REPORT 1:

AN INTRODUCTION TO THE SCIENCE OF CLIMATE CHANGE

Prepared For:

The Assembly of First Nations

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The views expressed in this paper are those of the author and not necessarily shared by the Assembly of First Nations

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1.0 INTRODUCTION

> "*First Nations have inherent rights that are constitutionally recognized and protected, including the right to hunt, fish, and gathering in our traditional territories. Our ability to pursue and enjoy our rights will be undermined by climate change. A failure to address the causes of climate change constitutes a failure to protect our rights.*"
>
> - National Chief, Phil Fontaine, Assembly of First Nations

There is a high level of consensus amongst the international scientific and government communities that global climate conditions are changing. There is also a great deal of scientific information focused on how climate change will specifically affect the Canadian environment, economy, and society at large. However, most of this information does not consider how climate change will uniquely impact First Nations. Research increasingly suggests that climate change will disproportionately impact the poor and marginalized, among which most Aboriginal and northern peoples are included. In the event of most of the predicted climate changes, First Nations will be significantly impacted due to their locations, reliance on the environment, and current limited adaptation strategies.

First Nations living in northern territories rely on long, cold winters to be able to hunt and trap for food and other necessities, and to travel over ice and to transport necessary goods over winter roads. Many First Nations rely on the environment for subsistence foods, commercial enterprises (commercial hunting, fishing, forestry, ecotourism), and for socio-cultural and spiritual health (medicines, commercial uses). Aboriginal and treaty rights, including the rights to hunt, fish, trap, utilise forest products and water, may also be threatened by a changing climate. Many First Nations may have difficulty in adapting to the impacts of climate change because of their economic circumstances and complex, and frequently constraining externally-imposed governance structures. The impacts of climate change on traditional economies (fishing, forestry, hunting, trapping, crafts) could force many First Nations to find new sources of revenue, which may require expensive investments in infrastructure and resources. Changes in climate may affect common transportation routes such as winter roads and will put pressure on communities to find alternative methods of transportation. Adaptations and responses to disastrous weather events associated with climate change will require communities to develop

emergency procedures that may be costly and hard to predict. The impacts of climate change on First Nations' economies, environments and ways of life need to be considered in order to shape future decision-making and policy considerations related to First Nations and climate change.

Impacts related to climate change are expected to occur to a greater extent in the Canadian Arctic than anywhere else in the country and as a result, much research has focused on this area and the effects of climate change on Inuit communities. Although some comparisons between lifestyles and reliance on resources in both Inuit and First Nations communities in the north can be made, similarities between Indigenous communities in the north and First Nations in the southern parts of the country are harder to establish. The lack of research and information available on how climate change will affect southern First Nations limits the opportunities to report on how southern First Nations can adapt to these changes.

The Assembly of First Nations (AFN) believes that a strong policy position is necessary in order for First Nations to be able to participate in effective strategies to mitigate and adapt to climate change. To assist the AFN in exploring climate change issues and engage with First Nations to develop policy responses, the Centre for Indigenous Environmental Resources (CIER) has been asked by the AFN to prepare five reports on climate change and the unique impacts and adaptations facing First Nations as a result of this issue.

First Nations across the country will be uniquely impacted by climate change and, to date, meaningful and comprehensive discussions of these impacts and the specific adaptations needed to mitigate them have not taken place. It is anticipated that the following series of reports will help to involve First Nations and other forms of government in policy discussions related to climate change and its effects on First Nations and that these discussions will bring about substantial change in the way that First Nations are considered in climate change impact studies and adaptation strategies. The titles of these five reports are as follows:

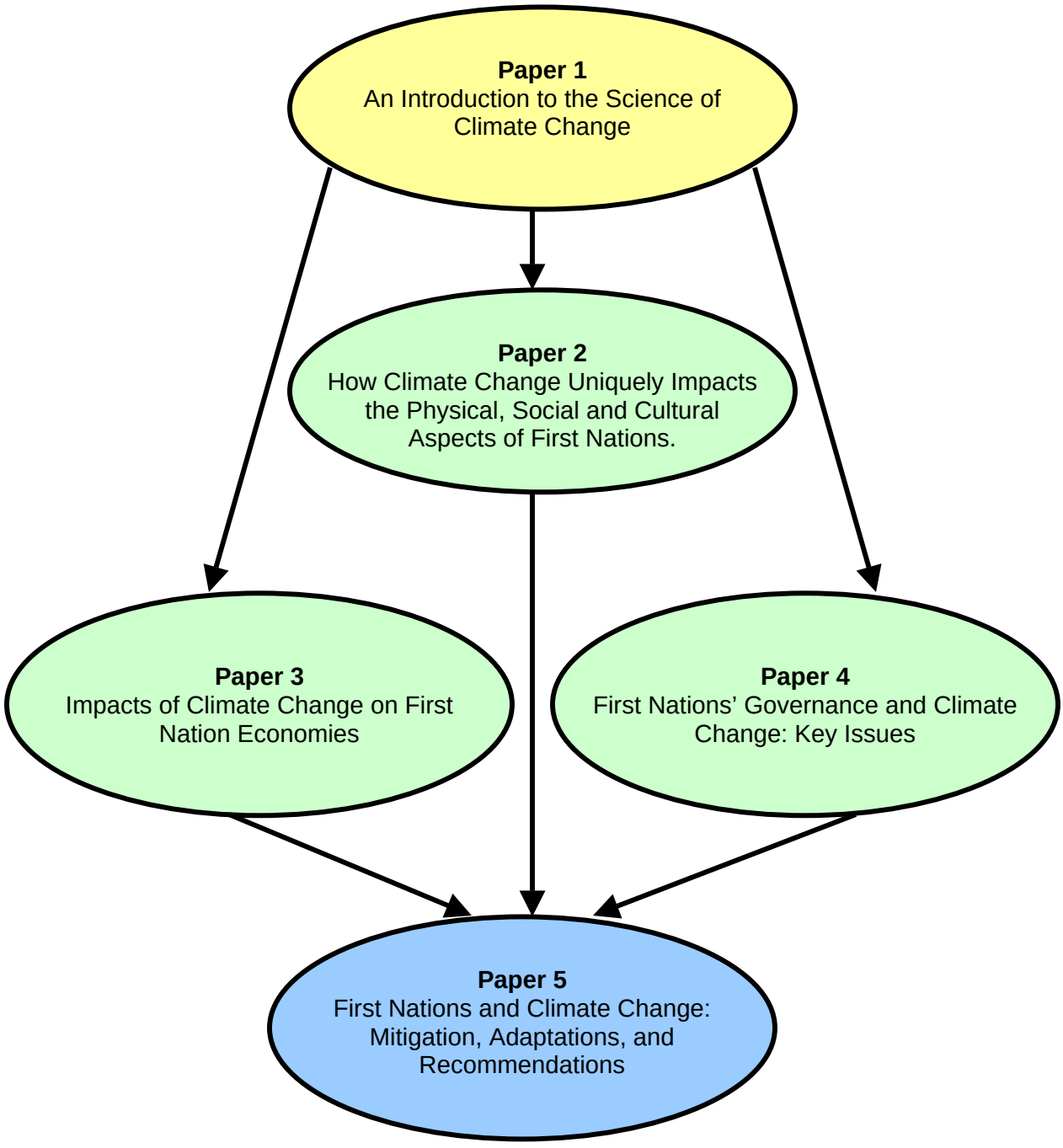
1) **Report 1: An Introduction to the Science of Climate Change**
2) **Report 2: How Climate Change Uniquely Impacts the Physical, Social, and Cultural Aspects of First Nations**
3) **Report 3: Impacts of Climate Change on First Nation Economies**
4) **Report 4: First Nations' Governance and Climate Change: Key Issues**

5) Report 5: First Nations and Climate Change: Mitigation, Adaptations, and Recommendations

Figure 1-1 shows how the five papers in this series relate to one another. Report 1 introduces the global and regional issues of climate change based on primary research conducted by leading scientists. Reports 2, 3, and 4 examine the unique issues associated with climate change as they relate to First Nations' economies, governance structures, and the physical, social, and cultural aspects of First Nations. Paper 5 draws on the discussion in Reports 1-4, and builds on them through the identification and examination of gaps in knowledge related to climate change impacts related to First Nations and also suggests areas where further research is needed.

This report relied on information accessed from peer-reviewed academic literature and from accessible published and unpublished reports and theses. Abstracts and proceedings from international and national conferences on climate change were also accessed and information was obtained from government sources and databases, universities and non-profit organisations.

Figure 1-1. Diagram representing the five papers in this series related to the issue of climate change and the unique impacts and adaptations facing First Nations.



2.0 WHAT DO WE KNOW ABOUT CLIMATE CHANGE?

2.1 RESEARCH RELATED TO CLIMATE CHANGE

Climate change is a challenging phenomenon to research and conclusions are particularly difficult to form, especially as the geographical scale of study increases. However, research on climate change and the ability to predict future changes in climate is continually improving. These improvements are enabling a better understanding of the processes of climate change and also allow researchers to make predictions of the implications of climate change on a regional scale. They also allow scientists to better separate natural causes of climate change with those brought about by human activities. The amount of research on climate change and the impacts of climate change on physical and biological systems is voluminous. Scientists around the world have participated in international research projects, conferences and conventions in order to bring the issue of climate change to government policy makers to develop strategies to help mitigate the impacts of a changing climate.

2.2 LEVEL OF CONSENSUS AMONGST SCIENTIFIC COMMUNITY

There is a high level of consensus in the scientific and Indigenous communities, and at the international level, that the climate is changing. This consensus should allow for adequate research money and effective policy-making regarding climate change from all levels of government in Canada, however very little is being done in terms of research and policies related to impacts and adaptation for First Nations communities in the southern portion of the country. Assessment and understanding of the unique impacts of climate change on First Nations deserves much more attention than they have received in the past, given that future impacts of climate change are projected to be severe and these communities may be more vulnerable because of their location, reliance on the land, and current limited adaptation strategies. First Nations need to have the opportunity to take a much more active role in how climate change research and policies are conducted and developed in Canada to ensure that their concerns are addressed.

2.3 CURRENT FOCUS OF CLIMATE CHANGE RESEARCH

Most climate change research focuses on future predictions of change; little research deals with adapting to climate change, especially regarding strategies that could be utilised by poor or marginalized communities such as First Nations. Since climate change appears to be currently

affecting the livelihood of First Nations people in Canada, research on the impacts and adaptations in these communities becomes particularly important.

Research on the effects of climate change on Indigenous communities in Canada is currently focused on those communities living in the Arctic, likely because the effects of climate change in the north are predicted to be much more intense than anywhere else in the world (IPCC, 2001; ACIA, 2004). The livelihood of First Nations and Inuit communities living in the north will be greatly affected by physical and biological changes brought on by increasing temperatures, but the livelihoods of First Nations in the south have significant likelihood of being affected by changes in climate.

Most scientists acknowledge that there are unique implications for climate change on natural resource dependent communities in different regions of the world, especially in third world or developing countries. Despite this, researchers have seldom extended this thinking to First Nations in Canada. While researchers and policy-makers may be of the view that Canada as a whole is economically stable and, thus, has the ability to adapt to impacts of climate change reasonably well, however, without a full understanding of the potential impacts of climate change in all areas of Canada, including in First Nation communities, the issue of climate change cannot be adequately addressed through adaptation policies.

2.4 CURRENT RESEARCH OR COMMITTEE STRUCTURES

The Intergovernmental Panel on Climate Change (IPCC) was established in 1998 by the World Meteorological Organisation and the United Nations Environment Programme. The IPCC involves over 2000 of the world's leading climate experts. The IPCC does not conduct research itself, but it studies the existing peer-reviewed literature and puts all climate research into the context of the mass of existing scientific information. Seventeen academies of science from as many countries, including Canada and the United Kingdom, indicated that the IPCC's work represents the consensus of the international science community on climate change science. The IPCC is the only organization that provides a thorough assessment of the state of knowledge on climate change and is the most reliable source of information on the science of climate change.

The *United Nations Framework Convention on Climate Change* (UNFCCC) is an international environmental treaty produced at the United Nations Conference on Environment and

Development, informally known as the Earth Summit, held in Rio de Janeiro in 1992. The UNFCCC aims at reducing emissions of the greenhouse gases. The United Nations Conference on Climate Change allows for a forum for delegates from governments, industry, the scientific community, the media and non-governmental organizations to discuss and advance commitments to reduce greenhouse gas emissions. The supreme body of the Convention is the Conference of Parties (COP), which is the assembly of all the countries that have approved the convention. The COP has met once a year since 1995. First Nations have been represented to some extent at the United Nations Conference on Climate Change as participants at the COP, although there a was little to no involvement from First Nations in the development of the *Framework Convention on Climate Change*. Ultimately, the discussions and debate of climate change impacts at the international level cannot substitute for a national debate on climate change and how it affects the First Nations in Canada. A national discussion is still required to adequately understand the issue of climate change at regional levels and how it will uniquely affect First Nations across the country.

2.5 INTRODUCTION TO THE ISSUES OF CLIMATE CHANGE

Most of the international scientific and non-scientific community accepts that the earth's climate is changing. The Intergovernmental Panel on Climate Change produced an extensive review document in 2001 that describes the most recent scientific data related to climate change from leading scientists around the world entitled, '*Climate Change 2001: The Scientific Basis*'. The most recent evidence on the effects of climate change demonstrating changes in global temperatures, precipitation, sea-levels, global snow cover and ice extent are included in this report. A detailed description of the scientific findings of the IPCC report is outside the scope of the current position paper. However, the main findings of the IPCC report are summarized for the purpose of informing the readers, but it is expected that readers will refer directly to the IPCC documents if a more detailed description of the scientific background of climate change is needed.

For a Canadian perspective on the impacts of climate change, Natural Resources Canada (NRCan) produced a report in 2004 entitled, "*Climate Change Impacts and Adaptation: A Canadian Perspective*" (Warren et al., 2004). The research relied upon in this report is similar to that in the IPCC report, although focused on research relevant to Canadian regions. Little discussion and a lack of research related to First Nations and climate change were found in this report.

Despite normal fluctuations in global temperatures, evidence shows that most of the increases in global temperatures over the last 50 years are attributable to human activities such as the burning of fossil fuels and to land use practices such as deforestation (IPCC, 2001). There is high confidence in available data (67-95% confidence rate by IPCC, 2001) that recent increases in regional temperatures have already started to affect many global physical and biological systems (IPCC, 2001). The use of global models can help predict the possible outcomes of global changes with great certainty but are still not capable of predicting regional impacts with the same degree of confidence. Most researchers indicate that the impacts of climate change vary geographically and are experienced to different degrees depending on regional differences. In Canada, some of these changes include the thawing of permafrost, the retreat of glaciers, changes in the extent of sea, lake and river ice, changes in snow cover, and shifts in the biological ranges of vegetative and animal species (Koshida and Avis, 1997; ACIA, 2004). These and other changes observed with respect to the physical and biological aspects of the climate change are discussed below.

2.6 WHAT CAUSES CLIMATE CHANGE?

2.6.1 A Brief Explanation

The Earth's climate system is complex, interactive, and consists of the atmosphere, the land surface, the hydrosphere (rivers and lakes), the cryosphere (sea ice, ice sheets, glaciers), and the biosphere (where living organisms are supported) (IPCC, 2001). Figure 2-1 represents the components and interactions that exist between them. The balance between incoming solar radiation and outgoing radiation from the Earth's surface controls the earth's climate, and anything that affects this balance of radiation, also affects the Earth's climatic system. A change in the average total radiation because of a change in either incoming or outgoing radiation is called '*radiative forcing*' (Baede et al., 2001)). Positive radiative forcing tends, on average, to warm the Earth's surface, whereas negative radiative forcing tends to cool the Earth's surface. If, for any reason, alterations occur in any of the following factors, a change radiative forcing and climate may occur (also represented in Figure 2-1):

- Changes in the amount of solar radiation entering the Earth's system;
- Changes in the make-up of the atmosphere (e.g. concentrations of certain gases);
- Changes in the hydrological cycle (e.g. precipitation, evaporation);

- Changes in or on the surface of the land which affects outgoing radiation (e.g. deforestation); or,
- Changes in the ocean (e.g. sea-level, circulation or composition).

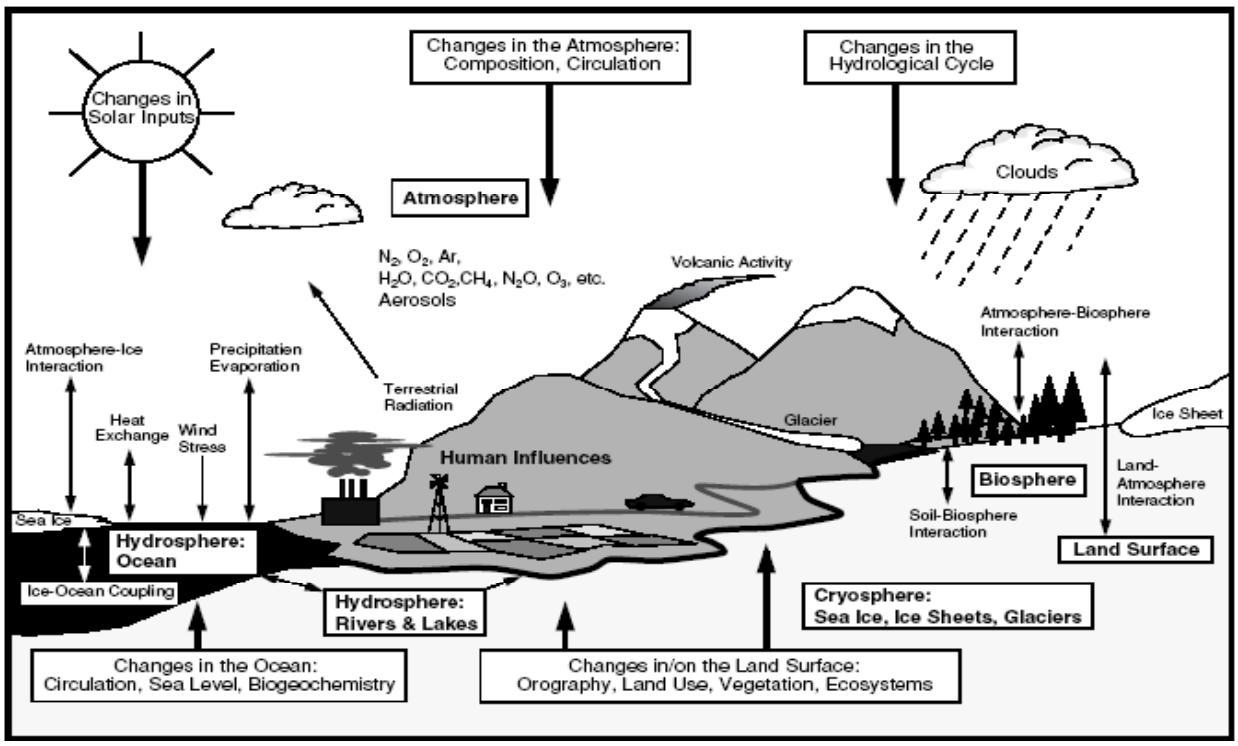


Figure 2-1. The climate system. Components of the system are shown in bold. Thin arrows represent processes and interactions in the climate system and bold arrows represent the aspects that may change in the system (source: Baede et al., 2001).

Radiative forcing caused by anthropogenic, or human-induced factors, such as the production of GHGs from fossil fuel use, is the focus of much scientific research and government policy discussions. Greenhouse gases (GHGs) provide natural insulation for the Earth by absorbing heat from the Earth's surface causing a natural '*greenhouse effect*'. The greenhouse effect helps the Earth maintain a stable temperature and climate. However, activities such as the burning of fossil fuels can have a significant influence on the amount of GHGs produced and stored in the Earth's atmosphere. As concentrations of GHGs, such as carbon dioxide (CO_2), methane, or nitrous oxide increase, additional amounts of outgoing terrestrial radiation are captured by the Earth's atmosphere leading to an enhanced greenhouse effect and a warming

of the surface and lower atmosphere (Baede et al., 2001; Government of Canada, 2005). The impacts of this warming are explained in further detail below.

2.7 PHYSICAL OBSERVATIONS AND IMPACTS

2.7.1 Air

2.7.1.1 Atmospheric changes

> Evidence from long-term data shows that since the Industrial Era (mid-1700s), concentrations of CO_2 have increased by 30% and are still increasing at an unprecedented rate because of human activities. Agricultural practices and other industrial processes are contributing to a 151% increase in methane and a 17% increase in nitrous oxide.

Atmospheric composition has been affected by human activities to a much greater extent than at any point in history since the beginning of the 18th century (IPCC, 2001a). Greenhouse gases (CO_2, methane, nitrous oxide and others) reached their highest measured concentrations in the 1990s. Evidence shows that human activities such as the combustion of fossil fuels, agriculture, industrial processes, and the clearing of forested land have contributed the most to the observed changes in the atmosphere (Ehhalt et al., 2001). Figure 2-2 shows the 1000-year record of the rise in carbon dioxide concentrations due to human activities and the subsequent rise in temperature. Table 2-1 shows the sources and characteristics of some of the most important GHGs affecting climate change.

Additional primary sources of the most recent scientific data related to CO_2 increases in the atmosphere can be found in Chapter 2 (for CO_2) of the IPCC (Folland et al., 2001) report, and in Chapter 4 (Ehhalt et al., 2001) for methane and nitrous oxide as well as for other GHGs.

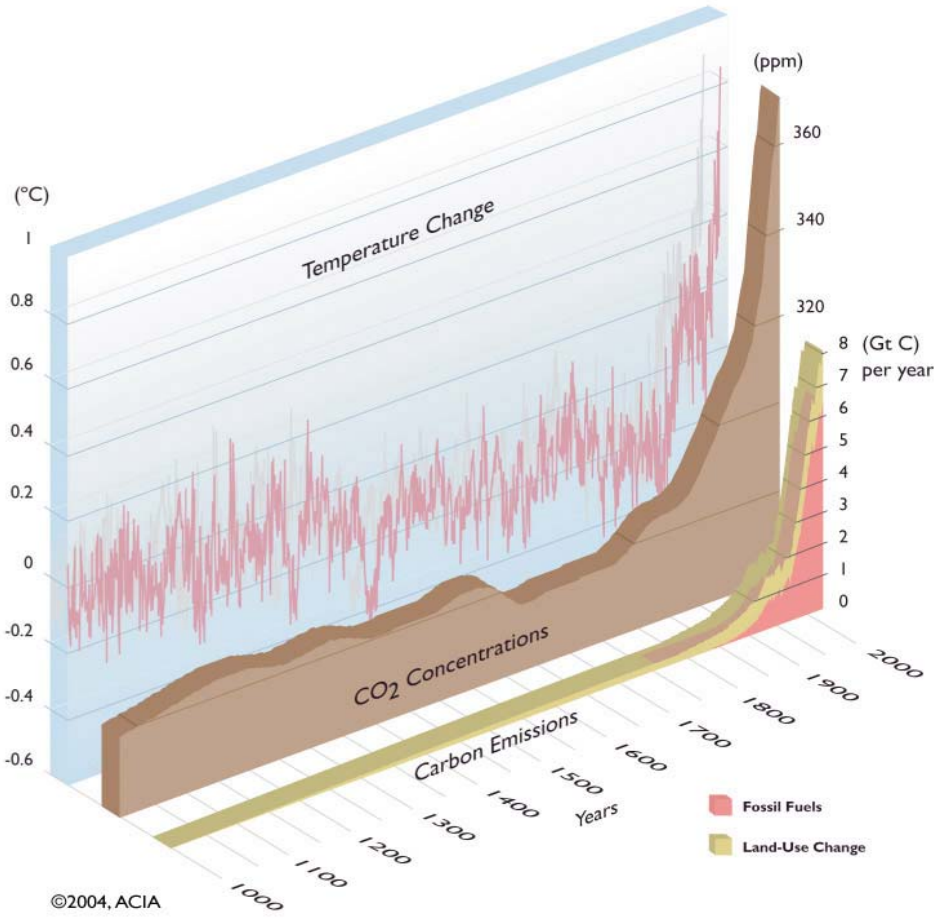


Figure 2-2. Representation of the increase in atmospheric carbon dioxide concentrations and air temperatures due to the rise in carbon emissions from human activities (fossil fuel burning and land clearing) over the last 1000 years (source: ACIA, 2004).

Table 2-1. Common greenhouse gas characteristics and sources in Canada (source: Climate Change Solutions, 2003).

Gas	Chemical symbol	Speed at which concentration in the atmosphere is rising	Lifetime in the atmosphere (years)	Main human sources (Canada)
Carbon dioxide	CO_2	0.4 % per year	50-200	Burning of coal, oil, gasoline, natural gas and wood
Methane	CH_4	0.6 % per year	12	Fossil fuel production, farm animals, landfills
Halocarbons	Various	2 % per year for the most common PFCs[1]	up to 50,000	Aluminium production, coolants in refrigeration/air conditioning
Nitrous oxide	N_2O	0.25 % per year	120	Agricultural soils, nylon production, vehicle emissions

[1] PFC = Perflourocarbon

2.7.1.2 Temperature

> One of the main indicators that the world's climate is changing is the change in global average temperatures. These changes may differ from region to region, however, evidence points to an increase in global average surface temperature over the last 100 years of 0.6 ^{o}C, over sea and land. (IPCC, 2001)

Figure 2-3 shows variations in the Earth's surface temperature for the last 140 years and the last 1000 years. Evidence from the IPCC (2001a) indicates that natural environmental factors, such as volcanic activity and variations in solar radiation do not explain the observed increase in temperatures, whereas human activities account for the majority of the warming (Mitchell et al., 2001). By the year 2100, global temperatures are expected to increase by 1.4 to 5.8 ^{o}C of 1990 levels. The impacts of a temperature increase will have regional impacts, however, not all

regions will be affected in the same way and effects will not be equally distributed. For example, warming in the northern regions of North America is predicted to increase by more than 40% of the global mean average, and in contrast, will be less than the mean global average in southern parts of the globe (Giorgi et al., 2001).

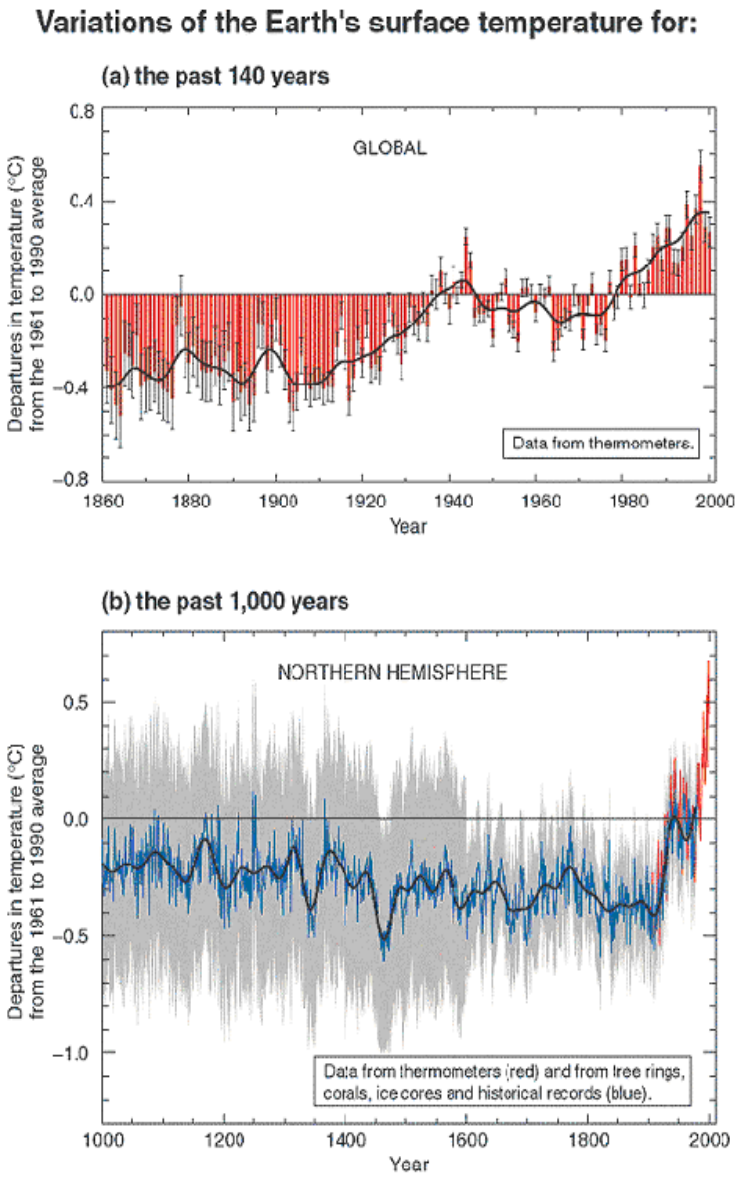


Figure 2-3. Temperature variations in surface temperatures for the last 140 years and 1000 years (source: IPCC – Climate Change: The Scientific Basis, Technical Summary, 2001).

In Canada, there have been increases in the amount of days of extremely high temperature (Warren et al., 2004). It is predicted from models that increases of 5-10 ^{o}C by 2090 are possible for Canada, which is much larger than the global average temperature increase of 1.4 to 5.8 ^{o}C (Environment Canada, 2003). Differences in temperature increase are also predicted for different regions in Canada. Some of these differences, as reported by Environment Canada include:

- A 1 to 4 ^{o}C increase in average temperature in British Columbia in the 21st century;
- A 3 to 5 ^{o}C increase in the Prairie regions;
- A 2 to 6 ^{o}C increase in the Yukon;
- A 5 ^{o}C increase in the Northwest Territories and Nunavut;
- A 2 to 5 ^{o}C increase in Ontario;
- A 4 to 6 ^{o}C increase in Quebec; and,
- A 3 to 4 ^{o}C increase in the Atlantic Provinces.

> In Southern Canada, surface temperatures have warmed by 0.5 to 1.5°C during the past century. Seasonally, warming has occurred the greatest in the summer and spring. Regionally, the greatest warming has occurred in the west (Environment Canada, 2005).

Departures from normal temperatures in the 2005-2006 winter season occurred in several regions across Canada. Although caution must be taken for drawing conclusions from one season's worth of data, Figure 2-4 is interesting in that it illustrates the northern parts of Canada having experienced the highest departures from normal. Canada is particularly vulnerable to the impacts of these predicted temperature changes (Standing Senate Committee on Agriculture and Forestry, 2003; World Wildlife Fund, 2005), and evidence points to the fact that even small differences in temperature can have profound impacts on physical and biological systems. These impacts will be discussed in further sections and in the second report of this series.

> The IPCC assessed the possibility of extreme weather events in the last half of the 20th century and the 21st century and predicted a very likely (i.e., 90-99% chance of occurring) occurrence of increased maximum temperatures and more intense precipitation events.

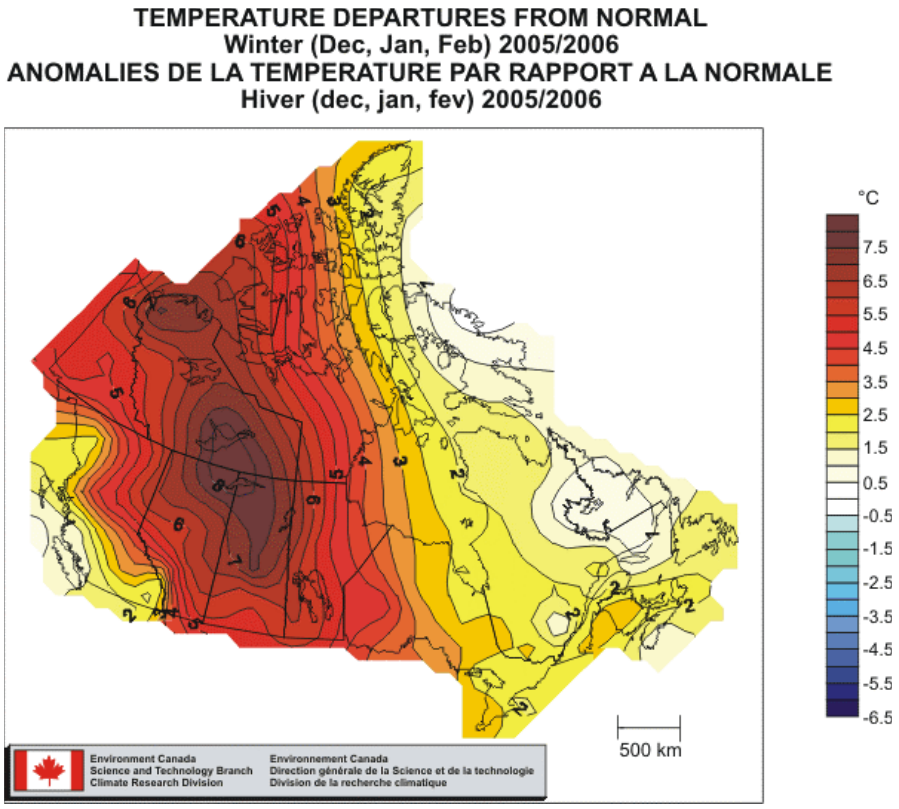
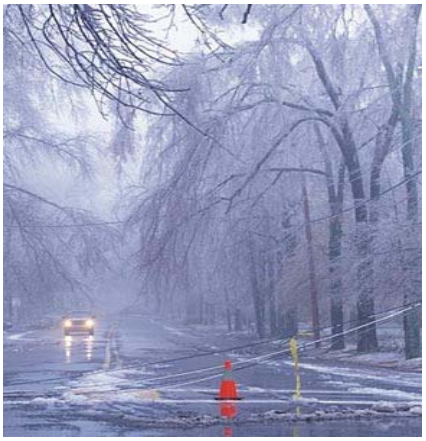


Figure 2-4. Temperature departures from normal in the winter of 2005/2006 (source: Environment Canada, 2006).

2.7.1.3 Weather Events



Extreme Ice Conditions in Manitoba
(Source: Innovation Canada)

Rising average temperatures do not simply mean balmier winters for all regions in Canada. Some regions may experience more extreme heat, while others may experience seasonal cooling. Increases in maximum temperatures and in precipitation may bring about extreme weather events such as drought (Hoffman et al., 1998), flooding (Loukas and Quick, 1999), and more intense storms (ACIA, 2004; IPCC, 2001), which will have physical, biological, social and cultural implications for First Nations and the rest of Canadians. The regional implications for these predicted weather events on First Nations are

discussed in more detail in the second report of this series entitled, '*How Climate Change Uniquely Impacts the Physical, Social, and Cultural Aspects of First Nations*'.

Flooding in Newfoundland
(Source: Environment and Conservation Newfoundland and Labrador)

2.7.2 Water

2.7.2.1 Sea-level changes

In the last 100 years, global sea-levels rose between 10 – 20 centimetres. It is projected that average global sea-levels will rise 10 – 90 centimetres between 1990 and 2100 due to the melting of ice caps and glaciers (IPCC, 2001).

> Rising sea-levels are one of the most commonly recognized potential impacts of climate change and many climate models predict that the rate of sea-level rise will accelerate in many regions in the future (Cohen et al., 2001)

An increase in sea-level will result in increased erosion and a loss of coastal ecosystems, including wetlands and spawning grounds for fish. Increased sea-levels will also impact the infrastructure and safety of coastal First Nations a result of increased risks from storm surges. Vulnerable areas in Canada include the Fraser River Delta, the Beaufort Sea Region, and much of the Atlantic region (Shaw et al., 1998; Environment Canada, 2006; Meteorological Service Canada (MSC), 2005). For example, there are over 30 First Nations in the Atlantic region, over 20 of which are located close to the coast and could be seriously affected by a sea-level rise. Figure 2-5 shows these potentially affected areas. These low-lying areas are extremely

sensitive to flooding from seawater, having ecosystems with salt marshes, barrier beaches, and lagoons that are habitats for many biological species.

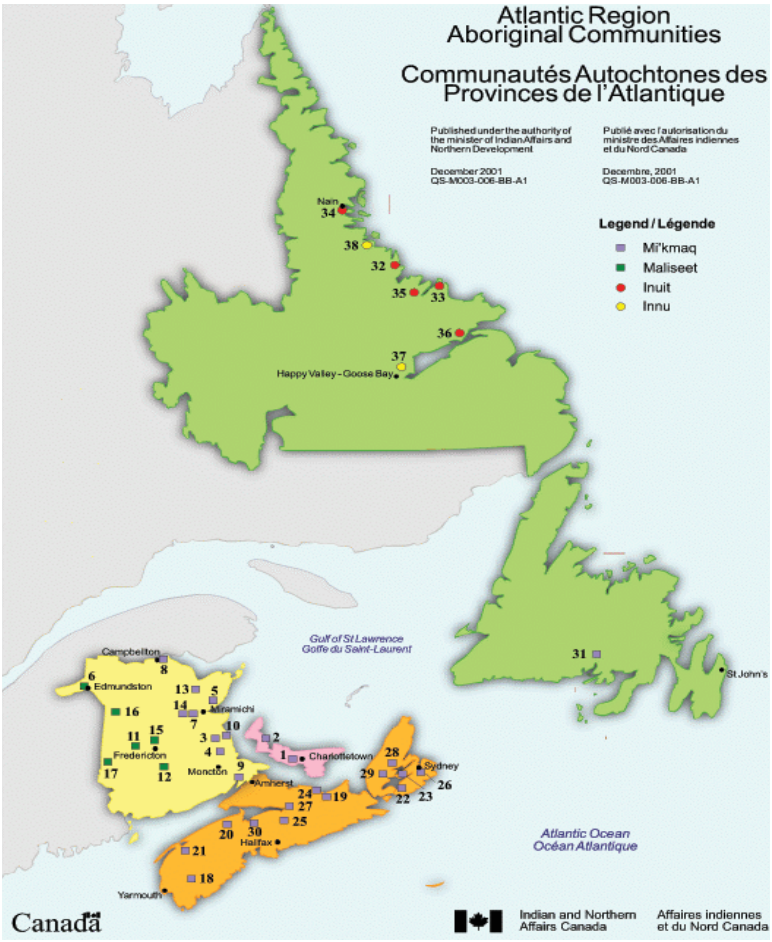


Figure 2-5. Atlantic Aboriginal communities, some of which may be affected by sea-level rise (source: Indian and Northern Affairs Canada, 2006).

2.7.2.2 Water quantity

Precipitation has increased by 0.5 to 1% per decade over the last 100 years over most mid- and high latitudes of the Northern Hemisphere. Precipitation is projected to increase even more in the next 100 years (IPCC, 2001).

The hydrological cycle (i.e. water cycle) is a major component of the climate system. Water availability issues may arise because of the impacts of warming on the water cycle. For instance, as a result of observed temperature increases over lands and oceans, and increased evaporation, increases in precipitation have also been observed. It is likely (60 - 90% chance) that there has been a 2 - 4% increase in heavy precipitation events. Between 1950 and 1998, yearly precipitation totals increased in most parts of Canada by 5 to 35% (MSC, 2005). The largest increases occurred in the central Arctic, where an 8% increase has been observed over the last 100 years (ACIA, 2004). An increase in precipitation along with increased temperatures, may lead to changes in annual flow and levels of rivers and lakes, increased risks of flooding in regional watersheds, and shifts in the composition of bodies of water (Cohen et al., 2001).

Water is a valuable commodity that will be affected by climate. Extreme climate events will affect the quality and quantity of our water. Lower flows of water in lakes and rivers caused by heat waves and droughts can lead to poor water quality and to an increase in waterborne diseases. Surface water is also often contaminated during heavy storms and floods by sewer overflows, and agricultural and urban runoffs (Government of Canada, 2005).

Drought Effects of Climate Change
(Source: Environment Canada)

In the Canadian prairies, one of the major risks of climate change related to water quantity is the projected frequency of droughts (Standing Senate Committee on Agriculture and Forestry, 2003). This will have serious implications for the agriculture sector, and for the vegetative and wildlife habitat in the prairies. In 1998-1999, the Great Lakes region of Ontario experienced low water levels which led to decreased water quality, a reduction in biodiversity, and increased dredging to maintain navigability (Canadian Climate Impacts and Adaptation Network (C-CIARN), 2006). Low levels in the Great Lakes could also affect wildlife and fish habitats, navigation, hydropower, and shoreline stability in this area (Mortsch et al., 2000).

Although the exact impacts of climate change on water quality are hard to determine, deterioration of water quality may affect vegetation and wildlife habitats, and may also affect drinking water quality for humans. This will have serious implications for all Canadians, including First Nation communities in all regions of the country.

2.7.2.3 Water quality

Water quality is affected by changes in temperature, precipitation, evaporation rates and by changes in the flow of streams and rivers in and out of a particular watershed. If water levels decline in lakes and streams, water quality may deteriorate because of their inability to flush out contaminants and other additions from agriculture and wastewater (Cohen et al., 2001). In the Great Lakes regions, increases in temperature have contributed to an earlier ice-cover break-up in the early parts of spring. Water quality is affected in these areas as a result of an earlier bloom of algae growth, which disrupts other processes in the lake throughout the year (Magnuson et al., 1997). Warmer water temperatures may also enable the proliferation of water-borne pathogens carrying infectious diseases, which is a concern for municipal water use and recreational purposes.

Water quality is a concern in the Prairie Provinces as a result of declining surface and groundwater resources due to higher temperatures, melting glaciers, and less snow cover in the Rocky Mountain regions and to higher temperatures (C-CIARN, 2006).

Further discussion of the impacts of climate change on First Nation water issues can be found in the second report in this series[1].

[1] '*How Climate Change Uniquely Impacts the Physical, Social, and Cultural Aspects on First Nations*'

2.7.2.4 Ice Cover

Increasing temperatures have affected the extent of large masses of ice in the Arctic. They have also affected the seasonal duration of ice cover and the depth of ice on lakes, rivers, and in the ocean.

As mentioned above[2], sea ice in the Arctic is melting as a result of average higher temperature. Over the last 30 years, the extent of annual average sea ice in the north has decreased by 8%, and in the summer, losses of late-summer ice coverage ranges between 15 and 20%, which is much higher than the annual average. Some models project that summer sea ice will decline by greater than 50% by the end of this century (IPCC, 2001; ACIA, 2004). In addition, evidence indicates that the depth of sea ice has decreased by 40% during late summer and early autumn between the 1960s and late 1990s (ACIA, 2004). Figure 2-6 shows the projected changes in the extent of sea ice cover in the Arctic to 2090. The decline in depth and coverage of sea ice will undermine the survival of wildlife such as the polar bear, seal and the walrus. Animals will have to travel to different areas to seek food if the sea ice moves or disappears. This will make it difficult for First Nation hunters who depend on the sea ice as a means to safely hunt these and other animals. A decline in sea ice accelerates warming in the Arctic because as snow and ice melts, the land becomes exposed. Land is darker than the snow and ice, and as a result, it absorbs more of the sun's energy. As the land warms, it helps to accelerate the melting of ice and snow and the cycle of warming continues. This regional warming helps to accelerate warming at a global scale as well (ACIA, 2004).

'*A 150-year trend in 26 lakes and rivers in the northern hemisphere averaging 9 days later freeze and 10 days earlier ice break-up has resulted from a 1.8 ^{o}C increase in air temperature*.' (Gitay et al., 2001)

[2] In section 4.3.2.1.

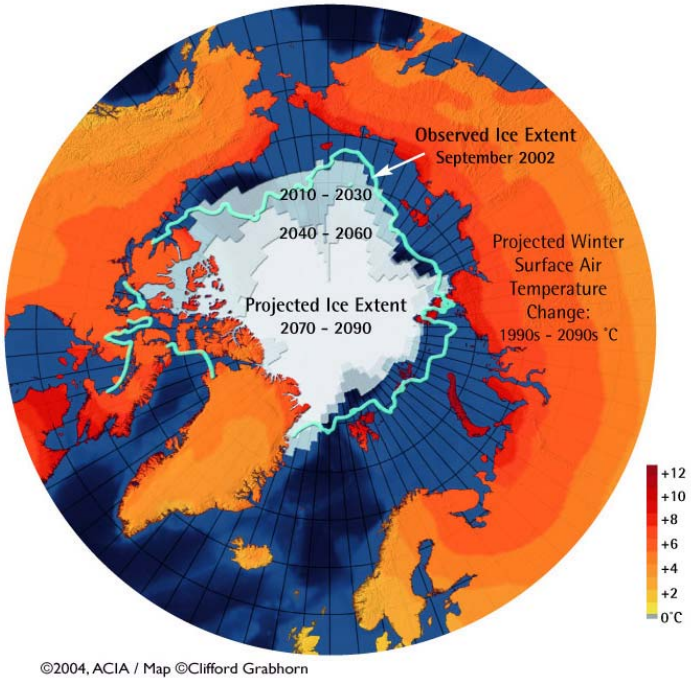


Figure 2-6. Projected changes in the extent of sea ice cover in the Arctic (source: ACIA, 2004).

Increasing temperatures have already begun to affect the duration of ice cover on lakes and rivers in Canada (Magnuson et al., 1997; ACIA, 2004). The IPCC reports that there has been a reduction of about two weeks in the annual duration of lake and river ice over in the northern hemisphere, with the strongest trends in North America and Eurasia (IPCC, 2001). Reduced ice cover will affect oxygen levels depending on an increase or decrease in water temperature, which will have negative implications on the biological life forms in these habitats. For example, as water temperatures rise, dissolved oxygen levels may decrease thus allowing favourable conditions for bacteria to overpopulate certain areas.

A reduction in ice cover is a concern for many First Nations because it could negatively affect their ability to transport goods and services to the community by winter road. Additionally, First Nations who rely on ice cover to travel for their subsistence economies will also be negatively impacted.

2.7.2.5 Melting of Glaciers

Glacier melting is already occurring in British Columbia and the Canadian Arctic, as well as in other parts of the world (Figure 2-7) (Brugman et al., 1997; ACIA, 2004). In British Columbia, the Rocky Mountains have approximately 1300 glaciers, which, by many estimates, have lost 25-75 per cent of their mass since 1850 (Environment Canada, 2000). Studies show that the reduction in these glacier areas is reducing the amount of water in the Saskatchewan-Nelson River Sub-Basins. The period from August to December is of significance as decreased water levels during this time impacts the spawning of several species of fish such as the endangered Bull Trout (Environment Canada, 2005).

Figure 2-7. Picture of Wedgemount Glacier showing glacial retreat between 1978 and 1998 (source: Canadian Council of Ministers of the Environment, 2003).

2.7.3 Land

2.7.3.1 Terrain stability

> '*Permafrost has warmed by up to 2 ^{o}C in recent decades, and the depth of the layer that thaws each year is increasing in many areas. Permafrost's southern limit is projected to shift northward by several hundred kilometres during this century.*' (ACIA, 2004)

Permafrost is the permanently frozen layer of soil found in northern portions of Canada. Increasing temperatures have already started to affect the depth of permafrost, but with increased warming, permafrost degradation is expected to occur over 10-20% of the present permafrost area in Canada (ACIA, 2004). This may cause landslides, slumping and other

physical changes on the land (Aylsworth and Egginton, 1994; Dyke et al., 1997). Melting permafrost is expected to cause damage to current and future buildings and infrastructure and increase the costs of construction and maintenance of roads in the north (ACIA, 2004; Government of Canada, 2005). Increasing temperatures may also affect vegetation species that grow and insulate permafrost, which will lead to an increased warming and disappearance of permafrost in certain areas. Water that is stored in ponds, streams, and wetlands on permafrost may be threatened as it melts. As the water from these systems comes into contact with the land and groundwater underneath the permafrost, they risk drainage into underground systems (ACIA, 2004). The drainage of these water bodies threatens the migration patterns of bird and wildlife species and therefore, also threatens the traditional hunting grounds of First Nations in these areas, and threatens infrastructure stability.

2.7.3.2 Soil erosion

The hydrological cycle (e.g. water cycle) has the greatest impact on soil erosion. The effects of climate change on precipitation levels are mentioned in section 4.2.2.2, with areas receiving more or less average precipitation per year depending on location. Areas receiving more average precipitation, with potentially intense storms, are especially vulnerable to water-induced soil erosion. This may lead to problems such as landslides and the loss of soil nutrients and vegetation.

Soil erosion by water
(Source: Agriculture Canada)

> Climate change will affect soil erosion caused by both water and wind, especially in areas with dryer, warmer climates and with sparse vegetation cover.

In areas where less precipitation is predicted with increasing temperatures with drought-like conditions, wind erosion may become a serious problem. The areas most at risk in Canada are the southern and central Prairies and the southernmost part of Ontario (Natural Resources Canada, 2005). The erosion of soil has implications for the agriculture and forestry sectors in Canada (Standing Senate Committee on Agriculture and Forestry, 2003), which will affect First

Nations who depend on these sectors across the country. Further discussion of these impacts on First Nations will be discussed in further sections and in the second report of this series.

2.7.3.3 Coastal erosion

> Coastal erosion and flooding due to sea-level rises caused by climate change will affect many aspects of coastal communities including, emergency preparedness, infrastructure, economies, and tourism.

Shoreline retreat in Prince Edward Island
(Source: Heidi Glaesel
(http://www.elon.edu/geo/carolina_beach.htm))

Rising sea-levels (discussed in section 2.2.2.1) are responsible for observed coastal flooding and erosion in areas such as coastal British Columbia, the Arctic, the Great Lakes Basins, and in the Atlantic provinces (Climate Change Impacts and Adaptation Research Network (C-CIARN), 2006). The specific impacts of sea-level rise on coastal erosion are still not known, prompting studies (currently underway in the Atlantic region) by provincial and federal government departments, universities and communities to look at the impacts of sea-level rise on coastal communities in New Brunswick (C-CIARN, 2006; Environment Canada, 2005). Coastal erosion can affect coastal stability, especially in low-lying areas that have soft sediment shores. It can also cause damage to existing infrastructure in coastal First Nations and may also affect archaeological or cultural resources that are located in coastal areas. The Climate Change Impact and Adaptation Network focuses some research on the impacts of climate change on coastal areas in Canada. It is important that First Nations be provided with the opportunity to voice their concerns about the impacts of climate change in order to be effectively involved in proposed adaptation strategies for these types of coastal impacts.

2.7.3.4 Ecosystem disruption

The observed and predicted impacts of climate change on temperatures and precipitation will have implications for terrestrial and aquatic ecosystems in Canada and throughout the world. The projected impacts on land and water ecosystems, which are habitats for birds, wildlife and

Animals in pasture.
Source: University of Moncton

vegetation are extensive and vary from region to region. For instance, some studies predict that increasing temperatures may help to move land suitable for agriculture northward, which may expand economic opportunities for landowners (Mills, 1994). Other studies predict changes in the forest ecosystem in Canada due to increased temperatures, although most scientists are uncertain whether this will result in increased or decreased productivity depending on factors such as increased forest fires and higher insect infestations (Standing Senate Committee on Agriculture and Forestry, 2003). The impacts of climate change for global ecosystems are reviewed extensively by the IPCC in Chapter 5 (Gitay et al., 2001) of the report entitled, ' *Climate Change 2001: Impacts, Adaptation, and Vulnerability*' (IPCC, 2001) and in Chapter 15 (Cohen et al., 2001) of the same report for North America specifically. The impacts, adaptations and vulnerabilities for the following ecosystems are included in IPCC review:

- Agricultural ecosystems;
- Rangelands (grasslands, savannas and deserts);
- Forests and woodlands;
- Lakes and streams;
- Inland wetlands; and
- Arctic and alpine ecosystems.

While the impacts of climate change for some Canadian ecosystems have been referred to in previous sections, it is outside the scope of the current report to list all of the impacts of climate change in every ecosystem in Canada and the implications for biological species within them. It is recommended that the scope of the possible impacts of climate change on biological systems be the focus of a future and separate report if one is deemed beneficial for the issue of climate change and its effects on First Nations. A brief summary of the issues is provided below.

'*Ecosystems are subject to many pressures (e.g., land-use change, resource demands, population changes); their extent and pattern of distribution is changing, and landscapes are becoming more fragmented. Climate change constitutes an additional pressure that could change or endanger ecosystems and the many goods and services they provide*'. (Gitay et al., 2001)

The fifteen ecosystems in Canada are represented in Figure 2-8. First Nations are located throughout these ecosystems and are often dependent on natural resources located within them. It is important to mention that the ecosystem most vulnerable in Canada is the Arctic due to the impacts that a warming climate will have on aspects such as ice and snow cover, permafrost depletion and, sea-level rise. However, all fifteen ecosystems will be uniquely affected due to regional variability due to climate change. For example, climate change will seriously impact the ability to grow high-yield crops in the Prairie regions of Canada because of potential drought-like conditions, whereas the Boreal areas of Canada may be more affected by the threats of forest fires due to droughts. Interior British Columbia (the Montane Cordillera in Figure 2-8) may be affected by increases pest outbreaks due to a warmer climate but may also experience higher vegetative productivity because of the warmer temperatures. The IPCC report mentions the importance of specific characteristics of ecosystems to Indigenous peoples in the world, including subsistence hunting and the cultural and religious importance of animals, however, most of the discussion centers around the effects of climate change on the Indigenous peoples in the Arctic. The second report in this series[3] discusses regional ecosystem impacts as they specifically relate to northern First Nations as well as First Nations located south of 60^{o} parallel.

[3] The second report in this series is entitled, 'How Climate Change Uniquely Impacts the Physical, Social and Cultural Aspects of First Nations'

Figure 2-8. The fifteen ecozones of Canada (source: Canadian Council on Ecological Areas (CCEA), 2006).

2.8 BIOLOGICAL (WILDLIFE, BIRDS, INSECTS AND VEGETATION)

Yellow Ladyslipper
(Source: Katharine Cherewyk, CIER)

The IPCC (Chapter 5 – IPCC, 2001) reviewed over 2500 studies that demonstrated a link between climate change and biological or physical processes. These studies were narrowed to 60 for the purposes of helping the IPCC view trends that exist between increasing temperatures and its effect on biological and physical systems. Sixty-one percent (61%) of biological species (plants, birds, reptiles, insects, mammals) and processes (such as earlier ice off and freeze up of lakes and streams) reviewed showed significant changes related to a temperature increase.

The World Wildlife Fund (WWF) recently studied the implications of a global 2 ^{o}C temperature rise on Canada's natural resources (2005). Their study focused on marine species in the Northwest Atlantic and on tree species in the Boreal forest of Ontario. They predicted changes in the distribution and abundance of certain fish and shellfish species in the Atlantic as well as a species and distribution shift of certain tree species in the Boreal region. In some areas, climate change may decrease the viability of fish populations through the alteration of habitats and biophysical changes to the marine/freshwater environment. In other areas, predictions indicate that there may be increases in the abundance of certain aquatic species. First Nations reliant on a particular species of fish for the subsistence or income-generating economies will be affected culturally and economically as a result of these changes. The Arctic Climate Change Impact Assessment (ACIA, 2004) similarly observed and predicted changes to biological species as a result of climate change in the north. The ACIA reported that some species of birds, fish and butterflies have already started to relocate as southern species move north and predicted that some seabirds, mosses and lichens will likely decline as warming increases. Migratory species such as the woodland caribou and reindeer are particularly vulnerable to climate change and are becoming increasingly stressed as their habitat becomes altered (ACIA, 2004; Brotton and Wall, 1997). The Woodland Caribou's major food source consists primarily of lichens, as well Woodland Caribou will forage shrubs, grasses, and willows. The Woodland Caribou's food source is negatively impacted by changing weather patterns, for example an increase in snow depth during the winter makes it harder for Woodland Caribou to paw through the snow and thin ice layer reducing the availability of food. The Woodland Caribou migrate mainly to avoid predators and deeper snow causes the Caribou to get trapped, making them easier prey. Weather conditions such as deeper snow, warmer falls, warmer summers, and earlier spring break-up will have a negative impact on the migrating caribou causing dangerous traveling conditions, for example crossing the ice during the winter will be more dangerous (Environment Canada, 2006). Some of the other possible impacts on biological systems were reviewed by Gitay et al. (2001) and are listed in Text Box 4-1.

Some of the possible effects on biological systems related to climate change include:

- Changes in the distribution of species;
- Changes in the seasonal processes of biological species and seasonal events;
- Northward shift of aquatic and land species;
- Changes in the structure of plant communities;
- Increases and decreases in the productivity of ecosystems;
- Changes in the cycling of nutrients in a system;
- Increases in diseases, pests, and insect infestations;
- Changes in ecosystem boundaries; and,
- Changes in the migratory patterns of species.

(Gitay et al., 2001)

Text Box 2-1. Possible impacts of climate change on biological systems (source: Gitay et al., 2001).

Many of the biological species affected by a warming climate are traditional food, medicinal plants, and sacred species to First Nations in Canada. The effects of climate change on these species will affect the health, economy, and livelihood of First Nation people. These issues will be discussed in detail in following two reports in this series.

3.0 CONCLUSION

4.0 REFERENCES

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