SYNTHESIS

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SUMMARY

Over the past 5 years, our understanding of climate change impacts and adaptation in Canada has increased both as a result of new research and through practical experience. Key conclusions arising from this update to the 2008 assessment report *'From Impacts to Adaptation: Canada in a Changing Climate'* include:

1. Canada's climate is changing, with observed changes in air temperature, precipitation, snow and ice cover and other indicators. Further changes in climate are inevitable.
2. Changes in climate are increasingly affecting Canada's natural environment, economic sectors and the health of Canadians.
3. Extreme weather events are a key concern for Canada and there is growing confidence that some types of extreme events will increase in frequency and/or intensity as the climate continues to warm.
4. Adaptation is accepted as a necessary response to climate change, complementing global measures to reduce greenhouse gas emissions. Adaptation enhances the social and economic resilience of Canadians to climate change impacts.
5. Adaptation is occurring with increasing frequency and enhanced engagement. Continued action will help to build capacity, address information needs and overcome challenges.
6. Adaptation can sometimes turn risks into opportunities, and opportunities into benefits.
7. Collaboration and adaptive management are approaches that governments and industry are increasingly pursuing to advance adaptation.

INTRODUCTION

The climate is changing – in Canada and throughout the world. Globally, international assessments continue to identify rising air and ocean temperatures, shifting precipitation patterns, shrinking glaciers, declining snow cover and sea ice extent, rising sea level and changes in extreme events (IPCC, 2013). While rates of change vary from one indicator to another, the directions of change are consistent with climate warming, and climate models project that many of the observed trends will continue over the coming decades and beyond. Reducing greenhouse gas emissions (GHGs; mitigation) is necessary to lessen the magnitude and rate of climate change, but additional impacts are unavoidable, even with aggressive global mitigation efforts, due to inertia in the climate system. Therefore, we also need to adapt – make adjustments in our activities and decisions in order to reduce risks, moderate harm or take advantage of new opportunities. All levels of government, researchers, the private sector and non-government organizations now view adaptation as an essential complement to mitigation.

In 2008, the Government of Canada released a national-scale science assessment of climate change impacts and adaptation (*From Impacts to Adaptation: Canada in a Changing Climate*). That assessment used a regional approach to discuss current and future climate change impacts and vulnerabilities in Canada, as well as adaptation options. It built upon the findings of Canada's first national-scale assessment (*The Canada Country Study*, 1998) and drew conclusions from all available relevant literature.

This report – *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation* – is an update to the 2008 assessment. It focuses on new information and knowledge, assessing advances made in understanding climate change impacts and adaptation from a sectoral perspective, based primarily on literature published up to the end of 2012. This synthesis draws from the individual chapters of the report, which include an overview of Canada's changing climate (Ch. 2), thematic chapters focused on sectors (Ch. 3 to 8) and the concluding chapter on adaptation research and practice (Ch. 9). The key findings of chapters 3 to 9 are summarized in Box 1. The rest of the synthesis is structured around high-level conclusions, supported by examples and insights from an integrative analysis across the report themes[1].

[1] This Synthesis does not repeat the references provided in the underlying chapters, but rather directs the reader to individual chapters of the report where specific references can be found. Occasional specific references are included when the source was not cited within another chapter or to provide additional context.

BOX 1

KEY FINDINGS FROM THE CHAPTERS

Natural Resources (Forestry, Energy and Mining, Chapter 3)

- Climate change will exacerbate existing climate risks related to the planning and management of natural resources. These risks relate to impacts and natural hazards associated with climate extremes (e.g. heat, cold, precipitation) and to gradual changes, such as permafrost degradation, sea level rise, and plant species migration. Climate change will also present new opportunities for the natural resource sectors, particularly in relation to northern economic development.
- Consideration of multiple stressors is critical to understanding adaptation in the natural resource sectors. Climate change itself is rarely identified as a priority concern, with industry focused on other immediate stressors, such as economic drivers. Opportunities exist to integrate consideration of climate change into current planning processes.
- Environmental assessment, risk disclosure, and sustainable forest management reporting are examples of processes that can help advance adaptation actions. These processes allow governments, investors and the public to evaluate industry understanding of changing climate risks and influence the steps taken to address those risks.
- While awareness of climate change impacts and implementation of adaptation actions is most evident in sectors where there is a clear and direct relationship between climate and resource supply, notably forestry and hydroelectricity, the application of adaptive management approaches to address climate change impacts is seen across all natural resource sectors.

Food Production (Chapter 4)

- The impacts of climate change differ significantly between agriculture, fisheries, and non-commercial food supply, but common challenges include increased losses from invasive pests and diseases, and risks to transportation systems upon which the sectors rely.
- The net medium-term outlook is for a likely modest increase in agricultural food production. Longer and warmer growing seasons would allow higher-value warmer-weather crops to be grown further north (where soil conditions permit), lengthen outdoor feeding seasons for livestock, and allow the maple syrup industry to expand northward. However, there will likely be new pests and diseases, as well as more severe outbreaks of current ones, and challenges associated with extreme weather events and the reduced predictability of inter-annual weather variability that could negatively affect production.
- Northern and remote communities are likely to see great changes in their environment – some will ease food security concerns, while others could exacerbate already decreasing country food stocks and difficulties in delivering supplies into isolated areas.
- Canada is expected to remain a net exporter of aquatic foods at the aggregate level, with total biomass of production from wild, capture fisheries in Canada expected to increase due to climate-induced shifts in fish distributions. Regional impacts from invading species, physical habitat changes and societal responses to shifts in availability and access to aquatic food resources will gradually determine future patterns of use and overall economic implications.
- Aquaculture has a greater scope for adaptation to climate change than other fisheries, making it less vulnerable and better positioned to take advantage of opportunities than capture fisheries, and subsistence fisheries in particular.

Box 1 continued on next page

Industry (Chapter 5)

- Industrial activity is sensitive to variations in weather and in extreme events, with considerable differences in the types and extent of impacts on production, operations, and revenue among and within sectors.
- Changes in industry practices have been predominantly reactive, responding to variation in the weather or extreme events, rather than proactive anticipation of future climate change. Examples of adaptation tend to be isolated rather than representative of a clear trend within the sector.
- Adaptive actions implemented by industry vary by sector, and may be under-reported for strategic reasons. Relative to other sectors, tourism and insurance show the most promise in using adaptive actions to take advantage of potential opportunities.
- There is little published research about indirect impacts of climate change on industry, such as changes associated with consumer demand, supply chains, real estate or other assets, adaptation by other sectors, legal liability or government regulation.
- Barriers towards effective adaptation include limited information on local impacts to businesses, uncertainties about the costs and benefits of different adaptive actions, and limited market demand for the implementation of adaptation.

Biodiversity and Protected Areas (Chapter 6)

- Climate-related shifts in species distributions have already been documented for plants and animals in Canada. In many locations, differential range shifts among species are likely to result in novel ecosystems that have different species assemblages, structural attributes, and ecological functions than existing ones.
- For some species, the current and projected rates of environmental change exceed their natural ability to adapt, increasing stress and threatening biodiversity. As a result, climate change is magnifying the importance of managing ecosystems in a manner that enhances resilience and preserves biodiversity.
- Protected areas, including parks, wildlife reserves and marine protected areas will play an important role in the conservation of biodiversity by providing "refuge" or migration corridors for native species, helping to maintain genetic diversity.
- Many Canadian jurisdictions are expanding their parks and protected area systems as part of their overall management plans and climate change adaptation strategies. Associated research, monitoring, citizen science, public awareness, and visitor experience programs build understanding, engage the public and help them contribute to meaningful participatory decision-making.
- Ecological restoration can strengthen resilience to climate change. Integration of climate change adaptation strategies into restoration decision-making in Canada, as elsewhere, is complex.

Human Health (Chapter 7)

- Stronger evidence has emerged since 2008 of the wide range of health risks to Canadians posed by a changing climate. For example, climate-sensitive diseases (e.g. Lyme disease) and vectors are moving northward into Canada and will likely continue to expand their range. In addition, new research suggests climate change will exacerbate air pollution issues in some parts of Canada, although further reductions in air contaminant emissions could offset climate-related changes to ground-level ozone and particulate matter concentrations.
- A range of climate-related natural hazards continues to impact communities, presenting increasing risks to future health. Recent flood and wildfire events have severely impacted communities through destruction of infrastructure and displacement of populations.
- Many adaptation activities are being taken from local to national levels to help Canadians prepare for the health impacts of climate change. Adaptation planning considers the underlying causes of health vulnerability, which differ across urban, rural, coastal and northern communities.

Box 1 continued on next page

- Provincial, territorial and local health authorities are gaining an increasing knowledge of climate change and health vulnerabilities through assessments and targeted research, and some jurisdictions have begun mainstreaming climate change considerations into existing health policies and programs. Efforts to increase public awareness about how to reduce climate-related health risks are also evident.
- Adaptation tools and measures, such as heat alert and response systems, projections of vector-borne disease expansion and greening urban environments can help protect Canadians from the effects of climate change being felt now, and those from future impacts.

Water and Transportation Infrastructure (Chapter 8)

- Well-maintained infrastructure is more resilient to a changing climate. This is especially true with respect to gradual changes in temperature and precipitation patterns. Key vulnerabilities are associated with the impacts of extreme weather events, which can overwhelm the capacity of water infrastructure.
- Over the past five years, the work of the PIEVC (Public Infrastructure Engineering Vulnerability Committee) has been an important driver of progress on understanding how to adapt Canada's infrastructure to climate change. The broadly applicable, risk-based assessment protocol developed by the PIEVC allows engineers and planners to view and address climate change as one factor among many affecting system resiliency, and plan accordingly.
- Consideration of climate change as an element of adaptive asset management encourages consideration of climate factors as part of ongoing system monitoring, and informs decisions regarding the most cost-effective approaches for infrastructure design, operation and maintenance.
- Codes, standards and related instruments (CSRI) are recognized as a potentially important driver of infrastructure adaptation, but there are few examples of CSRIs in Canada that considered historic changes or projected future changes in climate when they were developed. Further assessment of current and future climate-related risks to infrastructure systems would help to inform appropriate adjustments to design codes and standards for addressing future climate.

Adaptation: Linking Research and Practice (Chapter 9)

- Adaptation is being undertaken in Canada to achieve a range of goals, such as increasing capacity to adapt, improving resilience to specific climate events (especially extremes), and enhancing ability to deal with different climate conditions. Among sectors, those with a demonstrated high sensitivity and exposure to climate and weather are generally most active in taking steps to understand, assess and manage vulnerability and risk related to climate change.
- Adaptation is not solely a local issue, although examples from the municipal level still appear to dominate. There are examples of action by all levels of government, as well as community groups and industry, many of which represent collaborative initiatives.
- Understanding of the barriers and challenges to adaptation has improved, with recognition that factors beyond the basic determinants of adaptive capacity need to be addressed. As a result, understanding of how to overcome key barriers and enable adaptation has improved.
- Adaptation implementation in Canada is still in its early stages. Planning and policy exercises, and efforts to build capacity and raise awareness comprise much of the adaptation action documented, with relatively few documented examples of implementation of specific changes to reduce vulnerability to future climate change, or take advantage of potential opportunities.
- Several factors can help accelerate the transition between awareness and action, including leadership, targeted awareness-raising and supportive strategies or policies. Experiencing extreme weather events, as well as observing impacts of gradual changes (e.g. sea level rise) also stimulates adaptation.

CANADA'S CLIMATE IS CHANGING, WITH OBSERVED CHANGES IN AIR TEMPERATURE, PRECIPITATION, SNOW AND ICE COVER AND OTHER INDICATORS. FURTHER CHANGES IN CLIMATE ARE INEVITABLE (CHAPTER 2).

Over the last six decades, Canada has become warmer, with average temperatures over land increasing by 1.5°C between 1950 and 2010 (Figure 1). This rate of warming is about double the global average reported over the same time period by Hartmann et al., (2013). Warming has been occurring even faster in many areas of northern Canada, and has been observed in all seasons, although the greatest warming has occurred in winter and spring. The annual number of extreme warm days has also risen, while the number of cold nights has declined. Table 1 provides examples of documented changes in Canada for a variety of indicators of the physical climate system.

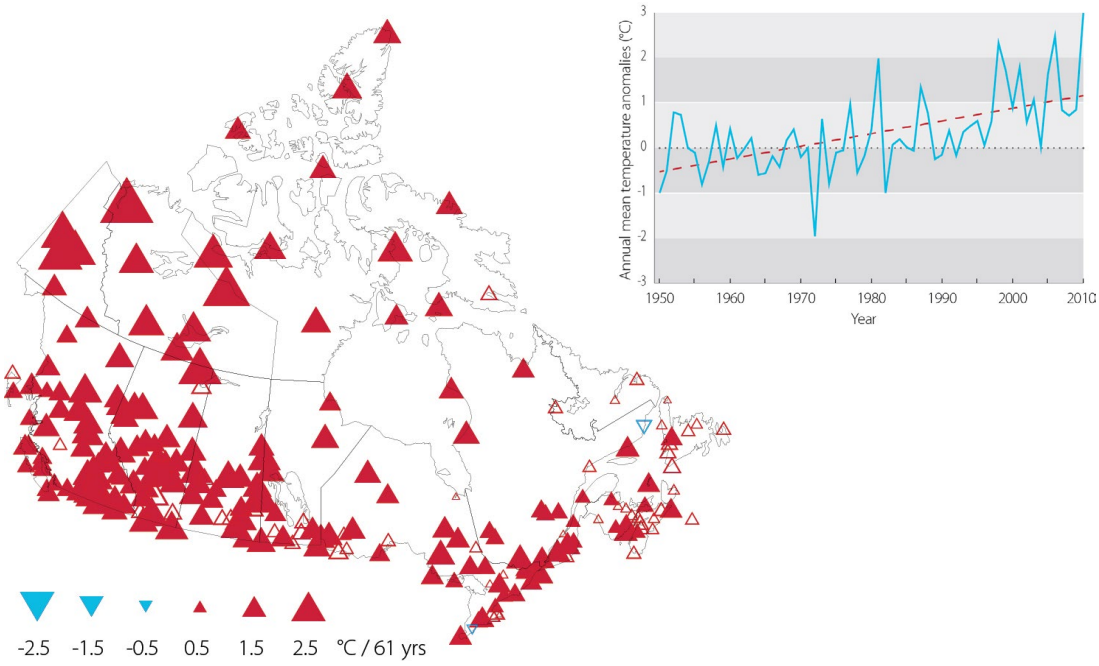

FIGURE 1: Patterns of change in annual mean temperature across Canada over the period1950–2010. Upward (red) and downward (blue) pointing triangles indicate positive and negative trends respectively. Filled triangles correspond to trends significant at the 5% level *(Source: Vincent et al., 2012)*. ***Inset:*** Annual mean temperature change for Canada (°C), 1950–2010, relative to the 1961–1990 average (represented by zero on the Y-axis) *(Source: Vincent et al., 2012; Environment Canada, 2011)*.

Climate System Element	Observed Trends
Temperature	
Annual air temperature – Canada	The annual average surface air temperature over the Canadian landmass has warmed by 1.5°C over the period 1950-2010
Temperature Extremes	
Hot extremes – Canada	The frequency of warm days (when the daily maximum temperature is above the daily 90th percentile) during the summer has increased nationally since 1950
Cold extremes – Canada	The frequency of cold nights (when the daily minimum temperature is below the daily 10th percentile) during the winter has decreased nationally since 1950
Precipitation and other hydrological indicators	
Annual precipitation – Canada	Canada has generally become wetter in recent decades, as indicated by the increasing trend in annual average precipitation
Snowfall/Rainfall – Southern Canada	In several regions of southern Canada, there has been a shift in precipitation type, with decreasing snowfall and increasing rainfall
Streamflow – Canada	Observations suggest decreasing trends in maximum and minimum river flows over the period 1970-2005 in much of southern Canada, with increases in minimum flows in western Nunavut, Northwest Territories, Yukon and northern British Columbia
Snowfall – Canada	Annual snowfall has declined over most of southern Canada and increased in the north over the last 6 decades
Snow cover – Canada	Negative trends in snow cover extent have been observed during spring over the Canadian landmass, with largest declines observed in June
Permafrost	
Ground temperature – Canada	Permafrost temperatures at numerous borehole sites across Canada have increased over the past two to three decades
Sea Level	
Sea level – Global	Global average sea level rose about 21 cm between 1880 and 2012 at an average rate of 1.6 mm/year
Relative sea level – Canada	Relative sea level rise of over 3 mm/year has been observed on coastlines of Atlantic Canada and the Beaufort Sea coast, with lower amounts along Pacific coastlines. Relative sea level fall of 10 mm/year has been observed around Hudson Bay where the land is rising rapidly due to post-glacial rebound
Sea Ice	
Seasonal ice extent – Arctic	End-of-summer minimum ice extent has declined at a rate of 13% per decade over 1979-2012, while maximum winter sea ice extent has declined at a rate of 2.6% per decade
Ice Type – Arctic	A shift in ice cover from one dominated by thick multi-year ice (MYI) to one increasingly dominated by thin first-year ice (FYI) has been observed
Eastern Canada	Declines in winter sea ice extent have been observed in the Labrador-Newfoundland and Gulf of St. Lawrence region
Glaciers	
Glacier mass – Yukon, British Columbia, Alberta	Western Cordilleran glaciers are losing mass and shrinking rapidly to the smallest extents in several millennia. Glaciers in British Columbia and Alberta have lost, respectively, about 11% and 25% of their surface area over the period 1985-2005, while glaciers in Yukon have lost about 22% since the 1950s
Glacier mass – High Arctic	Significant negative mass balances are evident from the early 1960s into the first decade of the 21st century. The rate of mass loss for glaciers throughout the High Arctic has increased sharply since 2005, in direct response to warm regional summer temperatures
Lake and River Ice	
Spring ice thaw – Canada	Trends towards earlier ice-free dates (lakes) and ice break-up dates (rivers) have been observed for most of the country since the mid-20th century but are particularly evident in Western Canada
Ocean Climate	
Canada's oceans	Long-term changes in ocean temperature (increasing), salinity (variable sign), and acidity (increasing) have been observed in all three of Canada's oceans. Long-term decreases in subsurface dissolved oxygen levels have also been observed in the Atlantic and Pacific oceans off Canada

TABLE 1: Examples of observed changes in Canada (*from* Chapter 2). The length of the observational record varies with the indicator.

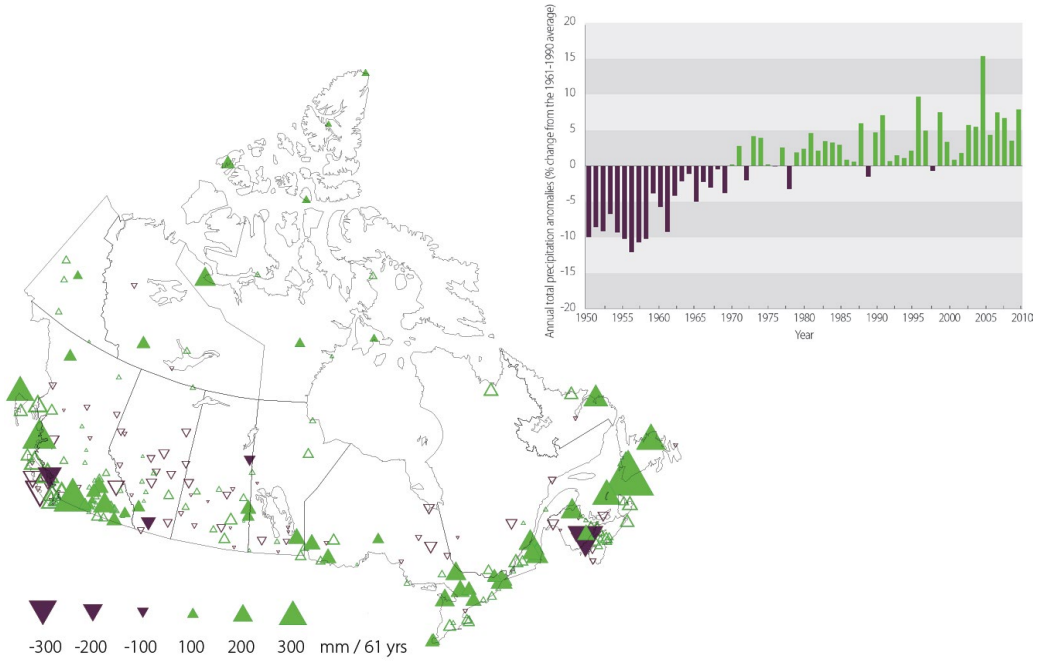

FIGURE 2: Patterns of change in annual total precipitation over the period 1950–2010. Upward (green) and downward (purple) pointing triangles indicate positive and negative trends, respectively. Filled triangles correspond to trends significant at the 5% level (*Source: Mekis and Vincent, 2011b*). ***Inset:*** Annual total precipitation anomalies (expressed in % change from the 1961–1990 average) for Canada, 1950–2010 (*Source: Mekis and Vincent, 2011a; Environment Canada, 2011)*.

Over the same time period (1950–2010), Canada as a whole has become wetter, with increasing annual average precipitation trends in many parts of the country and for the nation as a whole (Figure 2). Trends in annual precipitation have been less uniform across the Canadian landmass than those of annual air temperature. While significant changes in extreme precipitation have been observed in some areas of the country, no consistent pattern is evident for the country as a whole.

There have also been observed trends in other climate indicators in Canada (*see* Table 1). The Arctic has seen rapid declines in sea ice extent, both in summer and winter (Figure 3). In addition, snowfall has decreased across southern Canada, while snow cover is melting earlier in spring, and glaciers in western Canada and the Arctic are shrinking.

At the global scale, sea level over the past century has risen in response to warmer ocean temperatures (thermal expansion) and to the melting of glaciers, ice caps and ice sheets. Regional patterns of sea level rise along Canadian coastlines are strongly influenced by vertical land motion, with sea level rising rapidly at some sites where the land is subsiding, and falling in others where the land is rising (*see* Table 1).

Further changes in climate are inevitable. On average, warmer temperatures and more rainfall are expected for the country as a whole, with increases in extreme heat and heavy rainfall events, and declines in snow and ice cover. Sea level along many of our coastlines will continue to rise, and warmer waters and ocean acidification are expected to become increasingly evident in most Canadian ocean waters over the next century. An overview of projected changes in some key climate indicators for Canada is provided in Table 2[2].

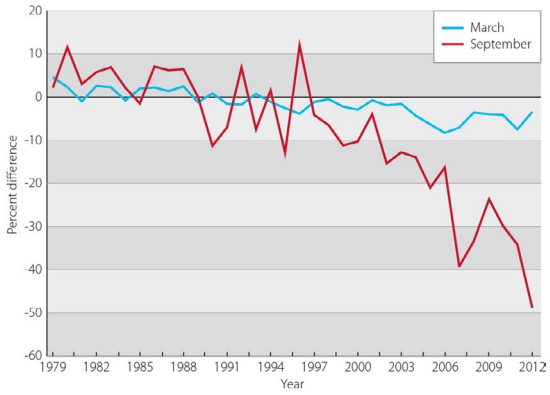

FIGURE 3: Trends in Arctic sea ice extent over the period 1979–2012 shown as time series of the percentage difference in ice extent in March and September relative to the mean values for the period 1979–2000. Both trends are statistically significant (*Source: Perovich et al., 2012*).

[2] While the changes presented in Table 2 are based on climate change projections commonly used up to 2012, they are broadly consistent with results using newer projections (such as those used in the IPCC Fifth Assessment Report).

Temperature	Projected Changes
Seasonal temperature	Warming will be greatest in winter, and in this season, the largest increases in air temperature are projected for northern Canada. In summer, the largest increases are projected for southern Canada and the central interior. The magnitude of projected warming varies substantially with the emission scenario
Extremes in daily temperature	Increases in the frequency and magnitude of unusually warm days and nights and decreases for unusually cold days and nights are projected to occur throughout the 21st century
Long duration hot events	The length, frequency and/or intensity of warm spells, including heat waves, are projected to increase over most land areas, including Canada
Rare hot extremes	Rare hot extremes are currently projected to become more frequent. For example, a one-in-20-year extreme hot day is projected to become about a one-in-5 year event over most of Canada by mid-century
Precipitation and other hydrological indicators	
Seasonal precipitation	Increases in precipitation are projected for the majority of the country and for all seasons, with the exception of parts of southern Canada where a decline in precipitation in summer and fall is suggested
Heavy precipitation	More frequent heavy precipitation events are projected, with an associated increased risk of flooding
Rare precipitation events	Rare extreme precipitation events are currently projected to become about twice as frequent by mid-century over most of Canada
Streamflow	Increases in winter streamflow are projected for many regions in southern Canada. Mean annual streamflow is projected to decreases in some regions of Alberta and Saskatchewan, while projections for other regions vary across different scenarios
Snow Cover	
Snow cover duration	Widespread decreases in the duration of snow cover are projected across the Northern Hemisphere with the largest changes in maritime mountain regions, such as the west coast of North America
Snow depth	Maximum snow accumulation over northern high latitudes is projected to increase in response to projected increases in cold season precipitation
Permafrost	
Ground temperature	Warming of the permafrost is projected to continue at rates surpassing those observed in records to date. Low average temperatures of much of the permafrost in the Arctic mean it will take many decades to centuries for colder permafrost to completely thaw
Sea Level	
Global sea level rise to 2100	Estimates of the magnitude of future changes in global sea level by the year 2100 range from a few tens of centimetres to more than a metre
Global sea level rise beyond 2100	Projections of global sea-level rise beyond 2100 indicate continuing global sea-level rise over the coming centuries and millennia. Global sea-level rise may eventually amount to several metres
Relative sea level change	Patterns of change along Canadian coastlines will continue to be influenced by land uplift and subsidence as well as by changes in the oceans. Sea-level rise will continue to be enhanced in regions where the land is subsiding, and sea level is likely to continue to fall in regions where the land is rapidly rising. Regions where the land is slowly rising may experience a transition from sea level fall to sea level rise.
Sea Ice Extent	
Arctic summer sea ice	A nearly ice-free summer is considered a strong possibility for the Arctic Ocean by the middle of the century although summer sea ice may persist longer in the Canadian Arctic Archipelago region
Lake Ice	
	With the continued advance of ice cover break-up dates and delays in ice-cover freeze up, ice cover duration is expected to decrease by up to a month by mid-century

TABLE 2: Examples of projected changes in the climate system for Canada, derived from ensembles of global climate models driven by the SRES scenarios[3]. In general, the magnitude of the stated changes will increase under higher emission scenarios.

[3] New projections for Canada will be available from the Canadian Climate Change Scenarios Network (cccsn.ec.gc.ca).

CHANGES IN CLIMATE ARE INCREASINGLY AFFECTING CANADA'S NATURAL ENVIRONMENT, ECONOMIC SECTORS AND THE HEALTH OF CANADIANS (CHAPTERS 3 TO 8).

The natural environment is inherently sensitive to climate. Shifts in the range of some species of birds, butterflies and trees in response to warming temperatures have been documented, as have changes in the timing of life-history events (such as earlier migration to breeding areas and earlier flowering of plants). Maple trees, for example, have experienced a significant northward shift since 1971 (*see* Case Study 1, Ch. 4). Northward shifts have also been observed in ecosystems of the Bering Sea, with examples of southern assemblages displacing northern aquatic populations (Ch. 4).

Declines in bird populations have also been documented, with 20 common North American bird species losing over 50% of their populations over the last 40 years (Ch. 7). Increased forest disturbance associated with insects, drought and forest fires have increased tree mortality in BC and the Prairies. Mortality rates have also risen in sockeye salmon, in response to higher water temperatures in the Fraser River (Ch. 7), while salmon production rates have declined (Ch. 4).

In addition to impacts on the natural environment, changing climate is affecting many of Canada's economic sectors as well as human health. This includes impacts on sectors with obvious climate sensitivities such as forestry, agriculture, fisheries, hydroelectricity, transportation, tourism and insurance. A prime example is the mountain pine beetle outbreak in western Canada. Warmer winter temperatures in the region are one factor that has allowed beetle populations to expand to unprecedented sizes, leading to the largest and most severe outbreak on record (*see* Case Study 1, Ch. 3). As of 2012, about 18.1 million hectares of forest were affected (Figure 4; Ch. 3). Health impacts include lengthening of the ragweed season (between 1995 and 2009, the season increased by more than 25 days in Saskatoon and Winnipeg (Ch. 7)) and spreading of Lyme disease vectors (ticks), which has resulted in the annual number of Canadian cases increasing from 30 to more than 250 in recent years (Ch. 7).

Northern Canada has experienced particularly rapid rates of warming over recent years (*see* Figure 1). Climate change impacts on livelihoods, culture, mental health and well-being have been reported by northern residents (Ch. 7). Safety concerns associated with less predictable ice conditions and marine storms are an issue, for example, as are the effects of reduced sea ice on traditional hunting activities (Ch. 4) and the impacts of permafrost thaw on infrastructure (Ch. 8). Winter roads in northern Canada have experienced reduced ice thickness and shortened operating seasons, which decreases their reliability and constrains the load volumes that can be safely transported. For example, the shortened road season in 2006 forced the

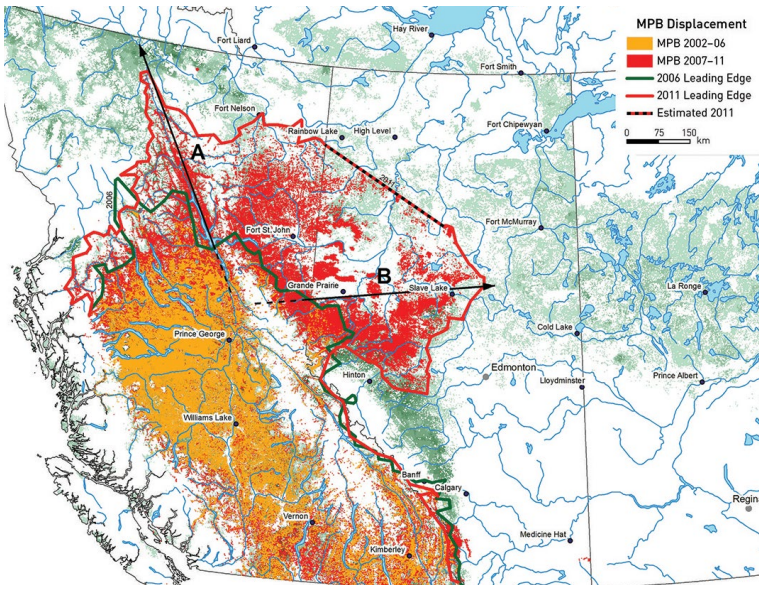

FIGURE 4: Map of Mountain Pine Beetle distribution, showing change for the 2002–2006 and 2007–2011 time periods and direction of change (*Source: Natural Resources Canada, 2012c*).

Diavik Diamond Mine to spend an extra $11.25 million to fly in fuel (Ch. 3). Northern communities also depend upon the winter road network for the supply of affordable food, medicines and other goods.

Together, these observed impacts illustrate that climate change is happening now, with impacts being felt across the country. While climate is one of several contributing factors in most cases, these examples provide an indication of the types of impacts that we can expect to see more of as the climate continues to change.

EXTREME WEATHER EVENTS ARE A KEY CONCERN FOR CANADA (CHAPTERS 3 TO 8) AND THERE IS GROWING CONFIDENCE THAT SOME TYPES OF EXTREME EVENTS WILL INCREASE IN FREQUENCY AND/OR INTENSITY AS THE CLIMATE CONTINUES TO WARM (CHAPTER 2).

Losses from severe weather have been rising across the country. Extreme events, including storms (wind, ice and snow), flooding and heat waves have had significant economic (Figure 5) and health and safety impacts on Canadians. In 2011, the Canadian insurance industry paid out a record $1.7 billion for property damage associated with weather events, such as flooding, wind and wildfires. This record will be broken in 2013, as the insured losses from flooding damage in Southern Alberta (June) and Toronto (July) are finalized (IBC, 2013a; IBC, 2013b). While factors other than climate also contributed to the rising payout trend (e.g. increased exposure of property, increasing wealth and aging infrastructure), these losses, along with the many possible health impacts (Ch. 7) demonstrate that Canadians are vulnerable to extreme weather events.

There is growing confidence that some types of extreme events will increase in frequency and/or intensity due to climate change (Ch. 2). For example, at the global scale, warm days and nights are *virtually certain*[4] to increase in frequency and magnitude and heat waves are *very likely*[4] to increase in duration, frequency and/or intensity. Heavy precipitation events and extreme sea levels are also projected to occur more frequently. In Canada, studies have suggested that droughts, especially in the southern Prairies, heavy precipitation events, with associated increased risk of flooding (Ch. 2), forest fires (Ch. 3), storms (Ch. 5) and hot days and warm nights (Figure 6; Ch. 7) would increase in frequency and/or intensity in a warmer climate.

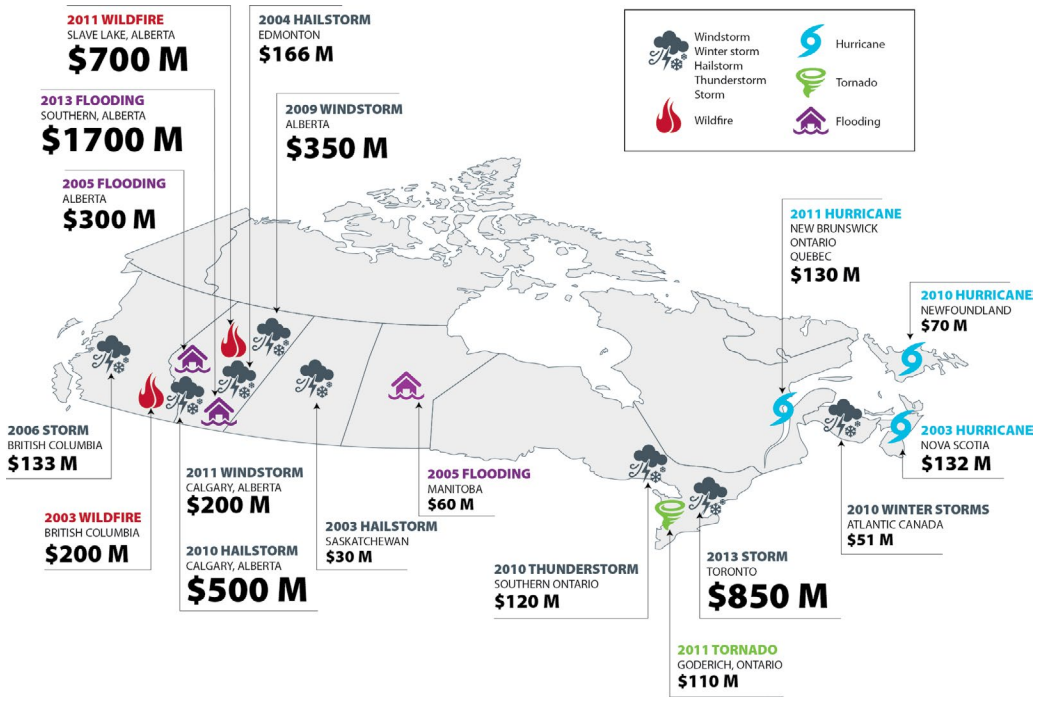

FIGURE 5: Examples of insured losses from extreme weather events in Canada (*Sources: IBC, 2008, 2011b, 2013a, b; McBean, 2012*).

[4] The IPCC denotes likelihood with the following scale: Virtually certain- 99-100% probability; Very likely- 90-100% probability; Likely- 66-100% probability; About as likely as not- 33 to 66% probability; Unlikely- 0-33% probability; Very unlikely- 0-10% probability; Exceptionally unlikely- 0-1% probability.

Extreme events were identified as key issues for all sectors discussed in this report. For example, events relating to water availability – both excesses and shortages – represent concerns for most economic sectors, as well as for biodiversity and human health. Flooding can overwhelm infrastructure, causing not only significant local impacts, but also leading to broader impacts by damaging transportation networks and compromising access and supply chains (Ch. 8). Drought is also associated with many immediate and long-term economic and social impacts (Ch. 4).

As an industry, farming relies upon the inter-annual predictability of seasonal weather as it facilitates crop selection and infrastructure investments (Ch. 4). Unpredictable conditions can cause unanticipated farm losses. For example, an unprecedented heat wave in Ontario in March 2012 caused fruit trees to blossom 5 weeks earlier than usual, and subsequent frosts in April destroyed approximately 80% of apple blossoms (Environment Canada, 2013). Total losses for tender fruits that year were estimated at $100 million (Environment Canada, 2013).

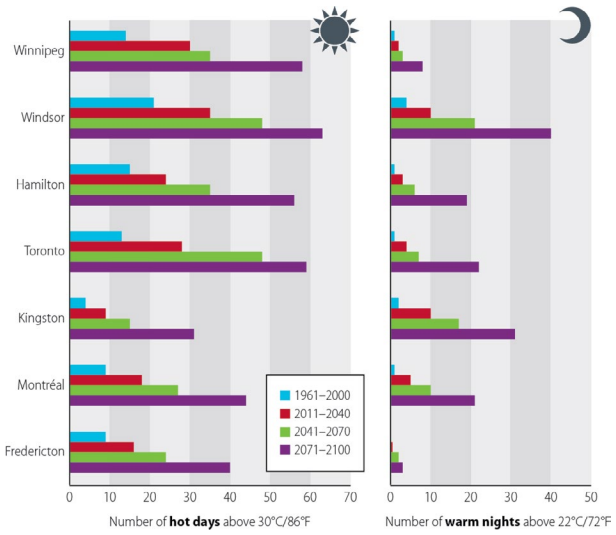

FIGURE 6: Historical and projected number of hot days and warm nights for selected cities in Canada (*Source: Casati and Yagouti, 2010*).

ADAPTATION IS ACCEPTED AS A NECESSARY RESPONSE TO CLIMATE CHANGE. IT ENHANCES THE SOCIAL AND ECONOMIC RESILIENCE OF CANADIANS TO CLIMATE CHANGE IMPACTS (CHAPTERS 3 TO 9).

Across Canada, there is evidence of increasing awareness and acceptance of the need to adapt to climate change (Ch. 9). Broadened engagement in adaptation is reflected across sectors, at all levels of government, in certain industries and companies, as well as in the academic literature (Figure 7) and the media. Discussions now tend to focus on determining where adaptive action is required and improving understanding of the process of adaptation – i.e. how adaptation can be addressed and where capacity to adapt needs to be enhanced.

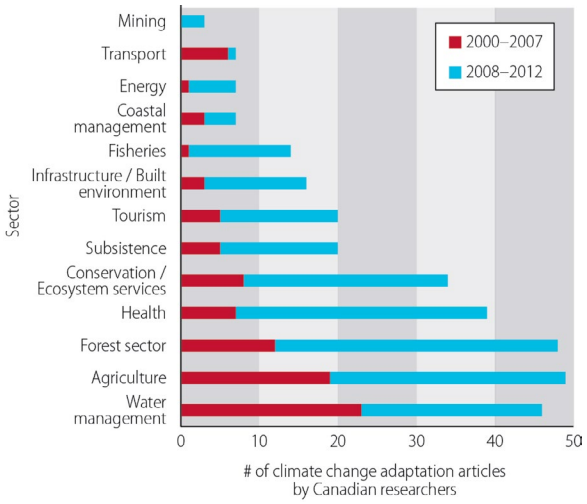

FIGURE 7: Number of climate change adaptation articles by Canadian researchers by sector (2000–2012).

This is especially evident for those sectors with greater exposure to weather and weather variability. Direct experience with changing conditions, such as shorter snow seasons for winter tourism (Ch. 5), shifting flow patterns for hydroelectricity generation (Ch. 3) and increasing health impacts from heat (Ch. 7), as well as extreme weather events (e.g. floods, droughts and wildfires) raises awareness of climate change and the severity of potential impacts. In the forest sector, for example, severe wildfires and pest outbreaks in British Columbia and Alberta have contributed to increased awareness of climate change adaptation, spurring industry and governments to begin to move towards adaptive management approaches that proactively address risks and opportunities, rather than depending on crisis management strategies (Ch. 3). Following the 2013 spring flood in Alberta, the provincial government introduced policies to help reduce losses from future flooding events, including new restrictions on redevelopment in floodways and flood fringes (Alberta Government, 2013).

Policies, regulations and guidelines are mechanisms that governments can use to raise awareness and encourage or require adaptive action. The City of Vancouver, for example, reviewed its flood-proofing policies and now encourages applicants with projects in identified flood hazard areas to plan for 1 metre of sea level rise (Ch. 8). For the private sector, factors that enhance awareness include reporting requirements for material risk, and the drive to stay competitive and meet trade demands. Financial disclosure of climate change risks shows promise as a tool to promote climate change adaptation within industry (Ch. 3, 5).

ADAPTATION IS OCCURRING WITH INCREASING FREQUENCY AND ENHANCED ENGAGEMENT. CONTINUED ACTION WILL HELP TO BUILD CAPACITY, ADDRESS INFORMATION NEEDS AND OVERCOME CHALLENGES (CHAPTERS 3 TO 9).

Since publication of the 2008 assessment there has been a significant increase in the number of adaptation activities in Canada, primarily with respect to planning (including strategies, frameworks, and guidance documents) and initiatives aimed at enhancing adaptive capacity (Table 3). From the breadth and scope of these examples, it is evident that there are many different approaches to adaptation. However, adaptation actions have been mostly incremental in nature, building on existing initiatives, assuming a continuation of current climate trends, and focused on no-regrets actions that are beneficial regardless of future climate. In many cases, action on adaptation was spurred by observed impacts or experience with extreme weather events.

Adaptation Activities	Sector
Provincial governments in BC, Alberta and Quebec are modifying seed transfer guidelines for reforestation to take shifting climate envelopes into account	Forestry (Ch. 3)
A hydroelectric corporation is integrating climate change considerations in demand forecasts, informing rate adjustments and procurement plans	Energy (Ch. 3)
The mining industry is applying techniques to protect northern infrastructure from permafrost warming (e.g. deeper pile foundations, adjustable foundations)	Mining (Ch. 3)
The federal government is revising taxation schemes to help producers manage weather-related risk (e.g. allowing income to be deferred)	Agriculture (Ch. 4)
Industry associations in BC are developing a tourism action plan to respond to mountain pine beetle damage	Tourism (Ch. 5)
Insurers are adjusting property insurance coverage (e.g. no longer offering sewer back up insurance in communities with recurring losses)	Insurance (Ch. 5)
Subsidy programs have been adopted by a number of municipalities to encourage the installation of backwater valves that can help to reduce flood damage from an increase in the frequency and intensity of rainfall events	Residential Housing (Ch. 5)
The Manitoba government is protecting winter habitat for the Qamanirjuaq barren-ground caribou herd in the transition zone between boreal and tundra ecosystems	Biodiversity and Protected Areas (Ch. 6)
The federal government is developing tools to guide public health managers on vector-borne disease surveillance and control methods	Health (Ch. 7)
Communities across the country are developing heat alert and response systems to protect health from extreme heat events	Health (Ch. 7)
A risk assessment of three coastal roads in Nova Scotia led to recommendations that include engineered shoreline protection and relocation of selected roads further inland	Infrastructure (Ch. 8)
Cambridge and Milton, ON are performing economic assessments of the implications of climate change for drainage infrastructure design	Infrastructure (Ch. 8)

TABLE 3: Examples of adaptation activities from different sectors.

Progress on adaptation is evident, and the examples presented in this report are indicative of the type of actions that will become increasingly necessary as the climate continues to change. However, more work is needed. All chapters in this report identify information needs and knowledge and data gaps, and many discuss barriers and challenges to adaptation, including limited resources, limited motivation and issues related to governance (Ch. 9). In addition, by analyzing the examples available, it is apparent that there are relatively few examples of concrete, on-the-ground adaptation measures being implemented specifically to reduce vulnerability to projected changes in climate. This indicates that, similar to other developed countries, adaptation in Canada is still in its early stages overall. It is also recognized that the methodology of this assessment, with its focus on scientific literature, may result in an underestimation of the actual number of adaptation actions being undertaken in Canada.

Planned adaptation takes time. Adaptation often requires research, stakeholder engagement and adjustments to policies and regulations. For example, while a year-round road has been proposed to ensure access to northern mining sites to help address the declining reliability of ice-road networks (Ch. 8), this type of project cannot be undertaken without detailed planning, consultations and environmental impact studies. In the fisheries sector, fishers cannot simply adjust their harvests in response to shifting species assemblages – this requires governments to revise management plans and fishing permits (Ch. 4).

There will also be cases where maintaining current activities is not feasible and/or cost-effective, requiring discussions to extend beyond consideration of incremental, no-regrets approaches to more transformative changes. The emerging concept of transformational change refers to larger-scale, more extensive adaptations that are new to a region or resource system (Ch. 9). Transformational change may also challenge the status quo and thereby question perceptions of what is acceptable. Examples include relocating entire towns due to sea level rise; converting forest plots to parkland to reduce losses from forest fires; and designing flood-control infrastructure to fail safely (with minimal damage and losses), rather than withstand large-magnitude events. The need for transformational adaptation is likely to become more prevalent as the climate continues to change.

ADAPTATION CAN SOMETIMES TURN RISKS INTO OPPORTUNITIES, AND OPPORTUNITIES INTO BENEFITS (CHAPTERS 3 TO 9).

While adaptation research and programming tend to focus on reducing vulnerability to negative impacts, some impacts of climate change could represent opportunities. Capturing these opportunities requires appropriate adaptation.

This may be most evident in the tourism and agriculture sectors, which both stand to potentially benefit from longer summers. With effective adaptation (e.g. strategies to deal with potential water shortages), major warm-weather tourism markets in Canada could benefit from climate change, with the golf industry, for example, profiting from increased season length and demand (Ch. 5). Similarly, with higher summer temperatures, different types of crops may be able to be grown farther north (e.g. corn and soybeans in new areas in Quebec, canola in Prince George, BC, and spring seeded small grains in western Alberta and northeastern BC; Ch. 4). Producers would need to adapt their crop selections and timing (e.g. seeding earlier in order to decrease exposure to drier late summer conditions) to take advantage of these opportunities. In all cases, risks related to increased pests, heat waves and other extreme events will also need to be addressed. In the North, changing climate and ice conditions bring potential economic opportunities related to natural resource development and tourism (Ch. 3, 5, 6). However, in addition to presenting opportunities for employment and investment, such activities also bring environmental and cultural risks.

Innovative ideas and approaches may help reduce losses associated with climate change, at least on a short-term basis. For example, faced with a surplus of blue stained wood from the Mountain Pine Beetle outbreak, the forest industry in BC began marketing the product for interior paneling and unique wood furniture, after completing studies to confirm the wood would perform to acceptable standards (Ch. 3). Also in BC, the city of Vancouver used the damage caused by the 2006 windstorm in Stanley Park as an opportunity to increase public engagement in the park and replant a more wind-resilient forest (Ch. 3). Some tourism operators and recreation sites are considering promoting "last chance tourism", where additional tourists are drawn to a park to see either changing landscapes or certain features (e.g. glaciers or certain wildlife species) before they decline or disappear (Ch. 5, 7).

COLLABORATION AND ADAPTIVE MANAGEMENT ARE APPROACHES THAT GOVERNMENTS AND INDUSTRY ARE INCREASINGLY PURSUING TO ADVANCE ADAPTATION (CHAPTER 9).

Collaboration has emerged as an important mechanism for successful and efficient adaptation to climate change. Across sectors, there is a common challenge of needing to adapt to continuous cumulative changes with limited resources. By learning from the work of others (e.g. through assessments, communities of practice and workshops) and collaborating with organizations that share similar goals, efficiencies and synergies can be found. Numerous examples of collaborations between different levels of government, as well as industry and non-governmental groups are discussed throughout this report (Box 2) and continued collaboration will be a key driver moving adaptation forward. While roles and mandates may differ between jurisdictions and organizations, the end goals of reducing vulnerability to climate change and enhancing resilience are shared.

Many sectors are starting to use adaptive management approaches (Figure 8) to deal with changes in climate and other stressors and related uncertainties (which will always be present in adaptation decision-making). Adaptive management involves ongoing monitoring, adjusting, experimenting and re-evaluating, and requires a flexible and responsive approach to adaptation. Examples of adaptive management approaches discussed in this report include operations related to hydroelectric generation (Ch. 3), water level management on the Great Lakes (Ch. 8, 9), and forest stand management (Ch. 3).

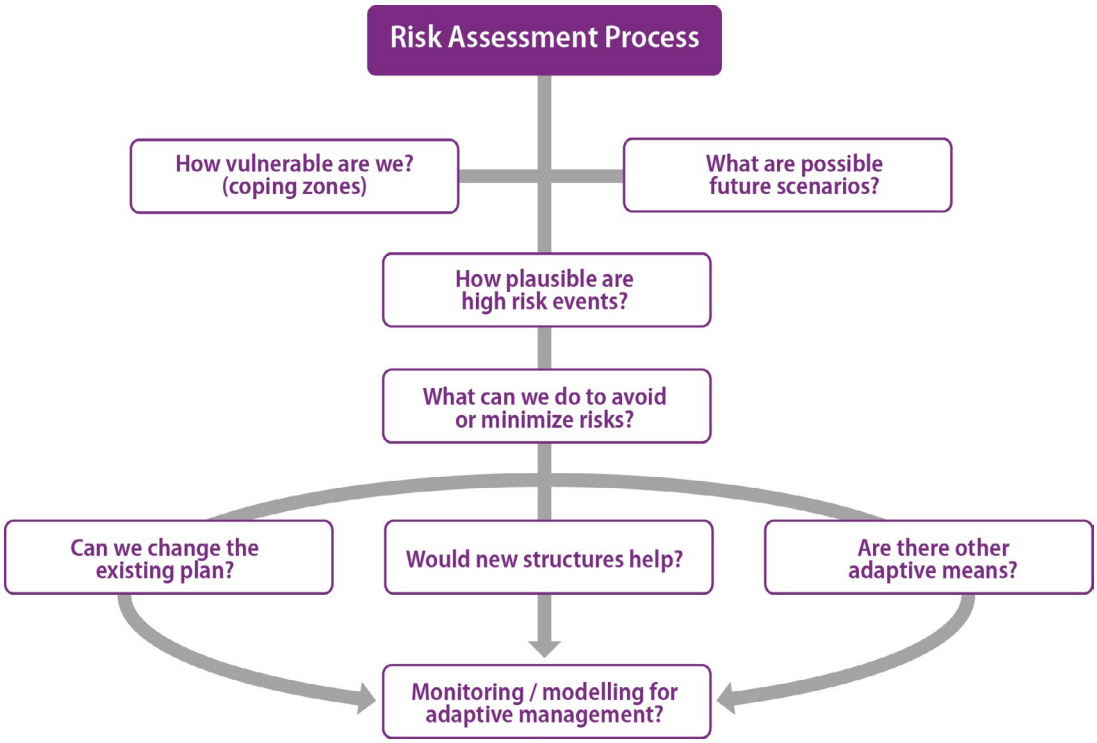

FIGURE 8: Adaptive management assessment process (*modified from Leger and Read, 2012, Figure 2-1, p. 8*).

BOX 2

EXAMPLES OF CASE STUDIES HIGHLIGHTING COLLABORATION

Collaboration to enhance adaptation decision-making (Chapter 9, Case Study 1): Canada's federal, provincial and territorial governments have invested in collaborative programming as a cornerstone for advancing knowledge and action on adaptation, through past activities (e.g. the Canadian Climate Impacts and Adaptation Research Network [C-CIARN]) and ongoing initiatives. The most recent mechanism to enhance collaboration on adaptation across Canada is the Adaptation Platform which brings together governments, professional organizations, industry associations and financial sector representatives to address shared adaptation priorities.

A Historical Example of Institutional Capacity for Adaptation in the Agricultural Sector – The Prairies (Chapter 4, Case Study 3): Local communities and the farm industry worked in collaboration with academic researchers and the provincial/federal governments to establish solutions to improve resiliency to drought conditions experienced in the early 1900s. Through this collaboration, new innovative farming methods were introduced and agricultural management was made more efficient.

The Municipal Risk Assessment Tool (Chapter 5, Case Study 2): The Insurance Bureau of Canada brought together a team of experts including hydrologists, climate scientists, risk managers and infrastructure engineers to develop a tool (The Municipal Risk Assessment Tool – MRAT) that identifies risk zones for exposure to basement flooding at the neighbourhood level.

Building a "Better than Building Code" Home (Chapter 5, Case Study 4): The Institute for Catastrophic Loss Reduction and The Co-operators General Insurance Company worked together to demonstrate the benefits of enhanced construction by building a demonstration home in West Point, Prince Edward Island. Designed to be more weather resilient, the demonstration home incorporated new technologies and practices to ensure the home's ability to withstand extreme wind events.

A landscape approach to ecological restoration (Chapter 6, Case Study 4): Conservation partners from the public and private sectors supported efforts to plant over 4.5 million native trees and shrubs, and currently use restoration techniques to mimic features of old-growth Carolinian forests to help preserve biodiversity in the Long Point World Biosphere Reserve, which includes the Long Point National Wildlife Area along the north shore of Lake Erie (Ontario). This work is helping to create corridors and enhance ecosystem resilience and adaptive capacity throughout the Biosphere Reserve.

Citizen-based Monitoring Programs (Chapter 6, Case Study 5): As part of The Reef Environmental Education Foundation's (REEF) volunteer fish and invertebrate monitoring program, participants are trained to identify target species and implement a simple roving diver survey method. More than 3700 volunteer surveys have been carried out along the British Columbia coastline through this program, representing more than 2800 hours of underwater observations at more than 300 sites.

Manitoba Flood 2011: Impetus for a Provincial Approach to Psychosocial Adaptation to Natural Hazards (Chapter 7, Case Study 3): Many organizations, including Manitoba Health's Office of Disaster Management, Emergency Social Services, Emergency Measures Organization, Aboriginal Affairs and Northern Development Canada, Manitoba Agriculture and Food Rural Initiatives, Manitoba Family and Rural Support Services, Water Stewardship and Conservation, and Aboriginal and Northern Affairs worked in collaboration to establish the Provincial Psychosocial 2011 Flood Recovery Table in response to the 2011 flood in Manitoba.

Box 2 continued on next page

City of Calgary Water Supply Infrastructure Vulnerability Assessment (Chapter 8, Case Study 1): In 2011, the City of Calgary, together with Engineers Canada, conducted a vulnerability risk assessment of its water supply infrastructure. The team worked together to determine which climatic conditions pose the greatest risks to the design, construction, operation and management of the water supply infrastructure, in order to enhance the resiliency and quality of the system.

British Columbia Sea Dyke Guidelines (Chapter 8, Case Study 2): The BC provincial government, the Association of Professional Engineers and Geoscientists of British Columbia, and others worked with policymakers and planners to incorporate sea level rise into coastal floodplain mapping, sea dyke design and land use planning. Building on these outputs, a working group went on to develop a national Sea Level Rise Primer (www.env.gov.bc.ca/cas/adaptation/pdf/SLR-Primer.pdf) to help other communities identify, evaluate and compare adaptation options, and showcase different types of tools for adaptation.

Promoting adaptation by sharing information and knowledge through a virtual community of practice (Chapter 9, Case Study 4): The Climate Change Adaptation Community of Practice (CCACoP) is an interactive online portal that provides space for researchers, experts, policymakers and practitioners from across Canada to come together to ask questions, generate ideas, share knowledge and communicate with others working on climate change adaptation. It is a key information and knowledge-sharing network on climate change adaptation in Canada.

CONCLUSION

Changes in the climate system and associated impacts on both natural and human systems are occurring in Canada. As a result, the need to adapt is increasingly recognized and acted upon by governments, industry and other organizations. Over the past 5 years, our understanding of the adaptation process has improved and examples of adaptation implementation have grown. We have seen broadened engagement on the issue, and changes being made to policies, plans and practices to increase resilience to climate change. Further adaptation is necessary to complement mitigation in helping to prevent and reduce future impacts, as well as to take advantage of potential opportunities. We now have the awareness and capacity to adapt in many cases; translating this to action will require continued collaborative efforts to reduce barriers, overcome challenges and enhance motivation to adapt.

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