TOWARDS AN ADAPTATION ACTION PLAN: CLIMATE CHANGE AND HEALTH IN THE TORONTO-NIAGARA REGION

SUMMARY FOR POLICY MAKERS

A Pollution Probe Report

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Climate Change Action Fund Project A077

Adapting Health Infrastructures to Cope with the Health Effects of Climate Change: A Case Study in the Toronto-Niagara Region

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Projected Climate Change Impacts and Health Effects in the Toronto-Niagara Region

- The number of days exceeding 30°C could double by the 2030s and surpass 50 days by the 2080s. The number of heat-related premature deaths among the elderly could reach 171–447 annually during an average summer by the mid 2020s.

- The frequency of extreme weather events is projected to increase, with associated increases in injuries, illnesses and deaths caused by heat waves, severe wind storms and intense precipitation events.

- The transmission vectors for West Nile Virus and Lyme Disease are already present. Increased exposure to these and other vector-borne and rodent-borne diseases, such as Malaria, Dengue fever, and Hantavirus is projected as they spread northward due, in part, to climate change.

- Background ambient levels of ground-level ozone are projected to double under climate change, while the frequency of occurrence of oppressive air masses could increase from 5 percent of summer days to 23–39 percent by 2080. This would result in a substantial increase in illness, hospital admissions and death caused by air pollution, which is currently estimated to cause 1,925 premature deaths in Ontario and over $1 billion in health care costs.

- In areas dependent upon ground-water, increased exposure to water-borne and food-borne illnesses are expected to occur, such as diseases caused by *Giardia, E. coli and Cryptosporidium,* due to changes in the intensity and frequency of excessive rainfall events.

- The stratospheric ozone layer may not begin to recover until 2020–2050, thus elevating the health risks caused by UV radiation relative to the 1970s. In Ontario, it is estimated that there will be 370 deaths due to melanoma in 2002.

Key Messages

1. Global warming is happening now.

2. The Toronto-Niagara region will experience considerable climate change and variability within the next 20 to 50 years and beyond.

3. There is strong scientific support for the conclusion that climate change will cause significant direct and indirect adverse effects on human health.

4. Although some negative health effects may be unavoidable, the extent and severity of the health effects resulting from climate change can be largely reduced by the ability of health infrastructure to adapt and respond.

5. Our present state of knowledge about the adaptive capacity of health infrastructure in the Toronto-Niagara region to climate change needs to be improved.

6. An inclusive approach, involving public health, family doctors, social workers and others, will be required to monitor, diagnose and treat the health-related impacts of climate change.

7. While much of the needed health infrastructure already exists to deal with the health impacts of current climate in the Toronto-Niagara region, a coherent, integrated approach is required to address climate change which builds on this infrastructure and takes advantage of stakeholder strengths.

8. Challenges in adapting to climate change may be met through considerable coordination of stakeholder activities, the enhanced sharing of climate and health science information, the expansion of surveillance and monitoring efforts, improved education and awareness among health professionals and the public, and advocacy for the allocation of more resources for public health.

9. Identification of all stakeholders and the development of an appropriate coordinating agency or structure are vital to the successful development and implementation of a climate change adaptation action plan.

Executive Summary

Canadians harbour a long-standing fascination with the weather, and in recent years they have had much to discuss. During the last two decades, drought, floods, tornadoes, ice storms and other extreme weather events have affected Canadians from coast to coast. In the Northern Hemisphere, the 20th century was the warmest in over a thousand years, while the 1990s were the hottest decade on record. Some of the severe weather we've experienced can be explained by natural variations in climate. However, as the new millennium begins, it appears that the pace of climate change is accelerating.

With the publication of the *Third Assessment Report* of the Intergovernmental Panel on Climate Change (IPCC), a broad scientific consensus has emerged around the finding that the global climate is being affected in a significant and deleterious manner by human activities. A steadily warming and more variable climate is now widely accepted as a valid scientific reality. Furthermore, it is projected that global emissions of greenhouse gases (GHG), the primary causal factor driving climate change, will continue to increase. Unless substantial reductions in emissions occur, carbon dioxide (CO_2) concentrations in the atmosphere are predicted to double, if not triple, pre-industrial levels by the middle to end of this century. As a consequence, it is vital that decision-makers in the public and private sectors address options available for adapting health care policies, infrastructure and services to respond effectively to the full range of health impacts that are likely to be associated with a changing and more variable climate.

While some aspects of climate change are well understood, there are also areas of scientific uncertainty. There is a high level of confidence in the science that explains how the climate may be changing. However, there is less certainty about the projected impacts of climate change on natural and human systems, especially at the local or regional level, which can make it difficult to formulate and implement effective adaptive action. Uncertainty still clouds such key issues as: how climate change might impact the environment and human health; how the health infrastructure should be restructured and adapted to meet the looming health challenges; and whether the adaptive measures currently being planned will be effective in ameliorating the impacts of a changing climate.

In response to these uncertainties, Pollution Probe assembled a team of leading scientists, physicians and policy-makers to assess the capacity of the health infrastructure in the Toronto-Niagara region to anticipate, plan for and eventually cope with the impending health problems that will occur with a changing climate. Relatively more attention has been paid to the impact of climate change in broad geographical terms (such as water basins), for natural ecosystems (terrestrial and aquatic), managed ecosystems (forestry and agriculture), and traditional aboriginal lifestyles (especially in the north) compared to the health effects in urban areas. However, it will be in the heavily populated urban areas of Canada, such as the Toronto-Niagara region, where the human health effects could have the greatest cumulative impact. Developing an effective adaptation action plan will be essential to minimize and alleviate such possible negative effects.

Purpose of the Study

The purpose of this study is to provide decision-makers with some of the information needed to improve the adaptive capacity of the health infrastructure in the Toronto-Niagara region in order to deal effectively with the projected human health effects of climate change. The authors have undertaken an assessment of the current science regarding climate change and its potential health effects, as well as the adaptive capacity of a health care system (that is already under budgetary stress) to handle the increased demand for services. The results of this study are intended to contribute to the development of a national strategy to address climate change, as well as support a multi-stakeholder regional assessment of atmospheric change being led by Environment Canada. The findings should also contribute to the national debate on Canada's Kyoto commitment to reduce GHG emissions, in addition to future discussions on health care planning. Preparing the health infrastructure to adapt effectively to the impacts of climate change will be complementary to any national mitigation response; it cannot be a substitute for taking concrete action to reduce GHG emissions now.

Organization of the Reports

The study has produced two reports. In the first report, *Summary for Policy Makers*, emphasis is placed on the integration of science and public policy, with specific attention to the adaptive capacity of our health infrastructure to deal with the implications of climate change in the Toronto-Niagara region. This analysis includes identifying the actions needed to develop an effective regional adaptation plan for health infrastructure. Parts of this plan, such as the City of Toronto's Hot Weather Health/Watch Warning System, have recently been introduced in certain municipalities within the region.

Part 1 of this report provides some background information on the climate change/health issue, and discusses why the current health care infrastructure might not be positioned to effectively address and contain the full range of adverse health effects that are likely to occur in the Toronto-Niagara region under reputable and widely-accepted climate change scenarios.

Part 2 summarizes the current scientific knowledge about the expected impacts of climate change and the associated health effects, including those related to heat stress, extreme weather events, deteriorating air quality, vector-borne diseases, food and water-borne diseases, and elevated exposure to UV radiation. Part 2 also covers the interactions between the various projected health effects, and describes those segments of the population (including children, the elderly and those with pre-existing medical conditions) that are most vulnerable.

Part 3 outlines an adaptation action plan that would be employed to inform and amend the current health care infrastructure to better cope with the projected health implications of climate change. Part 3 describes the current Canadian health care infrastructure, the evolution of the debate over climate change/health issues, the adaptive actions that have already been adopted to address each of the six categories of health effects discussed in Part 2, the barriers to further reform, the opportunities for future action and models for change, and the steps that need to be taken to further

adapt the health care infrastructure in the Toronto-Niagara region. Finally, current gaps in the knowledge base and key research needs are discussed.

In the second report, *Technical Report*, an in-depth assessment of the current state of knowledge on climate science, climate impacts, health effects and adaptation options for the Toronto-Niagara region is presented. Current climate conditions are assessed at the regional level in the context of projected climate change scenarios. The interaction of atmospheric conditions, health effects and potential response actions is also considered. In addition, uncertainties, knowledge gaps and key research questions are identified. For example, further research is clearly required to determine if health infrastructure is well designed and has the capacity to deal with some of the projected impacts of climate change. The *Technical Report* also consists of appendices that provide:

- a summary of the interviews and consultation meetings conducted with regional stakeholders;
- a synthesis of interviews conducted with key informants during the winter and spring of 2001;
- the results of a consultation meeting with physicians held on April 27th, 2001;
- a case study of climate change, health and adaptation issues for the City of Mississauga and the Region of Peel carried out by a fourth-year undergraduate class from the University of Toronto's Erindale Campus; and,
- an explanation of how estimates for heat-related mortality have been calculated.

Potential Health Effects of Climate Change

The results from this study highlight the need to develop and implement an adaptation action plan for health infrastructure in the Toronto-Niagara region to deal with projected human health implications of a changing climate. There is growing evidence that climate change would impose a wide range of deleterious health effects on the residents of this region. Significant increases in morbidity and mortality will result from projected increases in the intensity, severity and frequency of heat waves, smog and extreme weather events, and the northward shift of diseases borne by insects, rodents and other vectors. In addition, the population would be at greater risk to water-borne and food-borne diseases, and from exposure to elevated levels of ultraviolet (UV) radiation.

Excessive heat could kill more than 800 Toronto residents a year by 2080, a 40-fold increase over the current death toll.

Based on data collected from 1961 to1990, temperatures exceed 30°C on 15 or 16 days during an average summer in the City of Toronto. As a result, an estimated 19 heat-related deaths occur in the city each year; however, this number can increase dramatically during hotter summers. The number of days exceeding 30°C could double to 30 days by the 2030s and surpass 50 days by the 2080s. The scientific literature provides a wide range of estimates for future heat-related deaths, based upon various climate change scenarios that could occur under a doubling of carbon dioxide concentrations by 2070–2080. These mortality rates for the total population (all age groups) range from 9.63 per

100,000 people to 33.65 per 100,000 people. Using 2001 population statistics, it is estimated that 239–835 additional premature deaths could occur annually in the City of Toronto alone. The actual number of heat-related deaths in the Toronto-Niagara region will depend upon a number of factors, including the minimum and maximum temperatures that occur, the acclimatization capacity and vulnerability of the affected population, and the adaptation measures adopted.

By 2020, excessive heat could kill over 400 elderly residents in the Toronto-Niagara region each year.

The heat-related mortality data that's been collected for the elderly (individuals over 65 years of age) is much stronger than the statistics that exist for the general population. Recent estimates for heat-related mortality are 0.94 deaths per 100,000 elderly persons in Toronto and 1.32 per 100,000 in Hamilton. It is projected that between 171 and 447 elderly people could die during an average summer by the mid-2020s in the Toronto-Niagara region (depending upon the assumptions used for population growth, demographic shifts, and temperature change).

While it is difficult to predict long-term changes in extreme weather events, there is good evidence that damaging winds, tornadoes and intense precipitation events are becoming more common.

The frequency of extreme weather events is projected to increase over many areas of the Northern Hemisphere, with associated increases in the number of injuries, illnesses and deaths caused by heat waves, severe windstorms, and intense precipitation events. Generally, there is insufficient information to assess recent trends, and low confidence in the ability of regional climate change models to make firm predictions about many extreme weather events. However, the region has been subject to extreme weather events in the past (such as hurricanes, tornadoes, snow storms), and there is evidence that some conditions (for example, damaging winds and tornadoes) have been increasing in recent years.

Birds, insects, rodents and other organisms are carrying a number of serious diseases, common in warmer climates, northward into the Toronto-Niagara region.

The transmission vectors for West Nile virus and Lyme Disease are already present in the Toronto-Niagara region. There could be increased exposure to these and other vector-borne diseases, such as malaria, dengue fever, and the hantavirus as the range of the birds, insects, rodents and other organisms that carry them spread northward due, in part, to climate change.

A warmer climate may be accompanied by more frequent smog episodes and other unhealthy air pollution problems.

Under various climate change scenarios, the background (ambient) levels of ground-level ozone are projected to double under a 2 X CO_2 scenario (2080) across the Toronto-Niagara region. In addition, the occurrence of oppressive air masses — accompanied by smog episodes, excessive temperatures and high humidity — could increase from five per cent of summer days to 23–39 per cent in the City of Toronto. This

would result in a substantial increase in the number of illnesses, hospital admissions and deaths caused by air pollution (which is currently estimated to cause 1,925 premature deaths in Ontario and over $1 billion in health care costs annually).

Heavy rains could increase the risk of more frequent outbreaks of water-borne diseases, especially in rural areas.

Increased exposure to water-borne and food-borne illnesses, such as diseases caused by *Giardia, E. coli* and *Cryptosporidium*, is expected to occur due to changes in the intensity and frequency of excessive rainfall events. Rural residents dependent on groundwater are particularly at risk to outbreaks of water-borne diseases.

Higher levels of ultraviolet radiation are expected to cause an increased incidence of melanoma-type skin cancers.

In Ontario, exposure to UV radiation is a major cause of melanoma, which will be responsible for an estimated 370 deaths in 2002. Many cases of skin cancer being diagnosed today are due to exposure to UV radiation in the 1960s and 1970s (before the stratospheric ozone layer began to thin). Since the stratospheric ozone layer may not begin to recover until 2020–2050, the incidence of health problems caused by exposure to elevated levels of UV radiation should increase.

Information Gaps and Other Barriers to Action

While the potential health effects related to climate change are serious, most can be minimized or prevented if appropriate mitigative and adaptive action is taken. There are, however, many barriers to taking such action, including significant gaps in our knowledge of the potential health effects and the effectiveness of the adaptive actions available, especially from an integrative perspective. To date, any adaptive actions in the Toronto-Niagara region have been implemented on an ad hoc basis and lack coordination. Physicians and other members of the health care community have only a limited understanding of the connections between the present climate and health, let alone the new and emerging health issues that could arise with climate change. Traditionally, societal responses to environmental problems have been more reactive than proactive, a mind-set that could be problematic in preparing for climate change. While health infrastructure planning has been more proactive than most sectors, a lack of funds, an overwhelming agenda, and competing health issues could limit the response capacity for those health risks that emerge with climate change.

Many of these barriers could be overcome if decisive adaptive action was taken in the Toronto-Niagara region. Such action could include the following:

- Existing efforts should be integrated to develop a coordinated response to climate change and health. For example, existing response plans for emergencies and pandemics should be applied to extreme weather events and vector-borne disease outbreaks.

- The current monitoring, reporting and surveillance network for air quality and health effects should be expanded to include other climate-related health effects.

- Professional and public education should draw upon the experience gained in addressing air quality problems. Organizations such as the Canadian and Ontario College of Family Physicians, the Ontario Medical Association and the Canadian Association of Physicians for the Environment should take a stronger role in raising awareness of climate change and health-related mitigative and adaptive actions.

- In the absence of a single agency or department taking responsibility for climate change and health, there are several organizational structures that could be used as models (such as the recently completed multi-stakeholder plan for achieving healthy indoor environments in Canada) for moving forward on an adaptation action plan.

By addressing the interactions between climate change and health issues, it should be possible to improve the cost-effectiveness of many adaptive responses (such as integrating those directed at smog, heat and indoor environments).

The Next Stage

Following the release of this report, a number of steps could be taken — including enhancing multi-stakeholder consultation, developing strategies, and building alliances — that are necessary prerequisites to effectively adapting the health care infrastructure to a changing and more variable climate. This report proposes activity in the following areas:

1. ***Research:*** The first step should be to identify the key elements of public health infrastructure that already exist or must be created to provide the baseline information needed for longitudinal assessments of climate change impacts on human health. This includes engaging stakeholders in identifying the most important indicators of health effects and climate change, and the appropriate response actions, in addition to assessing current adaptation actions to future conditions. Numerous knowledge gaps and key questions are highlighted in the *Technical Report* that warrant investigation. Research is needed on health effects and adaptive measures under consideration or being implemented in other countries, especially for health issues that may emerge in the Toronto-Niagara region under climate change (see sidebar for details of the recommended health effects and adaptive measures research that is needed).

2. ***Monitoring and Surveillance:*** Current monitoring, reporting and surveillance systems must be evaluated in terms of their capacity to provide the information needed to develop effective adaptive policies. This includes data related to climate variables, ecosystem function, social conditions and health indicators.

3. ***Education:*** Increased awareness, through education and outreach on climate change and health, is required for physicians, health care planners and the general public. Building upon the stakeholder engagement undertaken in this study, the logical next step would be to organize consultation meetings with a broader range of physicians across the Toronto-Niagara region. Discussion and planning sessions on how best to respond to climate change should be developed across the region, in consultation with regional public health units. The Climate Change Action Fund — Public Education and Outreach Program should be funding such activities.

4. ***Partnership Building:*** For an adaptation action plan to be effective, the input of many stakeholders (particularly those from the community level) will be required. This initiative involves participation of federal, provincial, regional and municipal governments (and their respective departments), as well as private sector industry, voluntary organizations and public interest groups. Agencies that are involved in community outreach and home care must be included in this process, and non-governmental organizations, especially those representing the medical community, should also be encouraged to participate.

5. ***The Development of Structures to Coordinate Responsibility for Climate Change and Human Health:*** Closer integration of federal, provincial and municipal responsibilities is required for effective policy development and implementation. Health Canada would be an appropriate agency to coordinate research activities and establish research priorities on health effects and adaptive actions, in consultation with other federal departments (such as the Adaptation and Impacts Research Group of Environment Canada, and the Climate Change Secretariat at Natural Resources Canada). The Canadian Climate Impacts and Adaptation Research Network (C-CIARN) is an example of a logical mechanism to assist in the coordination of research activities. Coordination among all research nodes will be essential.

The authors view the development and implementation of a health care adaptation action plan for the Toronto-Niagara region as an important step in effectively responding to climate change at both the regional and national levels. Working in partnership with local, provincial and federal governments and other key stakeholders (health professionals, industry, and environment organizations), we believe that an adaptation action plan could become a powerful and practical response to the human health issues likely to emerge in the Toronto-Niagara region due to the projected impacts of climate change. A properly developed and implemented adaptation action plan could have positive benefits on the health, well-being and productivity of all people living in the Toronto-Niagara region. At a minimum, the plan could minimize unnecessary suffering and save many lives that might otherwise be lost if we fail to forestall or reduce the threat of climate change. In addition, a successful adaptation action plan for the region could become a useful model for communities across Canada and around the world.

Essential Health Effects Research

- the number of heat-related deaths in all municipalities throughout the Toronto-Niagara region (expanding beyond Toronto and Hamilton);
- the potential reduction in the number of deaths due to warmer winters, relative to projected increases in deaths during hot summers;
- the health effects associated with past extreme weather events, as well as vulnerability to less severe events;
- the health risks associated with vector-borne and rodent-borne diseases, both in terms of domestic and imported transmission;
- the potential increase in a range of health effects (for example, morbidity, hospital admissions and premature mortality) due to increases in smog episodes under climate change, and the impact of these effects on health infrastructure;
- the linkage between climate change and indoor environments, such as the potential health effects from toxic moulds caused by excessive precipitation, particularly in tightly sealed buildings;
- the increased risk of water-borne disease, especially in rural areas dependent upon wells for groundwater; and,
- the impacts on nutrition, as local food production could be adversely affected through the interaction of drought, UV radiation and ground-level ozone.

Essential Adaptation Measures Research

- the effectiveness of current warning systems for extreme cold and hot weather conditions under climate change;
- the effectiveness of past adaptations in health infrastructure, such as severe storm forecasting and emergency response planning, and their relation to extreme weather events in the future;
- the effectiveness of adaptive measures adopted in countries where vector-borne and rodent-borne diseases are currently a problem (including research on measures to improve vector monitoring and control, change personal behaviours, and better inform family physicians), and their potential application to the Toronto-Niagara region;
- the effectiveness of the Air Quality Index and the smog advisory/alert system during days experiencing poor air quality;
- the need for additional mitigative actions directed at reducing emissions that cause air pollution (such as temporary curtailment of municipal and industrial activity) in response to increased morbidity, hospital admissions and premature mortality that could occur with an increase in the frequency and occurrence of smog episodes;
- the capacity of current regulations, such as those affecting water testing and agricultural land use practices, to protect the population from the increased occurrence of water-borne and food-related illnesses;
- the need to strengthen current adaptive measures directed at UV radiation, such as child education programs, and link them to climate change; and,
- the synergistic opportunities for adaptation to multiple climate change health issues (for example, there is some overlap in our response to both heat stress and smog incidents, or to concurrent extreme weather events and infectious disease outbreaks).

Part 1 — Introduction

Background

There is a growing consensus that global climate variability[1] and change will adversely impact ecosystem and human health. Extreme weather events, severe drought, vector-borne diseases, smog and other impacts caused by human-induced changes in climate will lead to increases in illness, injuries, hospital admissions and mortality. While scientists have broadly identified health risks and other effects at the global and national scale, less is known about the possible impacts at the regional level. Most communities across Canada have limited knowledge of the current health effects and impacts associated with weather and climate variability. It is also uncertain whether their health infrastructure has the capacity to respond quickly and effectively to future climate change. Health effects may be so significant that a comprehensive adaptive response is required, involving the participation and coordination of federal, provincial and municipal health authorities and other stakeholders engaged in health care planning and delivery.

It is now widely accepted that the increasing concentrations of greenhouse gases (GHGs) in the atmosphere are affecting the earth's climate. These gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), halocarbons (HCFCs, PFCs) and sulphur hexafluoride (SF_6). There is growing concern that changes in climate will have significant impacts on natural and human systems in all corners of the world. Temperatures will increase, precipitation patterns will be altered, and extreme weather events (such as storms, droughts and heat waves) will become more severe and frequent. Less developed countries and small island states may be most affected, but developed countries will also be impacted.

As a developed country, Canada has comparatively greater access to the technological and financial resources required to adapt its social and economic systems to climate change. However, changing rainfall patterns, drought and heat could negatively impact certain primary sectors of our economy, such as forestry and agriculture. In addition, there is much uncertainty regarding how municipal infrastructures may adapt to climate stress in the future. In part, this is due to our limited capacity to project climate change and its impacts at a regional scale, and uncertainty regarding how our social and economic systems may themselves change in the future.

For those areas of Canada included in international and national assessments of climate change impacts, it is projected that human health will be adversely affected.[2] Increases in morbidity and mortality are expected to result from projected increases in the intensity, severity and frequency of extreme weather events (for example, heat waves and extreme precipitation events) and, indirectly, through an increase in smog episodes, a greater frequency of droughts, and the northward shift of some vector-borne and rodent-borne diseases. An increase in water-borne and food-borne diseases and exposure to increased levels of UV-radiation could also occur. Children, seniors and other vulnerable populations (such as northern communities dependent upon traditional economies) may be particularly predisposed to adverse health impacts —

but ultimately all segments of the population are at risk.

The impact of such health effects will be determined, in large part, by how well the health infrastructure is able to cope with climate change impacts. Until recently, the prevailing view of many experts was that both Canada[3] and the United States[4] are well protected against adverse health outcomes due to a strong public health care system (especially in Canada), a high standard of living, and high levels of public awareness. Evidence emerging from climate change — human health research suggests that this may be an optimistic view for a number of reasons.

First, changes in the frequency, intensity and severity of extreme weather events may pose a greater challenge than small changes in mean temperatures.[5] This may be especially true for vulnerable groups, whose health is already being affected by current climate conditions. Extreme weather events — such as the Saguenay-Chicoutimi flood in 1996 and the 1998 ice storm — clearly demonstrated the vulnerability of municipal infrastructures in Canada to climate stresses, with harmful consequences for human health. Similarly, the illnesses and deaths due to a highly virulent strain of *E. coli* in Walkerton, Ontario in spring 2000, were triggered by weather conditions (drought followed by intense rainfall).[6] The Walkerton disaster has heightened public concern over the quality of our water and the ability of municipal infrastructure to deliver clean water. Ongoing health concerns over periodic heat waves, severe cold spells and, especially, intense smog episodes continue to attract the attention of politicians from all levels of government, as well as members of the health care community.

Second, the health care system has been able to cope relatively well with most climate stresses in the past. However, this is not a guarantee that the health of Canadians will be well protected in the future. In many regions of Canada, the health care system is already becoming overburdened. In Ontario, for example, there is growing concern that emergency hospital departments and home care services are in a state of crisis.[7] Further, the vulnerability of Canadians may also be increasing. The population is getting older, and in some urban centres, such as the Greater Toronto Area and the City of Hamilton, the disparities between rich and poor are on the rise, with areas of poverty becoming increasingly marginalized from the more affluent suburban communities.[8] Consequently, the ability of the health infrastructure to respond effectively to climate change impacts, such as new and emerging diseases, and ensure the health of Canadians is by no means certain and, at the very least, demands closer attention.

In order to reduce the vulnerability of Canadians to the health effects resulting from climate change, it is necessary that decision-makers have a strategy for developing an effective adaptation action plan. Such a plan requires a clear understanding of (1) the health risks associated with current climate and climate change, (2) the adaptive options that are available; and (3) the capacity of health infrastructure to adapt to future climate change impacts.

Objectives and Design of the Study

The purpose of this study is to provide decision-makers with the information needed to improve the adaptive capacity of health infrastructure to the health effects of climate change in one area of Canada — the Toronto-Niagara region.

The objectives are to:

- assess the potential health effects of climate change in the Toronto-Niagara region, including the interactions between direct and indirect effects, and the health effects that may emerge from interactions between responses;
- prioritize potential health effects and identify key adaptive actions that are required to help the current health infrastructure in the Toronto-Niagara region to cope with these changes; and,
- recommend the next steps in implementing an effective response plan for the Toronto-Niagara region involving appropriate adaptive actions.

To achieve these objectives, the study was organized into two phases. Phase I involved a thorough literature review of the science of climate change, its impacts and health effects, as they applied to the Toronto-Niagara region. Emphasis was placed on identifying the known impacts and health risk uncertainties associated with current climate, in addition to future climate change. An adaptive framework was adopted that addressed six key questions:

1. What are the most important health effects, related to weather and climate change, to which the health infrastructure must respond (for example, temperature extremes, extreme weather events, etc.)?

2. Who will be the most vulnerable groups impacted (for example, children, the elderly, homeless people, rural residents, etc.)?

3. What are the current and potential effects on health (for example, heat-related mortality, respiratory illnesses, injuries, etc.)?

4. What components of the health infrastructure (such as family physicians, emergency departments in hospitals, public health units, emergency response planning, etc.) must be in a position to cope with increased occurrences of temperature extremes, extreme weather events, smog episodes, and so on?

5. Which adaptive actions are currently employed to reduce the effects of climate change (including public education, monitoring and surveillance, medical intervention, etc.)?

6. How well will the health infrastructure adapt to the health effects from climate change?

Specific adaptive options are identified for each climate change/health issue. Interactions are also considered, in terms of chemical processes in the atmosphere, the causal pathways between climate change and health effects, and the connection between mitigative and adaptive responses. The substantive assessment conducted in Phase I of the study is included in this report as a technical document.

Phase II involved the engagement of health care stakeholders in the identification, evaluation and recommendation of effective policy and adaptive actions. Given the breadth of the health infrastructure and the complexity of the climate change/health issue, three separate groups of stakeholders were

engaged through a combination of interviews and consultation meetings. Key informant interviews were conducted (by telephone and in person) with decision-makers employed in primary care delivery. A stakeholder consultation meeting was held with a small group of environmentally-informed physicians, many of who are members of the environmental health committee of the Ontario College of Family Physicians. A case study of public health preparedness was also carried out in the City of Mississauga and the Region of Peel. The latter was done in conjunction with a fourth year undergraduate course on Environmental Health, offered through the Environmental Studies Program at the Erindale Campus of the University of Toronto (in Mississauga). Summaries of each initiative are included as appendices in the *Technical Report*. Although these stakeholders represent only a sampling of the total health infrastructure in the Toronto-Niagara region, they provided useful information about knowledge gaps, the effectiveness of current adaptive actions, and how adaptive capacity needs to be improved so that there can be a more effective policy response to the health effects arising from climate change.

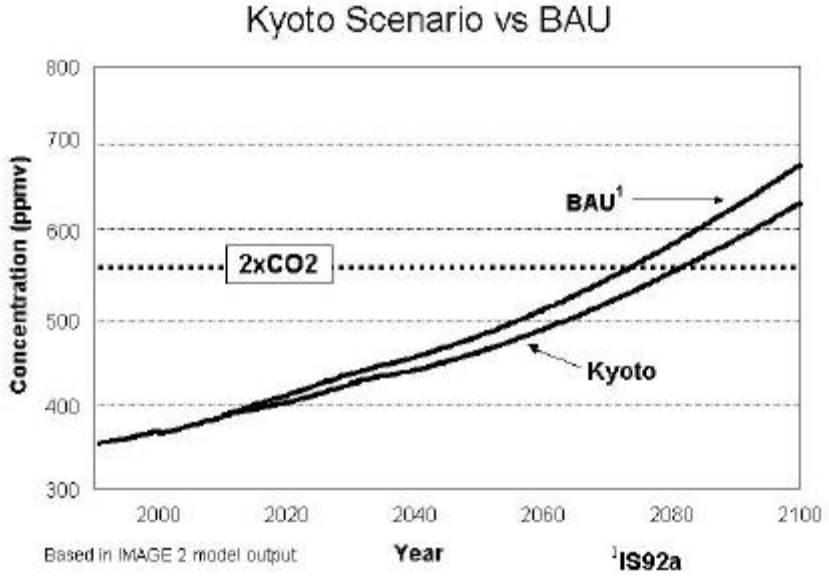
Part 2 — Scientific Evidence for the Impacts and Effects of Climate Change

The Impacts of Climate Change

There is now a strong scientific consensus that changes in the earth's climate cannot be entirely explained by natural variability. In 1996, the Intergovernmental Panel on Climate Change (IPCC) acknowledged that anthropogenic activities were having a discernible influence on the earth's climate.[9] Concentrations of carbon dioxide (CO_2) in the atmosphere are currently approaching levels higher than anything recorded over the past 200,000 years, due largely to the combustion of fossil fuels and unsustainable land use practices. Climate change is already occurring; the U.S. National Academy of Sciences recently concluded that global warming "is real and [has been] particularly strong within the past 20 years."[10]

Concern over climate change has led to an international response to the issue, initially with the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, followed by the Kyoto Protocol in 1997. In the former case, as a signatory to the UNFCCC, Canada is committed to the stabilization of greenhouse gas concentrations in the atmosphere in order to prevent dangerous anthropogenic interference with the climate system."[11] In the latter case, with an average commitment from developed countries to reduce GHG emissions 5.2 per cent below 1990 levels by 2008–2012, it is important to note that the Kyoto Protocol will delay a doubling of CO_2 concentrations by only six years[12] (Figure 1). For GHG concentrations to be stabilized at current levels, which are already 30 per cent higher than pre-industrial levels, global reductions of GHG emissions would have to be decreased by at least 50 per cent.[13] While we may be resigned to some degree of climate change and its impacts, the Kyoto

Figure 1: Global CO_2 Concentrations



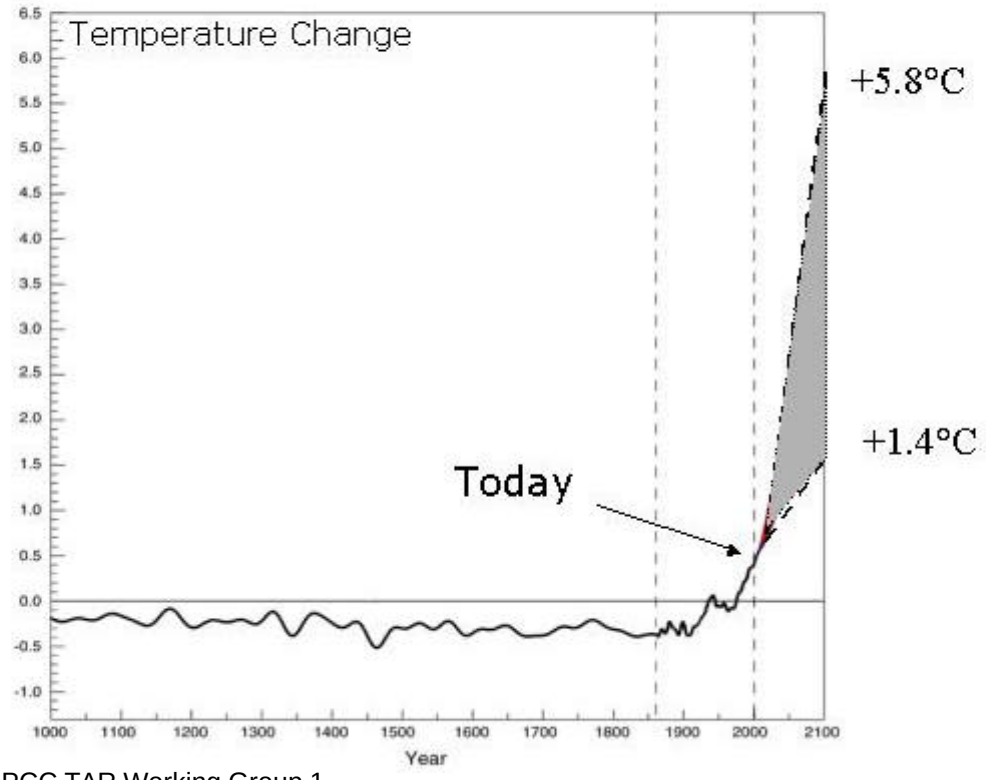
Source: Environment Canada.

Protocol represents an important first step towards reducing GHG emissions even further in the future (that is, taking action to prevent a tripling if not quadrupling of CO_2 concentrations), and in meeting the objective of Article 2 in the UNFCCC.

In the Second Assessment Report of the IPCC, general circulation models projected that increases in GHG concentrations will result in a global temperature increase of 1–3.5°C, with the Canadian model projecting an even higher increase. Lower projections of sulphur dioxide (SO_2) emissions from the IPCC Special Report on Emission Scenarios have led to an upward revision of the global temperature increase, in the IPCC's Third Assessment Report, to 1.4–5.8°C (Figure 2) by the end of this century.[14] This change in temperature is greater than anything experienced in the past 10,000 years. Moreover, changes in the mean temperature may be even less significant than variability in temperature and precipitation patterns and, especially, an increase in the frequency and intensity of extreme weather events.[15]

As a country with vast areas in high latitudes, Canada will experience a significant change in its climate. By 2050, temperatures could increase from 4–6°C in Central and Northern Canada and from 3–4°C along its eastern and western coastlines. By the end of this century, these temperature rises could even double, representing an amount two to three times the global average increase.[16] Changes in temperature, precipitation patterns and extreme

Figure 2: Hemispheric Temperature Trends of the Past Millennium and Predicted Increase by 2100



Source: IPCC TAR Working Group 1.

weather events could affect virtually all regions and sectors across Canada. While adverse impacts and effects are projected — most notably in regions whose primary resource economies are weather-dependent — climate change will also open up opportunities (such as the potential increase of agricultural production in northern regions). However, on a national basis, it is projected that the net effects of climate change will be negative.

Although there is less confidence in modeled projections and impact assessments of climate change at the regional scale, it is fairly certain that the climate in the Toronto-Niagara region will undergo considerable change. In the Great Lakes-St. Lawrence Basin, for example, general circulation model (GCM) scenarios of climate change project an average year-round warming of 3–8°C, with increases being greater in the winter than in the summer.[17] Higher temperatures and changes in precipitation patterns will lead to more frequent and severe droughts, intense smog episodes, and extreme weather events (such as heat waves, severe wind storms and intense precipitation). The timing and duration of heat waves and smog episodes will also be highly variable, with such events occurring earlier and re-occurring later in the season, and lasting for longer periods of time. Water levels in the Great Lakes could drop by up to one metre, while water temperatures will increase. Many of these changes could take place fairly rapidly. In the case of temperature extremes, for instance, the number of days exceeding 30°C could double by as soon as 2030.[18]

Potential Health Effects

On a global basis, both the Intergovernmental Panel on Climate Change[19] and the World Health Organization[20] have said that human health could be significantly impacted by climate change. Generally, the most severe health effects are projected to occur in less developed countries, although the populations of developed countries will also be affected, especially vulnerable groups (such as children and the elderly). National assessments of climate change impacts in both Canada[21] and the United States[22] have arrived at similar conclusions, projecting significant health risks associated with climate change. A broad range of health effects have been identified (including morbidity, injuries, hospital admissions and mortality) as a result of the following climate change–health issues: temperature extremes, extreme weather events, vector-borne and rodent-borne diseases, deteriorating air quality and indoor environments, water-borne and food-related illnesses, and exposure to elevated levels of UV radiation. Since the relationship between climate change and human health is highly complex, there are many direct and indirect effects that could result in a variety of distinct health outcomes (Table 1) and would require a range of adaptive responses.

While national assessments have broadly described the health effects and risks associated with climate change, the assumptions employed and significant regional knowledge gaps limit the usefulness of such information for health care planning, especially at the local level. This is particularly problematic for urban regions in Canada, where over 80 per cent of the population lives. In-depth information is required at the regional

Table 1: Mediating Processes and Direct and Indirect Potential Effects on Health of Changes in Temperature and Weather

Mediating Process	Health Outcome
Direct Effects	
Exposure to thermal extremes	Changes rates of illness and death related to heat and cold
Changed frequency or intensity of extreme and less severe weather events	Deaths, injuries, psychological disorders; damage to public health infrastructure
Indirect Effects	
Disturbances of ecological systems: effect on range and activity of vectors and infective parasites	Changes in geographical ranges and incidence of vector-borne disease
Changed local ecology of water-borne and food-borne infective agents	Changed incidence of diarrheal and other infectious diseases
Changed food productivity (especially crops) through changes in climate and associated pests and diseases	Malnutrition and hunger, and consequent impairment of child growth and development
Sea level rise with population displacement and damage to infrastructure	Increased risk of infectious disease, psychological disorders
Biological impact of air pollution changes (including pollens and spores); improper actions to reduce GHG emissions	Asthma and allergies; other acute and chronic respiratory disorders and deaths
Social, economic, and demographic dislocation through effects on economy, instrastructure, and resource supply	Wide range of public health consequences: mental health and nutritional impairment, infectious diseases, civil strife

Source: adapted from McMichael, A.J., A. Haines, R. Sloof and S. Kovats (eds) (1996) *Climate Change and Human Health* (Geneva: WHO, WMO, UNEP).

level regarding the potential health effects from climate change, the adaptive capacity of the health care infrastructure, and the types of policies and actions that will be the most effective when implemented. Improvements to the health care infrastructure to better cope with the pressures of climate change should also improve the level of health enjoyed by the general population. A population that is well protected from climate change impacts will reduce the demand for health care services.

In the Toronto-Niagara region, where over six million Canadians live, there is relatively more information on the health effects of current climate and

future climate change than there is in other regions in Canada. Still, considerable knowledge gaps remain. A few studies have been conducted on individual health effects (such as heat stress, malaria, and severe weather), but much of this research has addressed specific aspects of the climate/health relationship or has focused on unique events. For example, the effect of current and projected climates on heat stress mortality has been examined,[23] but little is known about the synergistic health effects of deteriorating air quality, or the location of those populations most vulnerable to the health effects of climate change. Vector-borne diseases have been assessed from either the perspective of current risks (most notably research on imported malaria[24]), or from the likelihood of domestic transmission under future climate change,[25] but few linkages between current and future risks are made. Similarly, while both the 1998 ice storm[26] and the 1999 Toronto snow storm[27] have been assessed (and included health effects in their economic analyses), health effects have received cursory treatment at best in other studies of extreme weather events that could occur under climate change, in some cases ignoring the health implications entirely.[28]

Nonetheless, the scientific literature strongly suggests that the health effects related to climate change could be significant in the Toronto-Niagara region; past experience has demonstrated that even current climate poses considerable health risks. However, the estimates of current health effects, not to mention those that may occur with climate change, vary widely (depending upon the health issue addressed and the assumptions employed). Direct health effects — and specifically heat-related mortality — provide a good illustration of the uncertainties surrounding projections of climate-induced health effects.

Heat-related Health Effects

There is a wide range of estimates in the scientific literature for heat-related mortality, both in terms of the current relationship and the projections under various climate change scenarios. It has been estimated that Toronto's heat-related death rate for the total population is less than one fatality per 100,000 people; however, death rates in extremely hot years rise to 6.45, a number comparable to the rates typically found in Chicago and Philadelphia.[29] During extremely hot years, the death rate for the elderly has been estimated to increase from seven per 100,000 elderly persons to over 66 per 100,000. This translates into 19 premature deaths annually, on average, but over 150 extra deaths during the hottest year.[30] Recent work in the Toronto-Niagara region suggests that heat-related mortality for the non-elderly (persons 64 years of age and younger) is negligible, but the relationship is significant for the elderly.[31] Revised heat-related mortality estimates for Toronto and Hamilton are 0.94 per 100,000 elderly persons and 1.32 per 100,000 elderly persons, respectively, on days when the apparent temperature exceeds 32°C.[32]

Under climate change scenarios, the number of days the temperature in Toronto exceeds 30°C could double by the 2030s (from the current 15 days, on average), and increase to over 50 days by the 2080s.[33] Heat-related mortality rates for general population range from 9.63 per 100,000 people to 33.65 per 100,000 people under various climate change models.[34] Using 2001 population statistics, it is estimated that 239–835 premature deaths could occur each year in Toronto

alone, due to the impacts of climate change. The actual number of heat-related deaths that will occur in the Toronto-Niagara region under climate change will be dependent upon many factors, including the minimum and maximum temperatures, the acclimatization capacity and vulnerability of the affected population, and the adaptation measures adopted. A "best-guess" estimate for the Toronto-Niagara region is between 171 and 447 elderly residents will die during an average summer by 2026 (depending upon the assumptions used for population increases, demographic shifts, and temperature change).[35]

Other Extreme Weather Events

Similar projections of the death tolls that could result from other extreme weather events are not possible, given the difficulty in modeling the exact timing, duration and intensity of storms; but past events suggest that the impacts could be extensive. There is also localized evidence that the frequency of severe wind storms and tornadoes are increasing.[36] Although the ice storm of 1998 bypassed most of the Toronto-Niagara region, most of eastern Ontario, southern Quebec and parts of Atlantic Canada were affected, including the cities of Kingston, Ottawa and Montreal. The ice storm resulted in 25 deaths (which is widely believed by local health experts to be a gross underestimate), an estimated 60,000 physical injuries,[37] plus tens of thousands of individuals potentially affected by post-traumatic stress disorder.

Notable extreme weather events that have directly affected the Toronto-Niagara region in the past include Hurricane Hazel in 1954, the Barrie tornado in 1985, and the Toronto snowstorm in January 1999, among others. Hurricane Hazel caused the most severe flooding in Toronto in over 200 years, resulting in 81 deaths, the evacuation of almost 2,000 families and damages that have been estimated to exceed one billion (1999) dollars.[38] The Barrie tornado also hit Grand Valley, Orangeville, Shelburne and Tottenham, killing 12 persons, injuring 155 others, and inflicting damage on property estimated at over $300 million (in 1999 dollars).[39] The Toronto snowstorm led to six reported deaths (attributed to overexertion), in addition to thousands of accidents and severely restricted access to hospital emergency departments. During the month of January 1999, it was estimated that there were over 1,800 excess traffic accidents, compared to the same period the previous year.[40] Since such events are consistent with those projected under climate change, it can be expected that as the frequency of severe weather increases, the impacts on the health care infrastructure will be significant.

Vector-borne and Rodent-borne Diseases

Many indirect effects of climate change (influenced by changes in ecological and/or social conditions) could also pose significant health risks in the Toronto-Niagara region. For example, the geographical range of parasites and other disease vectors could spread northward, increasing the health risks posed by new or emerging infectious diseases that otherwise might have remained dormant or absent in the Toronto-Niagara region. West Nile virus, for example, first appeared in New York State in 1999, and public health departments along the Ontario-New York border soon went on the alert regarding its potential spread into Canada. During the summer of 2001, dead birds infected with the virus

were found throughout the Toronto-Niagara region, and the first confirmed human fatalities were reported in Ontario in September of 2002. As of October 2002 Health Canada had reported 69 cases, with 49 suspected cases and 20 confirmed cases in Canada, most of them in Ontario. Although the arrival of the virus is unconnected to climate change, it has been suggested that a warming trend and sequential weather extremes helped the virus become established in the New York City area in 1999.[41] Rodents carrying the hantavirus have also appeared in southern Ontario, although (to date) no human fatalities have occurred east of Manitoba.

Lyme Disease, while endemic along the north shores of Lake Erie (specifically Point Pelee National Park, Long Point and Rondeau Provincial Park), may also be spreading into the Toronto-Niagara region. Blacklegged ticks, a carrier of the bacteria *Borrelia burgdorferi* that is known to cause Lyme Disease, have recently been collected from dogs resident in Mississauga and Etobicoke.[42] The first case of bebesiosis, another disease spread by deer ticks that is endemic in the northeastern U.S., was diagnosed in Toronto in 1997.[43] Two years later, in 1999, the first case of transfusion-transmitted babesiosis was reported in Ontario, suggesting that this parasite may now threaten Canadian blood safety.[44]

However, health risks are not limited to the domestic transmission of diseases, as Canadians traveling to locations where malaria, Lyme Disease and other infectious diseases are endemic may be increasingly at risk. In 1997, a reported 1,036 Canadians were diagnosed with "imported" malaria, while the actual number of cases (most which are not reported) could have ranged as high as between 2,000 to 3,000.[45] Similarly, of the 280 cases of Lyme Disease reported in Ontario between 1981 and 1998, almost 55 per cent were contracted outside of Ontario.[46] Although climate change may nurture environments that are more suitable for the spread of vector-borne diseases, it is unclear if Canadians will be at greater risk from domestic or imported transmission. Even if the former does not materialize, the health care system in the Toronto-Niagara region will be responsible for an increasing number of infectious diseases due to the continuing reliance on air travel.

Air Quality and Human Health

The indirect effects of climate change on air quality and, subsequently, on respiratory health could become an even greater concern. The Ontario Medical Association has estimated that there are currently 1,925 premature deaths in Ontario[47] and over one billion dollars in health care costs due to air pollution. For every premature death, thousands more are hospitalized, while even more suffer some form of respiratory illness, such as asthma. In some studies, the monetary value of these health effects is enormous, estimated to be in the millions, if not billions, of dollars. Poor air quality not only affects human health in Toronto and Hamilton, but throughout the Toronto-Niagara region, including rural areas as well.

Climate change will alter both the average and the peak air pollution levels. Projections based on some scenarios estimate that background levels of ground-level ozone (upon which much of the urban air pollution is built) will increase by more than 40 parts per billion (ppb) over most of the mid-latitudes of

the Northern Hemisphere.[48] In some urban centres, this increase would double the baseline concentrations of ground-level ozone. Between 1988 and 1997, the mean monthly ozone levels in southern Ontario varied from 10 ppb during the winter months, to approximately 30 ppb during the summer.[49] Under climate change scenarios, background levels during the summer would nearly reach the current one-hour ozone criterion of 80 ppb, a level at which persons with lung and heart problems are considered at serious risk.

The occurrence of offensive air masses — accompanied by smog episodes, excessive temperatures, and high humidity — could increase in frequency almost five-fold, from 4.7 to 23.3 per cent of summer days.[50] Some general circulation models project an even higher frequency, with offensive air masses settling over portions of the region on between 28.9 to 39.1 per cent of summer days.[51] To date, there are no credible projections of the health effects that would accompany the poor air quality resulting under a scenario where carbon dioxide levels double (that is, a 2 x CO_2 scenario). A joint study involving the City of Toronto and Environment Canada is currently underway to address this question, but is still a year away from providing credible estimates. However, the Ontario Medial Association has recently estimated that the number of premature deaths in Ontario attributable to smog episodes could exceed 2,500 a year by 2015.[52]

Water-borne and Food-borne Diseases

The incidence of water-borne and food-borne illnesses, such as *Giardia, E. coli,* and *Cryptosporidium,* are also expected to increase. Water-borne disease outbreaks have been linked to extreme precipitation events in the United States.[53] Changes in precipitation patterns, temperature and the frequency of droughts could trigger disease outbreaks, particularly in households and communities that are dependent upon groundwater, or in cities where sewer and storm water drainage systems are combined. Although most of the water consumed in the Toronto-Niagara region originates from Lake Ontario, many rural residents and small communities continue to rely upon groundwater. In Halton Region, for example, a recent survey indicated that only one-half of the private wells tested provided safe water, due largely to the location, depth and insufficient maintenance of the wells.[54] More significant, however, could be the fact that disease outbreaks in Walkerton and Collingwood have clearly demonstrated that residents of small communities in Ontario already may be at risk of contracting water-borne diseases.

Disease can also occur by eating fresh fruits and vegetables that have been irrigated or processed using contaminated water. Consequently, as an area that is well connected to the global marketplace, the residents of the Toronto-Niagara region could be placed at greater risk of exposure to tainted foods. Higher temperatures could further increase the risk of food poisoning by enhancing the bacterial contamination of locally prepared food, especially during the summer months (when most outdoor eating activities take place, and when food is more likely to be improperly refrigerated).

Health Effects of Elevated Levels of Ultraviolet Radiation

Although stratospheric ozone depletion and climate change are sometimes treated as separate air issues, they are interrelated. Many substitutes for CFCs are potent GHGs; however, the most important linkages involves the way that ozone depleting substances and GHGs alter radiation processes in the atmosphere so as to enhance both global warming and stratospheric ozone depletion.[55]

There is also widespread belief that in a warmer climate, increased outdoor activities will increase the risk of higher UV exposure. The number of days in Toronto when high or extreme UV readings were recorded increased from 30–40 days in 1989 to approximately 60 days by 1996.[56] Increased UV exposure is directly linked with an increased incidence of skin cancers and cataracts. UV radiation is a contributing cause of melanoma, which will be responsible for an estimated 370 deaths in Ontario in 2002.[57] Many cases of skin cancer being diagnosed today are due to UV radiation exposure in the 1960s and 1970s, a time before the protective stratospheric ozone layer had thinned considerably. Since the stratospheric ozone layer is not expected to begin to recover until some time between 2020 and 2050, the health risks associated with elevated exposure to UV radiation in the Toronto-Niagara region are expected to be even higher for decades to come. Even after the stratospheric ozone layer recovers, overexposure to UV radiation will remain a health risk.

Interactions Between Health Issues

In addition to the direct and indirect health effects associated with climate change, it is also important to consider any interactions between health issues; the total health effect could be synergistic, with the end result being more severe than the sum of the individual parts. For example, indoor environments could be contaminated by an increase in toxic moulds (due to the higher temperatures, higher relative humidity and an increase in the frequency of floods that could accompany a changing climate). In turn, these moulds could place vulnerable people at increased risk of developing respiratory illnesses, especially during heat waves and smog episodes (again symptomatic of most climate change scenarios). Reductions in GHG emissions achieved by improving the energy efficiency of residential, commercial and institutional buildings — if done improperly without sufficient ventilation — could also increase exposure to indoor pollutants.[58] This is most likely to occur from reductions in air flow, in buildings that are sealed against cold and/or heat, in response to a changing climate.

Interactions between extreme weather events and vector-borne diseases in less developed countries could also have health implications for Canada, through the creation of environmental refugees fleeing flooding or drought conditions. Refugees and immigrants could be at greater risk to infectious diseases, thereby placing the responsibility for treatment on the Canadian health care system. Since a large share of refugees and immigrants travel through Pearson International Airport, or choose to reside

in the Toronto-Niagara region, it follows that the health care system in this area will be primarily responsible for treating such new and emerging diseases.

Timing can also play an important role in compounding effects. For example, many Toronto-Niagara region residents seek relief from hot weather by swimming at one of the area's many beaches along Lake Ontario. In some cases, the hours for public swimming pools are even extended during heat waves. However, city officials had great difficulty in coping with an early heat wave that occurred in June of 2001. Intense rainfall overwhelmed the capacity of the city's storm sewers, resulting in unsafe levels of *E. coli* and forcing seven beach closures along Toronto's waterfront. A heat wave (and smog alert) immediately followed, but (due to the closures) residents were unable to avail themselves of the local beaches to avoid the heat. Compounding the problem, most of the city's swimming pools were still closed, undergoing repairs in anticipation of the traditional opening of the season on July 1st.[59]

Food production, recreational fishing and water quality could also be adversely affected by the interactions that could occur among various environmental factors, including the impact of climate change, ground-level ozone, acid rain and UV radiation. The combination of warmer temperatures, acid deposition and UV radiation has been known to have an adverse impact on aquatic ecosystems in Canada's boreal region.[60] Although no comparable analysis exists for the Toronto-Niagara region, there is evidence that warmer water temperatures are having a measurable impact on the diversity of fish species in the upper Grand River Basin.[61] Similarly, the interaction between warmer temperatures and increased frequency of drought conditions, in combination with increases in ground-level ozone and UV radiation, has been shown to have significant impacts on local food production.[62]

Actions to reduce the impacts of climate change could also generate unanticipated and negative health effects. The most obvious is the use of air conditioning to combat heat stress, and the resulting increased demand for electricity leading to an increase in emissions of air pollutants from coal-fired power plants. Another example is the dredging of lake ports and rivers in response to lower water levels, which could reintroduce heavy metals and other toxics from disturbed sediments directly into drinking water supplies and indirectly into the food chain.

Vulnerable Segments of the Population

In acting to effectively reduce the health effects associated with climate change and its environmental impacts, it will be important to identify vulnerable segments of the population. However, given the wide range of health effects that could occur, vulnerability varies considerably across climate change–health issues, making the identification and targeting of specific groups extremely difficult. Generally, the most vulnerable groups are children, the elderly, individuals with certain pre-existing medical conditions or illnesses, and persons with compromised immune systems. However, for some climate change-related health issues, all segments of the population are at risk. In the Toronto-Niagara region, an estimated 19.2 per cent of the population is under 15 years of age and 12.4 per cent of the population is over 65 years of age. These percentages translate into almost two million persons who could be classified as 'vulnerable' based on age alone.

Vulnerability can also be shaped by social and economic conditions, culture and ethnicity, gender, the conditions present in work and home environments, and access to health care, among others factors.

Children and the elderly are particularly vulnerable to heat stress and hypothermia (caused by temperature extremes), cardiovascular and respiratory effects (exacerbated by smog episodes), and water-borne and food-borne illnesses. In part, this is due to their sensitivity to extreme conditions, and their more limited physiological capacity to adapt. The homeless are an obvious group that is vulnerable to temperatures extremes, especially severe cold. Access to shelter, however, is no guarantee of protection, especially during heat waves. Hot temperatures, poor air quality, and unhealthy indoor environments can, individually or in combination, severely compromise the buildings where children and the elderly spend much of their time. Daycare centres, schools,[63] nursing homes and seniors' residences[64] may provide only limited protection — depending on their heating, ventilation and air conditioning systems — against the environmental conditions that may lead to respiratory illnesses, heat stress and even death. Cultural factors may also increase vulnerability to the effects of climate change. For example, communication barriers could limit the effectiveness of education and outreach programs designed to address potential health problems, and complicate direct actions such as an emergency evacuation in the event of an extreme weather event. Geography may be a contributing factor for Canadian travelers, notably visitors returning from the Indian sub-continent, who exhibit the highest incidence of imported malaria in Canada.[65] The significance of cultural and other factors on other climate change/health issues remain largely unexplored. For a region that has one of the most diverse populations in the world, these factors deserve closer attention.

Women are more likely to live in poverty than men, and hence they could be more vulnerable to certain health effects due to their lower socio-economic status. This especially may be the case for single parents (and their children) and the elderly who live alone.[66] However, more research is needed to determine a clear causal relationship between gender, climate and health. Melanoma is one exception. In the case of malignant skin cancer, males have slightly higher rates of incidence and mortality compared to women,[67] in part, due to greater exposure to UV radiation while engaged in job-related or recreational activities outside.[68] For the general population, leisure (recreational) activities will account for most of their UV exposure. Excessive exposure early in life may be an important factor in developing skin cancer, but intermittent exposure can also lead to melanoma.

Occupational or recreational considerations may also be contributing factors for heat stress, respiratory illnesses caused by air pollution, and UV radiation exposure. In the case of hot temperatures, for example, otherwise healthy people have been known to succumb to heat stroke in outdoor work or sport settings. Children playing outdoors and sports enthusiasts are exposed to particularly high air pollution in the early evening hours during severe smog episodes, while mid-day exposure to UV radiation poses the greatest risk. Exposure in early childhood to UV radiation has generally been regarded as a significant factor for developing skin cancer later in life.

Similarly, other UV-related health effects, such as cataracts, usually do not appear until old age. In rural areas, occupation may also be an important factor. For example, farmers are at greater risk of being exposed to airborne pollutants, such as pesticides, herbicides, particulate matter from soil and unpaved roads, and grain dust.[69] Response time to health care may be longer compared to urban centres (although recent redirect conditions for emergency hospital departments and [sub]urban traffic congestion may eventually negate such differences). Rural communities may also be more at risk to water-borne diseases, especially in areas that are dependent upon private wells and have high concentrations of livestock. Residents of urban areas in the Toronto-Niagara region are at less risk of contracting water-borne diseases, because their water supplies originate from Lake Ontario or deep aquifers. However, persons with compromised immune systems, who reside in major urban centres, are especially vulnerable to water-borne diseases.

While heat stress may be exacerbated by the urban heat island effect, dangerous smog conditions can blanket both urban and rural areas to a severe degree. There is no known safe threshold for exposure to particulate matter and ground-level ozone, two primary components of smog. This suggests that all residents in the Toronto-Niagara region (regardless of their location) are at some health risk during prolonged exposures to these pollutants. Due to transboundary pollution and the dynamics of atmospheric chemistry, rural residents may experience even higher exposures to air pollutants than their urban counterparts during some smog events.[70] Similarly, the entire population is at risk during extreme weather events, such as hurricanes, tornadoes and ice storms. Yet there is anecdotal evidence to suggest that (despite being more isolated) residents in rural areas may be less vulnerable than their urban counterparts due to their greater resourcefulness and experience with infrastructure failure.[71]

Part 3 — Developing an Effective Adaptation Plan

The Canadian Health Care Infrastructure

While it may be sufficient to define health infrastructure according to traditional lines of prevention, diagnosis, treatment and surveillance for most health issues, the issue of climate change requires a more inclusive approach. For the purposes of addressing climate change, health infrastructure includes: front line health care providers, family physicians, community health care and social workers, public health departments, health infrastructure and system planners, health researchers, federal and provincial Ministries of Health, professional organizations and social agencies, non-governmental organizations, etc. Instead of health infrastructure, per se, it may be more prudent to consider the infrastructure that is needed to protect population health. Federal and provincial Health Ministries will continue to play a significant role in providing leadership and strategic planning for health care delivery. However, in the case of climate change, responsibility must also be extended to other government departments, such as environment, natural resources, national defense (for emergency preparedness), and agriculture and food.[72] Health infrastructure can play a significant role in identifying and monitoring climate-related information (although, in isolation, they cannot be expected to make a direct connection between current trends and climate change).

Public health departments need to be aware of the range of issues that may arise, since they are well positioned to identify the early warning signs of climate change, and can also help shape and implement the adaptive responses required. In particular, public health departments can play an important role in prevention and surveillance. Medical officers of health and public health departments can play a pivotal role in raising awareness on the health issues related to climate change, as well coordinate the implementation of provincial policies at the local scale.

Diagnosis and treatment will fall, largely, upon the shoulders of front line health care providers, including hospital staff in emergency and other departments, as well as family physicians who are often the first to see new and re-emerging health issues. Family physicians are also well positioned to educate their patients, and, thus, take on an additional prevention function. Given the vulnerability of the elderly and children to climate change, community health care and social workers also have a very significant role to play in terms of providing treatment and recognizing indicators of change. This includes health care workers and staff employed at community health centres, long-term care facilities, nursing home/chronic care facilities and childcare centres, as well as those who provide in-home care. For some health issues, certain medical specialties are particularly important. In the case of vector-borne diseases, for example, travel clinics could play a significant role in prevention and diagnosis.

At the municipal level, it is often assumed that the responsibility for health falls solely within the mandates of public health departments, public health units, and district health councils. However, many other departments may exercise some authority over factors that contribute

to health issues. For example, public works departments may be responsible for sewage and water treatment, conservation authorities control flood plain management, and emergency response plans usually involve the coordination and participation of multiple departments (including fire and police, transportation, and public health, amongst others).

Other players in the health infrastructure include professional organizations, representing all of the groups above, and non-governmental organizations, representing environmental and health interests. Both can assist in communicating key messages to the general public or to targeted groups. Lastly, health infrastructure must also include primary care deliverers who sometimes operate at the margins of the formal health care system. This category includes the Salvation Army, church groups, and other social agencies that play a vital role in administering support and services to the homeless, the poor and the elderly (who may be particularly vulnerable to climate change). Cultural groups and organizations could also play a significant role in public outreach and education for the diverse cultural mosaic across the Toronto-Niagara region.

The Evolution of the Climate Change/ Health Issue

The issue of climate change and human health — and the subsequent need for adaptive strategies — has had a relatively short history in Canada, involving a variety of federal departments, agencies and non-governmental organizations. Initial interest in the issue can be traced back to the early 1990s; specifically, two workshops on weather and health in 1991[73] and 1992[74] and as part of a broader regional study of climate change impacts and adaptation in the Great Lakes-St. Lawrence Basin.[75] Contributions to the latter study represented an important first step in investigating the problem, while a Pollution Probe workshop in November 1996 helped to raise awareness regarding the need to address climate change and the health of Canadians in a broader, if not more comprehensive, manner.[76]

By 1997, as part of the Canada Country Study on Climate Change Impacts and Adaptation, health was addressed in a distinct sectoral chapter,[77] in addition to being incorporated into various regional studies, including one on Ontario.[78] An Environment Canada workshop in May 1998 further highlighted the need to address climate change and health on a regional scale, and the topic was identified as a key science policy issue within a larger study on atmospheric change in the Toronto-Niagara region. A working group on human health was established, recommending further research on specific aspects of climate change and health, the dissemination of a concise summary of what is known about climate change impacts and the effects on human health, and the identification of possible adaptive actions.[79]

The impacts of climate change on human health were notably absent in the sixteen issue tables established as part of the national implementation strategy to address climate change. As part of the national initiative to address the Kyoto Protocol, much of the responsibility to assess the implications for human health was given to the Environment and Health Impacts subgroup of the Analysis and Modeling Group. In this instance, emphasis was placed exclusively on the co-benefits associated with improved air

quality that could be achieved through reductions in GHG-related emissions.[80] The impacts on health from climate change itself were virtually ignored in the group's modeling activities, with research on this issue restricted to the Science, Impacts and Adaptation component of the Government of Canada's Climate Change Action Fund (from which this study has been funded). Of note, the analysis of co-benefits did not factor in how ambient air quality could be impacted by climate change, nor did it consider the projected increase in health effects associated with these changes.

As a partial response to the unequal treatment of health in the national climate change process, Health Canada organized a workshop that brought together a small group of climate and health experts to address strategies that were directed at capitalizing upon the science of climate change impacts and health effects. This workshop highlighted the linkages between climate change and air quality.[81] The Canadian Public Health Association was given the task of organizing a national roundtable on climate change and health in September 2000. The charge to the steering committee — "How do we get climate change into the health debate; how do we get health into the climate change debate" — encapsulated a history of relative neglect by its main constituents.[82] The establishment of a sectoral and regional Canadian Climate Impacts and Adaptation Research Network (C-CIARN) through the Climate Change Action Fund should help narrow the knowledge gap between climate change and health. The development of this network also represents a significant move forward in establishing research priorities and coordinating research activities. In January 2001, the Meteorological Service of Canada — Ontario Region, Environment Canada, organized a provincial C-CIARN workshop in Ontario, in which health was included as a sector of concern.[83] Through its Climate Change and Health Office, Health Canada took on the task of organizing the first annual conference on climate change and health in March 2001, and is coordinating the C-CIARN health node. The Climate Change Health Office soon followed with the first annual climate change/health policy conference (held in Canmore, Alberta, in September 2001), which proposed the creation of a climate change/health policy network that would be based in six regions across Canada. The mandate of the climate change/health policy network closely follows the more regionally-specific adaptive strategy proposed in this report.

Support for research on climate change and health is also emerging from various funding agencies. The Canadian Institutes for Health Research, the Canadian Population Health Initiative, the continuation of the Climate Change Action Fund — Impacts and Adaptation for a further three years (including $1 million for health research), and the Health Policy Research Program of Health Canada all offer funding opportunities for scientists and researchers doing work on climate change and health. The Health Canada Policy Research Program allocated a share of their $1.2 million fund towards research on climate change and population health in 2002. Indeed, having been a relatively low priority during much of the 1990s, climate change and health may finally be accorded the recognition that it richly deserves as one of the key issues facing Canada in this century.

One of the challenges facing climate change/health research is the absence of comparable analyses with other health

risks. It would be helpful to know how the health risks associated with climate change compare with other health issues, but (to date) few studies have provided this type of information at either a national or local level. In part, this may be due to the uncertainties surrounding estimates of climate change impacts and the associated health effects. It may also be due to the segmented nature of the research agenda (whereby studies tend to address individual health effects rather than all of the climate change/ health related issues in aggregate). Some comparisons of health effects have been presented in the literature (such as heat stress and air quality, air quality and other illnesses, imported malaria and AIDS), but none of these comparisons have been calculated for climate change scenarios.

While recognition as a key health issue may be overdue, the application of climate change and health clearly falls within the framework for health promotion, as articulated in the 1986 report *Achieving Health for All: A Framework for Health Promotion.* It also fits within the frameworks developed for Federal-Provincial-Territorial Committees that addressed various aspects of health during the 1990s.[84] Released by the Honourable Jake Epp, who was (at the time) Minister of Health and Welfare Canada, the 1986 report identifies three major challenges that were not being adequately addressed by current health policies and practices. These included the challenge of: reducing inequities and addressing the needs of disadvantaged groups; increasing the prevention effort against the occurrence of injuries, illnesses, chronic conditions and their resulting disabilities; and enhancing people's capacity to cope.[85] Although Epp's report predates the emergence of climate change as a health issue, his challenges, nonetheless, have clear application to the work in this study.

As is the case for most policy issues that are science-driven, policymaking and implementation lags behind knowledge generation and needs assessment. Studies have identified key research gaps, but have been reluctant to recommend actions beyond an expanded research effort and improved monitoring of health risk indicators. Perhaps the most noticeable characteristic of climate change/health policy in the Toronto-Niagara region is the absence of integrated planning at all levels of government. Climate change/ health issues are addressed largely at the municipal level; but even these policy efforts are, at best, ad hoc and piecemeal. They tend to focus on specific health issues related to current climate and weather (for example, Toronto's hot weather/ health watch warning system), rather than serve as part of a comprehensive adaptive strategy in response to climate change.

Adaptive Measures

Various adaptive measures are discussed in the technical science assessment, which is summarized in Table 2. The summary covers five of the six health issues addressed in this study, and adaptive measures are defined according to six different action categories. These include: (1) public education and communication, (2) surveillance and monitoring, (3) ecosystem intervention, (4) infrastructure development, (5) technical/engineering, and (6) medical intervention. Each adaptive measure is then evaluated according to its current status and placed into one of five status classes: (1) measure occurring, (2) measure currently being developed, (3) measure not occurring, (4) inadequate measures exist, and (5) information not available. No attempt is made to assess the capacity of these adaptive actions to respond effectively to climate change. Nor is there

Table 2: Possible Adaptive Measures to Atmospheric Stresses, and Current Implementation Status (CIS) in the Toronto-Niagara Region

	Heat Stress		Extreme Weather Events		Infectious Diseases		Smog		UV Radiation	
	Adaptation Measure	**CIS**	**Adaptation Measure**	**CIS**	**Adaptation Measure**	**CIS**	**Adaptation Measure**	**CIS**	**Adaptation Measure**	**CIS**
Public Education & Communication	Increase awareness of heat stress danger; Publicize precautions to take during heat waves.	✓ ~	Provide information about the risks of natural disasters; Publicize actions to take in preparation for, and during severe weather events.	~ ~	Educate residents, immigrants and travelers about disease risks, precautions (avoidance, immunization) and disease symptoms.	~	Publicize actions and precautions to take during smog events (e.g. reduce exertion levels and energy consumption; stay indoors or car pool).	✓	Educate public about risk, prevention and protection.	✓
Surveillance & Monitoring	Identify people at risk; Establish hot weather response plan and watch/ warning system.	× ✓	Weather advisories and warnings.	✓	Surveillance of vector populations; Monitoring & reporting of disease incidence.	~ ~	Identify those at high risk; Establish smog/ air quality monitoring & advisory system; Establish system for reporting and repair of polluting vehicles (Drive-Clean Program).	× ✓ ✓	Establish UV monitoring and advisory system; Monitor skin cancer rates; Monitor other UV-related disorders.	✓ ✓ ?
Ecosystem Intervention	Reduce heat-island effect (planting trees, increasing green space within cities, as well as vertical and rooftop gardens).	~	Land-use planning and management to minimize erosion, flash flooding and precarious residential & commercial areas.	✓	Control of disease vectors; Elimination of disease vector breeding sites.	× ×	Maintain and increase green space within cities; Reduce park spraying.	~ ✓	Develop UV-resistant seeds, plants and crops; Maintain natural shade in parks, beaches, resort areas, etc.	? ~
Infrastructure Development	Provide accessible air-conditioned public facilities and shelters; Extend hours of cooling facilities and waive user fees (e.g. on swimming pools); Provide accessible public drinking fountains in outdoor public places.	✓ ❖ ~	Maintain public shelters and develop evacuation plans; Maintain dams, floodplains, and storm run-off capabilities; Enhance insurance programs.	✓ ✓ ~	Maintain standards for travel clinics; Maintain adequate laboratory diagnosis facilities.	× ~	Improve public transit systems & bicycle lanes; Incentives for citizens, households, communities and corporations to reduce emissions & energy consumption.	~ ~	Develop UV-resistant glass for windows; Increase shaded areas in cities and public places.	~ ✓
Technological/ Engineering	Design and retrofit buildings, roofs, roads and parking lots to be more heat resistant.	~	Strengthen and enforce building codes and standards.	~			Develop alternative (clean) fuels and zero-emission vehicles; Reduce output of fossil fuel power generating stations.	~ ×	Develop UV resistant materials.	?
Medical Intervention	Adjust work schedules to avoid heat-stress exposure; Establish emergency response plans during heat waves (e.g. by Increasing staff & beds in hospitals).	❖ ×	Maintain disaster preparedness programs, including tools for local public health facilities to provide rapid health needs.	✓	Develop new vaccines and drugs; Offer immuniza-tion programs.	~ ~	Determine new criteria of smog to protect human health; Increase hospital staff & beds in emergency units during smog episodes.	✓ ×	Suncreens, vision care, etc.; Provide health-care profession-als with information and tools to assist people at risk.	✓ ✓

✓ = Measure occurring × = Measure not occurring ❖ = Measure being developed ~ = Inadequate measures exist ? = Information not available

(Adapted from UNEP, 1996)

Source: Edwards P., Maarouf A. and Kalhok S. (1999) Human Health Effects of Atmospheric Change in the Toronto-Niagara Region, Canada. unpublished manuscript (Downsview: Environment Canada)

any attempt to broaden the framework to include social and public health intervention, and their potential adaptive measures.

Measures to Address Extreme Temperatures

The adaptive response measures currently being adopted in the Toronto-Niagara region are by no means exhaustive (either in relation to communities throughout Canada or in comparison with jurisdictions in other countries). In some cases, such as measures taken to address extreme temperatures, existing policies apply more to current conditions than to concerns about climate change. Out-of-the-cold programs, which provide advisories to the general public and are targeted primarily towards the homeless, have been introduced throughout the Greater Toronto Area. Various agencies are contracted by public health departments to distribute hot drinks and sleeping bags, while additional beds are made available in shelters. However, such programs have not yet been widely adopted in other municipalities.

New provincial guidelines for the care of the elderly during heat waves were produced in 1990, in response to numerous heat-related deaths that occurred during the summer of 1988.[86] Heating, ventilation and air conditioning systems must comply with various building standards and codes (such as the Ontario Building Code, Canadian Standards Association, and the American Society of Heating and Refrigeration and Air-Conditioning Engineers), with mechanical cooling systems provided in all common areas, but not in resident bedrooms and washrooms.[87] The absence of air conditioning in bedrooms is potentially a large health concern since persons with limited mobility or who are mentally ill may spend a disproportionate share of their time confined to their rooms. In long-term care facilities, high night-time temperatures can pose a significant health hazard, especially since high-risk residents are unlikely to be moved to cooler common areas during sleeping hours.

Similar guidelines have not yet been established for buildings that house children, such as schools and child care centres. In the latter case, it is believed that many municipalities are not even aware which facilities have air conditioners installed, or, for that matter, if specific heat avoidance procedures are put in place during heat waves. The need to improve indoor environments in schools has been recognized as an important health issue in Ontario, but increases in humidity and excessive rainfall events can be expected to exacerbate the spread of toxic moulds even more. Although many school boards have embarked on programs to reconstruct playgrounds, there are limited budgets for additional tree planting. Trees offer a variety of health benefits, by helping to reduce the urban heat island effect, providing protection against UV radiation exposure, and even decreasing air pollution levels by lowering the demand for air conditioning.

On a broader scale, a hot weather/health watch warning system, introduced in the City of Toronto during the summer of 2001, is similar to systems that have been developed for cities in the U.S. (e.g., Philadelphia, Chicago and Phoenix) and other countries (Shanghai, China).[88] Customized for Toronto's meteorological conditions, the system provides 24-hour warnings of oncoming oppressive air masses, and involves various outreach activities, including facilitating greater

access to air-conditioned public buildings and swimming pools. While such a warning system may help reduce heat-related mortality, the program could be strengthened if it was coordinated with air quality advisories. Of note, no other municipality in the Toronto-Niagara region is currently developing their own warning system. Instead, they are taking a "wait and see" approach, with possible future action dependent upon the success of the Toronto experience. Environment Canada does, however, issue Humidex advisories, risk and precaution information up to a day or more in advance of extreme heat events.

Measures to Address Other Extreme Weather Events

Most municipalities across Ontario have emergency response plans in place. The Toronto-Niagara region had the added advantage of experiencing Hurricane Hazel in 1954, which led to a radical overhaul of flood plain management (following the establishment of numerous conservation authorities almost a decade earlier). Current land use regulations and water management programs should protect the health of most residents in major urban centres, although isolated neighbourhoods and some small rural communities continue to experience minor flooding. However, with an increase in the frequency and intensity of storms expected to occur with climate change, 30-year and even 100-year flood plains may no longer apply in some locations.

The 1979 Mississauga train derailment also represented a benchmark in emergency response planning, and clearly established the City of Mississauga as a national leader in this field. Collaboration and clear communication among federal, provincial and municipal levels of government is especially critical to an effective response to an extreme weather event. News media (such as The Weather Network), and the internet can play an important role in knowledge dissemination and emergency preparedness. In Dufferin County, for example, a local road watch weather system may prove to be effective in reducing winter traffic fatalities.[89]

Until recently, however, few (if any) emergency response plans included contingencies for a pandemic. It is more than likely that in the Toronto-Niagara region, pandemics will largely be the responsibility of local health infrastructure. The national response capacity to emergencies is limited, being largely restricted to the number of field hospitals (165) and beds (200 per field hospital).[90] However, even in this case there is some uncertainty regarding the availability of these beds during a legitimate health crisis.[91]

Measures to Address Vector-borne and Rodent-borne Diseases

Although its introduction into North America may be unconnected to climate change, the recent emergence of the West Nile virus in the state of New York, and its spread across the eastern United States and into Canada, has raised awareness regarding the domestic transmission of vector-borne diseases and the need to take preventative measures. Monitoring and surveillance programs are present in all municipalities throughout the Toronto-Niagara region, with the testing of sentinel chickens recently being replaced by the testing of dead birds, and even the testing of mosquito pools in some municipalities. During the summer of 2001, dead blue jays and crows infected with the disease were found in various municipalities

throughout the Toronto-Niagara region, while infected mosquito pools appeared in at least two municipalities during the summer of 2002. In September 2002, the first confirmed human cases of West Nile Virus were reported (two in the Region of Peel), and at least one death was attributed to the disease. In response to the growing risk of West Nile virus, the City of Toronto has just proposed a four-stage constituency plan.[92] This plan is structured largely around an educational outreach program, with the public, health care providers and city staff as the target audiences. Through public education, the plan will enhance surveillance activities, reduce mosquito breeding grounds, and encourage the adoption of personal protective measures.

Other vector-borne diseases that may be "imported" have received limited attention even though they may pose a significantly greater health risk than the West Nile virus. In some cases, such as Lyme Disease, vaccines may be available, but are generally considered to be too costly or the risks too low for widespread immunization. Although the risk of contracting imported malaria is high for specific ethnic groups in Toronto, many hospitals no longer carry the drugs that are needed for treating this disease.[93] The effectiveness of preventative action is also being compromised by the increasing marginal costs of consulting with a travel physician and purchasing anti-malaria drugs. No longer covered by the Ontario Health Insurance Plan, many travelers do not take preventative measures, thereby placing themselves and their family members at risk, and eventually imposing upon the health care system to treat the disease. Further compromising preventative measures is the fact that anti-malarial drugs are losing their effectiveness to prevent certain strains of malaria.

Measures to Address Air Quality and Human Health

The effect of air quality on health, in general, and its connection with mortality and cardiovascular/respiratory disease, in particular, has received by far the most attention by the medical profession and policy-makers. The scientific literature on health effects is extensive, with recent studies commissioned by public health departments in Toronto and Hamilton painting a rather grim portrait of air quality and illness.[94] Three successive smog summits have been convened in Toronto, highlighting the various federal, provincial and municipal initiatives to combat air pollution. These include stricter air quality standards at the national level through the Canada-Wide Standards Process, and stronger bi-lateral commitments to reduce sulphur dioxide and other precursors to acidic deposition and ground-level ozone. Emissions from automobiles, trucks and buses are monitored at the provincial level through the Drive Clean Program, and many municipalities have anti-idling by-laws in place. Most municipalities throughout the Toronto-Niagara region also have their own smog plans[95] aimed at public education and outreach, and at reducing their own emissions by regulating the activities of city departments.

Despite these efforts, air quality in the Toronto-Niagara region continues to be a significant health problem, especially during the summers of 2001 and 2002. Poor air quality impacts vulnerable groups, such as the elderly, children and persons predisposed to respiratory and cardiovascular illnesses, and imposes a considerable burden upon the health care system. Environmental groups have strongly criticized political inaction, citing the failure to address the fundamental

underlying causes of most air pollution, specifically transportation and land use practices. The dominant mode of transportation in the Toronto-Niagara region is the automobile and, combined with considerable truck traffic, vehicles of all types are the region's major source of air pollution. Funding for public transit has declined, ridership has fallen in many urban transit systems, and traffic congestion is becoming worse. There is also the problem of air pollution from coal-fired electric power plants. The Lakeview plant in Mississauga, which is a major source of CO_2, NO_X and heavy metals, is expected be converted from coal to natural gas according to recent Ontario government commitments, but the fate of other coal-fired plants in the province has not been specified. A recent study on alternative fuel sources has recommended that the Ontario government should mandate the closure of all remaining coal or oil-fired generating stations by 2015,[96] while some environmental groups are demanding an even earlier closure or conversion to natural gas.[97]

Measures to Address Elevated UV Exposure

Like many countries, Canada has borrowed extensively from the Australian experience in dealing with skin cancer and cataracts in developing its UV radiation policy. The UV-Index is widely communicated throughout the Toronto-Niagara region, although its influence on human behaviour has not yet been determined. There are many gaps in the monitoring system, with limited information on a local level. However, Environment Canada has recently introduced a pilot education program and monitoring of UV radiation in primary grade schools, including schools in the Toronto-Niagara region.[98]

Measures to Address Water-borne and Food-borne Diseases

Until the Walkerton disaster, public policy on water-borne and food-borne issues had not generally been viewed as a significant problem in most regions of Ontario. Climate-related water issues have surfaced in recent years, such as disagreeable taste and odour due to the growth and decomposition of algae, but the cities of Toronto and Mississauga have invested in activated carbon filtration systems to reduce the effects. Significant infrastructure investments in storm sewage storage facilities should also help reduce, if not eliminate, beach closures in Toronto. However, the current procedures for monitoring coliform counts do not properly assess the occurrence of pathogenic *E. coli,* nor take into account the presence of viruses.[99] Moreover, other Ontario communities and households, specifically those who draw water supplies from municipal or private wells, may be at increased risk from water-borne illnesses. Although the province has responded to the Walkerton disaster by introducing stricter standards and improved monitoring and surveillance, it is too early to tell if these new measures will be sufficient to ensure the health of rural residents.

Barriers to Adaptive Action

In order to manage human health risks effectively, decision-makers will require comprehensive and credible information about the potential impacts of climate change and the capability of the current policy, social and health care systems to address these impacts. Monitoring, surveillance and modelling activities will provide part of the information that is needed, but further research will be necessary to fill in key knowledge gaps so

that sound management and policy decisions can be made. This includes, for example, the need for more epidemiological and clinical studies in applied research, directed at air quality and respiratory illnesses or the transmission of emerging infectious diseases. Perhaps most important will be the need to adopt an integrative approach to climate change and health, involving all three levels of government in addition to other pertinent stakeholders.

The development and implementation of effective integrative adaptive policies, however, faces many significant challenges and barriers. Like much of the science research on climate change and health, the adaptive policy response has generally followed a 'silo' or 'stovepipe' approach, reflecting a conventional understanding of health issues and, in many cases, resulting in an equally conventional policy response. Health infrastructure in the Toronto-Niagara region has undertaken a wide range of actions that have been developed on an ad hoc basis and lack co-ordination in their administration. Fragmentation of policies may be partially attributed to the complexity of the climate change/health problem, and the fact that governments and research communities are also structured on a 'silo' basis. While climate change and health are both an environmental and a health issue, in practice, responsibility is likely to fall into the orbit of one or the other government departments (if not fall between the cracks entirely).

Another key challenge is the lack of knowledge regarding climate change/ health issues. Evidence suggests that even well informed physicians have a limited understanding of the interconnections between climate change and health; most primary care delivers and health care administrators are not making the link between health effects and current climate, let alone future climate change. In some cases, a deficiency of knowledge may reflect the lack of experience regarding specific health issues (for example, malaria), and could easily lead to a misdiagnosis or the provision of inappropriate preventative advice. Even with public health departments, response actions may be fairly effective in adapting to current climate problems, but they are no guarantee against new and emerging health issues that could occur with climate change.

A related barrier concerns the lack of a comprehensive monitoring and surveillance system and the absence of a longitudinal database that could provide the type of information on climate change and health (such as death registry, disease and diagnostic data, etc.) that will be required by decision-makers to develop effective adaptive policies. There is limited monitoring, reporting and surveillance of climate variables, health effects and adaptations required to reduce the health risks arising from impacts of climate change. For example, there is more data collected on the economic costs associated with extreme weather events than on the health effects. In some cases, historical data may be available; but in other cases, it will be necessary to ensure that suitable components are in place today to facilitate the collection of new information well into the future. The specific data and infrastructure required could vary considerably between different climate change/health issues, thereby necessitating stakeholder engagement to identify the most appropriate indicators, information sources, data collection systems and monitoring networks required to develop useful databases on climate, ecosystem

function, social conditions, health effects and adaptation measures for longitudinal analysis.

Lastly, a fundamental barrier involves the ability of the health infrastructure to respond effectively to the health risks that will emerge with climate change. Generally, societal response to climate-related problems has been reactive, rather than proactive (such as the case with flood plain management). Although, historically, health infrastructure planners have been more proactive than other policy-makers, they face a constant stream of new and emerging issues. Not only does this lead to 'fatigue' for health care planners and limit their capacity to respond quickly, but also the health risks associated with climate change will undoubtedly be forced to compete with other pressing health issues for their attention. Further, the time frame for climate change planning (20–80 years) may exceed that for other long-term health care planning issues. Public health departments, for example, may respond well to recent problems or immediate conditions, but long-term planning rarely exceeds a few years, when new health concerns materialize and become a higher priority for policy.

Opportunities for Adaptive Action

Despite the many barriers for developing an adaptation response plan in the Toronto-Niagara region, there are opportunities to integrate existing efforts and develop a coordinated response to climate change and health. There are numerous climate-related issues being addressed on an individual basis by public health departments, many in collaboration with provincial and federal health ministries. Many public health activities are coherent and integrative, demonstrating considerable leadership within the health care system. It will be important to build upon what already exists and functions well, particularly stakeholder strengths, when developing an adaptive strategy that capitalizes upon new opportunities for the effective adaptation of the health infrastructure to climate change.

Examples could be drawn from virtually the entire suite of climate-health issues, but the most obvious would be measures related to vector-borne illnesses (and, specifically, the West Nile virus), air quality, and UV radiation. In the case of vector-borne diseases, it may also be relevant to look more closely at the reintroduction of malaria through travelers infected abroad, or the spread of Lyme Disease by hosts and vectors responding to climate-related environmental changes. The experience in other countries may provide useful insights regarding the relationship between climate change and the spread of disease (for example, the northward spread of ticks observed in Scandinavia or their upward spread into the mountains in parts of Switzerland). In addition, these experiences could help identify the types of adaptive actions that have proven to be effective.

The health risks associated with heat stress and water quality could also be added to this list. The opportunity exists to integrate information and adaptive actions in response to these issues under a unified climate change banner. This would serve to help communicate and educate the health care community and the general public about the connection between health effects and climate change, as well as stimulate discussion regarding how adaptation can help reduce vulnerability to multiple issues.

The recent emergence of pandemic planning in the Toronto-Niagara region may offer important lessons that can be applied to climate change and health. Under a provincial Ministry of Health directive, the Regional Municipalities of Niagara and Peel, among others, are developing pandemic plans in response to the possible reemergence of Spanish Influenza.[100] The plans represent an innovative approach to integration and planning, incorporating surprises and framing the problem within a broader context. This includes planning for worst case scenarios (75 per cent of the population affected), and considering the implications upon a broad spectrum of health and municipal infrastructure, including mortician capabilities, hospital room readiness, and the ability to deliver essential services such as water, police and fire protection. The engagement process itself is unique, whereby the Chief Medical Officer is taking the lead in communication and outreach to the health community, including physicians, hospitals and public health departments.

There may already exist the basis for developing a strong monitoring, reporting and surveillance network. Ontario has a registry network in place to monitor and assess the health effects from air quality, some cancers and causes of birth defects, and this could be expanded to include other climate-related health effects. Family physicians and other front-line health care professionals can play a significant role in this regard, especially if they are able to record and link specific health effects to climate change.

Professional education on climate change and health should draw upon the experience gained with other air quality issues. Communication, education and outreach programs have been very effective in raising awareness (regarding the links between cardiovascular/ respiratory illnesses, premature death and air quality) among the health care community and the general public. Professional organizations, such as the Ontario Medical Association and the Canadian Association of Physicians for the Environment, have taken a leading role in research and professional education, and could make a similar contribution towards raising the profile of climate change and health.

In the absence of a single agency or department taking responsibility for climate change and health (or any of its individual issues), organizational structures that are being proposed for other 'marginalized' health issues may offer a model for moving forward on a climate change adaptation action plan. The process used to address healthy indoor environments is particularly informative, as it involves all levels of government, not-for-profit organizations and even private sector interests. A cross-country stakeholder consultation and alliance-building process has just been completed, resulting in the development of a comprehensive, multi-stakeholder plan for achieving healthy indoor environments in Canada. This model could be applied to climate change and health, initially in the Toronto-Niagara region and, if it is successful, to other regions across Canada.

By its very nature, climate variability periodically offers prime opportunities to raise awareness on climate change and health. Ice storms, emerging diseases, and smog episodes all offer the opportunity to communicate the linkage of these events to climate change. Currently, heat waves may provide the best example of how climate change can

affect health, which segments of the population are the most vulnerable, and how important it is to develop an effective adaptive plan for our health care infrastructure in order to cope with climate change/health problems.

By addressing the interactions between climate change and health issues, it may also be possible to improve the cost effectiveness and efficiency of adaptive responses. For example, there may be benefits from addressing the issues of smog, heat and indoor environments together. Similarly, it may be more effective to address rural water quality and intensive livestock agriculture jointly, rather than as separate issues.

Lastly, it may appear simplistic to suggest that more resources are required in all aspects of health infrastructure to improve its ability to address climate change impacts. Nonetheless it is true. More resources are required, be it funding, time, support staff or physicians. A decade of health care cuts and downloading of responsibilities has undoubtedly contributed to an overextended health care infrastructure that can barely respond effectively to current climate stresses. It may be impossible to predict with any confidence how health infrastructure will change in the future, but it is possible that it will be fundamentally different than its current form. In response to the challenges posed by climate change, it may be prudent for decision-makers to consider how reinvestment in health infrastructure will help improve its adaptive capacity, and ultimately result in improved health for Canadians (in addition to lower costs to the health care system).

The challenges of addressing climate change are daunting, but most may be met through the development of a comprehensive and integrated adaptation action plan. This must include considerable coordination, the exchange of climate and health science information, the expansion of surveillance and monitoring, improved education and awareness among health professionals and the public, and advocacy for the allocation of more resources for public health.

Towards an Adaptation Action Plan

There is growing evidence that climate change could have a deleterious impact on human health in the Toronto-Niagara region. Increases in morbidity and mortality could result from projected increases in the intensity, severity and frequency of heat waves, precipitation events, and smog episodes, as well as the northward shift of some vector-borne and rodent-borne diseases. Despite the risk to human health, there is no concerted and focused adaptation action plan to address these potential impacts.

For the most part, the impact of climate change on human health has received scant attention from government agencies and others responsible for protecting human health. Since the early 1990s, a variety of conferences have been organized and numerous reports written that reiterate the urgent need for integrated research and adaptation action plans to address this serious issue. Unfortunately, very little has been done to develop, coordinate and implement action plans to mitigate the potential impacts of climate change on human health.

To a large degree, this situation has developed because we have neither clear structures nor national strategies in Canada for addressing the issue of climate change and human health. This point is

underlined by the fact that the direct and indirect impacts of climate change on human health were not addressed in the sixteen issue tables established as part of Canada's national implementation strategy. Unfortunately, three years later there is still very little happening in a coordinated and integrated fashion to deal with this issue, other than from a research perspective.

A partial explanation for the limited response to date might be due to the crosscutting nature of the issue. Climate change and human health transcends traditional policy lines, involving various federal, provincial and municipal levels of government in the decision-making process. As a result of this diffusion of "issue ownership," no one agency is accorded the required legal authority, resources and responsibility to develop an integrated response to the problem. Competing issue priorities, resource constraints and politics combine to make this problem worse.

On a positive note, there are recent examples where a concerted environmental effort has been successfully led by a single government agency, which spurred the participation of other federal and provincial departments, and other stakeholders. The Green Plan, for example, that was developed by the federal government in the late 1980s and continued until the early 1990s was successfully led by Environment Canada, before budget cuts and a change in government ended the program. Given the complex and integrative nature of the climate change/health problem, it may be more appropriate for a collaborative effort by Environment Canada and Health Canada to move forward in developing an effective mitigative and adaptive strategy.

Prerequisites for an Adaptation Action Plan

There are also a growing number of local initiatives and programs underway that address various aspects of the climate change/health issue, such as Toronto's hot weather/health watch warning system or the Region of Peel's Emergency/ Pandemic Response plan. What seems to be missing, however, is an overarching strategy that brings the "pieces" together in a uniform and organized way to implement an adaptation action plan in the Toronto-Niagara region. One option might be to create a new coordinating body to bring the municipalities, province and federal government together to work cooperatively on an adaptation action plan for the region. Ideally, in developing such an action plan for the Toronto-Niagara region, the following conditions should apply:

- a shared understanding of the science of climate change, its impacts and associated health effects at a regional level;
- a health care community that is well informed about the science of climate change and the potential health effects;
- sufficient knowledge by stakeholders to identify adaptive options, to integrate those that have already been adopted in response to current climate issues, and to determine their capacity to cope with future climate change;
- health care planning that is well coordinated and can effectively address all reasonably foreseeable climate change/health issues;

- monitoring and surveillance systems that are well developed and maintained for the collection of climate and health data;
- clearly recognized indicators and determinants of health denoting the effects of climate change;
- data and information inventories created for all climate/health issues, and which are readily available to the scientific research and policy communities; and,
- mechanisms in place to communicate information on health effects and adaptive actions to stakeholders engaged in delivering health care, including the general public.

Key Steps in Developing the Adaptation Action Plan

Initially, the coordinating body would act as a third party ambassador to bring the different parties and interests together in the Toronto-Niagara region, and would be responsible for coordinating the development and implementation of an adaptation action plan that would undertake the following key steps:

1. ***Research:*** The first step should be to identify the key elements of public health infrastructure that already exist or must be created to provide the baseline information needed for longitudinal assessments of climate change impacts on human health. This includes engaging stakeholders in identifying the most important indicators of health effects and climate change, and the appropriate response actions, in addition to assessing current adaptation actions to future conditions. Numerous knowledge gaps and key questions are highlighted in the *Technical Report* that warrant investigation. Research is needed on health effects and adaptive measures under consideration or being implemented in other countries, especially for health issues that may emerge in the Toronto-Niagara region under climate change.
2. ***Monitoring and Surveillance:*** Current monitoring, reporting and surveillance systems must be evaluated in terms of their capacity to provide the information needed to develop effective adaptive policies. This includes data related to climate variables, ecosystem function, social conditions and health indicators.
3. ***Education:*** Increased awareness, through education and outreach on climate change and health, is required for physicians, health care planners and the general public. Building upon the stakeholder engagement undertaken in this study, the logical next step would be to organize consultation meetings with a broader range of physicians across the Toronto-Niagara region. Discussion and planning sessions on how best to respond to climate change should be developed across the region, in consultation with regional public health units. The Climate Change Action Fund — Public Education and Outreach Program should be funding such activities.
4. ***Partnership Building:*** For an adaptation plan to be effective, the input of many stakeholders (particularly those from the community level) will be required. This initiative involves the participation of federal,

provincial, regional and municipal governments (and their respective departments), as well as private sector industry, voluntary organizations and public interest groups. Agencies that are involved in community outreach and home care must be included in this process, and non-governmental organizations, especially those representing the medical community, should also be encouraged to participate.

5. ***The Development of Structures to Coordinate Responsibility for Climate Change and Human Health:*** Closer integration of federal, provincial and municipal responsibilities is required for effective policy development and implementation. Health Canada would be an appropriate agency to coordinate research activities and establish research priorities on health effects and adaptive action, in consultation with other federal departments (such as the Adaptation and Impacts Research Group of Environment Canada, and the Climate Change Secretariat at Natural Resources Canada). The Canadian Climate Impacts and Adaptation Research Network (C-CIARN) is an example of a logical mechanism to assist in the coordination of research activities. Coordination among all research nodes will be essential.

Health Canada, or another body established for this purpose, could act as a clearinghouse for information on health effects and adaptive options. Other federal and provincial departments with overlapping jurisdictions should also be encouraged to participate, including agencies such as the Canadian Institutes of Health Research. In particular, the provincial Ministry of Health must take a more active role, especially in terms of health care planning. Regional public health units must also provide strategic planning for adaptation.

The authors view the development and implementation of a health care adaptation action plan for the Toronto-Niagara region as an important step in effectively responding to climate change at both the regional and national levels. Working in partnership with local, provincial and federal governments and other key stakeholders (health professionals, industry, and environment organizations) we believe that an adaptation action plan could become a powerful and practical response to the human health issues likely to emerge in the Toronto-Niagara region due to the impacts of climate change. A properly developed and implemented adaptation action plan could have positive benefits on the health, well-being and productivity of all people living in the Toronto-Niagara region. At a minimum, the plan could help minimize unnecessary suffering and save many lives that might otherwise be lost if we fail to forestall, contain or reduce the progression of climate change. In addition, a successful adaptation action plan could become a useful model for communities across Canada and around the world.

Endnotes

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