REPORT FOR

The National Secretariat On Climate Change
Municipalities Table

MUNICIPAL RISKS ASSESSMENT:

Investigation Of The Potential Municipal Impacts And Adaptation Measures Envisioned As A Result Of Climate Change

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MUNICIPAL RISK MANAGEMENT ISSUES RESULTING FROM A CHANGING CLIMATE

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EXECUTIVE SUMMARY:

Objective

The objective of this report is to provide the most up-to-date and reliable estimates and projections available regarding specific climate change impacts and potential adaptation measures affecting communities across every region of the country. In particular, adaptation and risk reduction measures will be identified from the municipal perspective for the impacts of extreme weather events and other climate change phenomena upon: governance, infrastructure and operations; business and commercial concerns; and, residential, health and the general population. In addition, the report will highlight examples of risk avoidance, risk control and risk management related to climate change impacts.

The potential impacts of a changing climate are closely related to the safety and protection of people, the protection of property, and the environment, public health and safety of municipalities. Therefore, adaptation to climate change is in the interest of municipal governments. Currently, there is a need to better educate the public and municipal officials about the climate change issue, and its potential impacts upon our municipalities.

With the aid of such organisations as the International Council for Local Environmental Initiatives and Partners for Climate Change Program, municipalities have begun to address climate change issues through the development of policies and plans, training, educational seminars, information tools and project advice to local authorities. In addition, municipalities are indirectly acting upon climate change and greenhouse gas reduction by 'co-benefit' actions currently underway, such as the reduction of local air pollution, efficient use of energy and water, coping with natural disasters and development of treed streets and areas. Although these achievements are a step in the right direction, it is estimated that only 100 to 200 of the over 5,000 municipalities in Canada have a significant capacity to respond to climate change challenges.

Greenhouse Gases and Climate Change

Greenhouse gases are emitted both naturally and though human activities. The most prevalent greenhouse gas influenced by humans is carbon dioxide (CO_2). Its atmospheric increase in concentration has been due primarily to deforestation and the burning of fossil fuels as a source of energy in industrial processes, transportation and home energy needs. Methane (CH_4) from agriculture and landfill sites is also another key greenhouse gas that leads to climate change. Most scientists agree that an increase in these and other greenhouse gases emitted from human activities [water vapour, nitrous oxide, chlorofluorocarbons (CFCs), sulphur hexafluoride (SF6), and ozone] have a discernible and increasing influence on our climate.

Some may think that as the concentrations of greenhouse gases continue to rise in the atmosphere, a gradual, uniform global temperature change will occur. However, the emerging scientific consensus is that climatic changes will not occur in a steady progression; rather, they will be felt through increases in the frequency and intensity of the natural modes of variation of the global climate system (e.g.- El Niño and La Niña events). Statistical analysis of the data confirms a trend toward increases in the frequency, intensity and severity of storms, floods and weather-related disasters in some regions. Further, climate model projections (such as the Canadian Climate Change Modelling Centre's 'General Circulation Model') show a continuance of this trend as greenhouse gas concentrations continue to be augmented in our atmosphere.

In spite of mitigation measures to reduce greenhouse gas emissions, climate changes will continue to occur. The estimates and projections that have been provided in this report generally forecast that the atmospheric CO_2 levels will double from their historic (pre-industrial) concentrationssometime in the latter half of the next century. This doubling of CO_2 is expected occur even if the provisions of the Kyoto Protocol (an agreement meant to push back the CO_2 doubling point timeline, not eliminate its existence) are fully met by all participating countries. As we head toward a doubled atmospheric CO_2 concentration, municipalities can expect that increasing impacts of climate change will create both positive and negative results for communities, at home and around the world. The estimated overall climate change effects (and impacts) could include:

- An increase in the frequency and severity of extreme weather events (violent winter storms, short-duration/high-intensity rainfalls, extended heat waves and accompanying smog conditions, wildfires and forest disturbances, severe thunderstorms and tornadoes).
- A change in precipitation, distribution, amounts (lack or abundance of precipitation creating drought or flood conditions, respectively), and types (e.g.- freezing rain and hail damage).
- Overall temperature increases would vary regionally across Canada. Projected increases are estimated for most populous communities in Canada to be between 1.5^{o}C to 4.5^{o}C, with regional increases in central and northwestern Canada as great as 5^{o}C to 8^{o}C (increased cooling demand, increased heat-related illnesses, northward movement of natural ecosystems, and changes to agricultural crops and forests)
- Polar ice and permafrost melt in northern Canada (landslides and sinking of terrain, ice-free waterways)
- Sea level rise (threatening sensitive coastal areas, e.g.- Atlantic Canada, Fraser delta, southern Vancouver Island.)

Also, certain changes in our climate may have multiple national, regional and municipal impacts. For example, an increase in the frequency and duration of drought conditions in the Great Lakes-St. Lawrence system would lead to lowered water levels, which will adversely affect many activities such as shipping, hydro-power production, and municipal water supply and quality.

Municipal Adaptation Measures

The Canadian climate is often described as being brutally harsh and extreme, from our severe winter storms to our summer heat waves. Canadian experience indicates that adaptive measures and policies that are sensibly and consistently applied over the long-term allow us to persevere under such difficulties on national, regional and municipal scales. For example, water use restriction, efficiency measures, and conservation programs must be adopted to ensure that municipalities have adequate reserves during periods of water shortages. Since it is anticipated that these shortage periods will only increase in severity and duration in the future due to climate change in most regions, municipalities must be prepared for this impact.

The *Risk Management Guideline for Decision-Makers* is a Canadian National Standard developed by the Canadian Standards Association (CSA), which lays out the steps of the risk management process. It is widely used by governments, industry and professional bodies for the identification, analysis, evaluation and control of risks and potential risks. Where extreme weather-related events are concerned (which could result in serious emergencies or disasters), a risk management framework for decision-making should be considered an imperative. Therefore, as climate change effects increase the frequency of the occurrence and intensity of these disasters, the risk associated with them is thereby increased. In order to be better prepared for this and other climate change impacts and weather-related events, municipalities should set objectives (including actions, measures, strategies and policies) that offset or reduce the effects and impacts of our changing climate.

Municipalities that increase their adaptive capacity decrease their vulnerability to climatic change. Success will depend upon their ability to meet the various adaptation objectives required as we experience increases in the frequency and intensity of Canadian weather phenomena. Although the climate is changing at an unprecedented rate, sufficient time is available for steady, affordable progress to be made, provided that recognition is given now to the need for adaptation to begin immediately and be allowed to proceed at a reasonable pace. The costs associated with successful adaptation can be high, and can only be very roughly estimated at the present time. However, the costs associated with weather variability and extreme events (e.g.- forest fires, floods, droughts and storms), and other events will remain significant and are likely to increase over present levels as recent trends already indicate.

Some of the key adaptation areas that will have to be addressed include: water and energy conservation measures; reviews of standards, codes, regulations (including the use of "best practices"); and, warning systems, emergency preparedness and response programmes.

It is also important for Canadian communities to adapt and take advantage of benefits that may be presented with a changing climate. Winter temperatures may be less severe in much of Canada, thereby extending the shipping season and the growing season in and along the St. Lawrence Seaway, for example. There is also expected to be a longer ice-free period in Northern Canada, thus increasing the duration of 'navigable' waters and the length of the shipping season in the Arctic. It will require effort, initiative and investment by municipalities to determine and exploit the opportunities that may arise, and limit the adverse affects that may occur, as a result of a changing climate in Canada.

Finally, it is important to note that many adaptation measures, especially those which should be taken for extreme weather-related events have merits quite apart from those related to climate change. Also, on a human scale, even considering the replacement schedule for some infrastructure items, climate change will occur relatively slowly. The case for avoiding denial, deferral and delay and initiating timely, appropriate and carefully considered action is very strong.

MUNICIPAL RISK MANAGEMENT ISSUES RESULTING FROM A CHANGING CLIMATE

BACKGROUND:

> ***"…municipal organizations have been at the forefront of informing and educating municipalities about climate change and the risk it holds for local communities. This said, appreciation of these risks, and the related opportunities to reduce Greenhouse Gases, has yet to penetrate the Canadian municipal landscape."***

From page 12 of the Municipalities Table Options Paper (draft).

In general, when making policies or taking action on any matter, municipalities seek to consider and respond to the views of the several publics they serve. Given the general lack of understanding about climate change and its potential impacts there is a need to better educate publics and municipal officials about these issues. Also, it is evident that municipalities do not see the reduction of greenhouse gases as part of the mandated core services that they deliver to their taxpayers. This reality underlines the importance of action on greenhouse gas emissions reduction being seen as a co-benefit arising from actions municipalities take on issues important to their responsibilities such as reduction of local air pollution, efficient use of energy and water, coping with natural disasters and development of treed streets and areas.

Thus, adaptation to the expected and potential impacts of a changing climate, is more closely related to two of the 14 mandated core areas of municipal services:

1. Policing (the safety and protection of people and the protection of property). and
2. Environmental and public health and safety.

Adaptation to climate change is therefore an interest and responsibility to which municipal governments would be expected to react with vigour. Their concerns could include: how to obtain cost reductions from energy-efficiency initiatives, the possibility of generating revenue from more sustainable forms of energy production, the achievement of improvements in air quality through reduced fossil fuel emissions in the community, promoting quality of life benefits from an improved environment, and the preservation of local eco-systems.

Canadian municipal organisations have a very strong track record of commitment to environmental issues including climate change. For example, the Federation of Canadian Municipalities, provincial and municipal associations and organisations such as the International Council for Local Environmental Initiatives and Partners for

Climate Change Program demonstrate municipal commitment on the climate change issue. These organisations have made significant contributions to assisting municipalities develop policies and plans.

This commitment has had a catalytic effect on a number of Canadian municipalities. Municipal organisations have provided training, educational seminars, information tools and project advice to local authorities. On the other hand, the capacity of municipal associations to assist local authorities with action on climate change issues is modest. Given the over 5,000 municipalities across Canada, it is estimated that between 100 and 200 have significant capacity to act on climate change.

An Introduction to Climate Change

Greenhouse gases are emitted both naturally and though human activities. They include water vapour, methane, nitrous oxide, chlorofluorocarbons (CFCs), ozone, and the most prevalent greenhouse gas influenced by humans, carbon dioxide (CO_2). Naturally occurring levels of greenhouse gases contribute to making the overall mean temperature of the earth a habitable +15°C. Without the heat-trapping or "greenhouse" effect of CO_2 and the other greenhouse gases, the earth's mean temperature would be closer to –18°C.

For 1000 years prior to about 1800, there existed a steady concentration of global atmospheric CO_2 of about 280 parts per million by volume (ppmv). Since then, concentrations of CO_2 have increased by 30%, to approximately 368ppmv. This increase has been due primarily to deforestation and the burning of fossil fuels as a source of energy in industrial processes, transportation and home energy needs. When the increases of other greenhouse gases are factored in (expressed as CO_2-equivalents), the overall increase since the industrial revolution amounts to about 50%. If we continue to follow a "business as usual" approach, it is predicted that the concentration of CO_2 will rise to approximately 550-600 ppmv (and even higher if other greenhouse gases are taken into account), to about double the historic concentration by the latter half of the next century.

Most scientists agree that the increase in greenhouse gases from human activities has had a discernible and increasing influence on our climate. The results of climate change will create a number of positive and negative results for communities around the world. The estimated overall climate change effects could include:

- A global average temperature increase which is projected to be 1.5 ^{o}C to 4.5^{o}C, regional increases in central and northwestern Canada may be as great as 5 ^{o}C to 8^{o}C.
- Polar ice and permafrost will gradually melt.
- Sea levels will continue to rise threatening coastal areas and small island nations.

- The frequency and severity of extreme weather events such as heat waves and heavy rains will increase.
- The precipitation types, amounts and distribution will change.

Beginning to Identify and Manage the Issues

Internationally, it is now largely accepted that increasing greenhouse gas emissions from human activity is causing the climate to change. International, intergovernmental and national actions commenced in the 1980s to better understand the climate change issue. Governments around the world are currently examining mitigation actions that could slow or delay climate change effects, and scientific studies are beginning to identify impacts and adaptation measures to climate change.

The table at Annex A presents a summary and chronology of key international climate change events. Even with modest international reductions in greenhouse gas emissions in developed countries, there will continue to be global, regional, and municipal climate change impacts. The Kyoto Protocol targets for global greenhouse gas emission reduction will not solve the climate change problem, but only delay the doubling of global atmospheric equivalent CO_2 concentrations by 10 to 20 years.

For Canada, the amount of the climate change may be particularly large because of the continental location and our high latitude. National efforts are underway within internationally co-ordinated programmes to better understand the science of climate change, to identify mitigation strategies and estimate the magnitude of their results and to assess the impacts of climate change and potential adaptation measures. Domestic science assessment in Canada is co-ordinated through the Canadian Climate Program Board (CCPB). The CCPB has prepared reports on the state of the science, impacts of climate change on Canada, and mitigation and adaptation response options (some key references including a suggested reading list are at Annex B).

At the third meeting of the Conference of Parties to the United Nations Framework Convention on Climate Change at Kyoto in 1997, Canada agreed to reduce emissions of greenhouse gases to 6% below 1990 levels by between 2008 and 2012. Canadian federal, provincial and territorial leaders agreed to work together on the implementation effort towards this goal. The Federal Climate Change Secretariat was created to oversee a multi-stakeholder consultation initiative to examine the policy options, costs and benefits. Fifteen “issue tables” were established to consider critical climate change areas and to develop options for considerations by federal and provincial ministers. The Climate Change Action Fund was established to provide a source of funds ($150 million over three years) to support the work of the Issue Tables and other activities to help meet the Kyoto commitment.

By the end of 1999, Canada intends to have produced a national strategy and a plan to meet its commitment to reduce GHG emissions, and options to address scientific and adaptation needs. Key elements of the strategy are that Canada's global competitive position will not be damaged nor will actions that are recommended impact unfairly on any particular region of the country.

Among the adaptation options under consideration by the government should be the development of a national strategy for the prevention, mitigation and preparedness for extreme weather-related events and the concomitant natural disasters.

About this Report and Possible Climate Change Weather Phenomena

This report will provide the most up-to-date and reliable estimates and projections available regarding specific climate change impacts upon communities in every region of the country and on potential adaptation measures.

In particular, adaptation and risk reduction measures will be identified for the impacts of extreme weather events and other climate change phenomena on three main groups or structures within the community:

1. Governance, infrastructure and operations.
2. Business and commercial concerns.
3. Residential, health and general population.

The investigation will continue with an examination of the risk management process, as outlined in the National Standard of Canada, CAN/CSA-Q850-97, *Risk Management: Guideline for Decision-Makers*, Canadian Standards Association, 1997. The value of this risk management process, and whether it offers a useful model for the management of community concerns related to weather and climate change phenomena and their impacts will be determined. In addition, the report will highlight examples of risk avoidance, risk control and risk management related to climate change impacts.

GLOBAL IMPACTS OF CLIMATE CHANGE

The conventional thinking on climate change has been that as greenhouse gas concentrations continue to rise, a gradual global increase in temperature will be felt, and the sea level will continue to rise. Global mean temperatures are projected to rise by 1.5^0 C to 4.5^0 C by the latter half of the coming century, and the median projection of sea level rise is ½ metre by 2100 due to expansion of warming seawater and further glacier melt. These changes would be a consequence of the doubling of historic CO_2 levels in the atmosphere, taking into account all other greenhouse gases, and aerosols.

However, the emerging scientific consensus is that these climatically large changes will not be experienced in a steady progression. Rather, climate change is most likely to be felt through increases in the intensity and frequency of the natural modes of variation of the global climate system, the El Niño Southern Oscillation (ENSO), the Arctic Oscillation (AO), and the Northern Atlantic Oscillation (NAO). This is especially true of alternating El Niño and La Niña events.

El Niños are events in which the equatorial surface water temperatures are much above normal in the eastern Pacific. Up to 20 or so years ago, they occurred every 4 to 7 years and were interspersed with normal or colder than normal eastern equatorial Pacific waters (La Niña events). El Niños, and to a lesser extent La Niñas, are accompanied by major distortions in weather patterns, changing the usual paths of jet streams, bringing abnormal weather conditions to many regions of the world. In the past two decades prolonged and intense El Niños have occurred with very strong events in 1982-3 and 1997-8.

Strong El Niños cause drought and flood devastation in much of the tropical, sub-tropical and temperate world. La Niña conditions tend to produce opposite conditions – floods where droughts had occurred with El Niño. Research now strongly suggests that El Niño-like conditions will continue to increase with greenhouse gas forcing of climate and La Niñas, although less frequent, more intense, (Knutson and Manabe, 1997, Timmerman et al., 1999). This suggests more frequent and prolonged droughts interspersed with floods in many regions and an increase in frequency and intensity of extreme climatic events. Both climate model results, and the recent record of extreme events, tend to support this view of the ways in which human communities and natural systems will experience anthropogenic climate change.

In the period from the mid-1960s to the mid-1990s, climate-related disaster losses increased from about $5 billion to about $50 billion per year worldwide (expressed in constant dollars). Eighty-five percent (85%) or more of these total disaster losses were from climate-related storms, floods and droughts. Losses from climatic disasters are increasing 3 to 5 times more rapidly than losses from earthquakes and volcanoes. Much of the increase in losses is attributable to greater populations and infrastructure exposed to the risks. However, insurance analysts consider that these factors alone cannot explain all of the disturbing trends. The differential rates of change between disasters of climatic and geological origin cannot be readily explained by increased exposure to the risks. They must reflect, in part, a greater magnitude and impact of climate extremes in recent decades.

As the atmospheric concentrations of greenhouse gases continue to increase it is expected that many of the world's major storm tracks could shift significantly. Polar ice and permafrost will gradually melt and sea levels will rise in most areas as a consequence. As noted above, climate related disasters will likely increase markedly. From 1986 to 1995 about 1.9 billion people were affected by natural disasters and the number appears to rise an average of about 6% per year. Disaster deaths are estimated at 760,000 world-wide, over the past decade with 88% of them occurring in low income countries.

However, it should be noted that disaster deaths are increasing more slowly than economic losses or the numbers of people affected probably because of warning and preparedness measures.

Statistical analyses of observations over the past century of the increased frequency of heavy rainfalls, very severe winter storms, and of heat waves in Canada, the US and some other countries are consistent with climate model projections (General Circulation Model). At the same time, the northward retreat of permafrost, the rise in mean sea level, increased fire and insect damage in boreal forests, less ice in the Arctic, the shrinking of glaciers and northward migration of both benign and damaging species are manifestations of the longer term trend. The next section describes how such changes are affecting Canadian communities and will probably do so increasingly in coming decades.

CLIMATE CHANGE IMPACTS IN CANADA

El Niño Southern Oscillation (ENSO) Effects

Projected greenhouse gas increases appear likely to ensure continuation of the trend of the past century towards increasing duration and intensity of El Niños punctuated by short La Niñas. The implication in Canada of these alternating states of the climate system have been well studied (Shabbar and Khandekar, 1996, Shabbar et al., 1997). A consistent response to El Niño is much increased winter storminess for west coast communities. For southern Canada as a whole, as far east as Ontario, significantly drier and warmer conditions and droughtiness accompany El Niños. For La Niñas, abnormally wet conditions are felt from interior B.C. through to southern Quebec and significantly cooler weather in western, especially northwestern regions.

It is evident that significant dry periods in winter and spring, accompanying El Niños, can lead to interior B.C., Prairie and Ontario droughts. With anthropogenic climate change, impacts appear likely to be increasingly severe on farming communities. Also, lower water levels, possibly as much as 1 to 1½ metres, in the Great Lakes-St. Lawrence system will adversely affect shipping, water supply and quality and hydro-power production.

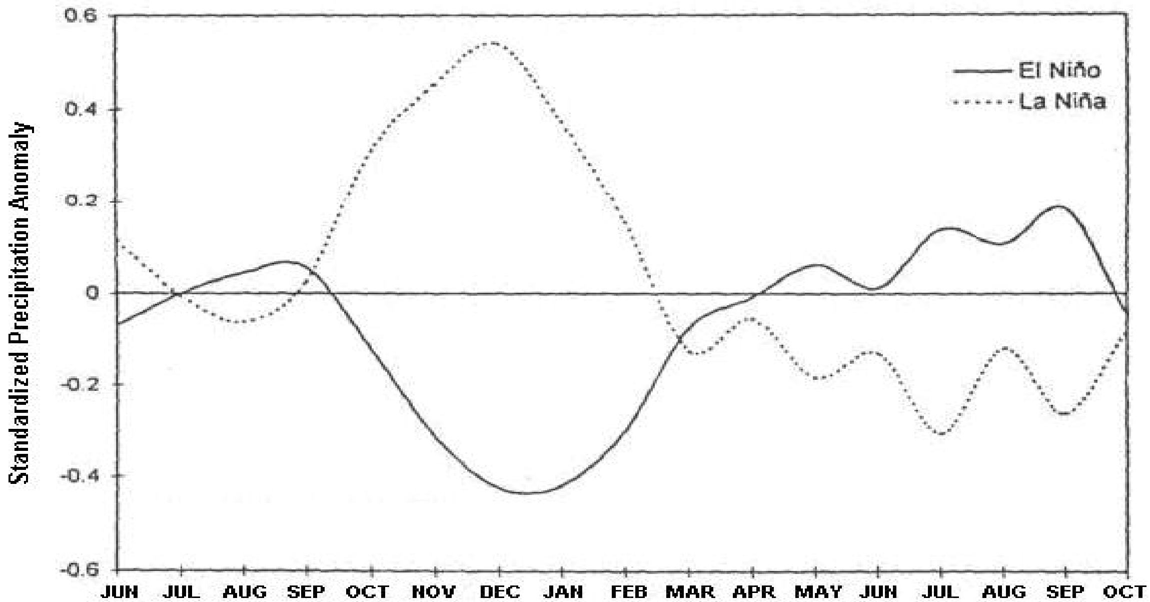

Figure 1. ENSO Events and Precipitation[1].

This graph illustrates the historical differences in precipitation in southern Canada following year-end peaks in El Niño and La Niña conditions. The data indicate that drier than normal weather will prevail in winter and spring in an El Niño year. Conversely, wetter than normal weather will prevail during the same period in a La Niña situation. El Niños generally bring higher than normal temperatures in southern Canada, augmenting the drought-inducing effects of lower than normal precipitation. If several recent research results are confirmed, El Niño (*dry*) conditions are likely to continue to become more frequent with the continued greenhouse gas forcing of climate change. These recent research results also suggest stronger La Niñas, punctuating the El Niños and thus leading to prevalent dry conditions, interspersed with wet, flood-producing years such as experienced in the central prairies in 1999 [Shabbar *et al*, 1997]. Fluctuations in climatic conditions in northern parts of Canada, particularly the northeast, are affected by trends and variations in the Arctic Oscillation. These effects are just beginning to be understood.

Longer Term Trends

Average temperatures over Canada have increased more than 1^{o}C in the past century with the largest increases in central, northwest and northern regions, and decreases in temperature in furthest east regions. Atmosphere-Ocean General Circulation Models (AOGCMs) including the Canadian Climate Model's latest runs with projected greenhouse gases and aerosols indicate that a doubling of atmospheric CO_2 equivalent would result in further rapid intensification of this pattern over Canada. Much of

[1] Shabbar *et al.*(1997).

central and northern Canada is projected to experience a mean temperature increase of 5°C or more by the second part of the next century while the waters off the coast of Labrador and Newfoundland and nearby coastal areas are projected to continue cooling. The rest of Canada, including most of the larger communities, is in the 3°C to 5°C temperature rise region. These changes will have profound impacts on:

- the survival and northward movement of components of natural ecosystems,
- the ability of cod and other fisheries in eastern Canada to recover,
- declining energy demand for heating and increasing for cooling especially in southern cities,
- changes in agricultural crops, including increased pests and diseases,
- health concerns over vector borne and heat related illnesses.

Evaporation losses are expected to be greater than the small total precipitation gains in the warming climate. A projection of the precipitation minus evaporation balance for summer months (June, July and August) over North America is that by 2100, it will have declined 35% with serious impacts on soil moisture availability (Boer, Flato and Ransden, Canadian Centre for Climate Modelling and Analysis, Atmospheric Environmental Service and University of Victoria, Sept. 1998). The same analysis projects the gradual decline and disappearance of Arctic sea ice by 2100. These projections suggest strong impacts on water availability and greater conflicts between farm and city and between Canada and U.S.A. over allocation of a depleted water supply. Retreat northward of permafrost and gradual loss of Arctic ice would profoundly affect northern communities and their hunting/fishing way of life.

Of course, there are potential benefits, such as possibly greater use of the Northwest Passage, as well as disbenefits of warming conditions, but wise adaptation measures will be required to seize the benefits and minimize the potentially devastating adverse effects.

"Turn off the taps on bottlers"

Letter by Christine Stewart
Minister of Environment to the Globe and Mail, July 7, 1999, A9

…We are among the highest per-capita water consumers in the world.
Climate change experts estimate that during the next 50 years, water levels in the lower Great Lakes could decline by nearly a meter and a half and average flows in the St. Lawrence by close to 40 per cent.

We know that the deterioration of the watershed basins, due to changing water flows and levels, pollution and land use, can have catastrophic effects on human health, national economies and ways of life. Last February, the Government of Canada announced its strategy to prohibit bulk water removals from watersheds, including water for export: We must respect our water. After all, we are all downstream.

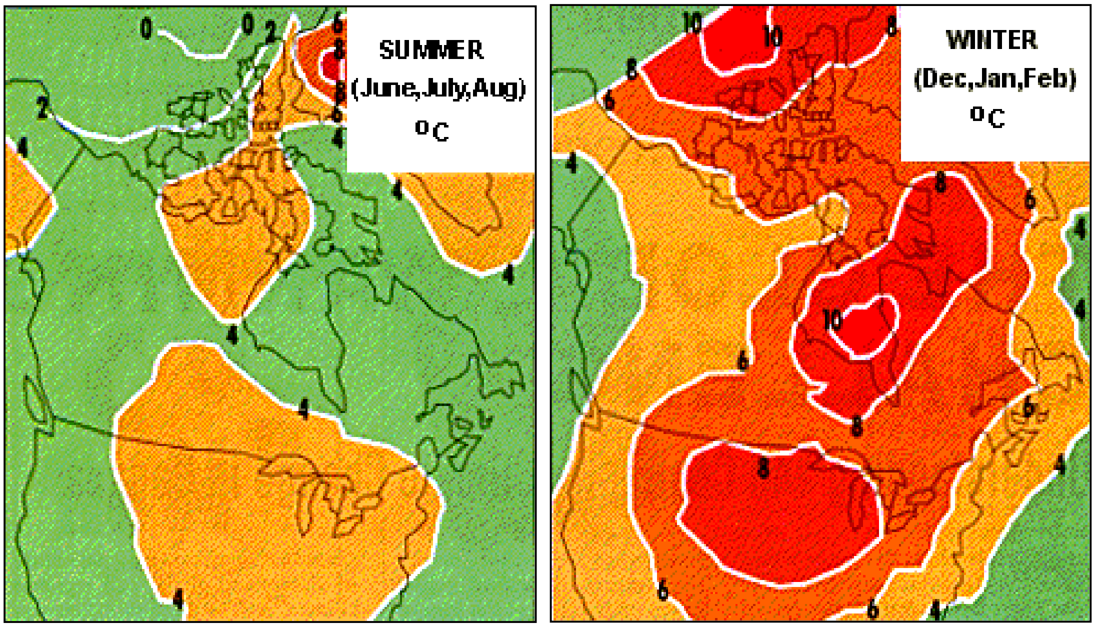

Figure 2. Summer and winter temperature change predictions (increase in °C) for a doubled CO_2 environment.[2]

Sea Level Rise

While the mean sea level has risen 10 to 20 cm over the past century, its rise with global warming is expected to be 2 to 5 times that rate over the next century. In some coastal regions of Canada, the land is subsiding as well, but in others is still rebounding from the last ice age, offsetting sea level rise. Erosion of most coastal shorelines will accelerate with a higher sea level.

Using an index of coastal "sensitivity" some scientists (Shaw, et al., Geological Survey of Canada, 1998), conclude that "Atlantic Canada has the largest extent of highly sensitive coasts". This includes much of the coasts of Nova Scotia, Prince Edward Island and New Brunswick. Particular problems would arise in communities such as Placentia, Newfoundland, Saint John, N.B. and Charlottetown, Prince Edward Island, which have been the subject of special studies. In the Pacific region, there are relatively small number but very important communities with high sensitivity including the Fraser Delta adjacent to Vancouver and a few sites on Vancouver Island. On the Arctic coasts, crustal rebound will minimize the impacts of sea level

[2] Canadian Atmospheric General Circulation Model II, *in* Canada Country Study: Climate Impacts and Adaptation – National Cross-Cutting Issues Volume VIII.

rise although more open water would allow greater wave development during storms, increasing shoreline damages.

Permafrost

Permafrost is present where ground temperatures are below 0^0C all year. About one half of Canada's land area is underlain by permafrost. A large portion of the area, where communities of significant size exist, has an average temperature higher than minus 2^0C. Ice rich permafrost in these areas is at risk of thawing from global warming. Increased landslides, landslips and sinking of terrain is already occurring. Increased thaw and settlement is likely to occur beneath buildings, utility systems, roads, railroads, pipelines, dams and dykes. Communities may need to take remedial adaptive actions. The wide band at risk is between James Bay and Inoucdjouac on the east, north end of Lake Winnipeg, and Churchill in the middle, and between Lesser Slave Lake and Great Bear Lake or Dawson City in the northwest.[3]

Severe Weather Events

Municipalities, with their higher population densities and sophisticated infrastructure are particularly susceptible to increases in climate-related disasters, as recent rapidly increasing trends in Canada's disaster losses indicate (See Table 2, Disaster Losses in Canada and Figure 2, Costs of Weather-Related Disasters, below). The observed changes in the past few decades, and the climate model projections for a number of kinds of extreme events are outlined here. Their likely impacts on various segments of the community are expanded in Table 3 and potential adaptation measures are given in Table 4 below.

a) Short Duration Heavy Rains:

Observations - No analyses of Canadian data have been undertaken of trends in very short duration (minutes to hours) heavy rain events which cause city flooding, sewer overflow and landslides, but some analyses of heavy one-day events have been undertaken. These show that an increase in percentage of precipitation in heavy events (90th percentile) have occurred in the period 1940-1995. This is especially true for larger population centres on the west coast, the Winnipeg area, the Montreal-Ottawa corridor, southwestern Ontario and the Atlantic provinces. In some other regions such as the rest of the Prairies and northern Ontario, there has been a negative trend. (Mekis & Hogg, 1999). In the adjacent U.S.A., the frequency of heavy one-day rainfalls (>50 mm) has increased by about 20% over the past 90 years (Karl et al., 1995).

[3] Sensitivities to Climate Change in Canada, Natural Resources Canada, 1999 (draft)

Projections - Model results indicate there will be an increased frequency of heavy one-day rains in a doubled CO_2 climate, with return periods halved, e.g. a 20 year return period rainfall becomes a 10 year event. (Zweirs et al. 1998)

b) Severe winter storms:

Observations - The frequency of Northern Hemisphere severe winter storms (central pressure lower than 0.970 kpa) has nearly doubled since the mid 1970s, (Lambert 1996)

Projections - The Canadian General Climate Model indicates that in a doubled CO_2 world, the number of weak to moderate winter storms in the northern hemisphere would decrease but the number of very severe storms would increase. (Lambert 1995) For municipalities, this result combined with the projected increased El Niño conditions and higher temperatures suggests that on average snow amounts requiring removal would decline, but this general trend would be punctuated by some very severe snow and freezing rain events.

c) Heat waves (and accompanying smog conditions):

Observations - There are no available analyses of trends in Canada of 3 to 10 day hot spells. However, it has been shown that there is a high correlation between much warmer average conditions such as those projected for Canada, and heat waves which last several days or more. (Karl et al., 1996)

Projections - With a generally warming climate, more heat waves of several days' duration are projected but have not been quantified. Estimates have been made of increases in numbers of days where the temperature will be above 30^{o}C. For example, for London, Ontario, these would increase from 10 to 50/year and for Winnipeg, from 13 to 32/year. With increases in night-time temperatures projected to be greater than increases in day-time maximum, there would be less nighttime relief in such events. More intense and prolonged heat waves would lead to increased frequency and intensity of health and life threatening smog episodes in and near population centres.

d) Wildfires and other Forest Disturbances:

Observations - With a maximum of warming in Canada having occurred in the central and northwest regions over the past several decades, boreal forests have experienced a doubling of areas affected by fires and insect infestations especially in northwestern Ontario, northern Manitoba and Saskatchewan and the Northwest

Territories (Kurtz and Apps, 1995). Such fires have frequently threatened communities in the boreal forest region. Little change in fire occurrences has been observed in Quebec and eastern Canada, where warming has been less pronounced or cooling has even occurred.

Projections - With additional warming of 5^{o}C plus in central, western and northern boreal forest regions with a doubled CO_2 atmosphere, higher fire weather indices and greater insect infestations can be expected. Lightning strikes, which set off most fires in more remote regions, are projected to increase by 44% in the U.S.A. with CO_2 doubling (Price and Rind 1994). While specific projections for Canada are not available a similar increase is probable.

e) Severe Thunderstorms and Tornadoes:

Observations - These events are often not well observed especially in less populated regions. However, it has been recognized that warmer springs and summers bring more severe thunderstorms, damaging downbursts, hail and tornadoes. (Etkin, 1995)

Projections - While climate models do not have the fine scale spatial resolution to resolve thunderstorm tornado events, they do project increases in atmospheric conditions, warmer springs and summers, more moisture in lower atmosphere, which lead to these damaging weather events. Tornado events in the prairies, particularly in central Alberta, southern Ontario and near the Ontario/Quebec border are likely to increase.

f) Catastrophe Scenarios:

Major disasters usually require the coincidence of a combination of factors. Since such coincidences are rare, their likely frequency is impossible to predict. However, it can be instructive to envisage worst-case scenarios. Several examples of infrequent but increasingly plausible scenarios have been suggested which would affect Canadian municipalities. With sea level rise continuing, such catastrophes could occur on both coasts. For Vancouver, Richmond and nearby communities, major floods on the Fraser River under increased Westcoast storminess and rapid snowpack melt are increasingly likely. If such a flood was combined with a significant storm surge from the Juan de Fuca Straits along with a higher mean sea level or seasonal tides, many dykes could be overtopped and great devastation could occur.

For communities along the Bay of Fundy, rising sea levels, and an increasingly likely very severe winter storm, could result in overtopping the salt-marsh dykes, inundating and salinating large areas of valuable agricultural land and many near-shore municipalities.

With the possibility of prolonged El Niños and greater evaporation with higher temperatures, large-scale, intense drought scenarios are also plausible for much of southern Canada.

Weather-Related Disaster Losses in Canada

As discussed above, economic losses due to weather-related events in Canada are increasing rapidly. It is difficult to determine a comprehensive estimate of all losses because of the large number of data sources and differing methods of computation. These include: insured losses, federal and provincial governments' financial assistance, individual and farm-borne losses (such as deductibles, uninsurable or non-eligible items etc.), provincial, municipal, community and not-for-profit organisations' social services costs and general community economic losses.

The data shown in Table 1 and Figure 3 are neither comprehensive nor complete, but they serve to show the dramatic increase in some of the recent losses associated with extreme weather-related events in Canada.

Table 1. Insured Disaster Losses in Canada, 1984-1998[4]

YEAR	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
LOSS $million	39	101	12	170	87	14	16	484	94	255	200	376	760	205	1450

[4] **Note**: Figures are insured losses only, and do not include all economic losses such as residential losses in floods which are not insurable (from Angus Ross, Sorema Reinsurance).

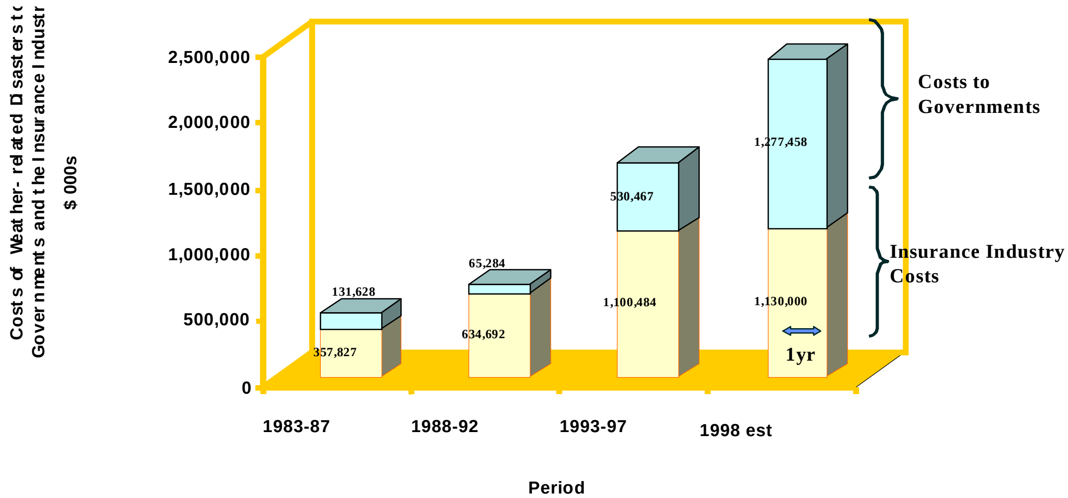

Figure 3. Costs of Weather-Related Disasters to the Federal Government and Insurers (1983-1998).

Possible Benefits of Climate Change

While much of the focus of this climate change analysis has been to identify the potentially negative impacts so that measures can be taken to offset or counter them, it may be instructive to identify some of the possible benefits of climate change to Canada.

- **Prairies -** In the northern prairies and Northwest Territories, growth rates of the boreal forest could improve. Increasing temperatures may also allow for some freshwater fish species to extend their range into higher latitudes.

- **Atlantic -** In the Atlantic, a warming trend in all but the extreme eastern coastal regions could be beneficial to agriculture and reduce heating costs.

- **Arctic and Sub-Arctic -** As temperatures increase in the Arctic, the composition of terrestrial vegetation will change (more shrubs and moisture tolerant vegetation, less nonvascular plants). It is expected that increasing temperatures may move the treeline northward by up to 750 km in the coming century. As lake temperatures rise, the effect on fish habitats in freshwater is uncertain (i.e.- the potential for adaptation of cold water species is not completely known). It is estimated that for every 1°C increase in air temperature, many fish species in lakes and streams are likely to shift poleward by about 150 km. The range and numbers of some Arctic marine mammals, such as beluga and bowhead whales, may increase or at worst hold steady.

In an economic context, warmer temperatures would likely aid the oil and mining industries' exploration and development of the Arctic. Agricultural opportunities could be presented in areas such as the Mackenzie Basin. Easier transit is expected in arctic waters, due to the expansion of channels and the reduced need for icebreaker support. As in central and southern Canada, warmer temperatures are expected to benefit the recreation and tourism industry, due to the potential for extended summer activities, although the ski industry may suffer. It is expected that climate change would lead to an increase in sustainable harvests for most fish populations, due to increased ecosystem productivity (as ice cover shrinkage will permit for greater nutrient recycling and energy for growth).

- **Ontario and Quebec -** In these provinces, climate change may extend the agricultural growing season, and lead to increased opportunities for alternative crop selection. An increase in atmospheric CO_2 concentrations may improve water utilisation by plants and overall yields for some crop types.. The construction industry may benefit from a longer building season. Winter heating costs will be reduced (although savings may be negated by an increased demand for summer cooling). The duration of ice cover on the Great Lakes is expected to decrease, thus extending the length of the shipping season if water levels remain adequate. A shortened winter season will improve transportation by reducing the frequency of need for winter road maintenance and snow removal.

POTENTIAL IMPACTS ON CANADIAN COMMUNITIES

From this extensive data and information about the projected or expected impacts of a changing climate, we have made reasonable estimations of the effects focussing on three segments of the community:

a) Governance, infrastructure and operations.
b) Business and commercial concerns.28
c) Residential, health and general population.

The data are shown below in tabular form and are attached in list form in ANNEX B.

Table 2. Potential impacts on Canadian communities in a doubled CO_2 environment.

CLIMATE CHANGE IMPACT	AREAS OF IMPACT			
	COMMUNITY INFRASTRUCTURE, OPERATIONS	BUSINESS AND COMMERCIAL	RESIDENTIAL, HEALTH AND GENERAL POPULATION	COMMENTS
General long-term rise in temperature of 3^0C to 5^0C (except in extreme Eastern Canada.)	• Increase in cooling load, decrease in heating requirements. • Increase in pests and insects • Possible water availability problems especially Great Lakes/St. Lawrence basin and Prairies.	• Soil moisture decreases by about 10% in central and western regions • Eastern fisheries struggle to recover • Hunting/fishing economies of northern communities in jeopardy.	• Increase in heat-related and vector-borne illnesses • Heat stress • Residential cooling load increases, heating requirements decrease.	Disappearance of sea ice (no Arctic sea ice by 2100). Northern areas could experience lengthened growing season.
Lake and river levels, ground and surface water quantity and quality.	• Municipal water supplies may require expansion or conservation measures. • Water shortages possible in many areas.	• Draft for shipping in Great Lakes, St. Lawrence and some canals likely reduced. • Tourism impacts. • Irrigation impacts. • Water shortages may impact industrial usage.	• Possible residential water shortages in some areas. • More algal blooms and possible water quality problems.	• Possible conflicts between urban and rural water usage. • Regional and international conflicts possible over inter-basin water transfers.

CLIMATE CHANGE IMPACT	AREAS OF IMPACT			
	COMMUNITY INFRASTRUCTURE, OPERATIONS	BUSINESS AND COMMERCIAL	RESIDENTIAL, HEALTH AND GENERAL POPULATION	COMMENTS
Sea level rise especially in Maritime provinces, Placentia region of Newfoundland and lower Fraser delta.	• Increased erosion, and coastal flooding (in a few cases irreversibly destroying low-lying coastal communities). • Water supply and waste water disposal problems	• Coastal agriculture affected • Impact on ports and shipping. • Tourism industry may be affected.	• permanent inundation of some natural ecosystems. • residential flooding.	
Extreme weather – related events (freezing rain, wind storms, prolonged rain, river flooding, drought, landslides – see following sections of table for specific situations)	Increase in municipal risk and emergency situations	Increase in business risk and emergency situations	• Increase in individual and family risk and emergency situations • Increased load on health care facilities.	Municipalities with their higher population densities and sophisticated infrastructure are very susceptible to more frequent disasters.
Permafrost retreat:	• Buildings • Transportation • Other services.	• Buildings • Pipelines and transportation infrastructure. • Hunting/fishing operations		

CLIMATE CHANGE IMPACT	AREAS OF IMPACT			
	COMMUNITY INFRASTRUCTURE, OPERATIONS	BUSINESS AND COMMERCIAL	RESIDENTIAL, HEALTH AND GENERAL POPULATION	COMMENTS
Increased frequency and intensity of short-duration, heavy rains (especially west coast, Winnipeg area, Montreal-Ottawa corridor, southwestern Ontario, Atlantic provinces.	• Local flooding, storm water overflow and stream/lake pollution • Stress on water and sewage systems. • Parks, municipal green spaces of special concern. • "Flash"-floods	• Agricultural economies, golf courses, tourism industry at risk. • "Flash"-floods	Basement and foundation level flooding, landscaping problems, residential leakages, flash-flooding.	
Increased frequency and intensity of heat waves, droughts and smog episodes.	• infrastructure heat stress • smog episodes • insects and ozone • trees, parklands and greenspaces • increased water demand and purification requirements • increased cooling energy demand and reduction in heating requirements	• agricultural effects • decreased stream flows and fish populations	• Increase in hospitalisation and mortality resulting from smog episodes, heat stress other health effects. • Residential cooling load increases (day and night).	• Prairie region, southern interior of B.C. and southern Ontario expected to suffer an average of 10% decrease in soil moisture, loss of waterfowl wetlands. • Night time temperatures expected to increase more than day temperatures.

CLIMATE CHANGE IMPACT	AREAS OF IMPACT			
	COMMUNITY INFRASTRUCTURE, OPERATIONS	BUSINESS AND COMMERCIAL	RESIDENTIAL, HEALTH AND GENERAL POPULATION	COMMENTS
Wildfires, frequent lightning and other forest disturbances.	• Lightning strikes increase. • Forest communities fire risk increased.	• Boreal forests in central and northwest regions experience continued increase in incidence of fires and insect infestation.	• Residents in boreal forest regions at increased fire and lightning-strike risk. • Increased insect problems.	Little change in fire occurrences in Quebec and eastern Canada.
Severe winter storms and heavy snowfalls (less frequent, more intense)	• Removal costs. • Health and infrastructure hazards. • Temporary isolation of community.	• Business interruption. • Snow removal costs.	• Temporary isolation possible.	
Landslides in unstable mountainous regions and permafrost zones.	• Road, sewer, utilities and other infra-structure damage. • Community structural damage	• Business and commercial structural damage	• Loss of life. • Residential damage.	Particularly in mountainous regions of BC, Alberta and permafrost regions of a wide band across mid-Canada.

Summary of Impacts on Canadian Communities

In spite of mitigation measures taken under the Kyoto Protocol to reduce greenhouse gas emissions, changes in climate will continue to occur and at a rapid rate compared to historic and even recent changes in climate. The estimates and projections that have been provided generally represent what could be expected in an environment with doubled CO_2 concentrations and will gradually increase in intensity towards the second half of the century, when doubling is expected, and beyond.

Municipalities can expect the average temperature to gradually increase three to five degrees C except in northwestern and northern areas where the increase will be five degrees and more. The major impacts of rising temperatures will be increased cooling demand, decreased heating load, northward movement of natural ecosystems, increased heat-related illnesses, insects and pests and changes to agricultural crops and forests which are the mainstays of many smaller communities.

More pronounced variability in precipitation, storms and other weather-related events caused by more frequent, stronger and more persistent El Niños with occasional La Niñas will result in more prolonged droughts interspersed with wet years over much of southern Canada, depending on which phenomena is in force.

Sea level rise will affect “sensitive” coastlines in Atlantic Canada, south of Vancouver and in some areas of Vancouver Island. Many municipalities will be affected by water supply changes as ground and subsurface water levels fall. Melting of permafrost will cause landslides and foundation problems in a wide band across mid-Canada.

Almost all communities will have to deal with more frequent and more severe weather-related extreme events, including violent winter storms, short-duration, very high intensity rainfalls, extended heat waves and accompanying smog conditions, wildfires and forest disturbances and severe thunderstorms and tornadoes. The increase in natural disaster frequency will create perhaps the most serious and possibly the most costly challenges for communities in a changing climate.

ADAPTATION MEASURES

Adaptation to the climate is not new. Over thousands of years human societies have successfully adapted to climate in all its varieties. The process of adaptation has been so successful that human beings, unlike any other species, can live and flourish in practically every climate on the planet. Climate varies much more from place to place, than from time to time, and human ingenuity has brought about successful adaptation everywhere.

The main concerns about adaptations to climatic changes are that it takes time, are costly and the projected changes will occur over a relatively short time span of decades. Adaptation to our current climate has, over decades and centuries, been carefully and painstakingly built into virtually all our designs and practices so gradually that it is scarcely recognised. The design of highways, bridges and culverts, residences, all industrial and commercial structures, airports, coastal ports and harbour installations, drainage systems, communications cables and transmission lines, are all designed and built to suit the present climate and to withstand most extremes. Similarly, all our farming practices, our water resources and river basin management, forest practices, health standards, land use planning, power supply, and insurance policies are designed and carried out in a way that provides effective protection from the existing climate. Change the global climate and these things will also have to change. The key questions are: *'What has to be changed?', 'When or how fast must changes be made?'*, and, *'At what cost?'*.

The process of adaptation

Adaptation refers to actions, measures, strategies and policies that offset or reduce the effects of climate change. They range from actions by individuals or enterprises to policies related to planning and infrastructure development. As the adaptive capacity of the country, region or community increases, the vulnerability to climate change lessens, resulting in smaller costs associated with impacts. Successful adaptation will depend upon, among other factors, technological capability, institutional arrangements, availability of financing, and exchange of information.

To assist in better understanding adaptive measures, a useful classification of responses to climate change identifies six categories: bearing capacity, modifying capacity, preventative capacity, research capacity, education capacity, and avoidance capacity[5]. Each of these is described briefly below:

- ***Bearing Capacity*** refers to the ability of a system to absorb impacts without taking any action to prevent or avoid the potential negative effects. For example, insurance is a common adaptive strategy that allows people to absorb impacts through a risk sharing process.

- ***Modifying Capacity*** are actions directed at minimising losses by modifying events at the outset including actions that limit the causes of the problem. An example is cloud seeding thought be some to prevent hail.

[5] Burton, I., Kates, R.W., White G.F., 1993. The Environment as Hazard, Second edition, Guilford Press, New York.

- ***Preventative Capacity*** refers to mechanisms that reduce vulnerabilities to climate change, such as dykes that prevent flooding and land regulations that prohibit building in flood plains.

- ***Research and Education Capacities*** include activities that enhance or promote societal understanding of adaptation and the actions that can be taken.

- ***Avoidance Capacity*** refers to mechanisms that are adopted when drastic changes are required to avoid unacceptable losses. An example is moving a whole community from a landslide-prone area.

Canadians have built a large and powerful country in an area subject to a very harsh climate. Adaptation to climate is not inexpensive, but the Canadian experience indicates that adaptive measures and policies sensibly and consistently applied over the long-term can produce excellent results.

When considered from the perspective of the municipality or community, adaptation to a changing climate becomes a very practicable and competitive issue. Practicable, because most policies and strategies are implemented by the community or municipal government. Competitive, because difficult choices must be made about program costs that are borne by local taxes. However, many adaptive measures are valuable for other reasons as well and can be considered "no regrets" options or worth doing anyway.

Adaptation measures have been organized to correspond with the three areas that reflect the make-up of most local governments in Canada. They are:

- areas controlled directly by the municipal or community government such as governance policies, by-laws and processes, infratructure and operations;
- areas of primary interest to the business or commercial community of the locality, and
- areas of primary concern to the residents including health and other general matters.

Table 3: Adaptation measures for Canadian communities.

CLIMATE CHANGE IMPACT	ADAPTATION MEASURES			
	COMMUNITY INFRASTRUCTURE, OPERATIONS	**BUSINESS AND COMMERCIAL**	**RESIDENTIAL, HEALTH AND GENERAL POPULATION**	**COMMENTS**
General long-term rising temperature of 3 to 5^0 C (except in extreme Eastern Canada.)	- Urban design - Tree planting - Water conservation - Insect and pest controls	- Actions to reduce "heat island" effect e.g. building design, green space - Agricultural techniques	- Better insulation - Design for efficient cooling Pest, insect controls. - Water conservation	- Temperature rise will be higher in the north and central regions (as much as 5^0C by latter half of next century)
Lake and river levels, ground and surface water quantity and quality.	- Water use restrictions ex. Fines during water shortage periods - Optimise reservoir releases (based on historical data, drought anticipation) - Expand storage capacity - More realistic water pricing or greater regulation of withdrawals of surface and ground water.	- Water efficiency and conservation programs - Water pricing e.g. marginal cost pricing to replace average cost pricing, use water metering - Irrigation practises - Revise shipping and tourism regulations	- Water efficiency and conservation programs e.g. reduce size of flush, install residential water conservation technologies - Irrigation practises	- Water conservation measures incentives/penalties. - Interbasin transfer negotiations/agreements

CLIMATE CHANGE IMPACT	ADAPTATION MEASURES			
	COMMUNITY INFRASTRUCTURE, OPERATIONS	BUSINESS AND COMMERCIAL	RESIDENTIAL, HEALTH AND GENERAL POPULATION	COMMENTS
Sea level rise especially in Maritime provinces and Placentia region of Newfoundland and lower Fraser delta.	- Land use planning - Construction or improvement of levees, dikes - Water reservoir, waste discharge designs	- Coastal protection phased retreat - Harbour/port operation and engineering	- Land use planning - Ecosystem protection	- Northern communities should be protected by crustal rebound.
Extreme weather – related events (freezing rain, wind storms, prolonged rain, river flooding, drought, landslides – see following sections of table for specific situations)	- Emergency preparedness plans - Construction or improvement of levees, dikes - Elevate buildings - Land use planning (e.g. consider adequacy of flood plain zones) - Diversify power supply - Upgrading transmission lines - Tree trimming policy - Strengthen emergency communications.	- Emergency preparedness plans - Flood proof buildings - Elevate buildings - Rescheduling of production and marketing - Business resumption/restoration planning.	- Emergency preparedness plans - Flood proof homes, have elevated basements, move the power supply box upstairs - Publicly sponsored flood insurance (for areas ***outside*** of flood plains). - 72 hour self-sufficiency (have emergency supplies on hand, canned food, water, medical, back-up power supplies, generator, fuel, radio with batteries etc.)	- Redefine flood plains. - Publicly sponsored flood insurance program (for areas ***outside*** of flood plains). ***Note: Flood insurance may encourage development of a flood plain and could be considered a maladaptive measure.*** - Review drought insurance programs

CLIMATE CHANGE IMPACT	ADAPTATION MEASURES			
	COMMUNITY INFRASTRUCTURE, OPERATIONS	BUSINESS AND COMMERCIAL	RESIDENTIAL, HEALTH AND GENERAL POPULATION	COMMENTS
Permafrost retreat.	- Redesign structures - Retrofit existing structures			
Increased frequency and intensity of short-duration, heavy rains (especially west coast, Winnipeg area, Montreal-Ottawa corridor, southwestern Ontario, Atlantic provinces.	- Increase the size of storm drains, culverts, bridge openings etc. -Increase water absorbing capacity of urban landscape.	- Address water absorbing capacity of large paved areas.	- Ensure that storm sewers are clear of debris - Storm sewer protection programs. - Increased attention to landscape design for reducing rapid run-off.	
Increased frequency and intensity of heat waves, droughts and smog episodes.	- Heat contingency plans - Use of air conditioners - Water and energy conservation measures - Air pollution abatement - Reduction of urban traffic - Planting more trees	- Use of air conditioners - Rescheduling of production in some cases - Reducing energy and water consumption and air emissions.	- Hospital emergency preparedness - Education on what to do in the event of a heat wave i.e. reduce exercise, consume liquids, stay indoors etc. - Use of residential air conditioners	

CLIMATE CHANGE IMPACT	ADAPTATION MEASURES			
	COMMUNITY INFRASTRUCTURE, OPERATIONS	BUSINESS AND COMMERCIAL	RESIDENTIAL, HEALTH AND GENERAL POPULATION	COMMENTS
Wildfires, frequent lightning, and other forest disturbances.	- Land use planning - Emergency plans for settlements in or near forested areas	- Fire safety plans - Evacuation planning - Emergency preparedness plans	- Education about what to do in the event of a fire - Evacuation education - Emergency preparedness plans	- Provincial forest fire fighting capacity.
Severe winter storms heavy snowfalls (less frequent, more intense)	- Snow removal equipment in working condition with ploughs on the front - Snow removal plans - Emergency planning	- Buildings built to withstand the weight of snow - Communications and power transmission equipment standards	- 72 hour self-sufficiency - Cancel or postpone non-urgent activities - Family emergency plans	- Overall snow removal costs may decrease, but intensity of operations may increase. - Update building codes and structure standards for snow loads.
Landslides in unstable mountainous regions and permafrost zones.	- Avoid risk locations - Identify hazard zones - Slope stabilization projects - Land use planning	- Business relocation	- Advise public of risk - Family emergency plan	

Summary of Adaptation Measures

The difficulty with adaptation to climate change in the current situation is that the climate is changing at an unprecedented rate and in ways that are not yet fully understood. Policies and procedures, both public and private, will have to be reviewed and in many cases changed. Even though a wealthy society like Canada, with a high availability of technical and organizational skills, will be able to offset at least some of the impacts of climate change there are some important reservations:

- The costs associated with successful adaptation can be high and can only be very roughly estimated at the present time. It is very likely, however, that they will vary substantially from measure to measure, from region to region, from municipality to municipality and from social group to social group.

- In spite of the success of adaptation programs, there will remain significant residual costs resulting from variability and extreme events. For example, the costs of forest fires, floods, droughts and storms, and other events will remain significant and are likely to increase over present levels as trends already indicate (see Table 1 and Figure 3).

- There will be some inevitable and irreversible losses to, for example, some species, landscapes and parts of the natural heritage of Canada.

It is very important to note that many communities and commercial operations have already adapted successfully and economically to warmer climates than Canada’s. They can offer valuable lessons, processes, procedures and experiences for Canadian municipalities and businesses. The importance of using the experience of others, or “spatial analogues” to advance adaptation without making costly mistakes should not be underrated.

Adaptation processes are ruled by practicality and common sense. There is not a lot of “rocket science” here. Although the climate is changing at an unprecedented rate, sufficient time is available for affordable, steady progress to be made, provided that recognition is given now to the need for adaptation to begin immediately and be allowed to proceed at a reasonable and affordable pace. Also, the opportunity exists to provide for all key stakeholders to be involved in the adaptation process in such a way that reduces conflict and maximises opportunities for bright, new ideas to be applied. Some of the key adaptation areas that will have to be addressed:

- Water and energy conservation measures.
- Pragmatic and future-oriented reviews of standards, codes, regulations and other practises. The concept of “best practises” may offer a fruitful model.
- Emergency preparedness and response programmes.

These broad adaptation areas have been expanded to include additional considerations that might be applied in certain circumstances:

- Land use restrictions, especially for floodplains, coastal shorelines, landslide prone areas and other areas considered to be at risk.
- Revised flood plain mapping and codes for snow and wind loading and return frequencies. Adjusting to new realities (e.g.- "100-year" floods become "50-year" floods).
- Safety and fire codes for buildings and other structures that could affect public safety.
- The adoption of a system for emergency management, including education and training and public outreach.
- Public prevention and mitigation infrastructure adjustments - dams and weirs, flood channels, dykes, land stabilization works, transmission towers, communication devices and channels, etc.
- Establishing effective programs for post disaster recovery and support to provincial and local governments.
- Providing public health, agricultural and environmental programs that ensure the survival and effective functioning of critical public services.
- Modified and improved disaster response protocols:
  - new responsibilities for emergency services and other agencies to deal with the expected increase in disastrous events.
  - public expectations and the need for individual and family self-sufficiency for significant periods of time in the early stages of disasters.
  - modifying emergency services structures.
- Recovery phase may need new strategies for continuation of government and business operations. Getting community life back to "normal" should be a priority concern which is planned in some detail before the event.

Finally, it is important not only to reduce the impacts of a changing climate on Canada through well considered adaptation measures, policies and programmes, but also to take advantage of benefits that may be presented. For example, in much of Canada winter temperatures may be less severe, in some regions the growing season will be longer and in the St. Lawrence Seaway and in the Arctic there may be a longer ice-free period. Unless Canadians determine to exploit these opportunities there may be no economic benefits from them. This will require imagination, effort, initiative and investment, the costs of which must also be considered in examining the effects of climate change on Canada.

APPLYING THE PRINCIPALS OF RISK MANAGEMENT

This section of the investigation will examine the merits of the risk management process to determine whether it offers a framework that would help municipalities in dealing with adaptation strategies to climate change in the Canadian context.

Adaptation to climate change is a problem involving risk and choices. The complexity of assessing the optimal course forward where there are uncertainties about the needs, the objectives, the process or the outcomes or any number of other parameters, often encourages denial, delay or deferral of necessary action. The risk management process provides a framework for managing the selection of adaptation strategies for those aspects of climate change impacts that create or increase a risk to the community, its infrastructure, operations, economies or populations. Risk management is a decision-making tool which assists in the selection of optimal, or the most cost-effective, strategies using a systematic, broadly accepted public process.

Canada is fortunate to have a National Standard laying out the steps of the risk management process and defining the terms.[6] The process is widely used by governments, industry and professional bodies for the identification, analysis, evaluation and control of risks and potential risks, including risks to health and safety. It assists in developing strategies to avoid, reduce, control or otherwise manage risks including the perception of risk in the minds of stakeholders. The process is iterative and lends itself to the inclusion of new information when it becomes available. It also assists in priority setting and balancing complex risk control strategies, their effectiveness and costs. It uses a pragmatic or evolutionary approach, which would include existing organisations and functions within the community.

Communications with and among stakeholders is a very important element of the process ensuring that key parties are part of the decision-making process and that their concerns are included in the analysis. This unique aspect of Canada's risk management framework, that is, the iterative and continual communications process, tightly linked to the more technical risk assessment and risk control components, ensures that is highly credible and inclusive. Thus the process is particularly appropriate for public bodies or areas where the general public's concerns are high. The impacts of and adaptation to a changing climate within the community or municipality are issues which will certainly engage the community at large and therefore may benefit from the communications processes associated with Canada's risk management approach.

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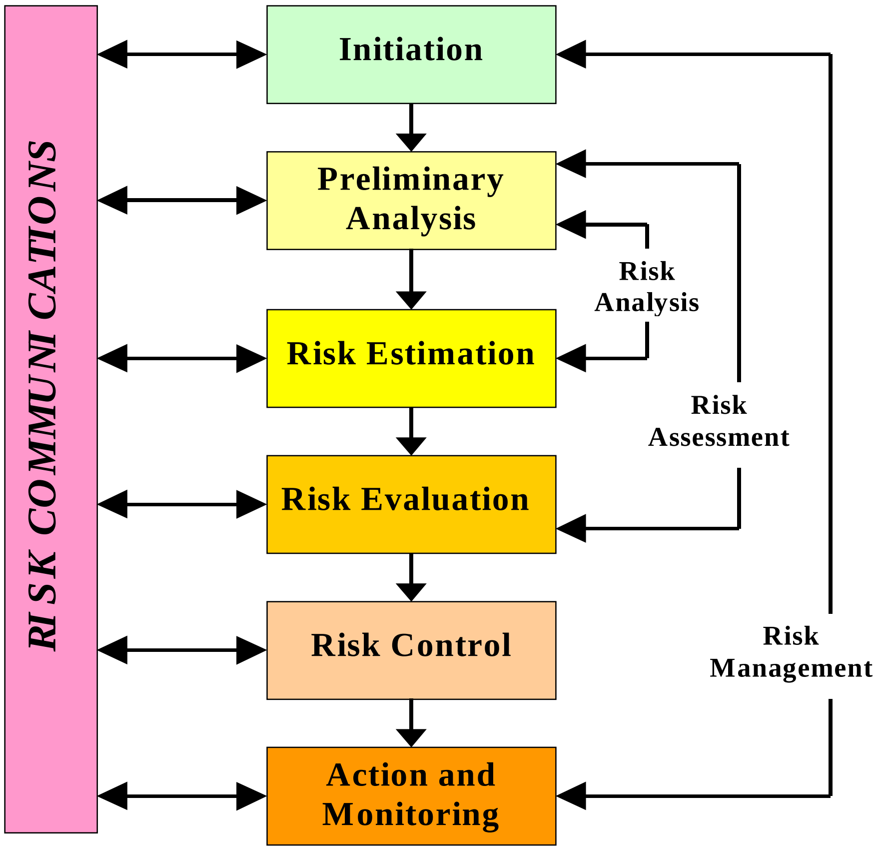
6 Canadian Standards Association, 1997, *CAN/CSA-Q850-97*, ***Risk Management Guideline for Decision-Makers,*** A National Standard of Canada. In 1998, the International Standards Organization (ISO) also began to develop a lexicon of common risk management terms, (*The First Working Draft of Risk Management Terminology for Comment,* ISO Secretariat).

Figure 4 illustrates in simplified form, the steps in the risk management process and shows the various feedback loops that ensure the process accounts for all information and perspectives. The figure also shows how the risk communications process with key stakeholders and the public integrates with all stages of the process.



<u>Figure 4</u>. Steps in the Risk Management Process[7]

Each step in the process is briefly described as it relates to adaptation to climate change:

1. ***<u>Initiation</u>*** **-** Define the climate change impact and the risks associated with it. Identify the stakeholders, organisations or groups that should be involved in the process. Assign responsibilities, resources, timeframes and authorities. Identify other stakeholders and interested parties and begin to define the consultative process and information needs.

[7] From *Q850***,** p 6. Further information about the process and how it can be applied to issues related to adaptation to climate change can be found in National Standard itself and in Shortreed and Burn, Institute for Risk Research, April, 1999. It is not intended to repeat this detailed and well-described information here.

2. ***Preliminary Analysis*** - Define the scope of the issue and the decisions that will be needed. Identify the hazards and the risks using risk scenarios and identify who could be affected. Begin the analysis of stakeholders who could be affected and/or interested. Begin to implement the consultative process. Start the risk information "library".

3. ***Risk Estimation*** - Define the methodology for estimating or quantifying the frequency and severity associated with the hazards. Estimate the frequency of risk scenarios. Estimate the consequences or potential results of the risk scenarios. Through consultation with stakeholders, refine the stakeholder analysis.

4. ***Risk Evaluation*** - Estimate and integrate benefits and costs. Consult with stakeholders. Assess stakeholder acceptance of risk.

5. ***Risk Control*** - Identify feasible risk control options and opportunities. Evaluate risk control options in terms of cost, benefits, effectiveness, acceptability with stakeholders, risks created and other factors. Through consultation process with stakeholders assess acceptability of risk control options.

6. ***Action and Monitoring*** - Develop and implementation plan. Implement selected control. Financing and communications strategies. Evaluate the effectiveness of risk
management decision process. Establish a monitoring process, "sunset" timeframes (if applicable). Continue dialogue with stake-holders. Begin process anew with up-dated information and experience.

7. ***Risk Communications*** - Risk communications *is not* the one-way provision of information at discreet points in the process. It is a continual and meaningful dialogue among stakeholders at all stages in the process, including allowing stakeholders to share in decision-making. Great care must be take in the selection of the stakeholders for the process to ensure that all who should be included are, including, perhaps, those who *think* they are stakeholders. Often it

The list in the sidebar box below (adapted from Scheraga, 1998) may provide principles which will assist in getting started with the risk management or adaptation decision-making process.

CLIMATE CHANGE ADAPTATION:
BASIC FUNDAMENTAL POLICY PRINCIPLES

1. The effects of climate change vary by region: (There is considerable regional differences in warming, precipitation and extreme events).
2. The impacts vary across demographic groups: (Health effects of warming may be more severe in elderly, poor may not be able to afford air conditioning, some areas may be able to adapt more easily than others).
3. Risk and opportunities: (Impacts on health, air quality, water quality, ecosystems, agriculture, forests etc. may be beneficial or detrimental. A lost opportunity is of concern as well as a risk).
4. Consider in context of multiple factors. (Many systems that are sensitive to climate change are already under stress, such as: populations, land use, pollution).
5. Adaptation comes at a cost. (There are opportunity costs associated with adpatation).
6. Adaptive responses vary in effectiveness. (Current efforts to cope with climate stresses, such as heat waves, illustrate effective and non-effective measures e.g. deaths and illnesses).
7. The systematic nature of climate impacts complicates adaptation. (Simultaneous impacts have wide ranging effects and adaptation measures may create other problems e.g. sea walls may damage wetlands).
8. Maladaption can result in serious negative impacts. (Non-climate related side effects can have adverse effects; e.g. fish hatcheries may lead to impoverished biodiversity instead of increased fish stocks).
9. Opportunities for adaptation make sense independent of climate change. ("No regrets" or co-benefits options where costs are recovered by benefits other than those related to climate change).

is instructive to look at the results of ineffective risk communications to achieve a fuller understanding of the alternative. "Ineffective risk communications may lead to irreplaceable loss of management credibility, unnecessary and costly conflicts with government, difficult and expensive approval processes …, bitter and protracted debates and conflicts with stakeholders, diversion of management attention from important problems …, non-supportive and critical employees, and unnecessary human suffering due to high levels of anxiety and fear."[8]

It may be helpful to briefly clarify the meaning of the terms "mitigate" or "mitigation" and some of the risk management and disaster management terms, since they are used somewhat differently by the climate change and the risk management/emergency preparedness communities.

Table 4. Risk management terminology.

hazard	A source of potential harm, or a situation with a potential for causing harm, in terms of human injury, damage to health, property, the environment, and other things of value, or some combination of these[9].
mitigation	In the climate change lexicon, a mechanism, means or process for reducing the net emission of greenhouse gases or increasing the capacity or number of carbon "sinks" or depositories.
mitigation	In the language of the risk management and emergency preparedness communities, mitigation means to cause to become less harsh, hostile; severe or painful; to moderate or secondarily, to carry out sustained action to reduce the risk to life, property and the environment from disasters of all types.[10]
prevention	An emergency preparedness term meaning an action or actions to keep from happening or forestalling an emergency, disaster, spill or release.
risk	The chance of an injury or loss as defined as a measure of the probability and severity of an adverse effect to health, property, the environment, or other things of value[11]. Risk is a product of the probability of the hazard and the consequences of or vulnerability to that hazard.
risk management	The systematic application of management policies, procedures, and practices to the tasks of analyzing, evaluating, controlling, and communicating about risk issues[12].

[8] Q850, Appendix C, *Risk Communication.*
[9] CAN/CSA-Q850-97, page 3.
[10] From the Emergency Preparedness Canada draft paper, *A National Policy for Mitigation*, October 1998.
[11] CAN/CSA-Q850-97.
[12] CAN/CSA-Q850-97.

As was noted above, many decisions about adaptation measures are made on a routine basis by individuals, business and other organisations, and governments without using a risk management decision-making framework. For example, the development of new seeds to accommodate a longer growing season or crops more suited to dry conditions, or better insulation to save heating or cooling costs are decisions made on a daily basis for economic or aesthetic rather than risk reasons. There is no reason to change these kinds of decision frameworks where is little or no risk or perceived risk or where there are no uncertainties that may affect safety, health or property.

At the municipal level, where risk exists or is perceived, or where there are complex risk-related concerns or where the situation is largely unknown it may be prudent for key decision-makers to initiate a risk management process. Senior governments should provide some of the key decision support information such as expected climate change impacts, national and regional environmental and sustainable development policies or regulations and economic instruments such as incentives, charges or taxes. However, in most cases, the important decision to initiate a risk management process is made closer to the level at which action will be taken. The objectives of the process are to provide a better understanding of the risk and how to prevent, avoid, reduce or control it.

Where extreme weather-related events are concerned which could result in serious emergencies or disasters, a risk management framework for decision-making should be considered an imperative.Many municipalities use the

Risk Management in Action: Follow-up to the 1997 Red River Flood

(Note: Adapted from Shortreed, 1999, pp 20-21)

The 1997 flood was the largest flood event on the Red River in 145 years with damages in Canada exceeding $500 million.

An existing (but inactive) organisation, the Manitoba Water Commission (MWC), was tasked to provide recommendations to the Manitoba Government on actions that could be taken to prevent or mitigate future flood events.

The MWC held extensive stakeholder hearings and conducted an analysis of impacts and risk control measures. The recommendations included:

- Revision of floodway policy with all impacted groups.
- Risk analysis of flood planning and flood proofing
- Development of an effective flood forecast system
- Development of an effective flood response plan
- Review of floodplain zoning and enforcement.

Potential risk control measures that are being considered:

- Individual dykes for individual properties
- Raising structures
- Abandoning vulnerable sites
- Revising compensation levels (this may be a maladaption)
- Revision of regulations and guidelines respecting flood on the Red River
- Implementation of additional adaptation measures

“Emergency Management System”, the “Incident Command System” or a more general prevention, preparedness, response and recovery paradigm. All of these fit comfortably within a risk management decision framework. The broader risk management framework is more comprehensive, provides more rigour in the risk assessment and analysis steps and requires much more consultation with and involvement of key stakeholders and others who consider that they have an interest in the process.[13] This latter aspect is a critical addition to the traditional emergency preparedness and response functions as they have been practised in Canada.

SUMMARY and CONCLUSIONS

It is clear from all the available evidence that the climate is changing and has been changing for some time. The more disturbing aspect of climate change is that rather than the mean Canadian temperature increasing slightly more than 1^{o}C in a 100 years or so, projections indicate that the increase is more likely to be on the order of 3^{o}C in about half a century; a six fold increase in the rate of change.

In spite of mitigation measures taken under the Kyoto Protocol to reduce greenhouse gas emissions, it is expected that doubled CO_2 concentrations will occur by the second half of the next century. Changes in climate will continue to occur and the impacts will be felt gradually but perceptibly.

Municipalities can expect the average temperature in Canada to gradually increase 3 to 5^{o}C, while northern and northwestern areas can expect even greater increases. The major impacts will be increased cooling demand, decreased heating load, northward movement of natural ecosystems, increased heat-related illnesses, insects and pests and changes to agricultural crops and forests. The expansion of ocean water due to warming and melting of glaciers on land will result in a rise in sea levels, which will affect “sensitive” coastlines in Atlantic Canada, south of Vancouver and in some areas of Vancouver Island. Many municipalities will be affected by water supply changes as ground and subsurface water levels fall.

More persistent El Niño conditions punctuated by strong La Niñas would result in more prolonged droughts (El Niño) interspersed with very wet years (La Niña) over central Canada and the southern Prairies.

There will be more frequent and more severe weather-related extreme events, including violent winter storms, short-duration, very high intensity rainfalls, extended heat waves and accompanying smog conditions, wildfires and forest disturbances and severe thunderstorms and tornadoes. The increase in natural disaster frequency will create

[13] It is not the intention of this paper to provide detailed instructions on the use of the risk management process. The reader who wishes more information or examples should refer to Q850, (1997), Shortreed, (1991), or other more detailed documents.

perhaps the most serious and possibly the most costly challenges for communities in a changing climate.

Canadians have been very successfully adapting to a harsh climate for many decades and there is no reason to suppose that this will change. The challenge will be the accelerated pace of change and the much increased frequency of extreme weather-related events. The costs of successful adaptation are likely to be high and will probably vary substantially from measure to measure, from region to region, from municipality to municipality and from social group to social group. There will likely be significant residual costs resulting from forest fires, floods, droughts and storms, and other events and these are likely to increase over present levels.

Although the climate is changing at an unprecedented rate, sufficient time is available for steady, affordable, steady progress to be made, provided that recognition is given now to the need for adaptation to begin immediately and be allowed to proceed at a reasonable and affordable pace. Adaptation processes should be governed by practicality and common sense. The involvement of all key stakeholders in the adaptation process will assist in reducing conflicts and allow opportunities for bright, new ideas to be applied. The importance of using the experience of others, or "spatial analogues" to advance adaptation without making costly mistakes should not be underrated.

Some of the major adaptation areas that will have to be addressed:

- Water and energy conservation measures.
- Pragmatic and future-oriented reviews of standards, codes, regulations and other practises. The concept of "best practises" may offer a fruitful model.
- Emergency preparedness and response programmes.

Some of the following measures will be useful in accelerating adaptation:
- Be prepared to apply land use restrictions, especially for floodplains, coastal shorelines, landslide prone areas and other areas considered to be at risk.
- Develop revised flood plain mapping and codes for snow and wind loading and return frequencies and adjust to new frequencies - eg."200-year" floods become "100-year" floods.
- Revise safety and fire codes for buildings and other structures that could affect public safety.
- Examine public infrastructure and make adjustments to ensure public safety - dams and weirs, flood channels, dykes, land stabilization works, transmission towers, communication devices and channels, etc.
- Provide public health, agricultural and environmental programs that ensure the survival and effective functioning of critical public services.
- Modify and improve disaster response protocols:

- encourage an overarching system of risk management to promote more effective emergency management, including education and training and public outreach.
- expand responsibilities and structures for emergency services and other agencies to deal with the expected increase in disastrous events.
- educate the public to the need for individual and family self-sufficiency for significant periods of time in the early stages of disasters.
- establish effective programs for post disaster recovery and support to provincial and local governments. Getting community life back to "normal" should be a priority concern which is planned in some detail before the event.

It is also important to take advantage of benefits that may be presented by climate change such as less severe winters, longer growing seasons in some regions and longer ice-free periods in the St. Lawrence Seaway and the Arctic. It will require imagination, effort, initiative and investment to exploit these opportunities.

The risk management process described in the National Standard of Canada, CAN/CSA Q850-97, provides a framework for managing the selection of adaptation strategies for those aspects of climate change impacts that create or increase a risk to the community, its infrastructure, operations, economies or populations. The risk management process and its step by step approach is widely used by governments, industry and professional bodies. It assists in developing strategies to avoid, reduce, control or otherwise manage risks including the perception of risk in the minds of stakeholders.

Adaptation decisions are made on a routine basis by individuals, business and other organisations, and governments without using a risk management decision-making framework. There is no reason to change these kinds of decision frameworks where is little or no risk or perceived risk or where there are no uncertainties that may affect safety, health or property.

Where risk exists or is perceived at the municipal level, it may be prudent for key decision-makers to initiate a risk management process. Senior governments should provide some of the key decision support information. The objectives of the process are to develop a better understanding of the risk and how to prevent, avoid, reduce or control it.

Where extreme weather-related events are concerned, a risk management framework for decision-making should be considered an imperative. The risk management decision framework accommodates the "Emergency Management System", the "Incident Command System" or a more general prevention, preparedness, response and recovery paradigm used by many municipalities. The broader risk management framework is more comprehensive, provides more rigour in the risk assessment and analysis steps and requires much more consultation with and involvement of key stakeholders and others who consider that they have an interest in the process. This latter aspect is a critical addition to the traditional emergency preparedness and response functions as they have been practised in Canada.

Finally, it is important to note that many adaptation measures, especially those which should be taken for extreme weather-related events have merits quite apart from those related to climate change. Also, on a human scale, even considering the replacement schedule for some infrastructure items, climate change will occur relatively slowly. The case for avoiding denial, deferral and delay and initiating timely, appropriate and carefully considered action is very strong.

ATTACHMENTS

ANNEX A: **THE ROAD TO KYOTO AND BEYOND**

ANNEX B: **LISTS OF CLIMATE CHANGE IMPACTS AND ADAPTATION MEASURES**

ANNEX C: **BIBLIOGRAPHY**

The Road to Kyoto and Beyond[14]

(A timeline of scientific research and conferences that led to the Kyoto Protocol)

1896 Svante Arrhenius, a Swedish chemist, predicts carbon dioxide emissions from burning of coal will lead to global warming.

1957 Revelle and Seuss, scientists with the Scripps Institute of Oceanography, report that much of the CO_2 emitted into the atmosphere by industrial activities is not absorbed by the oceans, as some researchers had proposed. They described the build-up of carbon dioxide in the atmosphere as "a large-scale geophysical experiment" with the Earth's climate.

1958 Keeling, a scientist with the Scripps Institute, initiates the first reliable and continuous measurements of atmospheric carbon dioxide at Hawaii's Mauna Loa Observatory.

1972 Stockholm: first U.N. Conference on the Human Environment where human induced climate change was identified as a pressing issue. The United Nations Environment Programme founded.

1979 Geneva: first World Climate Conference: launched the World Climate Program to co-ordinate global research on climate and climate change and collect meteorological and related oceanographic and hydrologic data.

1985 Villach (Austria) Conference: issued a warning that "Many important economic decisions are based on the assumption that past climate is a reliable guide to the future. This is no longer a good assumption."

1988 The Intergovernmental Panel on Climate Change (IPCC), made up of the world's leading climate scientists, is established by the U.N. Environment Programme and the World Meteorological Organisation to assess the scientific research on climate change and its environmental impacts and remedial measures.

1988 Toronto: The Conference on the Changing Atmosphere calls for a 20 percent reduction in carbon dioxide emissions.

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[14] Adapted from: (1) Russell, Doug, and Toner, Glen, *Science and Policy when the Heat is Rising: The Case of Global Climate Change Negotiations and Domestic Implementation*, A Paper for the CRUISE Conference on Science, Government and Global Markets, Ottawa, October, 1998, *and* (2) IISD, *A Guide to Kyoto: Climate Change and What it Means to Canadians*: 19 - 20.

The Road to Kyoto and Beyond - (cont'd)

(A timeline of scientific research and conferences that led to the Kyoto Protocol)

1990	Geneva: First assessment report of the IPCC is endorsed at the Second World Climate Conference by more than 500 scientists and world leaders. A call is issued for an international agreement to mitigate global warming.
1992	Rio de Janeiro: One of the results of the United Nations Conference on Environment and Development (UNCED) was that 154 nations signed the U.N. Framework Convention on Climate Change, voluntarily agreeing to stabilize greenhouse gas emissions at 1990 levels by the year 2000.
1995	The IPCC, representing the consensus of the world's climate scientists, concludes that "…the balance of evidence suggests that there is a discernible human influence on global climate." It also concludes that the net benefits of greenhouse gas mitigation exceed the costs in many countries at least for the initial reductions.
1997	Warmest year on record since scientists began keeping accurate meteorological logs in 1860. The next two warmest years are also in the same decade: 1995, 1990.
1997	Kyoto, Japan: 159 nations negotiate a protocol to the UNFCCC setting out legally binding reduction targets for six greenhouse gases averaging 5.2% below 1990 levels for industrialized countries.
1998	Measurements indicate that 1998 is the warmest year on record in Canada and globally, even warmer than 1997.
1998	Parties to the UN FCCC in Buenos Aires agree to a plan to work towards the goals of Kyoto.
1999	Canada continues work of 15 "tables" to design a National Climate Change Strategy

LISTS OF CLIMATE CHANGE IMPACTS AND ADAPTATION MEASURES

(Cautionary Note: These lists of climate change impacts and adaptive measures, while convenient and relatively short, are by nature categorical and do not contain the full context needed to understand the issues. The reader should also refer to the full text in the paper, "Investigation Of The Potential Municipal Impacts And Adaptation Measures Envisioned As A Result Of Climate Change", July 1999, Bruce, J.P., Burton, I., Egener, I.D.M. and Thelen, J.)

CLIMATE CHANGE IMPACTS:

- El Niños continue to intensify and stay longer, punctuated with short but strong La Niñas:
  - Much increased West coast winter storms
  - Southern Canada s as far east as Ontario, significantly warmer and drier, especially in winter and spring giving:
    - droughts in BC, prairies and Ontario
    - lower water levels, water quality problems, hydro production difficulties, farm droughts in Great Lakes/St Lawrence River basin
  - When La Niña present abnormally wet from BC interior to southern Quebec, cooler in west and northwest.

- Average temperature increases for central and northern Canada +5^0 C plus and for the rest of Canada, +3-5^0 C except in the extreme east, giving:
  - Northern movement of ecosystems
  - Decline in heating demand, increase in cooling load
  - Increase in insects and pests
  - Increase in heat- and smog-related illnesses
  - Evaporation losses > increased precipitation (for example, in 2100, in summer, precipitation minus evaporation should be 35% less creating serious soil moisture reductions)
  - Arctic sea ice gone by 2100, retreat of permafrost = profound effect on northern communities' economies, way of like (hunting/fishing), building foundations, roads.
  - Water availability problems – conflicts between city/agriculture, Canada/US

- Sea level rise – median projection ½ metre by 2100 (shoreline erosion, flooding of low-lying land):
  - Atlantic Canada has highest extent of "sensitive" coasts
  - West coast – Frazer delta and south Vancouver Island vulnerable

- Severe weather:
  - Heavy rains – frequency of return periods halved (i.e.: 20 year return periods become 10 year return periods)
  - Winter storms – occasional very severe storms, average snow removal requirements decrease
  - Heat waves (and smog) – very hot days (30^0 C +) increase by 2 to 5 times, night temperature rise even more, giving heat stress, smog, increased air conditioning loads. . Wildfires and forest disturbances – higher fire and insect incidences, lightning strikes and remote fires up by ~44% (estimate for USA), increased threat to communities in boreal areasSevere thunderstorms and tornadoes – warmer springs and summers

- Possible rare catastrophic events – the result of coincidence of several factors:
  - Vancouver, Richmond, Surrey, Delta - major Frazer River flood due to rapid snowpack melt + ocean storm surge + sea level rise resulting in overtopping of dykes and major flooding of low-lying communities.
  - Bay of Fundy – severe winter storms + sea level rise = overtopping of slat-marsh dykes and extensive flooding.
  - Intense, large-scale drought for much of southern Canada.

- Benign Impacts:
  - Prairies, northern Ontario and northern Quebec – boreal forest northward extension, forest growth rate increases, longer agriculture growing season, northward expansion of fish and wildlife species.
  - Atlantic region: improved agriculture, reduced heating costs.
  - Arctic, sub-arctic:
    - change in vegetation,
    - treelines move north,
    - fish move north (~150kms for each 1^0 C increase in temperature),
    - oil and mining exploration would benefit,
    - recreation and tourism season longer,
    - agriculture in Mackenzie basin.
  - Ontario and Quebec:
    - extended agricultural growing season and yield increases
    - extended shipping season on Great Lakes
    - shorter winters – reduced winter road maintenance and snow removal.

ADAPTATION MEASURES:

Urban Infrastructure -

- Revise standards and/or best practices (in co-operation with industry associations, standards organization, academia) for:
  - Ventilation
  - Drainage and sewerage
  - Food protection
  - Corrosion resistance
  - Expansion capability
  - Snow loads
  - Location of flood plains (100 year or other criteria)
  - Facility siting
  - Increase number of community trees
  - Road beds
  - Insulation

- Water resources
  - Modify water supply plans and effluent discharges to accommodate surface water/aquifer changes
  - Increase water storage capacity, canals, pipelines pumping capacity
  - Encourage residential, industrial and institutional water conservation
    - Demand management, pricing policies, rationing, standards for water appliances
    - Regulations/incentives
    - Public/industry education programmes
    - Remove subsidies, price water to recover all costs
  - Substitute treated waste water for low quality uses
  - Trade low quality for high quality water
  - Protect and enhance vegetated watersheds
  - Reduce seepage, leakage and evaporation losses
  - Establish drought management plan

- Energy supplies
  - Efficiency improvements
  - Reduce energy requirements
  - Maximize use of local resources (e.g. local small hydro, landfill methane etc.)

- Extreme events
  - Upgrade community and individual emergency preparedness
  - Raise structures, adopt flood proofing practices
  - Expand flood plains

  - Public education, self/family sufficiency
  - Public education and awareness, previous experiences
  - Special needs groups (schools, hospitals, corrections facilities, elderly etc.)

- Risk management programmes
  - Hazard identification
  - Risk assessment
  - Risk analysis
  - Risk control measures
  - Communications process
  - Insurance
    - Degree of self insurance
    - Collective community insurance
    - Offsets

- Other
  - Arctic
    - Special needs of northern communities
    - Permafrost thaw abatement measures – foundations, roads etc.

  - Coastal areas
    - Levees, dykes and seawalls
    - Wetland migration policies
    - Special needs for water supplies, drainage, conservation, desalination etc.
    - Pumping capacity
    - Set-back policies for buildings

  - Forested areas
    - Protect against insects, disease, pests
    - Maximize adaptable species
    - Forest communities

  - Spatial analogues: Identify communities which are experiencing similar climatic conditions to those that are projected for 25 to 50 years in the future and utilise their experience.

  - Time frames: Steady adaptation process rather than crash programmes

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