142	6 404	42 973	184 922	45	2

Notes:

One square kilometre contains 100 hectares.

1. Data for Northwest Territories included in data for Yukon when not available separately.
2. Total production is the value of shipments of the logging industry.
3. Canada total includes areas burned in National Parks.

Sources:

Statistics Canada, ***Canadian Forestry Statistics***, Cat. No. 25-202, Ottawa, various issues.

Natural Resources Canada, Canadian Forests Service, Canadian Council of Forest Ministers, ***Compendium of Canadian Forestry Statistics 1993***, Ottawa, 1993.

Table 5

Nominal Catches and Landed Values of Fish by Species and Region, 1992-1993

Species	1992[1]						1993[1]					
	Atlantic coast		Pacific coast		**Canada**		Atlantic coast		Pacific coast		**Canada**	
	Quantity[2]	Value	Quantity[2]	Value	**Quantity[2]**	**Value**	Quantity[2]	Value	Quantity[2]	Value	**Quantity[2]**	**Value**
	tonnes	thousand dollars	tonnes	thousand dollars	**tonnes**	**thousand dollars**	tonnes	thousand dollars	tonnes	thousand dollars	**tonnes**	**thousand dollars**
Groundfish												
Cod[3]	186 522	152 023	10 111	5 519	**196 633**	**157 542**	71 889	59 936	7 700	4 377	**79 589**	**64 313**
Haddock	21 947	30 204	-	-	**21 947**	**30 204**	13 131	20 997	-	-	**13 131**	**20 997**
Redfish	97 990	27 706	24 752	18 252	**122 742**	**45 958**	77 734	21 070	22 527	16 031	**100 261**	**37 101**
Halibut	1 573	7 233	4 289	20 206	**5 862**	**27 439**	1 482	6 979	5 688	27 000	**7 170**	**33 979**
Flatfishes	48 500	29 245	7 802	5 728	**56 302**	**34 973**	38 597	23 659	9 341	6 712	**47 938**	**30 371**
Turbot	22 454	19 255	3 545	863	**25 999**	**20 118**	18 909	16 153	3 932	1 002	**22 841**	**17 155**
Pollock	34 056	24 007	3 006	911	**37 062**	**24 918**	21 970	12 370	5 744	1 877	**27 714**	**14 247**
Hake[4]	38 293	17 735	97 197	16 025	**135 490**	**33 760**	35 388	22 146	62 509	8 664	**97 897**	**30 810**
Cusk	5 077	4 271	-	-	**5 077**	**4 271**	2 948	2 347	-	-	**2 948**	**2 347**
Catfish	1 282	385	-	-	**1 282**	**385**	1 003	283	-	-	**1 003**	**283**
Other	3 641	1 687	8 954	26 339	**12 595**	**28 026**	3 583	1 281	9 127	23 325	**12 710**	**24 606**
Total	**461 335**	**313 751**	**159 656**	**93 843**	**620 991**	**407 594**	**286 634**	**187 221**	**126 568**	**88 988**	**413 202**	**276 209**
Pelagic and other finfish												
Herring	215 384	27 799	34 531	46 369	**249 915**	**74 168**	194 126	24 572	40 669	67 999	**234 795**	**92 571**
Mackerel	25 874	7 070	-	-	**25 874**	**7 070**	26 124	7 208	-	-	**26 124**	**7 208**
Tuna	494	7 468	309	789	**803**	**8 257**	524	5 678	322	755	**846**	**6 433**
Alewife	3 441	2 237	-	-	**3 441**	**2 237**	5 680	1 306	-	-	**5 680**	**1 306**
Eel	742	1 990	-	-	**742**	**1 990**	393	1 650	-	-	**393**	**1 650**
Salmon	283	1 095	64 856	161 284	**65 139**	**162 379**	134	625	81 743	189 338	**81 877**	**189 963**
Skate	491	78	259	52	**750**	**130**	293	47	224	38	**517**	**85**
Smelt	874	775	1	2	**875**	**777**	889	923	1	3	**890**	**926**
Capelin	30 966	4 813	-	-	**30 966**	**4 813**	47 441	13 409	-	-	**47 441**	**13 409**
Other	4 001	13 936	3 348	1 800	**7 349**	**15 736**	5 427	18 739	886	797	**6 313**	**13 409**
Total	**282 550**	**67 261**	**103 304**	**210 296**	**385 854**	**277 557**	**281 031**	**74 157**	**123 845**	**258 930**	**404 876**	**326 960**
Shellfish												
Clams	16 804	15 360	4 033	18 623	**20 837**	**33 983**	24 081	24 530	3 582	27 980	**27 663**	**52 510**
Oysters	600	992	5 000	4 000	**5 600**	**4 992**	621	1 193	5 250	4 200	**5 871**	**5 393**
Scallop	91 315	99 646	-	-	**91 315**	**99 646**	88 586	115 718	-	-	**88 586**	**115 718**
Squid	1 352	366	-	-	**1 352**	**366**	2 701	568	-	-	**2 701**	**568**
Lobster	41 560	313 968	-	-	**41 560**	**313 968**	40 098	293 718	-	-	**40 098**	**293 718**
Shrimps	39 241	81 241	3 505	10 864	**42 746**	**92 105**	38 037	81 299	4 262	12 140	**42 299**	**93 439**
Crab	37 861	58 817	2 492	9 336	**40 353**	**68 153**	62 611	112 544	6 242	18 550	**68 853**	**131 094**
Other	4 340	4 580	13 831	14 130	**18 171**	**18 710**	3 295	5 025	7 454	10 615	**10 749**	**15 640**
Total	**233 073**	**574 970**	**28 861**	**56 953**	**261 934**	**631 923**	**260 030**	**634 595**	**26 790**	**73 485**	**286 820**	**708 080**
Miscellaneous items[5]	**...**	**10 530**	**...**	**8 230**	**...**	**18 760**	**17 931**	**6 271**	**200**	**1 060**	**18 131**	**7 331**
Total sea fisheries	**976 958**	**966 512**	**291 821**	**369 322**	**1 268 779**	**1 335 834**	**845 626**	**902 244**	**277 403**	**422 463**	**1 123 029**	**1 318 580**
Total inland fisheries	**...**	**...**	**...**	**...**	**64 907**	**63 000**	**...**	**...**	**...**	**...**	**...**	**...**
Grand total	**976 958**	**966 512**	**291 821**	**369 322**	**1 333 686**	**1 398 834**	**845 626**	**902 244**	**277 403**	**422 463**	**1 123 029**	**1 318 580**

Notes:
1. Preliminary data.
2. Quantity in tonnes, live weight.
3. Pacific cod includes grey cod only.
4. Hake catches include over-the-side sales to foreign vessels.
5. Contains marine plants and lumpfish roe. May contain other miscellaneous items.

Source:
Department of Fisheries and Oceans Canada, Biological Sciences and Industry Development and Programs Directorate.

Table 6

Reserves of Crude Oil and Natural Gas by Province and Territory, December 31, 1986-1993

	Year	Canada	Eastern Canada	Eastcoast offshore	Ont.	Man.	Sask.	Alta.	B.C.	Mainland territories	Mackenzie Delta/ Beaufort Sea	Arctic Islands
Crude oil (thousand cubic metres)												
	1986	944 411	2	83 000	904	10 522	106 296	632 743	18 500	27 460	64 950	34
	1987	940 162	2	83 000	794	10 485	106 146	631 315	17 013	26 358	64 950	99
	1988	975 148	5	133 000	1 311	8 838	112 838	611 518	17 934	24 610	64 950	144
	1989	937 993	5	138 600	1 324	8 349	111 909	582 531	18 490	22 734	53 950	101
	1990	887 957	5	138 600	1 414	8 351	116 896	530 205	17 566	20 893	53 950	77
	1991	841 302	5	138 600	1 323	7 806	110 336	489 959	17 662	21 609	53 950	52
	1992	809 734	5	138 020	1 224	7 144	119 515	452 143	17 911	19 748	53 950	74
	1993	800 586	5	137 017	1 169	6 534	131 213	435 003	17 549	17 979	53 950	167
Natural gas (million cubic metres)												
	1986	2 745 510	141	-	17 444	-	61 305	1 749 997	240 307	11 636	258 310	406 370
	1987	2 692 783	125	-	17 949	-	60 705	1 727 725	210 327	11 272	258 310	406 370
	1988	2 670 545	98	-	18 311	-	56 283	1 688 054	210 094	11 205	280 130	406 370
	1989	2 732 449	90	-	17 529	-	74 791	1 705 559	218 393	10 987	298 730	406 370
	1990	2 725 390	72	-	16 903	-	78 880	1 689 884	223 638	10 913	298 730	406 370
	1991	2 710 869	72	-	16 718	-	71 182	1 678 553	229 215	10 029	298 730	406 370
	1992	2 671 554	71	-	16 881	-	70 409	1 621 875	247 335	9 883	298 730	406 370
	1993	2 232 256	111	-	17 217	-	80 927	1 578 959	246 957	9 355	298 730	- [1]

Notes:
Figures may not add due to rounding.
1. Reserves of crude oil in the Arctic Islands are no longer considered as economically recoverable.
Source:
Canadian Petroleum Association, ***Statistical Handbook***, Calgary, various issues.

Table 7

Quantity of Production of Crude Oil and Natural Gas by Province and Territory, 1986-1993

	Year	Canada	Eastern Canada	Eastcoast offshore	Ont.	Man.	Sask.	Alta.	B.C.	Yukon	N.W.T.[1]
Crude oil (thousand cubic metres)											
	1986	69 226	--	-	136	823	11 688	53 082	2 020	-	1 478
	1987	71 823	--	4	136	782	12 078	55 170	2 084	-	1 570
	1988	74 495	-	-	191	769	12 168	57 653	1 882	-	1 833
	1989	70 977	-	-	244	723	11 633	54 605	1 888	-	1 884
	1990	70 179	-	-	247	738	12 431	52 973	1 926	-	1 864
	1991	69 362	-	-	235	713	12 390	52 085	2 013	-	1 927
	1992	71 898	-	576	224	656	13 355	53 175	2 033	-	1 878
	1993	75 233	-	1 016	253	635	14 939	54 548	2 004	-	1 838
Natural gas (million cubic metres)											
	1986	91 667	1	-	504	-	2 204	80 303	8 374	-	282
	1987	99 490	1	-	508	-	2 751	86 259	9 724	-	249
	1988	114 135	-	-	509	-	4 156	98 577	10 687	-	205
	1989	118 706	-	-	492	-	5 506	99 747	12 788	-	171
	1990	121 696	-	-	449	-	6 552	102 748	11 800	-	147
	1991	129 596	-	-	428	-	7 172	106 851	14 712	-	434
	1992	143 205	-	-	427	-	7 030	118 895	16 134	506	213
	1993	155 030	-	-	411	-	7 372	129 129	17 399	491	228

Notes:
Figures may not add due to rounding.
1. From 1986 to 1991, production data for the Yukon and N.W.T. are reported together under the N.W.T.
Source:
Statistics Canada, ***The Crude Petroleum and Natural Gas Industry***, Cat. No. 26-213, Ottawa, various issues.

Table 8

Selected Metal Reserves by Province and Territory, December 31, 1986-1992

	Year	Canada	Nfld.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Yukon	N.W.T.
Copper (thousand tonnes)													
	1986	13 331	-	62	330	623	6 260	492	5	-	5 560	-	-
	1987	12 939	-	62	311	806	6 103	475	5	-	5 177	-	-
	1988	12 693	-	34	302	838	5 866	515	5	-	5 133	-	-
	1989	12 258	-	21	471	844	5 514	519	2	-	4 889	-	-
	1990	11 203	-	11	375	775	5 050	538	-	-	4 454	-	-
	1991	11 115	-	-	238	1 601	4 695	422	3	-	4 156	-	-
	1992	10 818	-	-	234	1 503	4 960	421	-	-	3 699	-	-
Nickel (thousand tonnes)													
	1986	6 704	-	-	-	-	4 908	1 796	-	-	-	-	-
	1987	6 605	-	-	-	-	4 822	1 784	-	-	-	-	-
	1988	6 279	-	-	-	-	4 546	1 733	-	-	-	-	-
	1989	6 132	-	-	-	-	4 461	1 672	-	-	-	-	-
	1990	5 792	-	-	-	-	4 208	1 584	-	-	-	-	-
	1991	5 691	-	-	-	-	4 162	1 529	-	-	-	-	-
	1992	5 605	-	-	-	-	4 160	1 445	-	-	-	-	-
Lead (thousand tonnes)													
	1986	7 167	-	-	3 648	-	133	25	--	-	1 256	1 275	831
	1987	6 694	-	-	3 551	-	104	25	--	-	1 180	1 212	621
	1988	6 969	-	-	3 482	-	101	20	-	-	1 071	1 755	540
	1989	6 941	-	68	3 839	9	100	17	-	-	999	1 404	506
	1990	6 317	-	29	3 383	28	94	13	-	-	957	1 358	456
	1991	4 954	-	-	2 463	23	63	9	-	-	908	1 093	397
	1992	4 348	-	-	2 264	20	53	11	-	-	786	856	358
Zinc (thousand tonnes)													
	1986	22 423	58	104	8 964	987	3 972	641	1	-	2 516	1 958	3 222
	1987	20 636	95	104	8 736	897	3 454	612	1	-	2 435	1 765	2 538
	1988	21 116	36	60	8 575	836	3 265	1 016	2	-	2 270	2 816	2 239
	1989	21 688	16	160	9 704	1 414	2 999	1 084	1	-	1 934	2 250	2 126
	1990	20 091	-	76	8 700	1 224	2 689	1 145	-	-	1 942	2 419	1 897
	1991	16 448	-	-	6 156	1 732	2 213	887	4	-	1 889	1 957	1 609
	1992	15 067	-	-	5 738	1 710	1 819	938	-	-	1 835	1 502	1 524
Silver (tonnes)													
	1986	26 694	-	-	9 759	1 506	6 893	721	2	-	5 838	1 849	126
	1987	25 648	-	-	9 699	1 501	6 057	729	2	-	5 621	1 896	143
	1988	26 959	-	-	9 933	1 200	5 802	812	3	-	6 140	2 943	127
	1989	26 790	4	-	10 761	1 620	5 504	787	1	-	5 624	2 349	141
	1990	23 227	4	-	9 498	1 311	5 027	757	1	-	4 162	2 339	127
	1991	19 069	2	-	7 003	2 074	4 422	654	3	-	2 838	1 953	121
	1992	16 300	3	-	6 456	2 008	4 106	398	-	-	2 098	1 119	113
Gold (tonnes)													
	1986	1 496	43	-	72	229	882	40	2	-	163	7	57
	1987	1 727	41	-	59	297	998	58	1	-	167	13	91
	1988	1 914	38	2	74	373	1 017	50	7	-	172	40	142
	1989	1 748	41	1	69	352	951	40	4	-	124	29	136
	1990	1 548	39	-	59	343	812	34	13	-	117	26	105
	1991	1 443	27	-	46	342	766	29	14	-	103	24	95
	1992	1 367	27	-	42	319	746	29	2	-	88	18	97

Note:
Figures may not add due to rounding.
Source:
Natural Resources Canada, ***Canadian Minerals Yearbook, Review and Outlook***, Ottawa, various issues.

Table 9

Production of Selected Metals by Province and Territory, 1986-1994

	Year	Canada	Nfld.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Yukon	N.W.T.
Copper (tonnes)	1986	698 527	-	-	6 298	51 622	264 870	65 369	3 506	-	306 855	6	1
	1987	794 149	-	x	7 233	66 848	287 354	66 121	2 335	-	364 134	x	2
	1988	758 478	-	-	7 966	47 633	286 536	53 072	2 168	-	360 570	x	1
	1989	704 432	-	x	7 802	65 135	271 914	50 484	x	-	308 348	-	-
	1990	771 433	-	x	8 620	99 198	273 448	55 506	x	-	333 883	-	-
	1991	780 362	-	x	10 476	113 931	261 899	54 875	x	-	338 642	-	-
	1992	761 694	-	-	13 697	91 950	272 242	60 024	-	-	323 781	-	-
	1993	709 650	231	-	11 190	78 973	277 461	56 502	-	-	285 293	-	-
	1994	583 271	600	-	7 566	65 597	225 066	40 863	-	-	243 579	-	-
Nickel (tonnes)	1986	163 639	-	-	-	-	121 851	41 788	-	-	-	-	-
	1987	189 086	-	-	-	-	130 171	58 915	-	-	-	-	-
	1988	198 744	-	-	-	-	128 558	70 186	-	-	-	-	-
	1989	195 554	-	-	-	-	130 632	64 922	-	-	-	-	-
	1990	195 004	-	-	-	-	128 828	66 176	-	-	-	-	-
	1991	188 098	-	-	-	-	125 790	62 309	-	-	-	-	-
	1992	177 555	-	-	-	-	118 860	58 695	-	-	-	-	-
	1993	178 529	-	-	-	-	125 833	52 696	-	-	-	-	-
	1994	144 323	-	-	-	-	113 648	30 675	-	-	-	-	-
Lead (tonnes)	1986	334 342	-	-	66 590	-	6 288	590	-	-	91 947	35 091	133 836
	1987	373 215	-	x	66 485	-	6 092	x	-	-	57 078	x	131 744
	1988	351 148	-	-	74 543	-	2 485	457	-	-	105 103	117 058	51 502
	1989	268 887	-	-	65 180	-	1 074	1 365	-	-	67 006	94 529	39 734
	1990	233 372	-	x	56 244	-	x	1 755	-	-	19 312	104 181	46 588
	1991	248 102	-	x	51 957	-	x	2 286	-	-	63 385	93 912	35 388
	1992	339 626	-	834	80 885	-	-	1 487	-	-	81 591	135 688	39 141
	1993	183 105	-	-	72 108	-	-	1 933	-	-	52 030	27 857	29 178
	1994	166 420	-	-	72 422	-	-	422	-	-	57 518	-	36 058
Zinc (tonnes)	1986	988 173	5 712	-	161 807	37 126	265 248	61 463	3 527	-	137 583	50 634	265 073
	1987	1 157 940	7 643	-	180 298	91 139	294 309	63 551	1 764	-	114 117	147 045	258 070
	1988	1 370 000	31 817	x	261 089	82 031	326 698	53 746	x	-	142 833	143 939	325 321
	1989	1 272 850	27 362	x	201 550	100 638	266 158	72 096	x	-	119 376	154 709	329 001
	1990	1 179 370	16 463	x	233 933	120 599	276 110	77 507	x	-	59 346	168 846	218 241
	1991	1 083 010	-	x	209 790	117 404	213 599	88 486	x	-	125 980	149 487	173 154
	1992	1 195 740	-	582	301 020	107 466	190 523	89 211	-	-	133 149	202 304	171 481
	1993	990 727	-	-	303 985	131 852	179 049	89 658	-	-	107 457	35 204	143 521
	1994	961 405	-	-	273 000	141 708	158 487	93 580	-	-	113 899	-	180 730
Silver (tonnes)	1986	1 088	-	-	163	62	348	37	3	--	380	73	22
	1987	1 475	-	--	182	163	441	41	2	--	401	133	13
	1988	1 443	x	x	203	140	434	32	x	-	447	159	26
	1989	1 312	x	x	191	148	349	36	x	-	498	71	18
	1990	1 381	x	x	145	164	330	41	x	-	598	84	19
	1991	1 261	x	x	158	164	294	43	x	-	497	87	17
	1992	1 169	x	--	254	143	248	40	x	-	345	124	16
	1993	879	x	-	223	143	232	38	x	-	201	30	11
	1994	708	x	-	211	134	191	38	x	-	116	1	17
Gold (kilograms)	1986	102 899	-	-	374	28 342	46 279	2 555	14	36	9 249	3 547	12 503
	1987	115 818	x	x	420	29 543	52 917	3 697	1 048	43	11 224	4 674	11 740
	1988	134 813	x	x	393	33 538	62 463	4 469	1 480	27	13 067	5 052	11 880
	1989	159 494	x	x	359	36 966	78 675	4 056	2 829	25	15 635	5 652	12 208
	1990	167 373	x	x	x	40 675	79 968	2 680	3 374	32	16 105	4 639	15 557
	1991	175 282	x	-	x	51 923	77 170	2 921	2 899	34	17 487	3 865	16 752
	1992	160 351	x	-	490	44 589	74 836	3 106	x	34	16 773	3 737	13 518
	1993	153 129	x	-	361	41 843	72 441	3 001	x	65	13 865	3 538	13 205
	1994	145 156	x	-	372	40 936	68 476	2 456	x	12	12 266	3 218	13 079

Note:
Figures may not add due to rounding.
Sources:
Statistics Canada, ***General Review of the Mineral Industries, Mines, Quarries and Oil Wells***, Cat. No. 26-201, Ottawa, various issues.
Statistics Canada, ***Canada's Mineral Production, Preliminary Estimates***, Cat. No. 26-202, Ottawa, various issues.

Table 10

Value of Mineral Production, 1986-1994

Year	Canada	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Yukon	N.W.T.
	million dollars												
1986	32 446	817	2	367	502	2 191	4 825	764	2 525	16 331	3 160	176	788
1987	36 361	743	3	407	624	2 780	5 652	1 000	3 151	17 080	3 615	437	870
1988	36 955	865	2	446	911	2 712	6 895	1 627	3 043	15 062	3 943	492	957
1989	39 333	897	2	442	859	2 878	7 308	1 668	3 017	16 456	4 123	534	1 149
1990	40 778	866	3	459	878	3 037	6 446	1 311	3 183	19 110	3 954	542	988
1991	35 190	772	3	460	671	2 930	5 101	1 125	2 863	16 373	3 840	349	703
1992	35 414	706	2	523	910	2 694	4 776	1 082	3 158	16 885	3 500	496	681
1993	36 564	699	1	558	772	2 692	4 535	862	3 238	18 925	3 538	140	603
1994	39 884	796	1	610	814	2 804	4 866	775	4 064	20 436	3 949	81	689

Note:
Figures include the shipments of fuels, metals and structural materials of all establishments in Canada, regardless of their industrial classification.
Source:
Statistics Canada, ***Canada's Mineral Production, Preliminary Estimates***, Cat. No. 26-202, Ottawa, various issues.

Table 11

Selected Statistics on Energy by Province and Territory, 1986-1993

	Year	Canada	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Yukon and N.W.T.
Production (petajoules)													
	1986	9 736.4	141.0	-	82.7	44.7	535.5	410.3	117.7	693.3	6 486.5	1 152.0	72.7
	1987	10 250.4	136.1	-	83.6	41.2	566.4	400.3	99.8	732.0	6 852.5	1 262.6	75.9
	1988	11 175.4	143.0	-	101.9	43.6	537.8	421.4	85.2	820.7	7 577.3	1 359.5	85.0
	1989	11 349.7	118.1	-	103.6	41.6	518.0	424.1	94.0	845.9	7 637.6	1 482.0	84.7
	1990	11 392.6	125.0	-	101.6	46.7	482.4	402.2	100.1	901.1	7 669.7	1 478.7	85.2
	1991	11 789.0	127.5	-	121.8	43.8	512.9	436.6	108.8	887.3	7 869.0	1 588.6	92.6
	1992	12 217.5	125.6	-	131.1	39.0	527.7	421.6	120.6	969.2	8 388.3	1 394.1	100.3
	1993	12 995.2	141.2	-	107.2	40.7	557.5	461.6	121.4	1 021.1	8 893.2	1 553.3	98.0
Total domestic consumption[1,2] (petajoules)													
	1986	7 844.6	129.7	17.5	221.6	175.7	1 421.5	2 700.6	240.7	408.0	1 769.4	725.6	34.2
	1987	8 070.2	137.8	19.2	227.8	190.1	1 444.4	2 771.4	234.4	420.7	1 824.8	768.2	31.3
	1988	8 585.6	143.2	20.5	236.5	214.6	1 540.1	2 919.7	260.0	454.7	1 943.3	821.1	31.9
	1989	8 947.0	155.6	22.2	243.4	234.4	1 574.4	3 033.7	260.6	460.0	2 053.6	877.9	31.2
	1990	8 590.8	156.1	22.5	243.2	225.6	1 521.4	2 785.3	257.5	457.3	2 019.2	871.1	31.6
	1991	8 515.6	145.7	22.1	236.1	221.6	1 473.5	2 788.0	255.8	443.9	2 042.2	855.6	31.0
	1992	8 756.7	142.8	21.9	243.4	228.3	1 523.8	2 859.1	257.8	513.9	2 084.2	849.1	32.5
	1993	8 830.5	142.8	22.4	242.3	223.7	1 555.5	2 828.4	263.1	520.0	2 102.1	897.1	33.0
Consumption per capita (gigajoules)													
	1986	299.4	224.4	135.9	248.4	241.4	211.1	285.0	220.0	395.0	725.6	240.2	426.4
	1987	304.0	239.0	148.8	254.2	260.2	212.2	286.2	213.0	405.9	746.8	250.7	388.8
	1988	319.2	248.5	158.1	262.7	292.7	224.5	295.4	235.4	440.7	789.0	262.5	393.3
	1989	326.8	269.5	170.0	268.4	317.6	226.6	298.9	235.6	449.7	820.0	273.6	379.1
	1990	309.1	269.6	171.8	266.5	303.6	216.7	269.3	232.3	452.4	789.9	264.0	375.3
	1991	302.8	251.1	169.0	257.2	296.1	208.1	266.2	229.9	441.1	785.1	253.2	360.0
	1992	306.8	244.6	166.4	263.1	303.1	213.0	268.6	230.5	509.6	786.8	244.1	371.9
	1993	305.1	244.4	168.2	260.2	295.9	215.2	261.6	233.7	513.9	782.0	251.0	374.1

Notes:
1. Domestic consumption data are equivalent to gross availability data in Statistics Canada Cat. No. 57-003.
2. Includes consumption of energy commodities for non-energy purposes.
Source:
Statistics Canada, ***Quarterly Report on Energy Supply-Demand in Canada***, Cat. No. 57-003, Ottawa, various issues.

Table 12

Federal Government Environmental Protection Expenditures, 1986-1994

	1986	1987	1988	1989	1990	1991	1992	1993[1]	1994[1]
	thousand dollars								
Pollution abatement and control									
Sewage collection and disposal	-	-	-	-	-	-	150	275	-
Pollution control	61 983	67 297	87 142	113 085	118 855	20 221	4 329	1 004	5 870
Other environmental services	383 744	430 794	442 869	497 185	571 471	682 955	709 679	749 906	929 389
Total[2]	**445 727**	**498 091**	**530 011**	**610 270**	**690 326**	**703 176**	**714 158**	**751 185**	**935 259**
Natural resource conservation and development									
Agriculture	3 238 420	4 720 870	3 614 210	3 011 500	2 592 670	4 622 130	3 237 910	2 881 500	2 436 520
Fish and game	388 334	328 401	393 464	402 070	470 382	483 973	693 646	692 158	573 942
Forests	224 701	660 250	311 776	284 463	215 421	206 653	236 048	237 655	225 869
Mines, oil and gas	1 094 980	708 981	767 246	365 551	383 426	325 310	321 573	497 388	568 992
Other resource conservation and development	702 999	650 481	707 769	760 003	725 538	623 016	620 308	591 718	522 337
Total	**5 649 440**	**7 068 990**	**5 794 460**	**4 823 590**	**4 387 440**	**6 261 080**	**5 109 490**	**4 900 420**	**4 327 660**

Notes:
Figures may not add due to rounding.
Includes transfer payments to other levels of government.
1. Estimates.
2. There are no federal government expenditures on waste collection and disposal.
Source:
Statistics Canada, Public Institutions Division.

Table 13

Provincial, Territorial and Local Government Environmental Protection Expenditures[1], Selected Years

Year	Canada	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Yukon	N.W.T.
	thousand dollars												
PROVINCIAL AND TERRITORIAL GOVERNMENTS													
Pollution abatement and control													
Sewage collection and disposal[2]													
1988	77 526	-	2 018	-	9 663	-	-	3 594	-	-	61 156	-	1 094
1989	72 412	-	-	720	9 554	-	-	-	-	-	59 729	2 409	-
1990	75 327	-	-	127	9 367	-	-	-	95	-	63 557	2 181	-
1991	100 597	-	-	92	8 191	-	-	-	64	-	89 873	2 377	-
Waste collection and disposal													
1988	54 022	330	2 098	2 878	3 899	-	27 488	2 039	-	262	15 028	-	-
1989	114 495	163	2 150	8 817	4 579	-	36 648	5 481	-	31 029	25 425	202	-
1990	125 943	296	2 268	12 546	5 850	-	50 234	5 415	-	38 515	10 673	158	-
1991	160 863	261	3 170	12 672	5 907	-	73 066	6 493	8	40 108	18 975	202	-
Pollution control													
1988	226 639	2 754	128	-	9 320	23 766	134 829	263	4 009	47 997	2 885	-	689
1989	280 066	3 679	113	4 601	13 802	19 820	188 239	393	4 314	40 973	3 437	32	662
1990	296 300	2 559	176	5 312	13 834	-	202 993	399	29 465	40 754	11	8	789
1991	341 901	2 956	348	6 103	18 420	-	240 212	746	29 730	42 626	-	-	759
Other environmental services													
1988	164 641	-	1 644	3 222	1 247	56 377	4 269	8 586	67 188	21 142	-	-	966
1989	202 524	1 525	2 585	15 722	1 840	74 925	4 530	8 537	71 500	7 813	12 936	500	111
1990	379 501	1 848	3 117	18 029	6 045	147 799	19 907	9 351	74 464	10 096	88 402	444	-
1991	465 220	1 822	3 012	18 437	17 624	157 476	20 832	10 100	121 699	11 787	101 778	589	62
Total pollution abatement and control													
1988	522 828	3 083	5 887	6 101	24 129	80 143	166 586	14 482	71 197	69 401	79 069	-	2 748
1989	669 496	5 367	4 848	29 861	29 776	94 745	229 416	14 410	75 814	79 815	101 527	3 143	774
1990	877 071	4 703	5 561	36 014	35 096	147 799	273 124	15 165	104 023	89 365	162 642	2 790	789
1991	1 068 580	5 039	6 530	37 304	50 143	157 476	334 111	17 339	151 500	94 521	210 627	3 168	821

Table 13

Provincial, Territorial and Local Government Environmental Protection Expenditures[1], Selected Years (Continued)

Year	Canada	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Yukon	N.W.T.
						thousand dollars							
Natural resource conservation and development													
Agriculture													
1988	2 726 916	16 943	31 592	42 838	25 308	654 287	340 495	242 983	636 169	636 311	99 634	346	10
1989	2 834 386	18 629	34 309	40 853	30 577	638 860	329 100	278 030	611 185	755 443	97 062	326	11
1990	2 901 736	18 095	33 405	42 658	36 413	717 880	416 988	177 629	631 442	720 653	106 207	347	18
1991	4 168 575	15 108	42 418	39 741	39 284	835 784	466 226	473 086	1 119 182	1 033 826	103 331	485	104
Fish and game													
1988	302 864	43 445	3 313	10 713	14 830	87 862	63 249	6 797	5 593	25 668	28 889	6 008	6 496
1989	342 942	50 158	3 363	8 562	27 608	95 092	70 067	10 403	6 876	27 198	29 529	6 462	7 624
1990	349 733	46 291	3 742	6 903	23 905	111 413	77 668	9 686	9 621	28 907	16 338	7 314	7 943
1991	338 934	34 140	4 066	7 628	21 611	99 392	85 151	8 538	10 819	31 457	22 125	5 796	8 212
Forests													
1988	1 247 665	25 560	5 120	42 272	26 773	288 803	284 927	13 670	11 748	113 933	416 771	10	18 079
1989	1 394 897	29 767	5 739	80 212	21 765	292 842	266 760	15 699	69 916	111 643	468 092	788	31 674
1990	1 413 677	31 032	6 603	51 736	26 445	298 177	286 626	14 035	50 442	143 210	481 294	875	23 202
1991	1 537 011	26 602	6 722	50 064	30 629	310 061	293 912	12 483	81 156	126 184	571 995	848	26 356
Mines, oil and gas													
1988	977 089	12 456	-	14 436	3 483	79 996	36 437	10 753	17 268	704 543	54 875	1 690	41 153
1989	1 340 073	13 385	-	9 741	3 229	76 756	41 753	10 203	379 331	707 789	48 868	3 037	45 983
1990	990 898	19 744	-	10 640	3 886	81 812	41 592	9 782	126 073	603 688	44 376	1 271	48 031
1991	1 167 788	42 329	-	11 567	2 871	78 486	41 690	10 950	316 613	531 617	81 028	1 331	49 308
Other resource conservation and development													
1988	837 672	4 470	5 101	4 834	28 103	76 748	212 819	52 283	22 579	366 462	45 786	9 101	9 386
1989	860 072	3 711	6 979	5 454	35 271	80 178	224 993	74 531	26 831	269 099	110 895	5 568	16 562
1990	764 131	4 311	6 131	5 053	33 160	79 882	263 859	49 141	22 768	212 998	61 890	5 513	19 424
1991	806 594	3 804	5 562	9 369	29 465	65 955	313 445	32 752	22 042	213 629	83 369	6 534	20 668
Total natural resource conservation and development													
1988	6 092 206	102 874	45 126	115 093	98 496	1 187 696	937 927	326 485	693 357	1 846 917	645 955	17 156	75 124
1989	6 772 370	115 650	50 390	144 823	118 450	1 183 728	932 672	388 865	1 094 139	1 871 171	754 447	16 180	101 855
1990	6 420 174	119 472	49 881	116 991	123 809	1 289 165	1 086 734	260 274	840 347	1 709 458	710 105	15 321	98 618
1991	8 018 902	121 983	58 768	118 368	123 860	1 389 678	1 200 424	537 809	1 549 811	1 936 712	861 848	14 994	104 648
Parks[3]													
1988	192 326	7 207	3 040	4 652	8 905	29 730	51 609	17 516	3 749	35 820	30 086	11	-
1989	227 059	6 458	3 293	15 289	9 575	30 048	57 660	17 157	16 402	33 074	37 243	861	-
1990	225 968	6 442	3 663	7 186	10 053	31 707	66 482	18 278	17 072	33 020	31 500	565	-
1991	204 713	6 644	3 654	6 838	9 450	32 569	57 214	16 374	15 449	27 559	28 550	412	-
LOCAL GOVERNMENTS[4]													
Pollution abatement and control													
Sewage collection and disposal													
1986	1 138 020	15 870	1 861	19 523	27 222	298 598	448 513	55 779	34 313	116 101	114 158	1 234	4 851
1987	1 208 600	19 216	1 797	25 389	31 212	287 120	476 460	39 115	35 169	130 956	152 517	1 078	8 573
1988	1 413 610	19 426	1 796	38 941	30 740	377 887	597 643	40 072	36 301	118 368	142 171	1 483	8 781
1989	1 734 760	19 028	1 945	31 176	30 702	531 371	723 837	49 106	41 358	138 229	154 934	1 061	12 009
1990	2 002 000	24 951	2 165	38 281	40 240	659 991	778 073	52 055	42 458	161 963	185 334	2 074	14 412
1991	1 954 270	19 420	2 580	63 118	42 898	537 628	838 006	55 495	37 362	146 430	192 799	4 216	14 320
1992	2 126 730	21 655	2 703	43 063	44 067	502 636	924 897	95 831	42 765	199 254	230 974	5 980	12 900
1993	2 236 360	20 064	2 517	62 161	39 313	601 071	853 683	67 825	54 572	198 465	314 877	6 218	15 591
Waste collection and disposal													
1986	627 753	12 110	549	17 372	6 514	143 005	267 841	19 445	16 066	47 835	93 584	799	2 633
1987	714 493	11 264	480	46 967	8 229	154 344	297 685	21 613	20 583	50 148	99 156	488	3 536
1988	817 079	10 576	497	21 941	9 824	178 308	391 866	24 526	17 841	53 813	103 199	625	4 063
1989	935 818	11 915	581	24 059	12 156	195 986	462 601	26 080	16 766	58 925	122 472	580	3 697
1990	1 125 910	12 044	612	31 928	13 305	223 016	584 145	25 682	17 595	66 592	146 467	640	3 879
1991	1 228 220	14 183	667	41 172	14 825	267 306	607 933	26 043	17 993	72 961	160 562	684	3 893
1992	1 389 770	12 438	906	42 751	14 638	314 984	670 971	35 925	21 013	91 831	178 296	939	5 082
1993	1 406 330	12 784	938	47 958	15 789	346 162	655 612	31 268	20 222	89 196	179 247	950	6 204

Table 13

Provincial, Territorial and Local Government Environmental Protection Expenditures[1], Selected Years (Concluded)

Year	Canada	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Yukon	N.W.T.
						thousand dollars							
Other environmental services[5]													
1986	76 909	5	-	200	-	33 978	39 960	471	58	163	2 058	-	16
1987	87 911	14	139	60	514	35 427	48 508	514	124	264	2 331	-	16
1988	75 200	14	151	107	404	32 988	37 769	676	193	273	2 614	-	11
1989	82 615	11	160	225	15	31 674	45 901	668	225	204	3 514	-	18
1990	82 331	6	176	286	1 854	32 024	43 182	733	274	-	3 695	-	101
1991	80 949	4	183	1 332	1 844	18 387	54 307	884	205	-	3 742	1	60
1992	92 083	310	192	1 304	1 547	20 411	61 518	515	302	449	4 995	515	25
1993	97 558	4	196	14	1 586	34 887	54 168	530	1 722	273	4 159	-	19
Total pollution abatement and control													
1986	1 842 690	27 985	2 410	37 095	33 736	475 581	756 314	75 695	50 437	164 099	209 800	2 033	7 500
1987	2 011 010	30 494	2 416	72 416	39 955	476 891	822 653	61 242	55 876	181 368	254 004	1 566	12 125
1988	2 305 890	30 016	2 444	60 989	40 968	589 183	1 027 280	65 274	54 335	172 454	247 984	2 108	12 855
1989	2 753 190	30 954	2 686	55 460	42 873	759 031	1 232 340	75 854	58 349	197 358	280 920	1 641	15 724
1990	3 210 230	37 001	2 953	70 495	55 399	915 031	1 405 400	78 470	60 327	228 555	335 496	2 714	18 392
1991	3 263 440	33 607	3 430	105 622	59 567	823 321	1 500 250	82 422	55 560	219 391	357 103	4 901	18 273
1992	3 608 580	34 403	3 801	87 118	60 252	838 031	1 657 390	132 271	64 080	291 534	414 265	7 434	18 007
1993	3 740 250	32 852	3 651	110 133	56 688	982 120	1 563 460	99 623	76 516	287 934	498 283	7 168	21 814
Natural resource conservation and development													
Agriculture													
1986	184 946	-	-	260	-	-	26 166	6 517	20 581	127 487	3 911	-	24
1987	170 102	284	-	259	-	-	27 041	6 792	20 420	111 012	4 261	-	33
1988	124 297	36	-	296	-	-	20 872	7 247	11 875	79 431	4 524	4	12
1989	163 413	-	-	346	3	1 912	22 126	7 864	20 632	105 507	4 995	17	11
1990	156 099	-	-	377	-	2 368	19 771	8 302	20 735	99 351	5 051	3	141
1991	168 376	-	-	373	-	2 645	26 245	7 801	25 811	99 764	5 610	6	121
1992	146 683	24	-	345	3	-	24 302	8 521	18 038	88 258	7 118	42	32
1993	139 388	25	-	346	52	40	14 492	8 776	18 215	90 055	7 309	44	34
Other resource conservation and development													
1986	153 199	139	181	537	2 090	34 051	73 469	8 162	3 750	17 392	13 104	-	324
1987	196 185	184	190	657	4 730	38 488	108 173	8 868	3 340	9 961	21 421	36	137
1988	225 945	533	148	953	5 273	41 905	119 391	9 888	4 349	8 223	35 204	23	55
1989	252 980	723	-	1 934	4 535	61 826	139 722	9 944	3 371	10 815	19 671	100	339
1990	316 331	789	-	837	4 898	76 782	173 697	11 103	4 050	10 327	33 488	194	166
1991	328 878	818	-	1 060	4 817	84 100	170 408	12 262	8 191	10 157	36 747	186	132
1992	307 959	788	-	1 357	4 162	52 497	182 251	11 063	4 453	11 336	39 709	222	121
1993	286 726	811	-	1 561	3 670	47 311	161 287	11 395	4 621	12 355	43 501	125	89
Total natural resource conservation and development													
1986	338 145	139	181	797	2 090	34 051	99 635	14 679	24 331	144 879	17 015	-	348
1987	366 287	468	190	916	4 730	38 488	135 214	15 660	23 760	120 973	25 682	36	170
1988	350 242	569	148	1 249	5 273	41 905	140 263	17 135	16 224	87 654	39 728	27	67
1989	416 393	723	-	2 280	4 538	63 738	161 848	17 808	24 003	116 322	24 666	117	350
1990	472 430	789	-	1 214	4 898	79 150	193 468	19 405	24 785	109 678	38 539	197	307
1991	497 254	818	-	1 433	4 817	86 745	196 653	20 063	34 002	109 921	42 357	192	253
1992	454 642	812	-	1 702	4 165	52 497	206 553	19 584	22 491	99 594	46 827	264	153
1993	426 114	836	-	1 907	3 722	47 351	175 779	20 171	22 836	102 410	50 810	169	123

Notes:
Figures may not add due to rounding.
1. Local government expenditures exclude transfers between municipalities. Provincial/territorial government expenditures include intergovernmental transfer payments.
2. Some provinces and territories report their sewage expenditures under water supply expenditures, which are not considered as environmental protection expenditures.
3. Data on expenditures for parks are only available for provincial/territorial governments.
4. Local government expenditures for 1992 and 1993 are estimated.
5. Local government expenditures on other environmental services may include expenditures specific to pollution control.

Source:
Statistics Canada, Public Institutions Division.

Table 14

Selected Statistics on Population by Province and Territory, Various Years

	Source	Canada	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Yukon	N.W.T.
Total population (thousands)														
1981	a	24 900.0	576.5	124.0	856.4	708.4	6 568.0	8 837.8	1 038.5	978.2	2 303.8	2 836.5	24.1	47.9
1986	a	26 203.8	578.1	128.8	892.1	727.7	6 733.8	9 477.2	1 094.0	1 032.9	2 438.7	3 020.4	24.8	55.4
1991	a	28 120.1	580.3	130.8	917.9	748.5	7 080.6	10 471.5	1 112.5	1 006.3	2 601.3	3 379.8	29.1	61.3
1993	a	28 940.6	584.4	133.2	931.2	756.0	7 228.8	10 813.2	1 125.8	1 011.9	2 688.1	3 573.9	30.6	63.4
1994	a	29 248.1	582.4	134.5	936.7	759.3	7 281.1	10 927.8	1 131.1	1 016.2	2 716.2	3 668.4	30.1	64.3
2016[1]	b	39 372.0	606.3	159.4	1 061.9	846.8	8 849.9	15 803.6	1 248.0	979.1	3 955.0	5 704.3	51.6	106.1
Average annual growth (percent)														
1981 to 1994	c	1.3	0.1	0.7	0.7	0.6	0.8	1.8	0.7	0.3	1.4	2.3	1.9	2.6
Total fertility rate[2]														
1990	d	1.8	1.6	1.9	1.7	1.6	1.7	1.8	2.0	2.1	2.0	1.8	2.3	3.1
Life expectancy (years)														
1981 - Male	b	71.9	..	..	..	..	..	..	..	..	..	..	..	..
Female	b	79.0	..	..	..	..	..	..	..	..	..	..	..	..
1986 - Male	b	73.0	..	..	..	..	..	..	..	..	..	..	..	..
Female	b	79.7	..	..	..	..	..	..	..	..	..	..	..	..
1990 - Male	b	73.7	73.5	74.1	72.9	73.0	73.0	74.0	74.1	74.4	74.1	74.4	70.1	70.1
Female	b	80.8	80.2	81.8	80.3	80.9	80.6	80.7	80.7	81.6	81.2	81.4	76.5	76.5
Age-standardized mortality rate (deaths per 100 000 population, 1990)														
Male	e	641.4	709.8	704.0	689.1	652.7	694.7	627.9	622.7	590.0	611.8	593.8	721.9	837.0
Female	e	454.0	515.1	477.7	487.7	454.6	455.2	457.4	456.6	430.5	429.9	441.4	729.2	594.0
Infant mortality rate (deaths per thousand live births)														
1981	f	9.6	9.7	13.2	11.5	10.9	8.5	8.8	11.9	11.8	10.6	10.2	14.9	21.5
1986	f	7.9	8.0	6.7	8.4	8.3	7.1	7.2	9.2	9.0	9.0	8.5	24.8	18.6
1990	f	6.4	7.8	6.9	5.7	6.1	5.9	6.3	6.4	8.2	6.7	6.5	10.6	12.2
Urbanization (percent)														
1991	g	76.6	53.6	39.9	53.5	47.7	77.6	81.8	72.1	63.0	79.8	80.4	58.8	36.7
Households (thousands)														
1991	g	10 079.4	175.7	44.8	326.5	255.0	2 650.1	3 661.7	407.1	366.1	914.7	1 251.4	10.1	16.3
1993[3]	h	10 247.0	182.0	47.0	336.0	256.0	2 688.0	3 765.0	387.0	361.0	923.0	1 302.0	..	..
Expenditures on education (million dollars)														
1980	i	22 879.8	467.7	95.2	712.1	532.6	7 151.9	7 814.4	839.1	843.1	1 941.3	2 225.1	98.5	158.8
1985	i	34 579.9	741.1	150.4	1 131.6	877.8	9 441.4	12 070.2	1 424.5	1 390.5	3 602.1	3 241.9	178.1	330.3
1990	i	48 183.7	1 029.0	195.8	1 473.9	1 198.9	11 869.3	18 147.3	1 957.8	1 788.9	4 562.4	5 200.1	285.9	474.4
Land area (thousand square kilometres)														
	d	9 215.4	371.7	5.7	52.8	72.1	1 356.8	891.2	548.4	570.7	644.4	929.7	479.0	3 293.0
Population density (persons per km^2)														
1981	c	2.7	1.6	21.9	16.2	9.8	4.8	9.9	1.9	1.7	3.6	3.1	0.1	--
1986	c	2.8	1.6	22.8	16.9	10.1	5.0	10.6	2.0	1.8	3.8	3.2	0.1	--
1991	c	3.1	1.6	23.1	17.4	10.4	5.2	11.8	2.0	1.8	4.0	3.6	0.1	--
1993	c	3.1	1.6	23.5	17.6	10.5	5.3	12.1	2.1	1.8	4.2	3.8	0.1	--
1994	c	3.2	1.6	23.8	17.7	10.5	5.4	12.3	2.1	1.8	4.2	3.9	0.1	--
2016	c	4.3	1.6	28.2	20.1	11.7	6.5	17.7	2.3	1.7	6.1	6.1	0.1	--

Notes:
Figures may not add due to rounding.
1. Projection 3 - Medium growth.
2. The total fertility rate is based on the age-specific fertility rates for a particular year and refers to the number of children that each woman would, on average, bear in her lifetime. A generation would be replaced if, on average, each woman bore 2.1 children.
3. The total number of households for 1993 are estimated figures. Estimates are unavailable for the Yukon and North West Territories.

Sources:
a. Statistics Canada, intercensal estimates adjusted for net undercount and non-permanent residents.
b. Statistics Canada, Demography Division.
c. Statistics Canada, National Accounts and Environment Division.
d. Statistics Canada, ***Canada Year Book, 1994***, Cat. No. 11-402, Ottawa, 1994.
e. Statistics Canada, Health Division.
f. Statistics Canada, ***Mortality: Summary List of Causes***, Cat. No. 84-209, Ottawa, 1993.
g. Statistics Canada, Census of Population.
h. Statistics Canada, ***Household Facilities by Income and Other Characteristics***, Cat. No. 13-218, Ottawa, 1993.
i. Statistics Canada, ***Financial Statistics of Education***, Cat. No. 81-208, Ottawa, various issues.

Table 15

Selected Statistics on the Economy by Province and Territory, 1981-1994

	Source	Canada	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Yukon	N.W.T.
Gross Domestic Product[1] (million 1986 dollars)														
1981	a	440 127	6 002	1 239	10 749	8 045	105 067	168 820	15 789	14 799	51 779	53 842	539	1 019
1986	a	505 666	6 970	1 567	13 239	10 447	116 536	204 494	18 588	17 453	56 844	56 204	587	1 414
1991	a	554 735	7 729	1 772	14 197	11 263	126 399	221 340	18 899	18 810	64 219	66 793	844	1 699
1993	a	570 541	7 634	1 822	14 677	11 824	129 689	225 807	19 110	18 401	68 235	70 332	735	1 624
1994	b	596 290	7 803	1 934	14 864	12 038	134 684	238 576	19 841	18 951	71 073	73 652	715	1 653
GDP per capita (thousand 1986 dollars per person)														
1981	c	17 676	10 411	9 992	12 551	11 357	15 997	19 102	15 204	15 129	22 475	18 982	22 365	21 273
1986	c	19 297	12 057	12 166	14 840	14 356	17 306	21 577	16 991	16 897	23 309	18 608	23 669	25 523
1991	c	19 727	13 319	13 547	15 467	15 047	17 851	21 137	16 988	18 692	24 687	19 762	29 003	27 716
1993	c	19 714	13 063	13 679	15 761	15 640	17 941	20 883	16 975	18 185	25 384	19 679	24 020	25 615
1994	c	20 387	13 398	14 379	15 868	15 854	18 498	21 832	17 541	18 649	26 166	20 077	23 754	25 708
Average annual real GDP growth 1984-91: Goods producing industries (percent)														
Primary	d	1.9	-4.0	-1.8	1.9	2.0	2.2	-1.0	2.2	4.6	2.0	2.7	28.4	-3.3
Manufacturing	d	1.1	-0.3	5.0	-0.1	2.2	1.5	0.5	1.1	3.1	3.3	1.7	21.0	7.7
Other goods producing industries	d	2.6	0.3	6.7	2.7	3.4	2.3	2.2	3.1	1.1	3.1	4.6	5.4	-4.0
GDP distribution by sector (1991): Goods producing industries (percent)														
Primary	d	20.7	24.2	34.6	20.7	17.9	9.6	7.7	26.9	61.5	53.9	24.3	55.9	64.3
Manufacturing	d	51.9	28.4	25.1	43.7	39.4	61.2	68.6	40.4	14.9	20.6	42.7	3.2	2.8
Other goods producing industries	d	27.4	47.4	40.3	35.6	42.7	29.2	23.6	32.7	23.6	25.5	33.1	40.9	32.9
Personal income per capita (1986 dollars per person)														
1986	a	16 853	11 731	12 535	14 088	13 044	15 774	18 612	15 224	15 017	17 744	16 902	19 167	19 865
1991	a	22 560	16 553	16 847	18 573	17 778	20 988	25 386	19 276	17 941	22 477	22 955	25 815	26 327
Passenger automobiles[2] (thousands)														
1981	f	10 199	142	49	350	252	2 379	3 831	461	392	1 216	1 116	7	6
1986	f	11 477	176	56	337	286	2 614	4 244	527	389	1 296	1 527	8	17
1991	f	13 061	202	64	426	312	2 978	4 847	544	416	1 424	1 807	20	20
1993	f	13 448	207	65	429	324	3 070	5 002	551	414	1 507	1 879	10	20
Passenger automobiles per capita (vehicles per thousand persons)														
1981	c	409.6	246.3	395.2	408.7	355.7	362.2	433.5	443.9	400.7	527.8	393.4	290.5	125.3
1986	c	438.0	304.4	434.8	377.8	393.0	388.2	447.8	481.7	376.6	531.4	505.6	322.6	306.9
1991	c	464.5	348.1	489.3	464.1	416.8	420.6	462.9	489.0	413.4	547.4	534.6	687.3	326.3
1993	c	464.7	354.6	484.8	461.0	429.0	424.7	462.6	489.5	409.3	560.7	525.7	317.8	310.5
Gasoline sales for automotive purposes (million litres)														
1981	g	30 782.5	587.1	171.3	1 141.1	1 070.8	8 104.6	12 610.2	1 323.7	1 460.3	..[3]	4 224.7	57.9	30.8
1986	g	25 859.2	521.9	165.1	1 039.8	914.1	6 578.4	11 715.2	1 293.0	..[3]	..[3]	3 551.8	54.6	21.7
1991	g	31 211.6	573.5	168.8	1 065.9	904.5	6 823.6	11 887.3	1 250.2	1 172.3	3 746.7	3 527.6	59.0	32.1
1993	g	32 734.9	585.1	174.0	1 085.3	961.1	7 037.7	12 255.2	1 253.9	1 544.9	3 873.7	3 869.5	61.3	33.1
Gasoline sales per capita (litres per person)														
1981	c	1 236.2	1 018.4	1 381.7	1 332.5	1 511.6	1 233.9	1 426.8	1 274.6	1 492.8	..	1 489.4	2 401.4	643.1
1986	c	986.9	902.8	1 281.9	1 165.6	1 256.2	976.9	1 236.1	1 181.9	..	..	1 175.9	2 201.2	391.3
1991	c	1 109.9	988.3	1 290.2	1 161.3	1 208.4	963.7	1 135.2	1 123.8	1 165.0	1 440.3	1 043.7	2 029.1	524.1
1993	c	1 131.1	1 001.2	1 306.4	1 165.5	1 271.3	973.6	1 133.4	1 113.8	1 526.8	1 441.1	1 082.7	2 002.5	522.5

Notes:

Figures may not add due to rounding.

1. The sum of the GDPs of the 12 provinces and territories is not equal to Canada's total GDP because the latter also includes wages and salaries of public servants working abroad.
2. Includes taxis and for-hire cars.
3. Net sales statistics are not available because the road tax was removed in both Alberta (April 1978) and Saskatchewan (April 1982).

Sources:

a. Statistics Canada, ***Provincial Economic Accounts: Annual Estimates, 1961-1993***, Cat. No. 13-213, Ottawa, 1995.
b. Statistics Canada, ***Provincial Economics Accounts, Preliminary Estimates, 1994***, Tables and Analytical Document, uncatalogued, Ottawa, 1995.
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f. Statistics Canada, ***Road Motor Vehicles, Registrations***, Cat. No. 53-219, Ottawa, 1992.
g. Statistics Canada, ***Road Motor Vehicles Fuel Sales***, Cat. No. 53-218, Ottawa, 1993.

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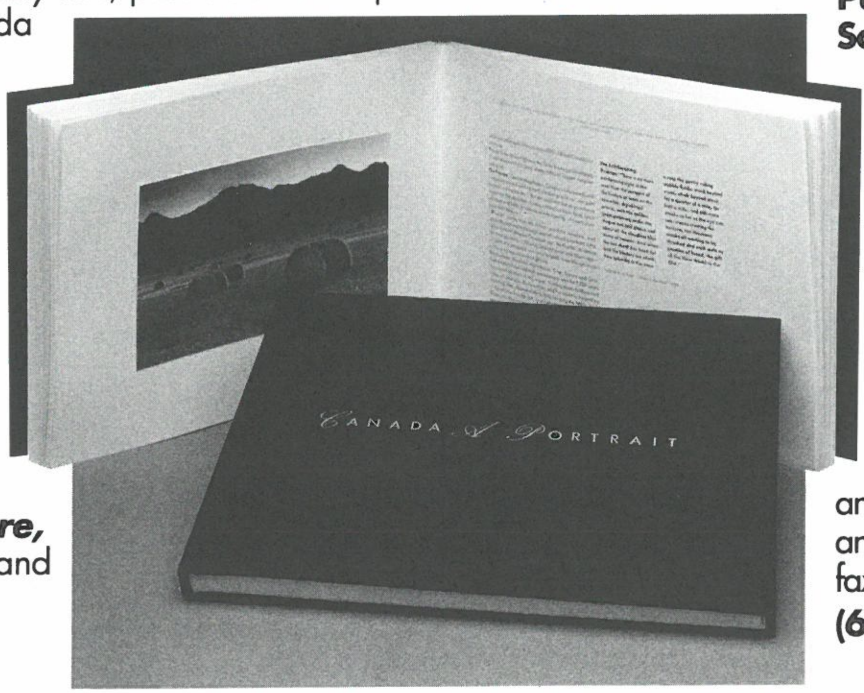

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