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Climate Change Impacts on Water Affecting Key Natural Resource Industries in Canada: Issue Scan

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Water, Climate Change and Natural Resources: Issue Scan

"Water will be the delivery mechanism for the impacts of climate change."
Kathy Jacobs, Director, Arizona Water Institute, chair of the recently announced US National Academies study on Adapting to the Impacts of Climate Change.2008

"We predict that in the near future, climate warming, via its effects on glaciers, snowpacks, and evaporation, will combine with cyclic drought and rapidly increasing human activity in the [western prairie provinces] to cause a crisis in water quantity and quality with far reaching implications.
Schindler and Donahue 2006.

"Adaptation to changing conditions in water availability and demand has always been at the core of water management. Historically, water management has concentrated on meeting the increasing demand for water. ..Traditionally, hydrological design rules have been based on the assumption of stationary hydrology, tantamount to the principle that the past is the key to the future. This assumption is no longer valid." *Intergovernmental Panel on Climate Change, Kundzewicz et al, 2007, 196*

1. Introduction

Most Canadians will first see the impacts of a warmer and more variable climate through changes to water. Rapidly diminishing glaciers, more droughts, earlier spring runoff, and reduced snowpacks are more visible than the projected gradual increases in mean temperatures. Scientists are increasingly sounding the alarm on this issue, as the quotes above illustrate.

Foremost among the numerous impacts from climate change will be significant and pervasive changes on Canada's water resources. Future scenarios forecast increased competition for water as a likely outcome of current Canadian water usage patterns coupled with climate change: "Growing populations and economic activity will lead to increasing demands, and competition, for resources. At the regional scale, perhaps the most important of these resources is water… One of the major implications of increasing water use is an increase in water stress. " (Stratos and IISD, 2007).

Water-stressed[1] areas will likely expand due to decreased runoff as a consequence of changes in precipitation and increased evapotranspiration. Seasonal reductions in water quality and quantity will become more common in every region of Canada, accompanied by increasing demands on water resources for agriculture, energy production, communities and recreation, often in competition with ecosystem needs (Lemmen, Warren and Lacroix, 2008). The changes will affect the supply of essential and undervalued ecosystem services provided by water, and will also affect the natural resource sectors of energy, mining, forestry and agriculture which are a vital part of the Canadian economy.

This issue scan looks at the relationships between climate change, water and four Canadian natural resource sectors and examines trends, potential impacts and vulnerabilities.

The scan reveals 4 key messages:

1. The effects of climate change on quantity and quality of Canada's water resources will be profound:
    - Impacts on precipitation will occur,

[1] Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. 'Water stress' is a term also used to describe a quantifiable threshold of water available per person.

- Changes in temperature will affect water temperatures and ecosystem functions,
- Changes in temperatures will also affect demand, drier hotter summers and increase in extreme events such as droughts will increase overall summer use and increase peak demand periods,
- Weather extremes such as floods and extreme storms are increasing,
- Glaciers are melting at an accelerating rate, adding water to flows now, with diminishing future flow predicted,
- Greater snow pack variability will become more evident, and
- Groundwater recharge for shallower unconfined aquifers will be affected.

2. Water will constrain future development in the Canadian energy, agricultural, forestry and mining sectors, with potentially serious economic impacts.

Not only will all these resource sectors face direct water availability concerns due to climate change, they will also potentially face further limitations related to the increasing need to ensure enough water is left to maintain basic ecosystem needs and services, and mitigation of cumulative impacts.[2] Water quality will also suffer as a result of climate change, with corresponding impacts on the identified sectors.

3. Adaptation and mitigation of these impacts are in the early stages in Canada.

Many agencies, businesses, NGOs, and researchers have programs examining the interrelationships between water, climate change and Canada's resource sectors. A significant amount of information and research exists regarding the coming changes, though determining the specific impacts from the global phenomenon of a changing climate at the watershed scale is not yet possible. Translating scientific information into a form that is usable for policymakers remains a challenge. Specific proposals for reform to address the challenges are few in number.

4. A mix of policy responses will likely be necessary to achieve the goals of mitigation and adaptation for the four water dependent resource sectors including:
    - "No Regrets" strategies that should include efforts to reduce emissions by reducing water use. For example, reduced water use through efficiency and conservation can mitigate climate change as building, operating and maintaining more infrastructure (such as dams, pumps, pipes, and wells) requires greater use of fossil fuels. Identifying how each natural resource sector can achieve greater efficiency in water use should be a priority.
    - Economic instruments such as markets and appropriate full cost pricing have a role to play, though these instruments are a complement to rather than an alternative to regulation.
    - Voluntary industry programs to increase water efficiency are a useful option, and increasingly common, however further incentives are needed,
    - Water law reform is a potentially critical element, in particular regulations to require efficiency and conservation, ensure provincial water allocation laws have enough adaptive capability in times of increasing water stress, and make certain that environmental assessment laws account for climate change.

[2] Numerous trends threaten the health of Canada's waters including overuse and waste, inefficiency, a rate of diversions among Canadian drainage basins that is unmatched in the world; effects on ecosystems from dam installations and removals; significant alterations to the hydrological cycle and increasing demands on provision on water services from growing urbanization; industrial demands and impacts; and natural hazards such as flooding. All these threats combine to produce cumulative impacts, which are often not adequately assessed, or their effects sufficiently mitigated. (Environment Canada 2004).

- National leadership is also essential. Canada lacks comprehensive plans on climate change mitigation and adaptation, and water efficiency and conservation. Experts agree that a change in the water paradigm is needed (e.g., Gleick 2000).
- Water governance reform is needed to enable the economic and legal reforms mentioned, as effective governance of water is impeded by the fragmented responsibilities, institutions and regulations for water management.

2. Key Trends and Issues

Research on the impacts of climate change on water resources continues to expand, ranging from reports from the scientists on the Intergovernmental Panel on Climate Change (IPCC), to assessments led by Natural Resources Canada, to locally led watershed forecasts and plans.

All these efforts have a common message: the future impacts of a changing climate on water resources are difficult to precisely quantify, but require urgent attention from policymakers now.

Global Trends- Water and Climate Change

Key Messages - Executive Summary, IPCC "Water Resources" Chapter, Kundzewicz et al, 2007

The impacts of climate change on freshwater systems and their management are mainly due to the observed and projected increases in temperature, sea level and precipitation variability (very high confidence).

Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater (high confidence).

Higher water temperatures, increased precipitation intensity, and longer periods of low flows exacerbate many forms of water pollution, with impacts on ecosystems, human health, water system reliability and operating costs (high confidence).

Adaptation procedures and risk management practices for the water sector are being developed in some countries and regions (e.g., Caribbean, Canada, Australia, Netherlands, UK, USA, Germany) that have recognised projected hydrological changes with related uncertainties (very high confidence).

The negative impacts of climate change on freshwater systems outweigh its benefits (high confidence).

The brackets indicate how likely the impact is, in the opinion of the IPCC expert authors.

In 2007 the IPCC amplified the findings on water and climate change from its earlier 2001 report:
• There are apparent trends in streamflow volume, both increases and decreases, in many regions.
• The effect of climate change on streamflow and groundwater recharge varies regionally and

between scenarios, largely following projected changes in precipitation.
• Peak streamflow is likely to move from spring to winter in many areas due to early snowmelt, with lower flows in summer and autumn.
• Glacier retreat is likely to continue, and many small glaciers may disappear.
• Generally, water quality is likely to be degraded by higher water temperatures.
• Flood magnitude and frequency are likely to increase in most regions, and volumes of low flows are likely to decrease in many regions.
• Globally, demand for water is increasing as a result of population growth and economic development, but is falling in some countries, due to greater water-use efficiency.
• The impact of climate change on water resources also depends on system characteristics, changing pressures on the system, how the management of the system evolves, and what adaptations to climate change are implemented.
• Unmanaged systems are likely to be most vulnerable to climate change.
• Climate change challenges existing water resource management practices by causing trends not previously experienced and adding new uncertainty.
• Adaptive capacity is distributed very unevenly across the world.

And the changes reported by the IPCC are accelerating faster than predicted in terms of shrinkage of the Arctic ice caps, sea level rises, and melting alpine glaciers and evaporating snow cover.[3]

Canadian Trends- Water and Climate Change

From Impacts to Adaptation: Canada in a Changing Climate 2007- Key Points

The impacts of changing climate are already evident in every region of Canada.

Climate change will exacerbate many current climate risks, and present new risks and opportunities, with significant implications for communities, industry, infrastructure and ecosystems.

Climate change impacts elsewhere in the world, and adaptation measures taken to address these, will affect Canadian consumers, the competitiveness of some Canadian industries, and Canadian activities related to international development, aid and peace keeping.

Resource-dependent and Aboriginal communities are particularly vulnerable to climate changes. This vulnerability is magnified in the Arctic.

Integrating climate change into existing planning processes is an effective approach to adaptation.

Barriers to adaptation action need to be addressed, including limitations in awareness and availability of information and tools.

Lemmen, D.S.,Warren, F.J. and J. Lacroix. (2008): Synthesis, *edited by* D.S. Lemmen, F.J.Warren, J. Lacroix and E. Bush; Government of Canada, Ottawa, ON, p. 1-20. (extracted from Key Points, pg 3)

[3] . Ben Block, Jan 14, 2009 , "Climate Change Outpaces Predictions", Worldwatch Institute online, at http://www.worldwatch.org/node/5990?emc=el&m=188242&l=8&v=12e976d3dd

There is no dearth of information about climate change and water in Canada, ranging from the Canada Country Study in 1998, to the 2004 NRCAN report which concluded that changes to water recharge patterns and depletion of groundwater supplies in shallow unconfined aquifers were potential results of climate change [4] to the most recent assessment in 2007: " Gradual changes in average temperature, precipitation, and sea level also affect community and ecosystem sustainability. Some of the most significant and pervasive impacts in Canada will be related to water resources. these impacts…are mostly adverse and are expected to continue and intensify in the future" (Lemmen et al, 2007, 7).

Regional Differences
There is no single answer to the question of how climate change will affect Canadian water resources, due to the fact that Canada is a "vast country with great variability between and within regions in terms of climate, landscapes, communities and economy". A summary of key findings from each region described in the most recent 2007 assessment from Natural Resources Canada, is attached as Appendix 1.

As an example of regional impacts and variations, the evidence for the province of BC shows that the climate is already changing, and several hydrological resources are projected to be at risk in the future. Warming trends across BC are consistent with global trends but larger. Precipitation trends are also generally positive, but spatially variable across the province. However, in the most recent periods (the last 50 years), some precipitation trends are negative. … Hydrologic impacts of a changing climate include significant decreases in snowpack, retreating glaciers, changes to streamflow timing and magnitude, and earlier lake ice break-up along with shorter lake ice duration. … Important changes in projected surface conditions will also change the soil moisture and evaporation feedbacks to the climate system, but quantitative estimates are not available. (PCIC, 2007, at 135)

An even more local example comes with more certainty about the projected impacts: "The Okanagan region in British Columbia, Canada, is a semi-arid watershed of 8,200 km2 area. The region's water resources will be unable to support an increase in demand due to projected climate change and population growth, so a broad portfolio of adaptive measures will be needed. Irrigation accounts for 78% of the total basin licensed water allocation." (Kundzewicz et al, 2007, at 194)

Observed Impacts of Climate Change on Canada's Water Resources
While the exact nature of the changes cannot be predicted with any degree of certainty, there is scientific consensus that change will occur. Climate variability and change will affect groundwater, rivers and streams, lakes and reservoirs, wetlands, and the cryosphere in different ways (Environment Canada. 2004).

The following impacts on water resources have already been observed in Canada.

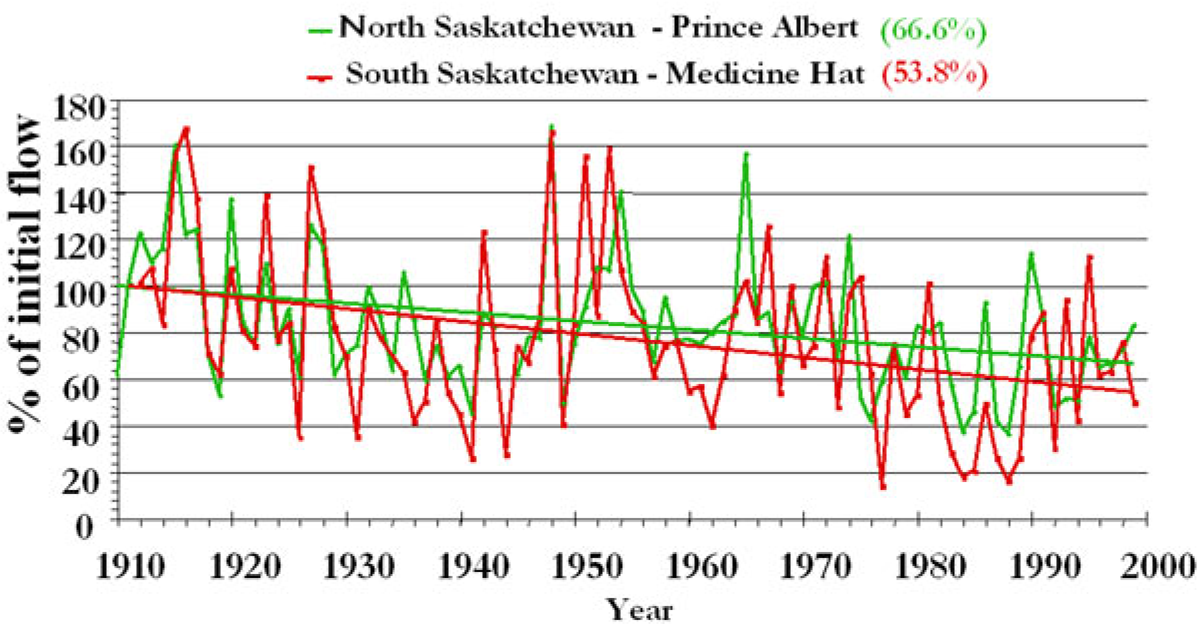
- *Glacier cover* has been declining (in both mass and area). In Canada's Arctic an estimated 25km³/a of ice mass has been lost from 1995-2000. BC's glaciers are currently retreating "at rates unprecedented in the last 8,000 years" (Lemmen et al, 2008, 9).

[4] "Water Resources." *Climate Change Impacts and Adaptation: A Canadian Perspective* (Ottawa: Natural Resources Canada, 2004.)

The Athabasca Glacier, in 1917 (left), and ~2000 (right)

The Athabasca Glacier in the Columbia Icefields of Banff National Park. The picture on the left was taken in 1917, while the one on the right was taken quite recently. This glacier loses 16,000,000 cubic metres of ice each year. Agriculture in southern Alberta depends largely on irrigation, and glaciers help by holding snowfall and slowly releasing it during summer months. When the glaciers disappear, river flows will be higher in the spring, but lower in later summer. This could have a significant impact on irrigation in southern Alberta. The ecology of the rivers will also be greatly affected. *Graphic from* http://www.ualberta.ca/ERSC/water/climate/impacts1.htm

- *Snow cover* has diminished in both area and duration. For the period 1972-2003 there has been a 10% reduction in snow cover over the Northern Hemisphere. Since 1950 there has been a loss of 20 days in the annual duration of Arctic snow cover.
- *Sea-, lake-, and river-ice cover* has reduced extent and duration.
- *Permafrost* has been warming, particularly in the western arctic, while the annual summer thaw has been deepening.
- *River & lake levels* have been changing due to variations in runoff and earlier spring peak flow events.



At Saskatoon, Saskatchewan, the flow of the Saskatchewan River has dropped to 20% of that at the beginning of the 20th century. Summer flows are very ecologically important, for such things as fish spawning and rearing, and riparian sustenance. They also provide water for human uses such as irrigation. Graphic from http://www.ualberta.ca/ERSC/water/climate/impacts4.htm

- *Coastal erosion* is increasing due to a combination of climatic changes (less ice-cover, sea-level rise, storm severity) and non-climatic factors (development, etc.).

- *Higher temperatures mean greater evaporation* Evidence of increasing temperatures, lower precipitation, and greater evaporation has already been noticed in many places of Canada.

All of these observed changes point to a general decline and greater annual uncertainty in Canada's water supply.

Scientists also note that multi-factor impacts may interact nonlinearly, leading to tipping points, and it is critical to recognize the potential for interactions among climate change impacts and with other kinds of local, regional and global changes (Field et al 2007).

Likelihood of Additional Future Changes
In addition to these already observed changes, future changes are highly likely:

- changes can be anticipated in the timing, volume, quality and spatial distribution of freshwater available for human settlements, agriculture and industrial users in most regions of North America.
- Some studies project widespread increases in extreme precipitation, but also droughts associated with greater temporal variability in precipitation.
- In general, projected changes in precipitation extremes are larger than changes in mean precipitation.
- Warming and changes in the form, timing and amount of precipitation will be *very likely* to lead to earlier melting and significant reductions in snowpack in the western mountains by the middle of the 21st century. In projections for mountain snowmelt-dominated watersheds, snowmelt runoff advances, winter and early spring flows increase (raising flooding potential), and summer flows decrease substantially. Hence, over-allocated water systems of the western USA and Canada that rely on capturing snowmelt runoff could be especially vulnerable, as are those systems that rely upon runoff from glaciers. (Bates et al. IPCC 2008, p 102, references to IPCC Working Group chapters omitted)

Climate Change Impacts Add Extra Stress in Areas of Greatest Existing Water Stress

In Canada, the areas of greatest existing water stress in the southern Prairies, southern and interior of BC, and the Great Lakes regions, are likely to face some of the greatest impacts from climate change.

(Potential Graphics for this section if they can be obtained as jpgs)
Figure 3.5: Water Use and Availability Ratio, by Drainage Area
The most significant water availability pressures in Canada are in the southern prairie region. The southern prairie region already experiences severe soil moisture deficits during most summers and has experienced long-term drought conditions. The map in Figure 3.5 illustrates the proportion of surface freshwater that is used by Canadians within each of Canada's major drainage areas. Although responsible for only 14% of total water intake, the South Saskatchewan, Missouri and Assiniboine-Red and the North Saskatchewan river basins have the

highest ratios of water intake to stream flow. Water flows in this watershed are already fully allocated. In southern Alberta and Saskatchewan, agricultural withdrawals are highest for irrigation where water supplies are lowest.
http://www.tdds.ca/default.asp?lang=En&n=C44E69C2-1&offset=1&toc=show

Figure 3.5: Water Use and Availability Ratio, by Drainage Area The water use to availability ratio map identifies what proportion of renewable fresh water is used by Canadians within each of Canada's major drainage basins. The South Saskatchewan, Missouri and Assiniboine-Red and the North Saskatchewan river basins meet the Organization for Economic Co-operation and Development (OECD) threshold for a "stressed watershed." A stressed watershed is defined by the OECD as a watershed in which more than 40% of the available renewable water within the watershed is used for human uses. According to the OECD, at least 60%of renewable flows are required to maintain a healthy, functioning ecosystem. However, ecosystem water requirements are not well understood and vary depending on the ecosystem. **Source:** Statistics Canada. Environmental Accounts and Statistics Division. See Annex C.6 for data table.
http://www.tdds.ca/default.asp?lang=En&n=C44E69C2-1&offset=1&toc=show

3. The Resource Sectors and Changing Water Availability

General Economic Impacts

The international community is increasingly emphasizing the enormous economic consequences of the impacts of climate change.

Box
Stern Review, The Economics of Climate Change, 2006

The 700 page report of Sir Nicholas Stern , The Economics of Climate Change, released Oct 30, 2006, commissioned by the UK government is the best known report on the economic impacts of climate change. It concludes that the benefits of strong and early action on climate change far outweigh the economic costs of not acting.

The evidence shows that ignoring climate change will eventually damage economic growth. The report states that the global community's actions over the coming few decades could create risks of major disruption to economic and social activity, later in this century and in the next, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be difficult or impossible to reverse these changes.

- The earlier effective action is taken, the less costly it will be.
- the less mitigation we do now, the greater the difficulty of continuing to adapt in future.
- The damages from climate change will accelerate as the world gets warmer.
- Climate change may initially have small positive effects for a few developed

countries, but is likely to be very damaging for the much higher temperature increases expected by mid- to late-century under business-as-usual scenarios.

- In higher latitude regions, such as Canada, Russia and Scandinavia, climate change may lead to net benefits for temperature increases of 2 or 3°C, through higher agricultural yields, lower winter mortality, lower heating requirements, and a possible boost to tourism. But these regions will also experience the most rapid rates of warming, damaging infrastructure, human health, local livelihoods and biodiversity.

- Emissions have been, and continue to be, driven by economic growth; yet stabilisation of greenhouse-gas concentrations in the atmosphere is feasible and consistent with continued growth.

- The transition to a low-carbon economy will bring challenges for competitiveness but also opportunities for growth.

http://www.hm-treasury.gov.uk/sternreview_summary.htm

In Canada, the economic impacts of climate change on water resources, and so on the natural resource industries that depend on water, will be significant. The magnitude of the impacts of climate change on the Canadian economy is difficult to predict because of demographic, commercial and technological changes. The 2007 NRCan report accepts the findings from the Stern review. [5]

There is no single answer to the question of how climate change induced impacts on water will affect Canada's each of mining, forestry, agricultural and energy sectors. It is not possible to generalize the effects of climate change on water availability and water use for an open pit gold and copper mine in northern BC, a potash production facility in Saskatchewan, a diamond mine in the NWT or an iron ore mine in Labrador. The impact on mining will depend on the mineral in questions, the location of the mine, and numerous other factors. The same is true for the other resource sectors.

Impacts on Resource Industries

Experts generally agree that Canadian natural resource industries will be affected by climate change.

The 1998 Canada Country Study concluded that "Harvest levels in the agriculture, forestry and fisheries sectors are sensitive to climate. Sustaining viable production levels will depend on the capacity of these sectors to cope with the projected rate of warming and changes in climate variability, as well as their ability to counter projected decreases in water availability and increased threats of competition, disease and other disturbances (e.g., fire)." [6]

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[5] "Impact modelling suggests that, although overall economic impacts may be slightly positive in the short term at moderate degrees of warming, further warming and associated changes in climate will overwhelm systems, causing net economic losses (Stern, 2006)." (Lemmen, Warren and Lacroix, 2008 chapter 2, s.4.1)

[6] Roger Street, Atmospheric Environment Service, "Canada Canadian National Assessments" Acclimations, Newsletter of the US National Assessment of the Potential Consequences of Climate Variability and Change September-October 1999, on line at http://www.usgcrp.gov/usgcrp/Library/nationalassessment/newsletter/1999.10/Cdn.html

More recently, the government's assessment of impacts stated that: "Although agriculture, forestry, fishing and hunting do not account for a large percentage of Canada's GDP, they are vitally important for the economic well-being of many subregions and communities where land- and resource-based activities remain the foundation of economic life. More than 1600 communities in all regions of Canada obtain 30% or more of their employment income from these sectors. The economic impacts of climate change at the community scale can be significant" (Warren, Lemmen and Lacroix, 2008)

All four sectors discussed in this report will be affected by changes in water resources. The changes have been noted by IPCC reports, Canadian assessments and related reports, (e.g, Environment Canada 1998, 2004, Sector Sustainability Table 2008) and academic analysis (Bakker et al 2007).

Agriculture

"Climate variability is encouraging an increase in the adoption of irrigation to ensure higher yields and to compensate for drought stresses…. Climate change has the potential to have the greatest impact on the Prairies and central BC." (Harker et al in Environment Canada 2004)

Agriculture is the sector that has received the most attention from climate change researchers as the impacts of changes on water supply are obvious, with immediate consequences for food production.

The potential impacts of climate change on water for Canadian agriculture include a greater need for irrigation due to potentially longer growing seasons for some crops in some areas, increased demands for water as a result of these potentially longer growing seasons, decreased river flows and reservoir levels, and increased conflict over water at pack irrigation times such as the summer months when supplies are likely to be most threatened.

Not all impacts will be negative. The most recent assessment of impacts says that "climate change will also bring opportunities, including longer and warmer growing seasons, which could increase productivity and allow cultivation of new and potentially more profitable crops and tree species. Although global-scale analysis suggests that climate change should benefit Canadian agriculture and forests, studies in Canada that factor in changes in disturbance regimes and more frequent drought are less optimistic and stress the need for timely and effective adaptation." (Warren, Lemmen and Lacroix, 2008)

Cropping patterns and irrigation needs vary widely. Many crops that are currently near climate thresholds, however, are projected to suffer decreases in yields, quality, or both, with even modest warming (*medium confidence*) (Bates 2008 102)

Climate change and water for agriculture

The following examples show how climate change might affect water and agriculture in Canada:

- In southern areas, warmer winter temperatures may lead to more precipitation falling as rain instead of snow, less snow pack, and a change in the timing and amount of spring melt and in initial soil moisture availability.
- Groundwater recharge and levels are expected to decline. Shallow aquifers will be more vulnerable initially, but if recharge remains low for long periods, regional aquifers will also be affected. Many wells would become dry and unusable, while others would become

less productive because of the loss of available drawdown. Less groundwater would be discharged to water bodies such as farm dugouts, and stream baseflow would drop.
- Low stream volumes would limit the capacity to assimilate agricultural nutrients and pesticides, and rising water temperature would further promote eutrophication and a drop in oxygen levels.
- Extreme weather events, such as droughts and floods, are expected to become more common. Convective rainfall would probably become more intense, but there may be more time between precipitation events. Precipitation may become more variable. Water shortages will be most severely felt in the Prairies and southern Ontario, increasing the need for irrigation. However, peak irrigation needs may come at a time when the water supply is dwindling.
- Higher temperatures may increase the summer stress on livestock, increasing their need for water at a time when water is least available, drying out pastures, and cutting the production of feed.

L.M. Wenger and L.D. Mortsch, Environment Canada, Health of Our Water Agriculture and Agri-Food Canada 2005.

Energy

Each method of energy production has different water needs and different impacts on water. Climate change related changes to water will affect each subset of the energy sector in different ways. The main water impacts of conventional oil and gas, oil sands, hydropower, coal, coalbed methane, nuclear and renewable energies such as biofuels, are catalogued in an unpublished report prepared by a Panel of Canadian Water Network researchers for Natural Resources Canada (Bakker et al 2007), and in a report of the Energy Sector Sustainability Table, a federal government initiative, which recently released an environmental and an economic scan of Canada's energy sector.[7]

The environmental scan notes that:

- energy production in Canada requires large quantities of water,
- water demands are projected to grow in most sub-sectors, and
- the most significant water uses across the energy sector value chain include hydroelectric generation, thermal power generation, and oil and gas production.

The issue of the impacts of climate change on water has received more attention for some energy subsectors, such as hydropower and the oil sands, than others, such as biofuels.

Hydropower production is known to be sensitive to total runoff, to its timing, and to reservoir levels (Bates 2008 at 102).

"In North America, potential reductions in the outflow of the Great Lakes could result in significant economic losses as a result of reduced hydropower generation at Niagara and on the St. Lawrence River. For a Coupled Global Climate Model projection with 2°C global warming, Ontario's Niagara and St. Lawrence hydropower generation would decline by 25- 35%, resulting in annual losses of Canadian $240 million to $350 million (2002 prices). A different climate model projects a small gain in hydropower potential (+ 3%), worth approximately Canadian $25 million/yr. Another study that examined a range of climate model scenarios found that a 2°C

[7] Two related Tables also established by the federal government, the Forest Sector Sustainability Table (FSST) and the Mining Sector Sustainability Table (MSST) have not produced any documents to date. The Sector Sustainability Tables were set up in 2005.

global warming could reduce hydropower-generating capacity on the St. Lawrence River by 1% to 17%." (Kundzewicz, et al 2007 193 , references omitted)

The oil sands have received substantial attention and have been the subject of numerous studies by governments, scientists and NGOs. (CCA 2009, NRCan 2008 , Pembina Institute 2003, Munk Centre 2007, WWF, 2006). Water availability is widely recognized as a limiting factor in oil sands development.

> What is the National Energy Board's outlook for oil sands development?
>
> It is expected that rapid development of Canada's oil sands will continue. There are, however, issues and uncertainties associated with the development of this resource. The rate of development will depend on the balance that is reached between the opposing forces that affect the oil sands. High oil prices, international recognition, stable investment climate, global growth in oil demand, size of the resource base and proximity to the large U.S. market, and potentially access to other markets, encourage development. On the other hand, **water use,** air emissions, local infrastructure and services, labour requirements, natural gas costs and the light/heavy oil price differential are concerns that could potentially inhibit the development of the resource. (emphasis added)
>
> National Energy Board, Canada's Oil Sands – Opportunities and Challenges to 2015: An Update 2006

However, other energy sources have not received as much attention. For example, biodiesel and bioethanol require substantial amounts of water, to grow the crops and transform them into fuels. This is an example of the need to look for unintended consequences. The chairman of Nestle argues that biofuels are a drain on water: "What is meant to alleviate a serious environmental problem (climate change) is making another even more serious problem (water shortage) worse."[8]

The energy sector also reveals the cumulative and frequently synergistic impacts of climate change on water resources. For example, increased frequency and magnitude of heat waves will result in increased peak electricity demand for air conditioning, while decreased runoff from mountain glaciers in western Canada and lower water levels on the Great Lakes are likely to reduce potential for hydroelectricity generation in these areas. Combined with anticipated increases in demand for electricity related to population and economic growth, a changing climate could result in increased numbers of blackout and brownout events.

[8] Peter Brabeck-Letmathe, "A Water Warning", The Economist, The World in 2009,112.

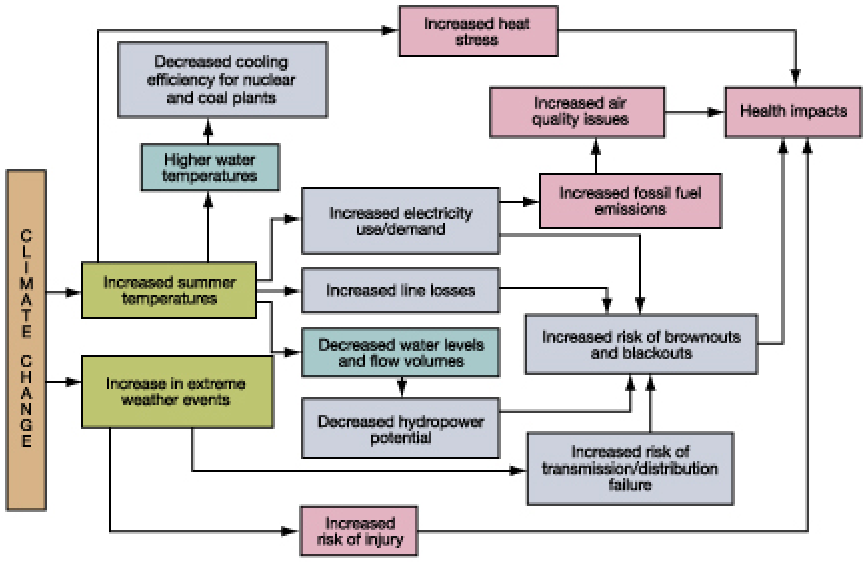

Figure SR-3: Illustration of the cumulative and synergistic impacts of climate change, using example of how impacts on the energy sector can amplify the direct impacts of climate change on human health. Lemmen, Warren and Lacroix, 2008

Mining

The mining sector uses water for extracting and concentrating metals and generating electricity required for crushing ore, on-site processing, smelting and refining (Ptacek et al, in Environment Canada 2004). "The primary threat posed by the mineral extraction industry to freshwater availability in Canada is not the direct intake of water during active ore extraction but rather the release of substandard quality long after ore extraction is complete." (Ptacek in Environment Canada 2004) Given the projected decreases in freshwater availability and the underemphasized role of water for ecosystem needs in Canada, it is likely that this threat will exacerbate conflicts in future with a changing climate.

One significant issue related to water and mining is using natural lakes for tailings disposal, an option favoured in some limited and site specific locations by the Mining Association of Canada, (Mining Association of Canada, 2008) and contested by environmental and aboriginal groups. This type of dispute will likely persist. If water scarcity increases, the mining sector will be pressured even more to avoid degrading fresh water sources.

In addition to tailings management, other water issues related to mines include managing mine water, acid rock drainage, and pit lakes. (Bakker et al 2007) Not all these issues relate to climate change impacts. However, problems associated with tailings storage and acid rock drainage generation are going to become even more relevant in Canada's north as climatic change impacts permafrost soils, affecting northern mines.

A Citigroup Global Mining Report in 2007 concluded that the most significant potential physical climate change impacts on mining companies included more frequent or more severe weather events, freshwater availability, and thawing permafrost impacts on Arctic infrastructure. News stories about the report (which is not publicly available) quote the report as saying: "reduced rainfall, higher evaporation, receding glaciers and shrinking aquifers may reduce water availability. Authorities may become more conscious of ensuring water availability for communities, and of environmental flows." The result "could reduce water availability for mining operations, leading to higher costs and cause quality issues (e.g. salinity),. In some areas, higher rainfall could require modification to tailings operations."[9]

Forestry

The potential for direct impacts of climate change on forest productivity, health and regeneration is emerging as a critical concern, especially across western Canada where record dry conditions during 2001-2003 have led to widespread forest dieback and mortality (Hogg et al. 2005, cited in C- CIARN forest key impacts sections).

Some provincial forestry agencies are taking action on the impacts of climate change. For example, British Columbia's Chief Forester launched the Future Forest Ecosystems Initiative at the end of 2005 to "start the process of adapting B.C.'s forest and range management framework to a changing climate". This Initiative warns that beyond the current pine beetle epidemic, the implications of climate change on forest and range management in BC are significant.

"Large portions of the Canadian and Alaskan forest are expected to be particularly sensitive to climate change. Climate change effects on forest growth could be positive (e.g., increased rates of photosynthesis and increased water use efficiency) or negative (decreased water availability, higher rates of respiration). It is difficult to predict the direction of these changes and they will likely vary by species and local conditions of soils and topography." (U.S. Climate Change Science Program and the Subcommittee on Global Change Research , 2008 at 122, references omitted)

Regional impacts of climate change on water for forestry include:

- Climate change in Alberta may affect forests faster than trees can adapt to evolving conditions. Dr. John Spence, head of University of Alberta's Department of Renewable Resources warns that "Unless we adapt current practices to the new realities of climate change, wildlife, biodiversity and forest-industry investments might be at risk." Climate change in Alberta may result in more frequent summer droughts and more frequent autumn and spring days with freeze-thaw cycles: both predictions are stressful for trees.[10]

- Key management challenges related to climate change for forests identified for BC include increased frequency and intensity of wildfires, storms, droughts, and floods, which would increase landslides, debris flow, wind throw, and variability in water quality and quantity. (BC Future Forest Ecosystems Initiative 2008) Large-scale change to land surface cover in BC watersheds as a result of the largest recorded outbreak in BC's history of mountain pine beetle (MPB) (more than 8.7 million hectares of pine forests in BC are currently infested) may lead to alterations in streamflow patterns and stream ecology. One pressing issue identified in the study of hydrologic impacts of the MPB infestation is the cumulative effects of MPB in conjunction with future climate conditions or other land cover changes, such as forest fires or logging, which will also influence hydrology.

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9 Dorothy Kosich, "Can international mining manage operational climate change risk?" 14 Sep 2007, Mineweb.

10 Cynthia Strawson, University of Alberta News, Climate change drives expansion of forestry protection research, Mar 8, 2006.

- In Ontario, an increase in summer temperatures with no or little increase in precipitation would increase the frequency and severity of drought by elevating evapotranspiration. The length of the forest fire season is expected to increase with longer growing seasons. In addition, increased moisture loss from forests due to elevated temperatures would increase forest fire frequency and severity. Forest plant diseases and insects attack plants that have been stressed: increases in drought could also increase the frequency of major insect and disease outbreaks. An increase in forest fires, insect outbreaks and diseases would, in turn, alter the age structure and plant species in forest ecosystems, with the greatest impacts expected in northwestern and southern Ontario. Extreme weather events, such as ice storms, floods, and very high or widely fluctuating temperatures could further damage or stress plants. (Colombo SJ et al 1998).

- In Quebec, climate change could change the makeup of forest ecosystems, particularly in more southerly areas. Natural Resources Canada research predicts that the overall long-term effect of a warmer climate could be to push the treeline farther north, while gradually changing the abundance and distribution of species. The department notes different possibilities: the most recent predictions indicate increased precipitation in Quebec, which perhaps would reduce the number of forest fires. Though that beneficial effect could be negated by an increase in the numbers of local and exotic forest pests. (NRCan website)

Accelerated forest fires brought about by changes to water availability will possibly affect forests across Canada. When snowpacks melt earlier in the year, the land becomes drier and the wildfire season may start earlier. The fire season may also end later as summer temperatures extend later into autumn.

4. Initial Identification of policy and governance mechanisms, tools and approaches affecting resource development practices and use of water

Water governance is the decision-making process by which water is managed. This includes the range of political, organizational and administrative processes through which communities articulate their interests, their input is absorbed, decisions are made and implemented, and decision makers are held accountable for the development and management of water resources and delivery of water services. Bakker 2006

Water is a far reaching, complex governance issue, involving more than a dozen federal departments, multiple provincial and territorial agencies, municipalities with decision making powers for infrastructure and land use planning, Aboriginal decision makers, Canada-U.S collaboration, and numerous important stakeholders ranging from businesses to community to consumer groups. Water governance bodies differ in terms of their genesis, legal status, mandate, geographic area of coverage, type of decisions made, reporting requirements, public involvement, user fee structure, revenue raising powers, multistakeholder water governance body with a taxing power), staffing, budget, and organizational structure.

Many experts in Canada agree on that current water governance arrangements are fragmented, with negative impacts on overall management of the resource (e.g, Bakker 2006, Conference Board 2006, Morris et al 2007).

A wide range of policy and governance mechanisms, tools and approaches exists to address climate change and water, including laws, economic instruments (usually authorized by regulation) and voluntary codes. A range of more specific tools also exists to address the relationship between climate change and water. Both the general categories and more specific tools are briefly described below.

Laws

Legal jurisdiction over water is complex, though as the *Currents of Change* report noted, Canadians don't care about these differences, they just want the job done (Pearse 1985). Provinces have the primary role in water and natural resource management, and there is wide variation in provincial laws and policies. The federal government has the overall responsibility for managing climate change, and has numerous constitutional and practical responsibilities for water. At present, there is no overriding federal water strategy or law. The federal climate action plan does not specifically address water and there is no national climate change adaptation plan. Other levels of government, such as municipal and Aboriginal, also have legal responsibilities related to water.

Economic Instruments

Trading water permits is seen as one potential policy response to water shortages brought about by climate change. Greater use of markets or economic instruments in general is often promoted as a solution for water management. Rather than an alternative to regulation, this set of tools needs to be authorized by regulation, and so is a different form of regulation than either traditional 'command and control', or results based regulation. Some argue that markets can provide stronger incentives for innovation and conservation by altering the economic landscape facing water users through the introduction of prices for water and/or the establishment of markets for water. Most observers agree that water is undervalued in Canada. However, low water prices persist, despite the criticism, and markets for water are used only in Alberta, and only recently.

Voluntary Codes

Businesses are adopting strategies to adapt to changes in water caused by climatic.

Adaptation cannot stop changes in climate from impacting water resources, but they can help to reduce the severity of negative impacts resulting from these changes on communities and ecosystems. The Government of Canada has defined adaptation to climate change as "any activity that reduces the negative impacts of climate change and/or takes advantage of new opportunities that may be presented" (Lemmen et al, 2008). Adaptation may occur before (anticipatory), during (concurrent), or after (reactive) the observed changes. Anticipatory adaptations tend to be made over the long-term and are generally less costly and more effective than reactive adaptations. Tailoring adaptation measures to the particular situation is important, and special attention needs to be given to the "feasibility, likelihood and mechanisms for uptake" if adaptations are to be successful (Lemmen et al, 2008 5).

Governments may assist in the development of voluntary programs. An example is the Alberta Water Council's work with seven Alberta sectors representing some of the largest water users in the province on setting and meeting water conservation, efficiency and productivity goals. These sectors have committed to developing Water Conservation, Efficiency and Productivity plans by December 2010, in accordance with Alberta's "Water for Life" strategy.

A caveat with voluntary programs is that they have not been a success to date in reducing greenhouse gas missions. Canada's GHG emissions per capita increased by almost one third between 1990 and 2006, making them among the highest in the world. (Conference Board 2008)

Specific Tools

In relation to mitigating or adapting to the effects of climate change on water resources, there are a number of relevant policy tools:

Laws

- Regulations on water allocation

" The institutions that govern water allocation will play a large role in determining the overall social impacts of a change in water availability, as well as the distribution of gains and losses across different sectors of society." (2007, WGII 191). Few provinces consider climate change in water allocation permitting or licensing systems (De Loe et al 2007). In addition, provincial water allocation laws do not usually contain mechanisms allowing regulators to reduce allocations for environmental or emergency reasons. The need to make adjustments to historically granted water rights is a major, and controversial, issue for water law reform.

- Regulations requiring water efficiency and conservation

Canada's per capita water usage is higher than any country except the United States. (Conference Board 2008). Many other countries are more efficient, and are placing more emphasis on efficiency at the national level: "Wasting water means wasting a resource on which is limited in its seasonal and regional availability, and wasting the energy required to supply, treat and distribute the water to where it is used, and to remove and treat wastewater. Water efficiency measures, particularly those that focus on hot water use, are therefore doubly beneficial, with water as well as greenhouse gas savings. We must do more to promote these types of water savings which have multiple benefits." (UK government, 2008)

Water can be used more efficiently in all 4 sectors, and ways in which water and sectoral laws can better promote conservation deserve greater examination. (This issue has received the greatest attention at the municipal level- see reports from the Polis Project on Ecological Governance).

"Water conservation is recognized as a concern in all jurisdictions, but mechanisms that promote conservation at the provincial or territorial scale are not widely used or consistently applied. Conservation practices include the beneficial use principle, sectoral best management practices, economic incentives, and linking conservation practices to allocation decision making. Pricing to promote conservation is not a commonly used instrument. The limited monitoring of actual water use in most jurisdictions poses a fundamental challenge to water conservation using pricing or other instruments." (De loe et al 207)

- Cumulative Impacts

Determining cumulative impacts from climate change and from competing demands for water and multiple land use activities is challenging, and the legal framework may not adequately assess these impacts. For example, in the energy sector, Alberta's laws have been criticized for not setting environmental limits and thresholds, not integrating decision making, and consequently making "effective cumulative effects management" difficult, if not impossible. (Vlavianos, 2007).

- Common law and statutory remedies

Lawsuits may be used to resolve water disputes. Recent examples relevant to this report include those related to allegations of failure to consult Aboriginal peoples when oil sands permits were granted, allegations of failure to properly conduct environmental assessments involving mines planning to use natural lakes as tailings ponds, and others.

Economic Instruments

- Economic instruments such as water permit trading systems

Some argue that creating a legal and market framework within which private agents trade their rights to water use can improve the efficiency of the allocation of surface water resources although there are continuing concerns about unintended negative impacts on in-stream flows and third parties affected by water trades. There is great interest in this topic in Canada. To date only Alberta is using water markets to any extent.

- Full cost accounting and pricing of water

Many economists argue that water is undervalued. Several provinces levy fees for water use granted by permit but the fees are usually quite low. The available empirical evidence on the economic features of water demand suggests that levying higher fees will result in reduced water use.

Voluntary Initiatives

- Business Adaptations

"Businesses in Canada and the USA are also investing in adaptations relevant to changes in water resources, though few of these appear to be based on future climate change projections. Examples of these types of adaptations include [from resource industries] With highly detailed information on weather conditions, farmers are adjusting crop and variety selection, irrigation strategies and pesticide applications The forest resources sector is investing in improved varieties, forest protection, forest regeneration, silvicultural management and forest operations." Bates 2008 , at 105 (references deleted)

- codes of practice and nonbinding standards,

Water efficiency is specifically addressed by policymakers in more arid parts of country such as in the Okanagan Water Sustainability Strategy, and in the work of the Alberta Water Council and its CEP sectoral study. Some businesses are using tools such as:

  - the water footprint,
  - the Global Water Tool (WBCSD, 2007) which was developed by an advisory group including Petro-Canada and Alcan and assists companies in mapping their water use and assessing risks relative to their global operations and supply chains, or
  - UNEP's indicative guidelines for water-related risks (UNEP, 2007) to assess risk and make changes to business operations.

Assessing water risks is also becoming more important from an investment perspective (JP Morgan 2008, UNEP FI 2007).

Disclosure of Water Risk- A Growing Issue

Analysts at JP Morgan released a report in April criticizing the level of disclosure among businesses of the impact of water shortages, calling the situation "seriously inadequate." Though the financial impact is unclear due to "spotty and partial" disclosure, JP Morgan predicts some sectors will be more affected by water scarcity than others. Power generation, mining, oil and gas production, semiconductor manufacturing, and the food and beverage industry could be hit particularly hard. Water shortages tend to be local, but the risk extends across entire supply chains, not just where a company has operations. Scarcity will also force industries that use lots of water to spend big to boost efficiency. To separate one litre of oil from tarsands requires up to five litres of water, for example, and metals mining can require up to 8,000 litres of water per tonne of ore extracted. To better communicate the impact to investors, JPMorgan recommends corporations provide detailed information about these risks and costs in regulatory filings, not just corporate social responsibility reports, which investors may overlook. When companies do address water issues, the most common way is to provide total water use measured in cubic metres. That's not good enough, according to the report, which argues companies should put the number in financial terms.

Joe Castaldo, "Water scarcity: A disclosure drought" *Canadian Business*, May 12, 2008

Mixed Initiatives: Law, Economics, Voluntary Codes

- Integrated water resource management

"Integrated Water Resources Management should be an instrument to explore adaptation measures to climate change, but so far is in its infancy. Successful integrated water management strategies include, among others: capturing society's views, reshaping planning processes, coordinating land and water resources management, recognizing water quantity and quality linkages, conjunctive use of surface water and groundwater, protecting and restoring natural systems, and including consideration of climate change. In addition, integrated strategies explicitly address impediments to the flow of information. A fully integrated approach is not always needed but, rather, the appropriate scale for integration will depend on the extent to which it facilitates effective action in response to specific needs. In particular, an integrated approach to water management could help to resolve conflicts among competing water users. In several places in the western USA, water managers and various interest groups have been experimenting with methods to promote consensus-based decision making. These efforts include local watershed initiatives and state-led or federally-sponsored efforts to incorporate stakeholder involvement in planning processes. Such initiatives can facilitate negotiations among competing interests to achieve mutually satisfactory problem-solving that considers a wide range of factors." (Kundzewicz, et al 2007, references omitted, at 196)

- Multistakeholder decision making (also known as collaborative, shared or delegated governance)

"Good governance" entails the democratization of water management decision-making, stakeholders more say in water policy. Many jurisdictions in Canada are trying new forms of delegated decision-making over water management to the local (usually watershed) level. (Nowlan and Bakker, 2007). Alberta's Watershed Planning and Advisory Councils and Quebec's Basin Organizations are two examples. To date, no province has completely changed the historical basis of water regulation, allocation and protection. New governance models will be constrained in their ability to govern if historical licences cannot be changed, and if compensation is payable for these changes to the public resource of water

5. Key climate change impacts on Canada's water resources

Impacts on water

Warming temperature

Air temperatures are predicted to rise in all climate change models. Arctic impacts are projected to be particularly intense, as the average temperature n the Arctic region has risen at almost twice the rate as the rest of the world (ACIA Highlights, 2005, 3).

Changes in supply and distribution,

Water supply and distribution is forecast to change in numerous ways as the climate changes, causing:

- changes in lake levels,
- changes in river flows, the influence of future regional projections of warmer temperatures, uncertain precipitation and a reduction in snowpack and glaciers will adversely affect both the timing and the volume of projected streamflow pg 122 PCIC
- changes in runoff, as the critical resource of snowpack which retains fresh water during winter and supplies streamflow to soils, lakes, and reservoirs during summer low-flow periods, is predicted to decline. The consequences of an earlier snowpack melt are an increase in the length of time between peak water flows and the summertime peak water needs of cities, farmers, utilities, and others, potentially requiring more reservoir storage to capture the earlier runoff.
- Glaciers provide streamflow during summer low-flow periods and maintain important ecosystem functions. However, glaciers are receding in response to climate variability and change.

Increased demand for Groundwater – the demand for groundwater is likely to increase in the future, due to the need to offset declining surface water availability due to increasing precipitation variability in general and reduced summer low flows in snow-dominated basins (Kundzewicz, et al 2007 at 185) Yet groundwater impacts from climate change are not as well studied or as well known in Canada.

Thawing of permafrost is having increasingly profound effects on water courses, groundwater, land slumps, and on water infrastructure (Cohen 1997).

More extreme weather events – "A warmer climate, with its increased climate variability, will increase the risk of both floods and droughts" (Kundzewicz, et al 2007, 186)

Seasonal variations

Increased demand for water will occur in summer months when supplies are at lowest.

Declines in water quality

Climate change is likely to make it more difficult to achieve existing water quality goals (high confidence). (Field 2007 at 629) Water quality challenges include**:** diminished streamflows during drought potentially resulting in less dilution of discharges; sediment loading from storm events that follow wildfires, saltwater intrusion along the coast resulting from rising sea levels, and warmer lake temperatures leading to algae blooms could follow.

Impacts from projected changes to water resources

Likely increase in water scarcity

Though there is no certainty about future water availability, likely trends arising from climate change will be that demands for water will increase and no 'new' supplies will be available. 'New' supplies have been found in the past from switching to groundwater from surface water, drilling deeper wells, or diverting or piping in water from farther sources. These options may not be available due to:

1. Diversion attempts will face greater opposition as all regions feel the stress from reduced water availability and will be more reluctant to allow 'their' water to be transferred out of basin.
2. Taking more water has natural limits, and the need to account for environmental needs is often neglected. Legal limits may also be- or should be- in effect.
3. All traditional means of getting more water require energy.

Existing supplies are already overallocated in key areas, and the need to improve environmental flows will reduce availability. Even without the additional pressures of climate induced changes to water resources, population and economic growth are already putting more demand on water resources in many water scarce areas of Canada such as Okanagan, southern Alberta, and the Great Lakes. The potential for increased water demands due to higher temperatures, and declining precipitation is strong.

Economic impacts on all sectors from water scarcity likely

Water may act as a constraint on future development in Canadian energy, agricultural, forestry and mining sectors. A national level economic analysis of climate change impacts in Canada has not yet been done.[11] The Stern review in the UK and the Garnaut review in Australia[12] are examples of this type of review.

Unknown consequences of cumulative impacts

Little of the literature reviewed in the chapter on North America in the IPCC's Fourth Assessment Report addresses interactions among the sectors that are all impacted by climate change, especially in the context of other changes in economic activity, land use, human population, and changing personal and political priorities. Similarly, knowledge of the indirect impacts on North America of climate change in other geographical regions is very limited. (Field et al, 2007 at 635)

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[11] The government has just announced plans for this type of study though Environment Canada appears to be engaged on a limited study in contrast to Australia and the UK. Jan. 14, 2009, Montreal Gazette , "Ottawa to examine economic impact of climate change" Environment Canada is accepting bids for the new research project to be completed in 8 weeks for a limited cost.

[12] The Garnaut Climate Change Review presented its Final Report to the Prime Minister of Australia and the eight states and territories on 30 September 2008. The Review was an independent study conducted by economist Professor Ross Garnaut, commissioned by Australia's Commonwealth, state and territory governments in 2007. The Review commissioned a number of studies related to resource based industries and communities, including 5 on agriculture, (Irrigated cropping in Murray Darling Basin, Dryland cropping – wheat, Livestock carrying capacity, Horticulture, Viticulture and the wine industry) one on mining, and one on the forests and wood products industry.

Ecosystem Needs Need More Attention

Not only will all these resource sectors face climate change induced changes in water availability and quality, they will also face future limitations related to the need to ensure enough water is left intact to support ecosystem needs and services. Environmental flows have not been well protected in Canada to date. (Morris et al 2007)

Increased conflict between water users

Growing water scarcity causes increasing conflicts and instability among water users within communities and across borders. Conflicts over water use are most likely to occur at the subnational level, and are usually development disputes, related to conflict over water allocation.[13]

Examples of water conflicts are proliferating across Canada.

One particular focal area of water related disputes is in the development of the oil sands in Alberta. Multiple disputes relate to this set of projects, including completed and pending lawsuits. The case of the temporary revocation of a water use permit granted to Imperial Oil Canada for its $8-billion Kearl Lake project on the basis that the company failed to assess the impact of the greenhouse gas emissions that would be generated by the project. The Federal Court said a joint review panel under the Canadian Environmental Assessment Act had erred by failing to provide a cogent rationale for its conclusion that adverse environmental effects of the GHG emissions of the Project would be insignificant, and by failing to comment on the effectiveness of intensity-based “mitigation”[14]. In the end the permit was reissued three months later. The case demonstrates the linkages between water, climate change and natural resource industries and particularly illustrates the economic impact of not addressing water and greenhouse gas emissions.

In a new case, the Beaver Lake Cree band have filed against the governments of Canada and Alberta, the court has been asked to rule that the government authorization for thousands of petroleum projects on the band's core territory are invalid. [15]

Water trades in Alberta are also giving rise to disputes, especially a proposed trade from an irrigation district to a major development involving a mall and casino (Ecojustice Canada, 2008)

Policy Challenges - Water/Climate Change/Natural Resource Sectors

Water-energy nexus

“Building and operating more supply-side infrastructure requires considerable amounts of energy, much of which is produced from fossil fuels. In contrast, water conservation reduces greenhouse gas emissions and allows communities to adapt to diminished supplies.” (Morris et al, 2007 at 40.)

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[13] Peter Gleick, 49th International Studies Association (ISA) Annual Convention, which took place March 26-29, 2008, in San Francisco, California roundtable entitled “Conflict and Cooperation over Shared Water Resources II”

[14] *Imperial Oil Resources Ventures Limited v. Pembina Institute for Appropriate Development et al*, 2008 FC 598, *Pembina Institute for Appropriate Development v. Canada (Attorney General)*.

[15] “Law Suit a Tar Sands Stopper?” July 28, 2008, The Tyee http://thetyee.ca/News/2008/07/28/LawSuit/

Adaptative capability to address water scarcity. "In addition, climate change will probably alter the desired uses of water (demands) as well as actual uses (demands in each sector that are actually met). If climate change results in greater water scarcity relative to demand, adaptation may include technical changes that improve water-use efficiency, demand management (e.g., through metering and pricing), and institutional changes that improve the tradability of water rights. It takes time to implement such changes, so they are likely to become more effective as time passes."(Kundzewicz, et al 2007,191)

Water inadequately valued

Appropriate pricing systems are in not in place. Allocation systems in Canada do not recognize non-economic values, unlike, e.g., the EU Water Framework Directive.

Water laws and governance overlook climate change

Provincial allocation laws do not generally address climate change impacts. The fragmented, multiple jurisdictional nature of water governance with fuzzy lines between different levels of government responsibility is not conducive to informed and adaptive management. One example relates to environmental assessment and the need to incorporate a climate change filter into all major environmental assessment decisions.

Full range of policy tools needed

"In some circumstances, more than information and guidance may be required to move forward on adaptation action. This may be especially true where extra costs are involved, or where institutional or other barriers exist. In such circumstances, governments and industries may wish to take further action, such as the provision of incentives or penalties. For example, water rates could be modified for different users, and improvements in water-use efficiency could be promoted and rewarded. Insurance may also have a role to play in facilitating adaptive behaviour. A range of market-type instruments can be used to promote and persuade people to move towards effective adaptation within various sectors. In circumstances where climate change presents significant risks to the security and safety of Canadians, it may be appropriate to mandate or require adaptation actions. Prominent among these needs is the importance of ensuring that construction of buildings and other infrastructure is robust to the changes in climate, including extreme weather risks." (Lemmen, Warren and Lacroix, 2008)

Managing Under Uncertainty

Uncertainty has two implications. First, adaptation procedures need to be developed which do not rely on precise projections of changes in river discharge, groundwater, etc. Second, based on the studies completed so far, it is difficult to assess in a reliable way the water-related consequences of climate policies and emission pathways. (Kundzewicz, et al 2007) 201

Substantial stresses on the water sector exist even in the absence of climate change, in terms of over-allocation, population growth, land use changes, and water needs for instream uses. "Climate change may pose additional stresses and could result in thresholds being reached earlier than currently anticipated. Because many of the impacts of climate change are not predictable, more flexible institutional arrangements are needed in order to adapt to changing conditions including not only climate change, but other existing stresses as well. Supply-side options are more familiar to most water managers, but demand-side options are becoming increasingly prevalent." (Western Governors Association. 2006)

Scale mismatch between water and climate change

The watershed is generally accepted as the most appropriate scale for water governance and management (O'Connor 2002, Parkes et al 2008) yet climate change is a global phenomenon. Environment Canada notes that uncertainties about the nature of regional precipitation patters, as well as the complexity of natural ecosystems, limit the ability to project hydrological changes at the watershed scale (Environment Canada, 2006, 180). Water is managed at the catchment scale and adaptation is local, while global climate models work on large spatial grids(Kundzewicz, et al 2007, 202.) This scale mismatch between the large-scale climatic models and the catchment scale needs further attention.

Avoiding unintended consequences

Policy makers must take care to ensure that actions taken do not have unintended consequences:
"Implementing important mitigation options such as afforestation, hydropower and bio-fuels may have positive and negative impacts on freshwater resources, depending on sites specific situations. Therefore, site-specific joint evaluation and optimisation of (the effectiveness of) mitigation measures and water-related impacts are needed. Expansion of irrigated areas and dam-based hydro-electric power generation can lead to reduced effectiveness of associated mitigation potential. In the case of irrigation, CO2 emissions due to energy consumption for pumping water and to methane emissions in rice fields may partly offset any mitigation effects. Freshwater reservoirs for hydropower generation may produce some greenhouse gas emissions, so that an overall case-specific evaluation of the ultimate greenhouse gas budget is needed." (Bates 2008, 130)

6. Gaps and Directions for NRTEE

Need for Change

The Intergovernmental Panel on Climate Change (IPCC) in its recent *Technical Report on Climate Change and Water* warns that traditional water management practices "are very likely to be inadequate to reduce the negative impacts of climate change on water supply reliability, flood risk, health, energy, and aquatic ecosystems"(Kundzewicz et al, 2007, 175).

An overarching question is how federal policy in Canada can address increasing water scarcity brought about by climate change, and how federal decision makers can work with the natural resource sectors and provincial and other levels of regulator to improve water efficiency.

Potential focal areas for further NRTEE work

Calculate costs of inaction on climate change with respect to impacts on water and 4 natural resource sectors

As the IPCC notes:" Impacts of climate change will entail social and economic costs and benefits, which are difficult to determine. These include the costs of damages and the costs of adaptation (to reduce or avoid damages), as well as benefits that could result from improved water availability in some areas… Costs and benefits of climate change may take several forms, including increases or decreases in monetary costs, and human and ecosystem impacts, e.g., displacement of households due to flooding, and loss of aquatic species. So far, very few of these costs have been estimated in monetary terms. Efforts to quantify the economic impacts of climate-related changes in water resources are hampered by a lack of data and by the fact that the estimates are highly sensitive to different estimation methods and to different assumptions regarding how changes in water availability will be allocated across various types of water uses, e.g., between agricultural, urban, or in-stream uses. " (190-91 Kundzewicz, et al 2007)

There are numerous existing examples of initiatives looking at this issue including, as mentioned, the Stern and Garnaut Reviews, and some aspects of the IPCC and Canadian national assessments. In the US, a multi-university program focuses on the *Economic Impacts of Climate Change and the Costs of Inaction*[16]*;* the Democratic Party has a series of policy briefs on *"The* Cost of Inaction*:* The Impacts of Climate Change", such as one focusing on agriculture; and think tanks and advocacy groups are increasingly focusing on economic arguments as well, e.g., the Natural Resource Defence Council's 2008 *The Cost of Climate Change,* the Worldwatch Institute's *State of the World 2009* report*.*

The impacts of climate change will entail social and economic costs and benefits, which are difficult to determine. These include the costs of damages and the costs of adaptation (to reduce or avoid damages), as well as benefits that could result from improved water availability in some areas.

Reform of existing provincial water allocation systems
Allocation of water is a major issue and one that deserves further exploration. How can laws achieve more efficient and adaptive allocation?

How do laws incorporate climate change? As Natural Resources Canada notes: " At present, most water laws do not take climate change into account, and would therefore be challenged by the projected changes " (Lemmen, Warren and Lacroix, 2008)

"Existing water management plans are based on historic climate and hydrological records and 'assume that future will resemble the past". There is a need to incorporate increased climate variability and occurrence of extreme events into water management planning (NRCan, 2004)

Water efficiency and conservation
What are the elements of a national policy on water efficiency? The Sector Sustainability Table report on energy efficiency is a helpful model for a similar effort on water efficiency. How should this initiative work? Should it be embedded in law, as some recommend (Morris et al 2007)? Or should it be voluntary as in Alberta's CEP approach? Or is a combination of these two approaches likely to be most effective?

"No regrets" policies
Uncertainties in impact projections have led many authors to advocate the implementation of 'no regrets' adaptation options Much of the literature on water infrastructure adaptation stresses the importance of implementing "no-regrets" measures. ""A "no-regrets" climate change adaptation provides benefits to the community whether anticipated climate changes materialize or not." (Mehdi, B., 2006 at 9). Policies to improve efficiency and conservation can result in reducing water use and reducing emissions. "These measures would benefit Canadians, irrespective of climate change, as they address other environmental issues. The engagement of stakeholders, including the general public, is critical to the development of effective adaptation strategies. Perhaps most importantly, the literature notes that water managers must be encouraged to address climate change impacts in their long-term planning activities." (Lemmen and Warren, 2004)

Mainstreaming climate change into water resource decisions
Many reports urge policy makers to 'mainstream' climate change considerations into decision making processes. This is an area that could be explored in greater detail for the resource industries in Canada.

16 http://www.cier.umd.edu/climateadaptation/

The most recent national assessment gives examples of opportunities for mainstreaming, though notes that these are " taking place at a very limited scale". The examples of mainstreaming canvassed in that report are:

- using recent climate trends and future projections to update building codes and
- standards to reduce infrastructure vulnerability,
- factoring sea-level rise into coastal development planning,
- considering the hydrological impacts of climate change on water supply and demand in water and energy conservation initiatives and
- considering climate change impacts in the environmental assessment process for major development projects. (Lemmen, Warren and Lacroix, 2008, chapter references omitted.)

Moe specific examples for the resource sectors is a potential focal area for the NRTEE.

Water governance reform
To address the challenge of fragmented governance, one option for the NRTEE is to analyze and propose a more rational integrated structure for more sustainable water management. Environment Canada (2006, 180) identifies further defining jurisdictional roles and responsibilities to provide for more integrated management as one way to facilitate climate change adaptation in the water resource management sector. The report cites the issue of water shortage management in Ontario as an example of this need for jurisdictional clarity, noting that three federal departments and agencies, three provincial departments and agencies, watershed organizations and municipalities all play significant roles in managing this issue in Ontario, and that clarifying responsibilities of these groups for this issue proved effective.

Many parts of Canada are experimenting with collaborative, delegated or 'shared' water governance (Nowlan and Bakker, 2007) The NRTEE could play a role in convening participants in these relatively new groups, such as Alberta's Water Planning and Advisory Committees, Quebec's Basin Authorities, Ontario's Conservation Authorities and newer source protection committees, as well as federal, Aboriginal, municipal, business and NGO representatives to examine the role of collaborative governance in the intersection of water, climate change, and natural resources in Canada.

Another governance area is participatory assessments. In one well studied area, where the local community taking water and climate change seriously, the Okanagan Basin in BC, a multi year study recommends an approach that explicitly integrates climate change response and sustainable development initiatives, in this case, the implications for regional development of impacts on water supply and demand (Cohen and Neale, 2006).

Best mix of policy instruments
A final task for the NRTEE could be to examine the best mix of policy tools to achieve water efficiency, reduce demand for water, and promote water conservation in natural resource industries.

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Summaries of Key Findings from Regional Chapters

Lemmen, D.S, Warren, F.J., Lacroix, J. and Bush, E. editors (2008): From Impacts to Adaptation: Canada in a Changing Climate 2007; Government of Canada, Ottawa, ON.

Chapter 3 Northern Canada

Key Findings

The climate of the Arctic has shown an unprecedented rate of change during the past 50 years. Over the last half century, the Canadian Arctic has experienced significant increases in both temperature and precipitation, consistent with trends in other circumpolar regions. Increases in air temperature have resulted in many of the most extreme warm years throughout the entire Canadian North being recorded in the last decade, with the greatest temperature increases observed over the western Arctic. All global climate models project continued increases in temperature and precipitation over the Canadian Arctic, with greatest temperature changes at higher latitudes. As a result, there will continue to be significant changes in the physical environment, particularly in the cryosphere (snow, glaciers, permafrost and river/lake/sea ice).

There is increasing evidence that changes in climate are already having impacts on ecological, economic and human systems in northern regions, and that some individuals, communities and institutions are already taking action to reduce harmful impacts. Current levels of exposure to climate-related changes and sensitivities, as well as limitations in adaptive capacity, make some northern systems and populations particularly vulnerable to the effects of climate change. Key findings include the following:

- **Climate-induced changes in the cryosphere (permafrost, sea ice, lake ice and snow) have important implications for infrastructure maintenance and design**. Much of the infrastructure in the North is dependent upon the cryosphere to, for example, provide stable surfaces for buildings and pipelines, contain wastes, stabilize shorelines and provide access to remote communities in the winter. Permafrost warming and thaw may require remedial action or further engineering modifications to existing infrastructure. Waste retention ponds and lakes that rely on the impervious nature of permafrost to retain environmentally hazardous materials are a particular concern. Climate change is already being considered in the design of most major projects in the North, including tailings containment structures, pipelines and roads, and large buildings. In the longer term, marine and freshwater transportation will need to shift its reliance from ice routes to open-water or land-based transport systems. Coastal areas and communities will also become more vulnerable to erosion due to loss of sea ice compounded by increased storminess and rising sea levels. Changes in the timing of river flows will require modifications to the infrastructure and flow strategies used in generating hydroelectricity.

- **As the climate continues to change, there will be consequences for biodiversity shifts and the ranges and distribution of many species, with resulting impacts on availability, accessibility and quality of resources upon which human populations**

rely. This has implications for the protection and management of wildlife, fisheries and forests. The northward migration of species, and disruption and competition from invading species, are already occurring and will continue to alter terrestrial and aquatic communities. Shifting environmental conditions will likely introduce new animal-transmitted diseases and redistribute some existing diseases, affecting key economic resources and some human populations. Stress on populations of iconic wildlife species, such as the polar bear, at the southern limit of their distribution will continue as a result of changes to critical sea-ice habitat. Where these stresses affect economically or culturally important species, they will have significant impacts on people and regional economies. Widespread proactive adaptation to these changes will be required in natural resource management sectors.

- **Increased navigability of Arctic marine waters and expansion of land- and fresh water –based transportation networks will lead to a less 'remote' northern Canada, bringing both opportunities for growth in a range of economic sectors and challenges associated with culture, security and the environment**. Diminishing sea ice, particularly in Hudson Bay and the Beaufort Sea, and a lengthened summertime shipping season associated with warming, will increase opportunities for shipping and passage within Canadian Arctic waters. It is likely that adaptations in the form of increased surveillance and policing will be required. Loss of sea ice and fresh ice will also lead to the development of marine ports and all-season road networks to interior portions of the northern mainland and Arctic islands, particularly to access natural resources whose development has previously been uneconomic. Socioeconomic and cultural impacts on Arctic communities from increased economic activity, including increased marine traffic and access associated with the opening of the Northwest Passage, may be far reaching.

- **While maintaining and protecting aspects of traditional and subsistence ways of life in many Arctic Aboriginal communities may become more difficult in a changing climate, new opportunities will also be presented**. Young and elderly Aboriginal residents, in particular those pursuing aspects of traditional and subsistence-based ways of life in more remote communities, are the most vulnerable to the impacts of climate change in the North. An erosion of their adaptive capacity via the social, cultural, political and economic changes taking place in many communities today will further challenge their abilities to adapt to changing environmental conditions. However, enhanced economic opportunities may provide significant benefits to communities, making the net impacts on human and institutional vulnerability difficult to predict.

Chapter 4- Atlantic Canada

Key Findings

Atlantic Canada will experience more storm events, increasing storm intensity, rising sea level, storm surges, coastal erosion and flooding. Coastal communities and their infrastructure and industries, including fisheries and tourism, are vulnerable to these changes. Impacts on coastal infrastructure, such as bridges, roads and energy facilities, have already affected trade and tourism in the region, and some coastal communities have started experiencing saltwater intrusion in their groundwater supply. Future disruptions to transportation, electricity transmission and communications will have widespread implications, including increasing the susceptibility of some communities to isolation.

Water resources will come under pressure as conditions shift and needs change. Seasonal and yearly variations in precipitation will combine with higher evapotranspiration to induce drier summer conditions, especially in Maritime Canada. Limited water resources would affect municipal water supplies and challenge a range of sectors, including agriculture, fisheries, tourism and energy.

For marine fisheries, impacts will extend beyond fish species to include numerous aspects of fishery operations, including transportation, marketing, occupational health and safety, and community health. Harvesters of wild marine resources are constrained in their potential responses to climate change by the existing regulatory regimes. Integration of climate change into assessments and policy development would allow more effective management of marine resources.

Although higher temperatures and longer growing seasons could benefit agriculture and forestry, associated increases in disturbances and moisture stress pose concerns. Changes in climate have implications for management of agricultural production and farm water usage. Re-examination of cropping systems and improved water management would help the agricultural sector to adapt, although non-climatic factors, such as socioeconomic and demographic trends, may limit adaptive responses. In some areas of the Maritimes, forested areas will be affected by drier summers, potentially leading to reduction or loss of species that prefer cooler and wetter climates. Options for short-term adaptation, although limited in the forestry sector, are likely to focus on minimizing other stresses and preserving genetic diversity.

Vulnerability to climate change in the Atlantic region can be reduced through adaptation efforts focused on limiting exposure and through careful planning. Identifying vulnerable infrastructure, incorporating river and coastal flooding in land-use policies, revising emergency response measures, and accounting for sea-level rise when planning and building infrastructure would reduce damage to infrastructure and the environment, and lessen the risk to human health and well-being. Other effective adaptation measures include managing development in coastal areas, preventing construction in areas of known vulnerability, and protecting coastlines around significant sites. In some communities, low adaptive capacity due to aging populations and average annual incomes lower than the national average will make adaptation challenging to implement.

Chapter 5- Quebec

Key Findings

Climate change will have many environmental, public health and socioeconomic impacts. In Quebec, these impacts will differ depending on the particular sensitivities of each region. The extent and costs of climate change impacts will likely increase over time. Key findings include the following:

The extent and magnitude of climate change impacts depend largely on changes in demographic, socioeconomic and environmental conditions. Apart from climate change per se, an analysis of anticipated impacts must also include an analysis of the factors that

will affect the vulnerability of each subregion. Accordingly, the following points should be considered:

- From 1960 to 2003, temperatures in southern Quebec increased by between 0.5°C and 1.2°C in the southwestern and south-central areas, and by less than 0.5°C in the southeastern part. In northern Quebec, a gradual cooling has been replaced by a sudden warming of about 2 °C since 1993.
- Despite uncertainties, the use of increasingly high-performance climate models makes it possible to produce detailed climate scenarios for several parameters and several regions, all of which point to major changes in climate trends.
- In Quebec, there is a slowing of population growth and an increasingly aging population, except among First Nations and Inuit communities. There has been a population shift from urban centres mainly to the outer edges of developed areas and suburban belts in southern Quebec, resulting in urban sprawl onto high-potential agricultural land.
- Although the general state of public health is improving, the future trend is uncertain due to several factors, including the fact that high-risk populations are becoming increasingly vulnerable.
- Quebec's growing economy is now based primarily on the tertiary (service) sector and is largely integrated into the North American and world economies. In contrast, infrastructure is aging and is largely exposed to the vagaries of the weather. In addition, many communities outside large urban centres are dependent on natural resources and are therefore also highly vulnerable to the vagaries of the weather.

The largest climate changes in absolute terms are anticipated to occur in the northern subregion. They will exacerbate the problems already being experienced in this region with respect to communities' high level of exposure to natural disasters and their dependence on critical infrastructure, access to resources and traditional ways of life that are closely related to the existing natural environment. Terrestrial and aquatic ecosystems have begun to change, specifically in terms of their structure, due to permafrost degradation, the formation of thermokarst lakes and ponds, the expansion of shrub communities and wildlife population displacements.

Climate change will result in alterations to the natural environment with potentially significant implicationsin areas where natural resource development is central to the economy. The landscape, hydrology and geomorphology of streams, the distribution of plant and animal life, and regional biodiversity could all undergo significant changes, particularly in areas already subject to a high level of human pressure. In contrast, this could have a certain beneficial effect, due to an anticipated increase in productivity in certain sectors, such as hydroelectricity and forestry. Nevertheless, these scenarios remain tinged with uncertainty for several reasons: lack of data, conflicting historical trends, poorly understood processes, uncertainties related to the tools used, and North American market effects.

In the maritime subregion, where the coast is highly exposed to the hydrosphere, there will likely be increased shoreline erosion along the Gulf of St. Lawrence and the St. Lawrence River estuary, the area where most of the subregion's socioeconomic activity is currently concentrated. The combination of sea-level rise, the gradual disappearance of surface ice, the geology of certain coastlines and possibly changing storm patterns all appear to result in an increase in the natural process of erosion, causing adverse effects on the built environment, tourist attractions and the quality of life for many communities in this subregion, which depends heavily on waterways for access.

In the south subregion, an increase in the frequency, intensity or duration of extreme weather events is believed to pose increased risks for the aging built environment, vulnerable populations and communities living in areas exposed to natural hazards.

Historical meteorological events have shown the high degree of dependency of urban and rural communities on water, energy supply and transportation infrastructure, all of which are exposed to the vagaries of the weather. Milder winters and hotter, more humid summers would lead to increased evaporation of natural waters; this could exacerbate water-use conflicts and lead to further degradation and loss of wetlands that rely on flooding. Climate change also poses significant risks to a number of threatened species already subject to various other stresses; these species have a low migration capacity and their habitat has become degraded. However, in this subregion, climate change could also result in energy savings (reduced demand) and development opportunities (increased plant productivity), resulting in annual gains of several hundred million dollars.

Adaptation to climate change offers many possible solutions to significantly reduce its adverse impacts. Human societies have always demonstrated an ability to adapt to climate variability and seem once again capable of overcoming the obstacles to climate change adaptation, which is based on the following elements: identifying and understanding the priority issues; collecting and disseminating information and data needed by the stakeholders involved in climate change adaptation; developing and applying the optimal techniques and technologies; amending or adapting policies, standards and organizational structures; and considering emerging uncertainties when making decisions. Quebec has a high degree of adaptive capacity, due specifically to its increasingly diversified knowledge economy. As for the natural environment, it adapts spontaneously and autonomously, and human systems may be able to assist with its adaptation. Although adaptation appears to be increasingly inevitable, little is generally known about its costs and limitations, particularly in the long term. Climate change adaptation measures should therefore be accompanied by reductions in greenhouse gas emissions in order to tackle the source of the problem and to minimize the 'nasty' surprises that the weather may hold in store for the future.

Chapter 6 Ontario

Key Findings

The social, economic and cultural health of Ontario is influenced by climate. Vulnerability to climate variability and change is demonstrated by the impacts of recent severe weather events, such as drought, intense rainfall, ice and windstorms, and heat waves. Those impacts include water shortages, lower Great Lakes water levels, flooding, forest fires, reduced agricultural production, damages to infrastructure and property, power outages and outbreaks of water-borne diseases.

Since 1948, average annual temperatures in Ontario have increased by as much as 1.4 °C. This trend is projected to continue, with the most pronounced temperature increases occurring in winter. Projections also indicate that intense rainfall events, heat waves and smog episodes are likely to become more frequent.

Physical infrastructure, water quality and supply, human health and well-being, remote and resource-based communities, and ecosystems are highly sensitive to climate. The degree to which the associated systems are vulnerable depends on their ability to successfully adapt to changes in both climatic and non-climatic stresses.

Disruptions to critical infrastructure, including water treatment and distribution systems, energy generation and transmission, and transportation have occurred in all parts of the province, and are likely to become increasingly frequent in the future. In recent years, flooding associated with severe weather has disrupted transportation and communication lines, with damage costs exceeding $500 million. Lengthy and extensive power outages have resulted from the failure of transmission grids and distribution lines. Projected decreases in Great Lakes water levels may compromise shipping and reduce hydroelectricity output by more than 1100 megawatts.

Water shortages have been documented in southern regions of the province, and are projected to become more frequent as summer temperatures and evaporation rates increase. Sections of Durham County, Waterloo and Wellington Counties, and the shoreline of southern Georgian Bay, where growth strategies indicate that the population will continue to increase significantly, will become more vulnerable to shortages within the next 20 years.

The health of Ontario residents has been at risk of illness, injury and premature death from such climate-related events as extreme weather, heat waves, smog episodes and ecological changes that support the spread of vector-borne diseases. Heat-related mortality could more than double in southern and central Ontario by the 2050s, while air pollution mortality could increase about 15 to 25% during the same interval. Extreme heavy precipitation events, such as the one in May 2000 that contributed to the E. coli outbreak in Walkerton, Ontario, which killed 7 people and made 2300 ill, are projected to increase. Adaptation, in the form of smog alert advisory systems, is now commonplace, and some cities have recently introduced heat-health alert systems.

Remote and resource-based communities have been severely affected by drought, ice-jam flooding, forest fires and warmer winter temperatures, which have caused repeated evacuations, disrupted vital transportation links and stressed forestry-based economies. Projected increases in winter temperatures will further reduce the viable operating season of winter roads, limiting access for the delivery of construction materials, food and fuel to many communities and mine sites in the far north. Increased frequency of forest fires and outbreaks of forest pests will adversely impact the health and economic base of communities dependent on the forest industry, particularly in the far northern parts of Ontario's boreal forest.

Ontario's ecosystems are currently stressed by the combined influence of changing climate, human activities and such natural disturbances as fire and outbreaks of insects and disease. Wetlands are particularly sensitive and have undergone dramatic declines in recent years, especially in southern Ontario. Observed changes in the relative abundance of fish species in southern Ontario show a shift from cold- and cool-water species to more warm-water species. Changes in the composition of aquatic and terrestrial ecosystems in the Hudson Bay region, and reduced numbers and health of polar bears and seals, are other examples of current impacts. Lower water levels in the Great Lakes, as projected for the future, will further compromise the wetlands that presently maintain shoreline integrity, reduce erosion, filter contaminants, absorb excess storm water, and provide important habitat for fish and wildlife. Invasive species in the Great Lakes are likely to increase, requiring modification to infrastructure and/or management activities.

Ontario has a strong capacity to adapt to climate change, based on a variety of indicators, such as economic wealth, technology, information and skills, infrastructure, institutions, social capital and equity. However, this capacity is not uniform across subregions and sectors. Adaptation is starting to occur in Ontario. For example, climate change has been incorporated into some long-term planning and decision-making, most notably by some conservation authorities (e.g. for storm-water management) and public health departments (e.g. with heat-health alert systems). Opportunities exist for mainstreaming adaptation to climate change into decision-making through, for example, the Clean Water Act, and other legislation, regulations or planned activities that relate to, among other things, infrastructure renewal programs, low-water response programs and growth strategies.

Chapter 7 Prairies

Key Findings

Increases in water scarcity represent the most serious climate risk. The Prairies are Canada's major dryland. Recent trends and future projections include lower summer streamflows, falling lake levels, retreating glaciers, and increasing soil- and surface-water deficits. A trend of increased aridity will most likely be realized through a greater frequency of dry years. Water management and conservation will continue to enable adaptation to climate change and variability. This could include technologies for improved efficiency of water use, as well as water pricing regimes that would more accurately reflect the real costs of water treatment and supply, and help to ensure that an increasingly scarce resource is properly allocated. Higher forest, grassland and crop productivity from increased heat and atmospheric CO 2 could be limited by available soil moisture, and dry soil is more susceptible to degradation. Water scarcity is a constraint on all sectors and communities, and may constrain the rapid economic and population growth in Alberta.

Ecosystems will be impacted by shifts in bioclimate, changed disturbance regimes (e.g. insects and fire), stressed aquatic habitats and the introduction of non-native plants and animals. Impacts will be most visible in isolated island forests and forest fringe areas. There are implications for livelihoods (e.g. Aboriginal) and economies (e.g. agriculture, forestry) most dependent on ecological services. Adjustments to ecosystem management are required to enable change to occur in a sustainable manner.

The Prairies are losing some advantages of a cold winter. Cold winters help limit pests and diseases, facilitate winter operations in the forestry and energy sectors, and allow access to remote communities though the use of winter roads. As winter temperatures continue to increase, these advantages will be reduced or lost. For example, the mountain pine beetle may spread into the Prairies' jack pine forests, exploration and drilling sites may become less accessible, and reductions in the length of winter road seasons are likely.

Resources and communities are sensitive to climate variability. The Prairies have one of the world's most variable climates. This variability has been both costly (e.g. an approximate $3.6 billion drop in agricultural production during the drought of 2001 –2002) and the stimulus for most of the adaptive responses to climate variability. Projections of future climate conditions include more frequent drought, but also increased precipitation in the form of rain and higher probability of severe flooding. Extreme events, and an expanded range of year-to-year departures from climate norms, represent greater risks to the economy of the Prairies than a simple shift in mean conditions.

Adaptive capacity, though high, is unevenly distributed. As a result, levels of vulnerability are uneven geographically (e.g. rural communities generally have less resources and emergency response capacity) and among populations (e.g. elderly, Aboriginal and recent immigrant populations are the fastest growing and more vulnerable to health impacts). Climate change could encourage further migration from rural to urban communities and to regions with the most resources (e.g. Alberta cities). Adaptive capacity will be challenged by projected increases in climatic variability and frequency of extreme events.

Adaptation processes are not well understood. Although a high adaptive capacity could reduce the potential impacts of climate change, it is unclear how this capacity will be applied. Most existing research does not capture adaptation measures and processes. Capacity is only potential — institutions and civil society will play a key role in mobilizing adaptive capacity. Recent adaptations, such as minimum tillage practices and crop diversification in the agriculture sector, water policy in Alberta, re-engineering of the Red River floodway, municipal infrastructure and water conservation programs, have enhanced resilience and increased adaptive capacity.

Chapter 8 British Columbia

Key Findings

Climate change is increasingly affecting British Columbia's landscapes, communities and economic activities. Future projections show that climate change will continue and suggest that direct and indirect impacts will become more pervasive. The following are some of the key risks and adaptation opportunities associated with climate change in BC:

Many regions and sectors of British Columbia will experience increasing water shortages. Smaller glaciers, declining snowpack, shifts in timing and amount of precipitation, and prolonged drought will increasingly limit water supply during periods of peak demand. Competition amongst water uses will increase and have implications for transborder agreements. Ongoing adaptive measures include the incorporation of climate change impacts into some official water management plans, upgrades to reservoir capacity and various demand management initiatives.

Hydroelectric power generation, especially during (increasing) peak energy demands in summer, is particularly vulnerable to climate change. Hydroelectricity currently accounts for nearly 90% of BC's power supply. Adaptation will involve managing electricity demands, which are expected to increase by 30 to 60% by 2025, and updating power-generating infrastructure, both of which are already part of current planning and management measures. Small hydro and 'run of river' alternatives can increase capacity but are more vulnerable to variable river flows than are facilities with large storage reservoirs. Alternative 'clean' sources of energy, such as wind power, will help meet increasing energy demands in the future, but are currently only a small contributor to BC's power supply. Coal-fired generating plants are also being considered, although their status is uncertain as they must now meet strict new zero net emissions targets established by the recently released BC Energy Plan.

Increasing frequency and intensity of extreme weather and related natural hazards will impact British Columbia's critical infrastructure. Windstorms, forest fires, storm surges, coastal erosion, landslides, snowstorms, hail, droughts and floods currently have major economic impacts on BC's communities, industries and environments. In low-lying coastal areas, certain risks will be magnified by sea-level rise and increasing storminess. The costs associated with managing and reducing impacts of extreme events are rising. British Columbia's transportation network, port facilities, electricity and communications distribution infrastructure are major investments where replacements or upgrades present adaptation opportunities for incorporation of revised hazards assessments that consider changing climate conditions and sea-level rise. Integrated stormwater management, an approach adopted by the Greater Vancouver Regional District, aims to manage stormwater run-off to protect urban stream health and includes consideration of climate change impacts. Integrating climate change and sea-level rise into infrastructure planning improves risk and life-cycle cost management, and will reduce the vulnerability of BC's critical infrastructure.

British Columbia's forests, forest industry and forestry-dependent communities are vulnerable to increasing climate-related risks, including pest infestations and forest fires. As of 2007, the mountain pine beetle outbreak affected approximately 9.2 million ha of BC's forests. The severity and longevity of this outbreak are linked to past management practices (e.g. fire suppression) and climate change. Major hydrological and ecological changes are expected in pine-dominated watersheds as a result of tree mortality and massive increases in logging activity to salvage beetle-killed timber. Initial economic gains will be substantial, but may give way to longer term social and economic instability without careful planning. Increasing international competition in the forestry sector will result in additional future challenges. The Future Forests Ecosystem Initiative of the BC Ministry of Forests and Range represents an early step toward long-term forest management planning that considers climate change in conjunction with other pressures.

Climate change will exacerbate existing stresses on British Columbia's fisheries. Future impacts include invasion of coastal waters by exotic species, rising ocean and freshwater temperatures, and changes in the amount, timing and temperature of river flows. Freshwater fisheries may experience increased water management conflicts with other uses (e.g. hydroelectric power generation, irrigation, drinking water), particularly in the southern interior. The vulnerability of Pacific salmon fisheries in both freshwater and saltwater environments is heightened by the unique social, economic and ecological significance of these species. Aquaculture, an increasingly important element of economic development on the coast, has potential to enhance food security while lessening the stresses on wild fisheries. However, the cultural and ecological impacts of aquaculture, and salmon farming in particular, are controversial.

British Columbia's agricultural sector faces both positive and negative impacts from climate change. Changes in precipitation and water supply, more frequent and sustained droughts, and increased demand for water will strain the adaptive capacity of most forms of agriculture. Growing conditions may improve in some regions or for some crops, although the ability to expand agricultural regions will be constrained by soil suitability and water availability. Increasing demand for irrigation will have to compete with other water uses, especially in areas of high growth.

Integrating climate change adaptation into decision-making is an opportunity to enhance resilience and reduce the long-term costs and impacts of climate change. Currently, this happens indirectly in larger urban centres, where sustainable building practices and demand management of water and energy arise from efforts to enhance sustainability and reduce greenhouse gas emissions. Drought-prone regions, such as the Okanagan region and the Victoria Capital Regional District, have aggressive restrictions on watering and rebates for high-efficiency consumer product replacements that have both adaptation and mitigation benefits for climate change. In remote coastal and rural communities, resilience arises from experience and exposure to the impacts of extreme weather on critical infrastructure (e.g. coastal highways, ferries, air service, power generation and communication) and on natural resources (e.g. fisheries and forests). Social networks, volunteerism, income diversification and food stockpiling also contribute to adaptive capacity and enhance resilience.

Appendix. 2 Who's doing what on climate change, water, and the resource sectors in Canada

This is a brief and incomplete list of research, programs and initiatives across Canada that are looking at the interrelationship between water, climate change and Canada's natural resources.

A International bodies
IPCC is the main body of experts. Canada is well represented especially on the relationship between climate change and water with experts Jim Bruceand Linda Mortsch. Another global report with far reaching research on climate change is the 2005 Arctic Climate Impact Assessment, more recent synthesis.

B Federal government
The 1987 Federal Water Policy states that: "The overall objective of the federal water policy is to encourage the use of freshwater in an efficient and equitable manner consistent with the social, economic and environmental needs of present and future generations." (Environment Canada, 1987). The Policy is currently inactive.

A Federal Water Framework was put together in 2004 by a committee representing 19 departments, but not released publicly. It established as a federal goal: "Clean, safe, and secure water for people and ecosystems." This goal is to be satisfied by "sustainable development through integrated water resources management within the federal government and within national and international contexts." (Government of Canada, 2004). The Interdepartmental ADM Committee on Water (IWAC) which developed the Framework has apparently recently been reactivated.

Many departments and federal agencies cover climate change and water. Natural Resources Canada has taken a lead role on climate change in terms of implementation (Climate Change Implementation Strategy); adaptation; and on the impacts of climate change on water and on Canada's natural resource industries. It has published *Freshwater: The role and contribution of Natural Resources Canada* (2005), and has commissioned additional unpublished reports.

It is currently preparing Fact Sheets on *Water Use in Canada's Natural Resource Industries* which will contain baseline information is available on water use in the natural resource sectors, including

- Water use
- Water source and discharge
- Purpose of Water use
- Ecosystem impacts
- Specific improvements in water use
- Emerging Issues

Its Climate Change Impacts and Adaptation Division is responsible for the recent assessment (Lemmen, Warren et al 2007) , the program "Climate Change Impacts and Adaptation for Key Economic and Natural Environment Sectors" with three focal areas: potential impacts of climate change (CC) on energy supply, agriculture, and on the natural capital of the north, and public information and education products such as a series of five posters created to explain the risks and opportunities and share what has been done to adapt to climate change in the sectors of agriculture, forestry, health, coastal zones, and water resources

The Canadian Climate Impacts and Adaptation Research Network (C-CIARN) was established by

Natural Resources Canada in 2001 with the mandate of promoting and encouraging research on climate change impacts and adaptation, as well as promoting interaction between researchers and stakeholders. In the last year of C-CIARN's mandate (July 2006-June 2007), each C-CIARN office was asked to write a report summarizing their perspectives on the state of climate change impacts and adaptation within their region or sector. The resulting "State-of-Play" reports identify, from the point-of-view of C-CIARN, the key climate change impacts, as well as the key stakeholders and adaptation decision- makers (including how these stakeholders/decision-makers were most successfully engaged) of each representative region and sector of Canada. Relevant state of play reports include: water resources, forests, agriculture

Environment Canada

Environment Canada produces National Reports on Climate Change, the most recent is the 4th National Report (2006) which has a section on water resources. It also has an Adaptation and Impacts Research Division (AIRD) , the Canadian Climate Change Scenarios Network (CCCSN)and produced two science assessments: *Threats to Sources of Drinking Water and Aquatic Ecosystem Health in Canada*, and *Threats to Water Availability in Canada*. The latter report contains 15 chapters, including one on each of the 4 resource sectors identified by NRTEE.

Other agencies relevant to natural resource sectors include the Canadian Forest Service, with three main study areas under the climate change business line including vulnerability assessments, productivity effects and the carbon balance, and Agriculture and Agri-Food Canada which assists the industry with climate change adaptation and water technologies.

The federal government produced the Climate Change Action Plan *Turning the Corner Action Plan* released on April 26, 2007, which is relatively silent on impacts of climate change on water and natural resources. The Senate in 2005 produced a report titled “Water in the West” which catalogues threats to water.

NRTEE has produced climate change studies, and advice such as Getting to 2050: Canada's Transition to a Low-emission Future.

The Commissioner on Environment and Sustainable Development also audits government performance in these areas, especially the 2006 report on climate change *Looking Back- Too Little, Too Slow* which found that Canada was not on track to meet its obligations to reduce emissions due to a variety of reasons: some programs were launched but others such as Large Final Emitters and domestic emissions trading lagged; some programs were not strong enough; emission reductions for transportation and energy sectors were not accompanied by programs expected to bring emissions below 1990 levels; ever shifting responsibilities and changes of plan caused delays; no plan was formed on adaptation; weaknesses in the government wide system of accountability for climate change; and overall no effective governance structure to manage climate change activities was found.

C Provincial and territorial governments and related bodies,

Most provinces devising climate change action plans and water strategies. Often these strategies overlap, but not always, as these select examples: Alberta, BC, and Ontario, demonstrate.

BC has a BC Climate Action Plan, and an independent BC Climate Action team . BC also has a new water plan, Living Water Smart, the water plan is linked to the climate action plan under the overall heading LiveSmart BC.

Alberta

January 2008, the Alberta government released its action plan to address climate change.

Water for Life: Alberta's Strategy for Sustainability has been the vehicle for managing Alberta's water resources since 2003,and was renewed Nov 2008
Alberta Water Council is a multi-stakeholder partnership with 24 members governments, industry, and non-government organizations, and monitors Alberta's *Water for Life* strategy. On December 16, 2008 it released a report outlining 21 recommendations for water conservation, efficiency and productivity sector planning to guide seven Alberta sectors in setting and meeting water conservation, efficiency and productivity goals. The seven sectors represent some of the largest water users in the province and are all active members of the Alberta Water Council. They have committed to developing Water Conservation, Efficiency and Productivity plans by December 2010.

Ontario
Ontario has established a central climate change secretariat – similar to BC's but much more streamlined (its focus is facilitating and encouraging work by all ministries on CC rather than housing the work itself) and has also struck an expert advisory panel on climate change adaptation now meeting with all relevant ministries in Ontario including, MOE, natural resources and mining, about their initiatives and what they are or are not doing to address climate change. In addition, the Environmental Commissioner of Ontario has examined provincial policies on drought and water, noting gaps in water management practices when low flow and drought conditions occur, and making recommendations to deal with the 'profound effects' of climate change, water withdrawals and other forces in the coming years (ECO, 2008, at 55)

D. Watershed level
Many communities across Canada are addressing the linkages between water, climate change, and resource industries. For example:

The Fraser Basin Council in BC held a workshop and issued a report on the topic Preparing for Climate Change in the Fraser Basin: How can our Water Management Systems Adapt? (FBC 2007)

In the Great Lakes Basin, the Ontario Chapter of the Soil and Water Conservation Society prepared a report discussing the need for soil erosion prevention and control on agricultural lands due to the quantified changes in the rainfall regime, the projected future changes, (SWCS, 2007)

The Columbia Basin Trust has held workshops and issued reports on these linkages beginning in 2006 with a report "Climate Change in the Columbia Basin - Starting the Dialogue" with sections on the impacts on the hydroelectric industry, forestry, and agricultural sectors, along with suggested measures for adaptation (Columbia Basin Trust, 2006)

Case studies of the implications of a 2 degree rise in temperature for Athabasca River and the Great Lakes were prepared for the World Wildlife Fund Canada (WWF, 2006)

The Okanagan Basin Water Board has instituted many relevant activities, including its recently released Okanagan Sustainable Water Strategy , which recommends incorporating climate change scenarios in watershed planning and modeling (Okanagan Watershed Stewardship Council, 2008)

E Universities and research institutes
The Canadian Water Network connects expert water researchers from the academic community across Canada. Other networks and specialist centres include the Ouranos Consortium in Quebec, the Prairie Adaptation Research Collaborative and the Pacific Climate Impacts Consortium.

F Nongovernmental organizations.
Pembina Institute is a leader, and has produced reports on :
Deep Reductions, Strong Growth An Economic Analysis Showing Canada can Prosper Economically While Doing its Share to Prevent Dangerous Climate Change, Dec 10, 2008; **Evaluation of the Government of Canada's GHG Reduction Policies** , Prepared for the Climate Change Performance Index 2009, Dec 4, 2008, and **Choosing Greenhouse Gas Emission Reduction Policies in Canada** Oct 24, 2008 which identifies and assesses policies against a set of criteria to determine the most efficient and effective options.

Forum for Leadership on Water, FLOW, (formerly the Gordon Water Group) produced a report Changing the Flow which pointed out the overall need for national water strategy, with a section on climate change, but no particular focus on resource industries and their vulnerabilities.

A number of other NGOs work on these issues including the Climate Action Network Canada (CAN Canada), Polis, IISD, WWF, and the David Suzuki Foundation.

G Business Groups
International and national business organizations are devoting an increasing amount of attention to water. The World Business Council on Sustainable Development developed a Global Water Tool with input from some of Canada's largest resource corporation such as Petro-Canada and Alcan. The UN's Global Compact helped convene a the CEO Water Mandate Initiative which aims at more efficient water use in industry.

National business groups such as the Conference Board of Canada are also looking at water and climate change policy issues of interest to business, such as Adapting to Climate Change: Is Canada Ready? as well as water focused reports such as Navigating the Shoals: Assessing Water Resource Management and Governance in Canada (2006) and a forthcoming report on water markets. It also developed the Leaders Forum on Water Resource Management , described as a three-year initiative whose mandate is to help resolve policy challenges and conflicts related to the management and governance of water resources.

The investment community is also increasingly aware of water and climate change risks and opportunities. For example, Lehmann Bros produced a report on the Business of Climate Change, 2008. The UNEP Financial Initiative has a program on water: "While climate change may be the single biggest environmental challenge of the coming decades, its effects on business will mostly manifest themselves via water: circumstances of too little, too much or inadequate timing and quality of supply will expose businesses to considerable financial stress. And yet, despite its material importance, water has, until now, only scarcely appeared on the radars of financial institutions." It produced a report to help businesses identify, assess, quantify and integrate water-related risks into existing due-diligence procedures: across geographies and industries; and both within the water/sanitation sector and with respect to businesses "downstream".(UNEP FI 2007)

National industry associations, such as the Canadian Forest Producers Association, the Canadian Association of Petroleum Producers, the Canadian Mining Association, and the Canadian Federation of Agriculture are all increasingly cognizant of the environmental constraints faced by their industries.

Industry specific groups such as the Canadian Water and Wastewater Association and the Canadian Water Resources Association WRA have, as yet, not focused specifically on how climate change's impacts on water will affect the natural resource industries.

Appendix 3 C-CIARN state of play water report

6. Unanswered Research Questions
LIST OF IMPACTS AND ADAPTATION ISSUES IN NEED OF RESEARCH (AS PER REGION IN CANADA)

Atlantic
• Streamflows: Shifting streamflow regimes could have ecological impacts, cause water apportionment issues, and lessen the hydroelectric potential (Lemmen, 2004)
• Ice cover: Changes in ice freeze-up and break-up timing can have implications for spring floods or coastal erosion (Lemmen, 2004)
• Groundwater: Loss of potable water caused by saline water intrusion. Resulting water conflicts could be a problem (Lemmen, 2004)
• Especially in PEI, examine the sensitivity of aquifers to future recharge rates and consider ground and surface waters together in managing resources (Rivera, 2002)
• Flooding: Increase in the occurrence and the severity of flooding events could cause an increase in water borne health effects (Lemmen, 2004)
• More frequent and severe ice jams could cause more flooding (Beltaos 2004).

Québec
• Québec City has seen a 30-40% decrease in streamflow. People are using deeper wells and the city is facing a problem of saline waters rising to meet the freshwater. This problem may be worsened by extreme events: the saline water could reach the surface, whereas the system can cope under normal circumstances. (Mailhot, 2002)
• Stream flow could be reduced by 30-40% due to climate change. It could then be further reduced due to drinking water demands. This decrease in flow will lead to water quality concerns. (Mailhot, 2002)
• Flooding and the resulting overflow of sewers could occur more frequently (Mailhot, 2002)
• Change in thermal regimes could affect demand for hydroelectricity, and could cost $500M (half of all profits) (Roy, 2002)
• Extreme events such as the 1996 Saguenay flood, the 1998 ice storm, and the 2001 drought could become more frequent (Bourque, 2002) Saint-Lawrence and the Great Lakes
• A decrease in the extent of lake-ice, as well as the occurrence of some years without ice cover can impact ecosystems and navigation by increasing water loss through evaporation (Lemmen, 2004)
• Lower water levels, caused by increased evaporation and dry spells, will impact municipal water supplies (less available and lower quality water due to pollutant concentration), navigation, hydroelectric power generation, recreation and natural ecosystems (Lemmen, 2004)
• Changes in precipitation intensity could increase erosion, cause land and water quality degradation, flooding, and infrastructure failure (International Joint Commission, 2003)
• Longer periods of dry weather could cause an increase in the contaminants on roads and land, which will cause a greater unloading into the land and water when precipitation finally occurs (International Joint Commission, 2003)
• Increasing air temperatures, which cause an increase in evaporation and evapotranspiration and changes in precipitation amount, timing and duration could possibly affect water supply variability in the GL region. The frequency of droughts and flooding is expected to increase. Stream flow regimes, lake levels and groundwater are affected by these changes. (International Joint Commission, 2003)
• Less rainfall, higher evapotranspiration, and lower soil moisture during droughts reduce recharge and lower water levels in aquifers. (International Joint Commission, 2003)
• Ground water inputs into the Great Lakes Basin is unknown (Rivera, 2002).

• The low water levels experienced in the Great Lakes during 1999 to 2001 could occur more frequently. These low levels can affect the aesthetics of recreational property along the lakeshores and impede the use of summer recreational boats and marinas. Low water levels restrict access of commercial navigation vessels in shipping channels, locks and ports. The shipping industry will have to reduce ship loads, incurring additional costs. (International Joint Commission,
2003)
• Low lake levels may put pressure on governments to dredge. However, dredging is very expensive and causes concerns for ecosystems and human health because of contaminated sediments. (International Joint Commission, 2003)
• Lower water levels may decrease coastal erosion in the Great Lakes. Erosion losses are high at the moment because of development on the coasts (USEPA, 1995)

Ontario
• Flooding and the overflow of sewers could occur more frequently (Pang, 2002)
• Communities and municipalities may experience flash floods (McBean, 2002)
• Due to drought, increased demand on groundwater supplies, warm summer temperatures increasing drinking water demand, less water available for hydroelectricity, and irrigation, we may experience water restrictions and apportionment challenges. (Water Resources, Group 1, 2002)
Decreased water quality will affect recreation (Water Resources, Group 2;2002)
• Changing lake levels will affect harbours and channels (Water Resources, Group 2, 2002)
• The ability to meet peak water demands will be challenged (Water Resources, Group 2, 2002)

Prairies
• Droughts could cause losses in agricultural production and changes in land use (Lemmen, 2004)
• Prolonged droughts in northern Great Plains affect water resources (Sauchyn and Skinner, 2001)
• Examine the sensitivity of aquifers to future recharge rates and consider ground and surface waters together in managing resources (Rivera, 2002)
• Changing streamflow regimes could affect agriculture, hydroelectric generation, ecosystems and water apportionment (Lemmen, 2004)
• With the potential decrease in river flow regimes, water allocations based on a percentage basis will be more robust than volume-based apportionments
• The mean flows and peak discharge of the Milk River at the border have decreased in the past 30 years, in part due to climate change. Future changes in the apportionment rules may be brought about (Bruce, 2003).
• Along the eastern slopes of the Canadian rocky Mountains, glacier cover is now approaching the lowest experienced in the past 10 000 years. The glacier retreat is causing a decrease in the downstream flow volumes. This trend in low flows is
expected to continue and will exacerbate drought-caused water shortages already occurring in many areas in Alberta and Saskatchewan. (Lemmen, 2004)
• The impact of more persistent and frequent occurrences of droughts are a concern for future hydropower production (Mehdi, 2002)

British Columbia
• Glacier retreat in Yukon and BC could increase spring flooding risks (BC) and impact river flow regimes. This would reduce hydroelectric potential, impact ecosystems such as the fisheries, damage infrastructure and cause water apportionment problems (Lemmen, 2004)
• Reduced flows could affect spawning grounds for certain fish species. The timing of the low flows (summer) coincides with salmon spawning season. Changes in water temperature could also affect the distribution of these species (Petticrew, 2003)
• Warmer winters are resulting in earlier spring melt and rain instead of snow

winter precipitations. Given BC's reliance on gradual snow melt to sustain summer flows, these trends can be expected to lead to reduced summer water supplies (Government of BC, 2004)

\ Water allocation could become a problem between communities (distribution, licensing) and hydropower (Lemmen, 2004)

• If precipitation increases from 5%-10%, whether due to seasonality, intensity and duration or a net increase in yearly precipitation, there will be a great increase in the number of landslides. (Clague, 2003)

• Wetter winters (more rain as opposed to snow), rain at higher elevations that affects snowpack, the occurrence of smaller snowpacks, and earlier spring freshets will all change the timing of the water entering BC Hydro's reservoirs (Smith, 2003)

• Columbia River Treaty may require renegotiation based on future flows (Power, 1985)

• More extreme rain events will affect flood protection planning for BC Hydro (Smith, 2003)

• Reduced summer flows will affect BC Hydro because they have many downstream fisheries and may have to supplement summer flows with water from their reservoirs (Smith, 2003)

• In the Okanagan Basin, population growth is causing a rising demand in water. Water supply is changing due to climate change: snowpacks are smaller and spring melts come earlier resulting in a change in water timing (Cohen, 2003).

• Water management in the Okanagan Valley in response to the potential of higher evapotranspiration, increasing population, increased conflicts among water users and transboundary implications related to shared water resources within the US-Canada Columbia Basin system (Taylor, 2004)

• GVRD reservoirs, such as the Capilano Reservoir, could encounter increased turbidity problems due to increased landslides. Such problems already cause the reservoir to shut down an average of 55 days per year because the increased turbidity impairs water treatment (NRC, 2003)

• Increased precipitation could cause more frequent avalanches and landslides (Geertsema, 2003)

Arctic and Subarctic

• Thinner ice cover and an increase in the ice-free season are having ecological impacts and impact the traditional way of life (Lemmen, 2004)

• Thinner ice cover might result in improved navigation, changes in viable road networks (Lemmen, 2004)

• Ruptures of drinking water and sewage lines from permafrost degradation could occur (Lemmen, 2004)

• Increased turbidity and sediment loads in drinking water (Lemmen, 2004)