S&E
SCIENCE AND THE ENVIRONMENT
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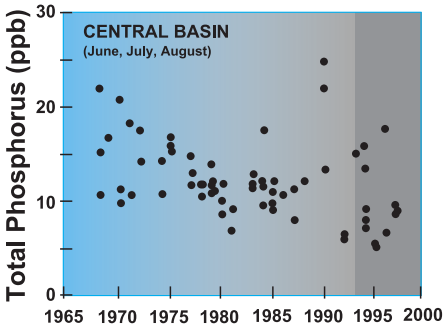
CONTROVERSY OVER NUTRIENT CONTROLS: LAKE ERIE

Phosphorus levels, and how they relate to zebra mussels, are the focus of some controversy in Lake Erie.

Excessive production of algae in Lake Erie has caused aesthetic problems over the years, and was the reason the lake was declared dead in the 1960s. The algal problem was caused by large amounts of phosphorus entering the lake from sewage and agricultural sources. At the same time, concerns were expressed about the taste and odour of Lake Erie water.

In response to those concerns, phosphorus loads to the lake were reduced by 50 per cent under the Canada/United States Great Lakes Water Quality Agreement. Long-term data (see below) show that phosphorus in the central and east basins of Lake Erie is not stable; in fact, there was a decrease in concentrations from 1992 to 1995, and an increase in 1996 and 1997. Phosphorus in the west basin is near target.

Environment Canada research indicates that increasing phosphorus could increase the presence of zebra mussels, an alien species first discovered in North America in 1988, and a major concern in the Great Lakes. By 1990, zebra mussels were in each of the Great Lakes and had moved into many Ontario lakes. The mollusks can remove a large portion of the plankton and dissolved nutrients within water. While this makes the water clearer, it also alters the food chain. Zebra mussels also colonize water supply pipes of industrial facilities, reducing water intake by constricting flow. Navigational and recreational boating can be affected by increased drag from attached mussels.



Variability in phosphorus levels in Lake Erie's central basin during summer

The impact of zebra mussels is most pronounced in the lower Great Lakes, particularly in western Lake Erie, where the combination of relatively warm, shallow water and eutrophic conditions provide a suitable environment for population growth. Initially zebra mussels colonized hard substrates and artificially constructed coastal structures. More recently, mussels were observed in deeper waters on soft muddy sediments. The expansion of the mollusks into habitats that were once regarded as inhospitable is cause for additional concern, since it opens up the largest surface areas of the lakes for colonization. Scientists from Environment Canada's National Water Research Institute and the University of Guelph have determined that regular patterns of zebra mussel colonization exist.

The decrease in phosphorus and the consumption of algae by zebra mussels have made the water clearer in the west basin of Lake Erie.

Some Lake Erie fishing interests have recently suggested that phosphorus controls have decreased lake algal production excessively, causing a reduction in desirable fish species. They advocate that nutrient loads to the lake be increased. At the same time, shoreline property owners are finding algae accumulations on their beaches. Increasing the phosphorus load would worsen this situation.

Approximately half of the Lake Erie shoreline is privately owned and/or used for recreation, and 13 million people live around the lake, so that any action taken to increase lake productivity will affect the various users in different ways. To restore the former algal production would require a massive "re-pollution" of the lake with phosphorus.

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Above photo: Zebra Mussel, Ron Dermott, DFO

INSIDE

AGRICULTURAL CULTIVATION AND THUNDERSTORM PATTERNS IN THE PRAIRIES

There seems to be a link between weather patterns and the kind of crops grown on Canada's Prairies. The widespread agricultural cultivation in the Prairies appears to have had an impact on the frequency and severity of thunderstorms in the region.

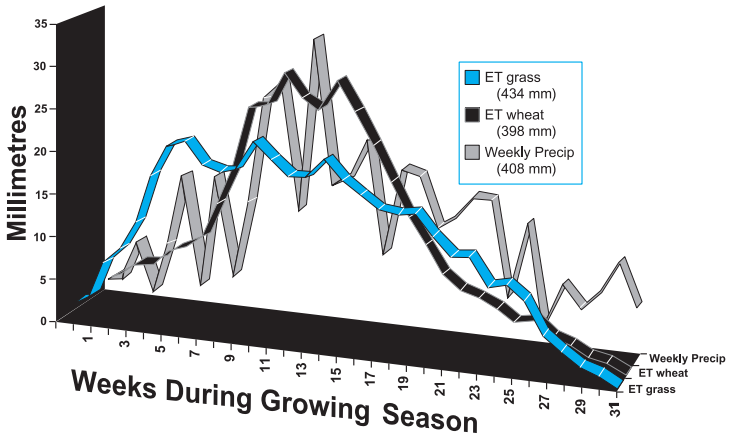
The conversion of nearly 60 per cent of Canada's prairie grasslands from native mixed grasses to annual crops has altered the pattern of evapotranspiration — the natural process by which plants release moisture back into the — atmosphere according to an Environment Canada study. This process is known to be at least partially responsible for the formation of weather conditions that cause thunderstorms.

The study shows a strong similarity between the evapotranspiration curve for spring wheat — the dominant crop in the Prairie eco-climatic zone — and the seasonal pattern for thunderstorms. Before crops emerge, as they age, and after they have been harvested, low evapotranspiration rates make thunderstorms less likely and probably less frequent. In the middle of the growing season, when rapidly expanding foliage and seed production cause high evapotranspiration, such storms are more likely and may be more frequent. The study also suggests that regional mid-summer thunderstorms are more severe, on average, than they were before the introduction of agriculture.

Observational studies done in the Great Plains region of the United States have also linked high evapotranspiration rates to increases in the frequency of both hail and tornadoes.

The research is helping to develop a better understanding of the impacts agricultural practices can have on Canada's climate. S&E

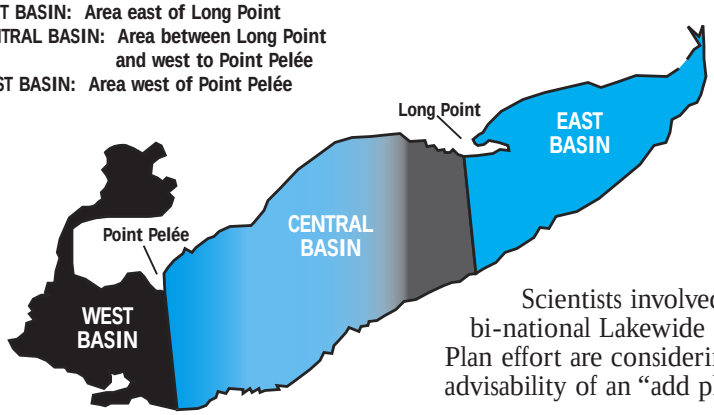
Rainfall and Evapotranspiration — Winnipeg 1988–1995



Controversy in Lake Erie–continued from cover page

LAKE ERIE BASINS

EAST BASIN: Area east of Long Point
CENTRAL BASIN: Area between Long Point and west to Point Pelée
WEST BASIN: Area west of Point Pelée



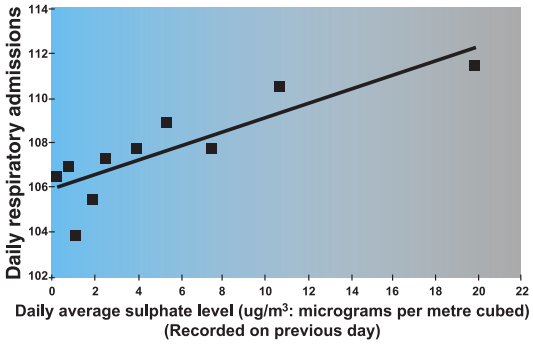
Scientists involved with the bi-national Lakewide Management Plan effort are considering the advisability of an "add phosphorus scenario". Environment Canada is not recommending any change in policy at this time, as increasing phosphorus would likely result in more zebra mussels, but not fish. It would be difficult to increase phosphorus levels in the central and east basins of Lake Erie without massive enrichment of the west basin. Meanwhile, Environment Canada scientists are continuing research on the role played by phosphorus and zebra mussels in algal productivity, and the link between phosphorus and fish production in Lake Erie. S&E

PARTICULATE MATTER: A CRITICAL ENVIRONMENTAL HEALTH ISSUE

Microscopic airborne particles, known as particulate matter, are created by the burning of fossil fuels and by other human and natural activities. There is growing evidence that particulate matter poses a health threat at lower concentrations, and to a broader spectrum of the population, than was previously thought.

For some time it has been known that high concentrations of particulate matter (PM) contribute to cardio-respiratory problems among children, the sick and the elderly, and are linked to the development of symptoms in healthy individuals. However, it is only recently that relatively low concentrations — like those commonly experienced across Canada — have been linked to these effects. The findings are contained in a science assessment published by Environment Canada and Health Canada.

There is no threshold level below which exposure to particulate matter is deemed safe to human health. Adverse effects are specific to the heart and lungs, and include increasing hospitalization (see below) and death rates because of cardio-respiratory diseases, decreased lung function in asthmatics and children, and increases in respiratory stress. Particulate matter also discolours and degrades certain materials, is harmful to vegetation because it blocks photosynthesis by smothering the leaf surface and causing chemical effects to the plant or soil, and reduces visibility outdoors by scattering and absorbing light.



Relationship between sulphate levels (airborne particles) and admissions to hospitals for respiratory problems (Source: Health Canada, 1994 data from southern and eastern Ontario)

Scientists studying the issue are most concerned with tiny particles, the so-called "suspended" portion of PM in air. This "suspended" portion cover particles that are up to 40 micrometres in diameter — about half the width of a human hair. Small particles remain suspended longer, and penetrate deeper into the lungs than larger ones. Of primary interest are those with an upper size limit of 10 micrometres, PM10 as it is known. Researchers are giving particular attention to the particles within that group that are fine (<2.5) and ultrafine (<0.1).

While coarse particulate matter comes from both natural sources, such as windblown soil, pollen, volcanic dust and bacteria, and human-caused sources, like construction or road dust, most fine particles are formed through chemical reactions involving gases and other particles in the atmosphere. The most common precursors to these reactions are nitrogen oxides, sulphur dioxide and volatile organic carbons emitted by the burning of fossil fuels and other industrial processes.

Data on ambient particulate matter levels in cities and rural areas show marked differences in concentrations and characteristics across Canada. Montréal, Windsor, Hamilton, Walpole Island (near Detroit) and Calgary have the highest PM10 levels, with Vancouver and the Windsor-Québec City corridor topping the PM2.5 charts. Pronounced weekly cycles showing the lowest concentrations on Sundays and the highest mid-week also support the connection with human-caused sources.

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TRIBUTYLTIN ANTIFOULANT HAZARDOUS TO AQUATIC ECOSYSTEMS

The pesticide tributyltin (TBT) is a highly toxic chemical used as a general lumber preservative and slimicide (a chemical toxic to bacteria and fungi). However, the use of tributyltin in antifouling paints on the hulls of ships and boats poses one of the greatest environmental concerns, leading to regulatory action in a number of countries, including Canada.

Antifouling uses of tributyltin began in the 1960s and 1970s. Its extreme toxicity to some organisms became evident in the mid 1970s. The organism most sensitive to the substance is the female dogwhelk *Nucella lapillus*, a small marine snail. At concentrations as low as half a nanogram (ng) per litre, female dogwhelks start to grow a penis which eventually blocks the oviduct, preventing reproduction, and leading to population declines and local extinction. This phenomenon is called "imposex," the imposition of male sexual characteristics on females of the species, and it is one of the more dramatic examples of the so-called "endocrine disruption" phenomena. In sediments, tributyltin is also extremely toxic, with population-level effects in several organisms noted at concentrations as low as 40 ng per gram dry weight.

Why people want antifouling agents

France was the first country to restrict the use of tributyltin in antifouling paints after French scientists observed, as early as 1975, that growth rates for oysters in some Atlantic coastal areas were declining. By the early 1980s effects on oysters in Arcachon Bay in France were linked to tributyltin, and in 1982 France banned the use of TBT-containing antifouling paints on vessels less than 25 metres in length.

Many other countries, including Canada in 1989, adopted the same regulations and another one stating tributyltin can be used on vessels greater than 25 m in length, if the release rate is less than 4 micrograms of tributyltin per square centimetre of hull surface per day. Antifouling coatings in Canada are regulated under the *Pest Control Products Act*, administered by Health Canada.

Canada is one of several countries monitoring the effectiveness of tributyltin regulations. Environment Canada's National Water Research Institute (NWRI) conducted a survey of water and sediment from across Canada in 1993-1994. The main conclusion was that the regulation had been only partially effective, having some effect in reducing tributyltin concentrations in freshwater, but not in sea water.

There was less effect in reducing TBT concentrations in sediment, where it likely persists longer. In many locations the concentration was high enough to cause acute and chronic toxicity to aquatic and benthic (living on the water bottom) organisms. In some areas, tributyltin from contaminated sediment may transfer back into the water column. It also appeared that large harbours handling ships legally painted with tributyltin antifouling paints continued to experience significant contamination. This situation was substantially the same in 1997 in some of the hotspots which NWRI continues to monitor.

It is expected that the International Maritime Organization will ban all antifouling uses of tributyltin by 2006, and possibly earlier. The organization and member countries are exploring several replacement antifoulants. One of these, Irgarol 1051, has been registered for use (with copper-containing formulations) in some European countries for several years, and

TBT hazardous–continued on page 8

Sampling the surface microlayer of water for TBT

POLLUTANT RELEASES DOWN BY 15%

DOWNWARD TREND CONTINUES FOR 3RD YEAR

Releases of pollutants to Canada's air, water, and land decreased by 14.9 per cent in 1996, even though the number of facilities reporting to the National Pollutant Release Inventory (NPRI) was up by 2.2 per cent from 1995. This is the third year in a row that the release of pollutants reported to the Inventory has decreased.

A total of 142,613 tonnes of pollutant releases were reported to the NPRI in 1996. Of that total, 69.3 per cent was released to air. Releases to land accounted for 9 per cent. Both are down from the previous year. Releases to water, which accounted for 9.1 per cent of the total, decreased much more sharply. In large part, the decrease to water is because of the closure of a copper mine in Port Hardy, British Columbia. Release by underground injection was the only area to show an increase, accounting for 12.5 per cent of all 1996 releases.

The 1996 report contains a new section on national, provincial and territorial analysis for toxic and carcinogenic pollutants listed on the Inventory. The analysis shows that releases of carcinogenic and toxic substances decreased in the two territories and in six provinces, while they increased in three provinces. No releases of toxic or carcinogenic substances were reported in Prince Edward Island. Additional details and a full analysis of releases by jurisdiction and by industrial sector are also included in the 1996 NPRI summary report.

In 1995, the five pollutants with the largest releases accounted for 51 per cent of total releases:

POLLUTANTS WITH THE LARGEST RELEASES

SUBSTANCE RELEASED	1996 Amount (tonnes)	% Change from 1995	(1995 Rank)
1–Ammonia (total)	32,037	+8.5%	(2)
2–Methanol	21,703	-30.4%	(1)
3–Xylene (mixed isomers)	6,509	-20.2%	(4)
4–Zinc (and its compounds)	6,291	-2.4%	(7)
5–Toluene	6,117	-10.5%	(6)

The Inventory also tracks transfers of listed pollutants in waste to off-site facilities for treatment or final disposal, which were up 24 per cent, to 64,626 tonnes, in 1996.

The NPRI was established in 1993 to provide information to Canadians on the release of 176 pollutants by facilities located in their communities. Participation is mandatory for all facilities with more than 10 full-time employees that manufacture, process, or use 10 tonnes or more of a substance on the NPRI list.

The 1996 report and a searchable database of all NPRI data are available on the Green Lane at: *http://www.ec.gc.ca/pdb/npri* S&E

POLLUTANT RELEASES, 1996

PROVINCE/TERRITORY	1996 Amount released (tonnes)	Change from 1995 (tonnes)	1996 Releases of toxic & carcinogenic substances[1] (tonnes)	Change from 1995 (tonnes)
Alberta	42,275	-957	1,351	-104
British Columbia	9,143	-13,850	302	-4
Manitoba	4,752	+1,851	505	+263
New Brunswick	4,183	-1,143	46	-0.6
Newfoundland	597	+67	45	+4
Northwest Territories	2,976	-679	2,905	-701
Nova Scotia	1,940	-2	179	+34
Ontario	55,842	-6,030	5,499	-236
Prince Edward Island	56	-1	None reported	None reported
Quebec	18,876	-3,999	2,374	-38
Saskatchewan	1,969	-262	47	-82
Yukon	5.6	+5	0.078	-0.03

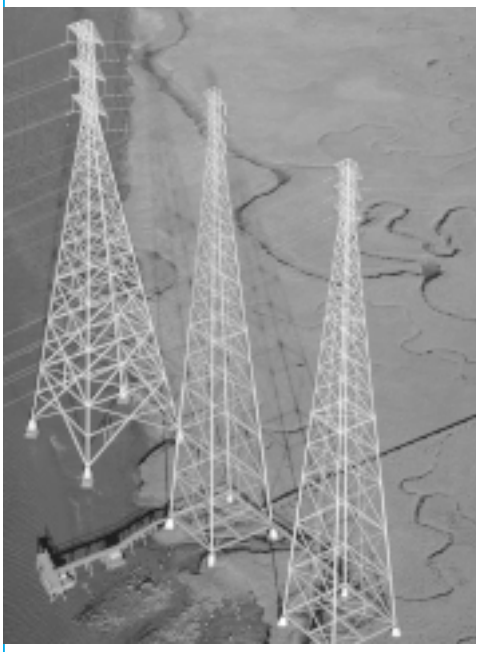
[1] *Toxic substances are those determined to be toxic under the Canadian Environmental Protection Act following a scientific assessment. Information from the International Agency for Research on Cancer (http://www.iarc.fr/) was used to classify carcinogens, or suspected carcinogens.*

CLIMATE CHANGE:
CHANGING THE GREAT LAKES

Climate change could reduce water levels in the Great Lakes to lower than they have ever been before — changes that would have an impact on the transport, power generation, and wildlife of Ontario.

Together, the Great Lakes are the largest freshwater body in the world, covering 246,000 square kilometres and storing 20 per cent of the world's freshwater. As part of the Canada Country Study reports examining the impact of climate change on Ontario, Canadian scientists looked at different climate models, and what they reveal about the future status of the Great Lakes. And the models are consistent: they all show decreases in water levels, in some cases of more than one metre, by the latter part of the 21st century.

That's because, even though most climate scenarios predict increased precipitation for the region around the Great Lakes, higher temperatures will mean greater evaporation of water into the atmosphere. They will also mean less snow in winter, so less spring run-off and snow melt entering the lakes. And that, in a nutshell, means less water in the Great Lakes — so much less that some scientists are predicting that water could become a continental issue in the 21st century in much the same way oil and gas were in the 1970s and 80s.



Areas of Ontario away from the Great Lakes that depend on groundwater for water supplies could face even greater water shortages because of increased evaporation.

The Great Lakes, together with the St. Lawrence River, form a transportation network that supports Canada's largest concentration of manufacturing and other industries. Together, they form the busiest waterway in the world, serving the needs of four provinces and 17 states in North America.

Low lake levels can restrict the maximum cargo capacity of vessels, and can increase the operating costs of ports and shipping channels, such as the costs associated with dredging a harbour. In the past, when the variability of climate has caused water levels in the lakes to be lower than usual, millions of dollars were lost because shipping was disrupted. On the other hand, however, reduced ice on the lakes could be expected to lengthen the shipping season.

Using water to generate electricity is one of the "cleanest" ways to produce power, without the environmental harms of burning fossil fuels such as coal. A significant proportion of water from the Great Lakes Basin is used for electricity generation and lower levels would affect power production. In the past, the same low flows that affected transportation also resulted in a 19-26 per cent decrease in hydro power production. Lower water levels in the Great Lakes could have the same effect. This will likely coincide with greater demands for electricity, at least in the summer, as people turn to their air conditioners at home and at work to offset higher temperatures.

Continued on facing page

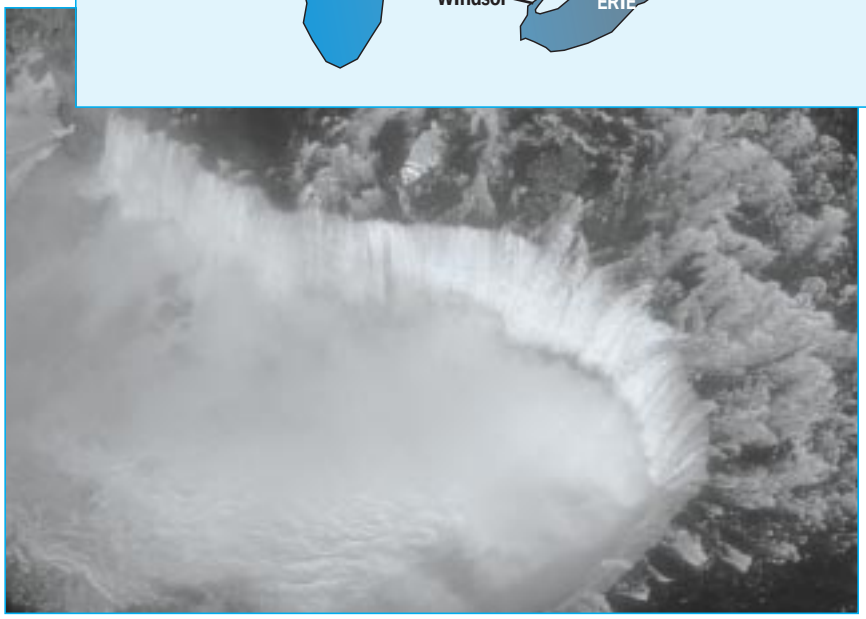
Climate Change–continued from preceding page

And, just as air temperatures are expected to be higher due to climate change, water temperatures are also expected to increase. This will have impacts on the fish and other wildlife in the Great Lakes, with many fish species expected to shift northward, and many southern species expected to "invade" the Great Lakes aquatic ecosystem, with unknown effects on the delicate balance of life. In the past, water temperature changes as small as one degree have caused substantial changes in the home range of species.

Lower water levels will also affect the wetlands, such as marshes, bogs and fens, around the Great Lakes. Water availability is critical to establishing and maintaining these important sources of Canada's biodiversity. Wetlands that are open to the shoreline may be able to migrate toward the receding shoreline which will result from lower water levels; closed wetlands may simply dry out, resulting in a loss of ecological diversity.

The *Canada Country Study* is a national evaluation of the impacts of climate change and variability on Canada as a whole. More than 55 experts in the field of climate impacts and adaptation worked with Environment Canada scientists to assess current knowledge and identify areas for further research for all the regions and sectors of Canada. Phase two of the study will address these research questions over the next five years.

The Study provides an understanding of the impacts of climate change and what may be required to adapt to these impacts. This work assisted the Canadian government in negotiations toward the Kyoto Protocol to the Framework Convention on Climate Change, the international agreement to reduce greenhouse gas emissions. Canada has agreed to reduce emissions to 6 per cent below 1990 levels between 2008 and 2010, becoming a signatory to the Protocol in April 1998. Federal, provincial and territorial governments are moving forward to develop an implementation strategy for the Kyoto Protocol. S&E



Global
Climate Change

TBT hazardous–continued from page 4

registration is expected soon in the United States, and possibly Canada.

Irgarol 1051 is fairly persistent in water, and there are concerns that concentrations in some European coastal waters may pose hazards to sensitive phytoplankton. NWRI has conducted research on the persistence and fate of Irgarol 1051 in water, and is undertaking baseline studies of large Canadian harbours to assess the potential impact of Irgarol 1051 leaching from ships painted in other jurisdictions. S&E

SCIENCE IN FRESHWATER MANAGEMENT

Communities across Canada have taken action on the central issues of water quantity, water use and water quality. These communities have acted to protect their sources of drinking water, maintain and enhance aquatic habitat, and increase awareness of water conservation. Details of these activities are in *Canada and Freshwater*, part of the Sustainable Development in Canada Monograph Series.

The report also highlights the contributions Canadian scientists have made in understanding the environment, including the role of phosphorus in the deterioration of the Great Lakes, the causes and effects of acid rain, the environmental effects of large dams, and the reduction of toxic substances, such as PCBs, mercury, and pesticides, in the aquatic environment. The report has been presented to the United Nations Commission on Sustainable Development.

For those interested in further information on these and other initiatives, the report provides a list of selected readings and Internet sites.

Bulletin READER SURVEY

Along the bottom of each issue of *S&E Bulletin* you'll find the words: *Connecting Canadians With Their Environment*. It is through its science that Environment Canada helps Canadians understand the impact they have on the environment, the solutions we can all bring, and the role that science plays in forming policy decisions. *S&E Bulletin* is designed to bring you detailed, accessible information about the leading-edge science at Environment Canada.

Your opinions about *S&E Bulletin* are important to us. In this issue, we have included a reader survey and urge you to take a few minutes to fill it out and return it to Environment Canada. Your answers will help us determine subjects for future articles in *S&E Bulletin* and to deliver meaningful information to you, the reader.

Particulate matter–continued from page 3

Many aspects of the particulate matter issue require further study, including the role that particle size, mass and composition play in health impacts. Environment Canada's contribution to this growing body of knowledge includes research on the characterization of ambient particulate matter levels, the composition of particles, the processes involved in its formation, emission and precursor gas inventories, forecasting models, and the long-range transport of air pollutants. Although current efforts to reduce fuel emissions will lead to gradual improvements, a better understanding of the connection among particulate matter, ground-level ozone, acid deposition and hazardous air pollutants will be essential to creating effective strategies for managing these critical air quality issues simultaneously. S&E

S&E GUIDE

Science and the Environment Bulletin is published regularly to bring leading-edge environmental science and technology work to Canadians.

More information is also available on **Environment Canada's Green Lane at www.ec.gc.ca.** Many of the publications mentioned in the Bulletin are posted on the Green Lane or can be ordered from the **Inquiry Centre at 1-800-668-6767**, including: *Canada and Freshwater* and *The Canada Country Study*.

Readers are encouraged to communicate with us by e-mail: **Paul.Hempel@ec.gc.ca** and to visit the Bulletin's Web site at **www.ec.gc.ca/science**

This issue of the Bulletin includes a Reader Survey. To assist us in planning future issues, we would greatly appreciate your feedback by September 11, 1998.

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