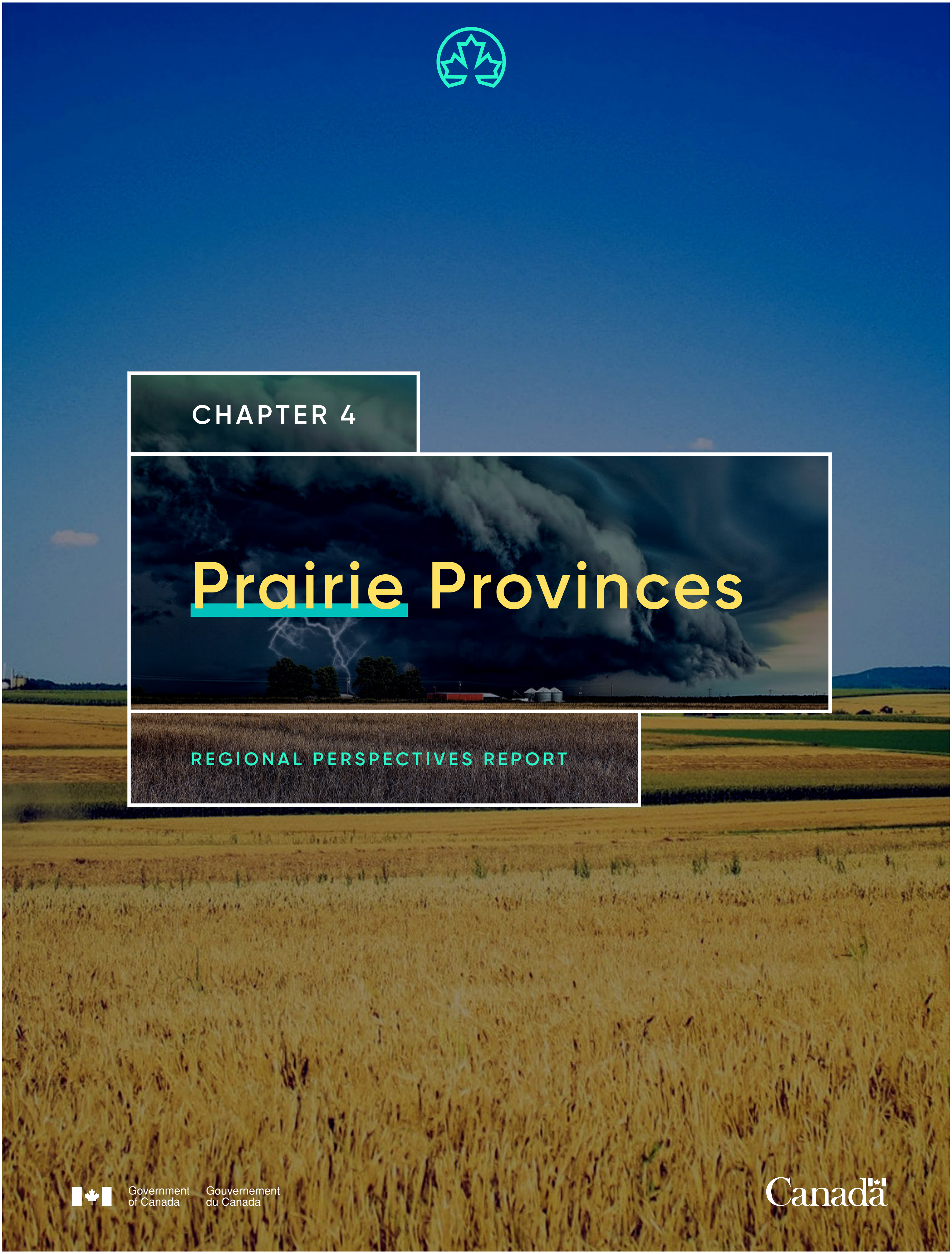

CHAPTER 4

Prairie Provinces

REGIONAL PERSPECTIVES REPORT

Government of Canada / Gouvernement du Canada

Canada

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Key messages

Prairie ecosystems will shift and transform as the climate warms (*see* Section 4.2)

As species respond to climate change, large regions of boreal forest could transition to aspen parkland and grassland ecosystems, while entire mountain ecosystems could disappear. Although biodiversity could increase overall, some species will be lost if the rate of warming exceeds their ability to adapt. Adaptation interventions are based mainly on standard conservation strategies—such as reduction of anthropogenic and other stressors and disturbances—and minimizing barriers to movement.

Floods, drought and wildfires are getting worse (*see* Section 4.3)

Extreme weather events of amplified severity will likely be the most challenging consequence of climate change in the Prairie Provinces. The impacts of flooding, drought and wildfire in recent years are unprecedented, and climate models suggest an increased risk of these events in the future. Provincial and municipal governments have responded by proposing policies, structures and practices to reduce the impacts of future extreme weather events.

Collaborative water management reduces negative impacts (*see* Section 4.4)

Regional land-use policy and planning, as well as emergency preparedness, are critical for reducing the impacts of flooding and drought in the Prairie provinces. Collaboration is needed among all levels of government, and with stakeholders such as watershed stewardship groups, rural municipalities and conservation districts, to implement these adaptation measures and to promote practices that prevent or minimize adverse effects of water excesses and shortages.

Climate change brings both benefits and threats to agriculture (*see* Section 4.5)

Prairie agriculture, particularly crop production, may benefit from higher temperatures and a longer growing season. Achieving net benefits will require adaptation to limit the impacts of climate extremes, including on water availability, and the increased risk of pests, vector-borne diseases and invasive species. Although agricultural producers are highly adaptable to fluctuations in weather and climate, barriers to adaptation include limited information and awareness of climate change impacts, combined with limited financial resources and institutional support.

Social groups have unique vulnerabilities and strengths (*see* Section 4.6)

The impacts of climate change may exacerbate existing societal inequities, especially among Indigenous peoples, women, people of low socio-economic status, youth and the elderly. Public policy and adaptation planning should consider the unique vulnerabilities and strengths of these social groups, and also the means by which race, age, gender and poverty amplify vulnerability or resilience to climate hazards.

Adaptation planning helps to reduce climate risks (*see* Section 4.7)

Cities are at the forefront of adaptation and resilience planning in the Prairie provinces. Governments and businesses have begun to assess climate risks and develop adaptation strategies, but few sector-specific plans and policies consider future climate risks, leaving some firms, governments and sectors unprepared. Assessing the effectiveness of adaptation measures and meaningful reporting would help achieve climate-resilient communities and local economies.

4.1 Introduction

The provinces of Alberta, Saskatchewan and Manitoba represent about one third of the area of Canada and lie south of 60 degrees latitude. This large region is known as the “Prairie provinces” or simply the “Prairies”, although only about 30% of the region lies within the Prairie Ecozone (see Figure 4.1). The ecosystems and landscapes of the Prairie provinces include the Rocky Mountains, boreal and cordilleran forests, semiarid interior plains, aspen parkland, subarctic shield and Hudson Bay lowlands (see Figure 4.1). The region features considerable economic and social diversity—including Canada’s third largest provincial economy (Alberta) and the nation’s fourth and fifth most populated cites (Calgary and Edmonton, respectively)—in contrast to the rural agricultural communities of the southern prairies, and the mining and forestry industries and remote, mostly Indigenous communities of the northern part of the region. Extraction and processing of non-renewable resources (e.g., oil and gas, mining) are a major economic driver, representing the largest contributing sector to the economies of Alberta and Saskatchewan (Western Economic Diversification Canada, 2018), whereas Manitoba’s economy is more varied. The economies of all three Prairie provinces are becoming more diverse, with a downturn in the oil and gas sector in recent years and more local manufacturing and high-tech industries.

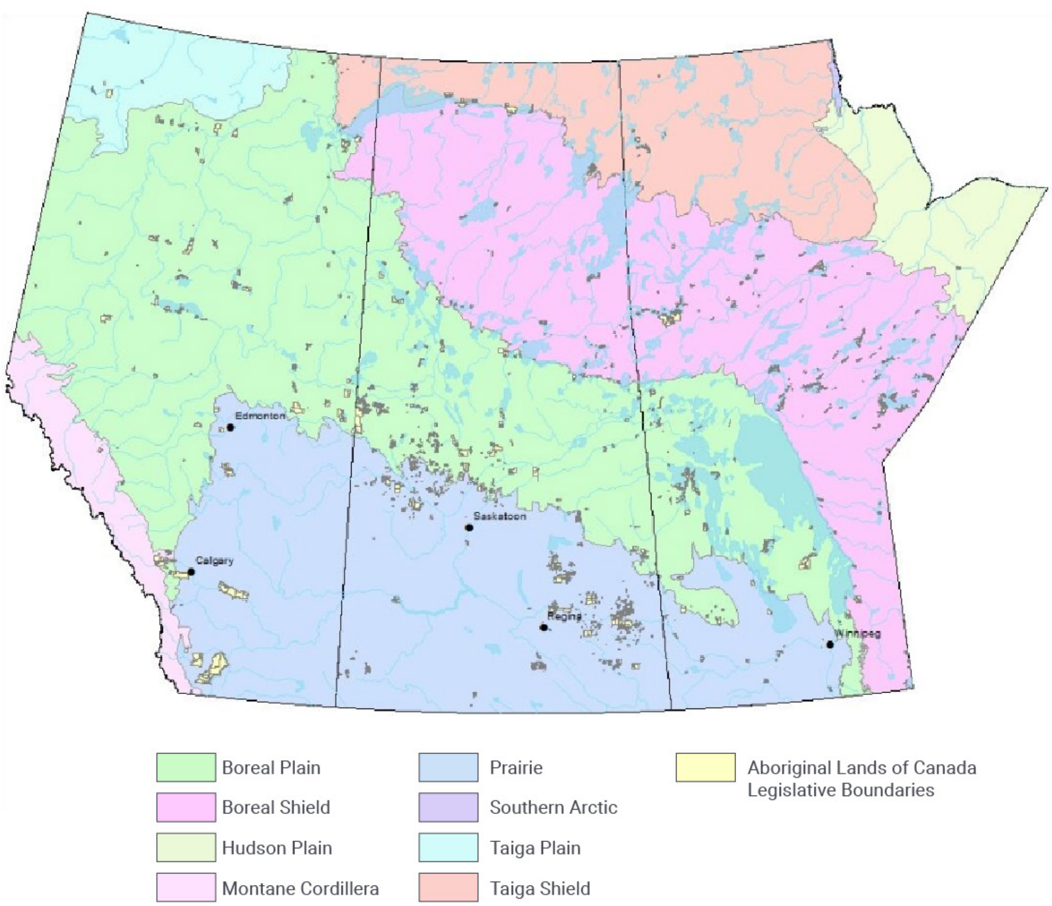

Figure 4.1: Map of the Ecozones of the Prairie Provinces, also showing the Aboriginal Lands of Canada Legislative Boundaries, and major cities, rivers and lakes. Source: Prairie Adaptation Research Collaborative.

In assessing existing knowledge of climate change impacts and adaptation, the following characteristics of the Prairie provinces emerge as important determinants of vulnerability to climate change:

- The Prairies, and western Canada generally, have had the strongest warming to date across southern Canada, especially in winter;
- More than 80% of Canada's agricultural land and most of the country's irrigated agriculture is located in the Prairies;
- Water resources, ecosystems and resource economies are subject to large seasonal and interannual variations in climate, and especially to departures from normal conditions (e.g., drought);
- Historically, the region has seen a population shift from rural to urban areas, and in-migration from other provinces and beyond Canada in response to economic opportunities. From 2007–2017, the four fastest growing cities in Canada were the major cities in Alberta and Saskatchewan. Western Canada has led the nation in the highest rate of employment of landed immigrants (Statistics Canada, 2018a).
- Most of the population and commercial activity is in the southern Prairies, which is also the part of the region with the most limited and variable water supply. Most rural communities depend on local runoff and groundwater. Urban communities access water from the major rivers and lakes, which also support the main industries, such as oil sand mining in northern Alberta.
- The Prairies are home to 39.2% (656,970) of Canada's Indigenous population—including 45.8% (246,485) of Canada's Métis population—with the majority of Indigenous people living off-reserve (Statistics Canada, 2019a). More than 10% of the Indigenous population in the region lives in Winnipeg and Regina (Statistics Canada, 2019b). The Prairie provinces are entirely covered by numbered treaties, which are the basis for the relationship between First Nations and the Government of Canada.

Recent extreme weather events in the Prairie provinces include the most costly natural disasters in Canadian history (*see* Figure 4.2; SeaFirst Insurance Brokers, 2018). The 20 most costly weather events in Canada since 1983 are listed in Table 4.1; of these events, 13 occurred in the Prairies. Six of the top 10 have occurred in the Prairies region since 2010. The concentration of losses in Alberta largely reflects the fact that its population is more than four times larger than Saskatchewan's or Manitoba's. While the cost associated with damage from recent storms, flooding events and fires—notably the 2013 flood in Calgary and 2016 wildfire in Fort McMurray—is in the billions of dollars, drought is the most costly type of weather event in terms of loss and damage in the Prairies. The dollar amounts listed in Table 4.1 represent insured losses. On the other hand, the socio-economic impacts of drought are widespread, both geographically and throughout the economy. During the drought year of 2002, crop losses alone were in the billions of dollars, with negative net farm income in Saskatchewan and zero farm income in Alberta (Wheaton et al., 2008).

Table 4.1: The twenty most damaging Canadian weather events since 1983

DATE	PLACE	EVENT TYPE	LOSSES ($ MILLION)*
May 3–19, 2016	Fort McMurray, AB	Fire	3,899.1
January 1998	Southern Quebec	Ice storm	2,022.3
June 19–24, 2013	Southern Alberta	Flooding, water	1,737.4
July 8, 2013	Greater Toronto Area, ON	Flooding, lightning, water	1,004.6
August 19, 2005	Southern Ontario	Hail, tornadoes, wind	779.7
May 4, 2018	Hamilton, ON; Greater Toronto Area, ON; Southern Quebec	Windstorm, water	680.0
May 15–16, 2011	Slave Lake, AB	Fire, windstorm	587.6
August 7, 2014	Central Alberta	Hail, lightning, water, windstorm	582.3
August 12, 2012	Calgary, AB	Hail, lightning, water	571.8
July 12, 2010	Calgary, AB	Hail, flooding, lightning, windstorm	557.7
September 7, 1991	Calgary, AB	Hail	552.2
July 30–August 1, 2016	Calgary, AB; Fort McMurray, AB; Yorkton, SK; Melville SK; Winnipeg, MB	Hail, lightning, water, windstorm	480.5
August 1–3, 2009	Calgary, AB; Camrose AB	Hail, lightning, water, windstorm	404.1
June 6–8 and 17–19, 2005	Alberta	Flooding	374.0
September 21, 2018	Dunrobin, ON; Nepean, ON; Ottawa, ON; Gatineau, QC	Flooding, hail, water, windstorm	334.0

DATE	PLACE	EVENT TYPE	LOSSES ($ MILLION)*
July 23, 1996	Outaouais, QC	Hail, wind	310.9
July 25–August 14, 1993	Winnipeg, MB	Flooding	288.1
July 31, 1987	Edmonton, AB	Tornado	282.5
July 21, 2015	Central Alberta	Flooding, hail, water, windstorm	273.3
Summer 2003	British Columbia	Forest fire	259.5

Losses are in 2018 $.

SOURCE: IBC WEATHER FACTS, 2019.

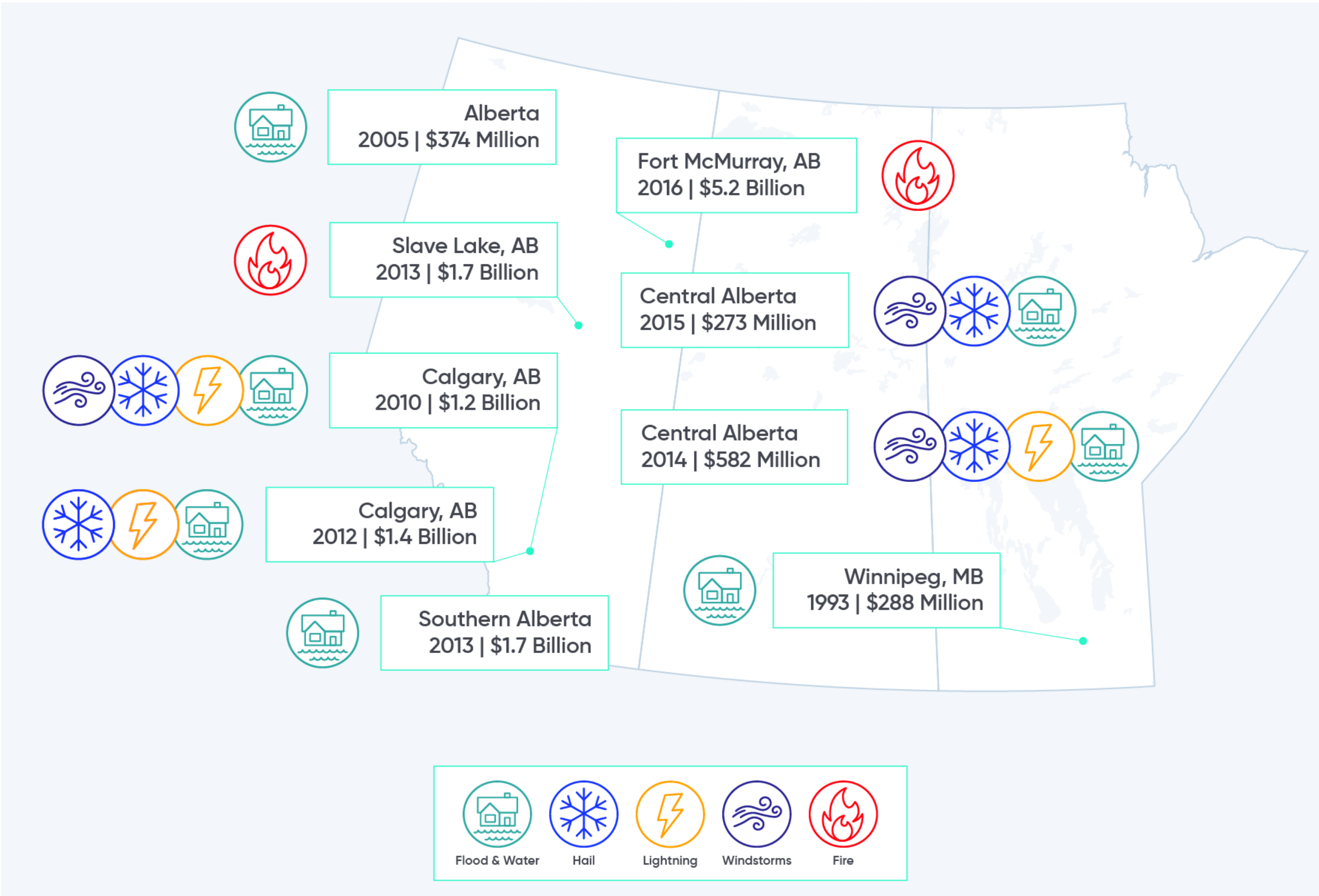

Figure 4.2: Economic impacts of the most damaging extreme weather events to date in the Prairie provinces. Costs represent insured losses in 2018 $. Total costs are generally much higher. Data source: Insurance Bureau of Canada, 2019.

With climate change, the Prairie provinces are projected to be much less cold than at present, with increased total precipitation, although mostly in winter and spring (Zhang et al., 2019). Evaporation and transpiration will also increase with warmer temperatures, leading to more frequent and intense droughts and soil moisture deficits over the southern Prairies during summer (Cohen et al., 2019). There will be far fewer cold days, higher maximum temperatures and heavier rainfall events, as warming amplifies the already wide variability in the prairie hydroclimate (*see* Figure 4.3). This natural variability underlies the changes caused by a warming climate, and accounts for differences among future projections of temperature and precipitation that cannot be explained by the use of different models and greenhouse gas emissions scenarios (Barrow and Sauchyn, 2019).

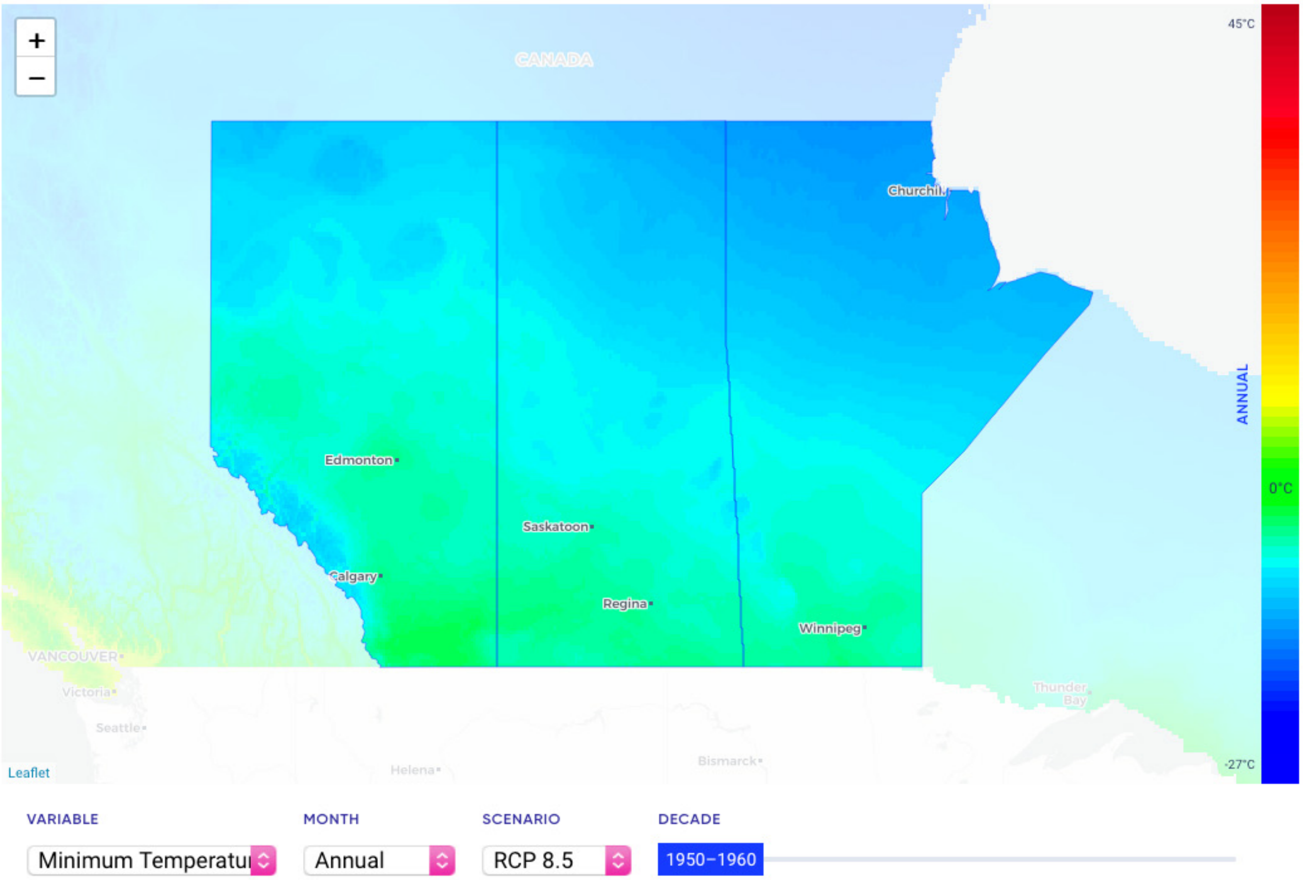

Figure 4.3: Regional map of the Prairie region illustrating historical and projected data using RCP8.5 for key climate change variables—minimum winter temperature, growing degree days and maximum one-day precipitation—from 1951 to 2100. Source: climatedata.ca

This chapter builds on the Prairies chapter in the previous national assessment (Sauchyn and Kulshreshtha, 2008) by emphasizing adaptation processes and planning, and highlighting progress made over the past 10 years. It focuses on knowledge that enables better adaptation, resilience planning and policy development. A recurring theme in this chapter is the distinction between the impacts of and adaptation to slow-onset climate change—such as changes in average temperature and precipitation patterns—versus shifts in climate variability and the occurrence of extreme weather events, which are associated with natural hazards such as floods, drought and wildfire.

4.2 Prairie ecosystems will shift and transform as the climate warms

As species respond to climate change, large regions of boreal forest could transition to aspen parkland and grassland ecosystems, while entire mountain ecosystems could disappear. Although biodiversity could increase overall, some species will be lost if the rate of warming exceeds their ability to adapt. Adaptation interventions are based mainly on standard conservation strategies—such as reduction of anthropogenic and other stressors and disturbances—and minimizing barriers to movement.

Climate change will result in broad-scale ecosystem shifts across the Prairie provinces. These shifts will lag behind changes in climate by decades, and will therefore continue well into the future. The extent to which forest, grassland and parkland ecosystems shift will depend on the rate of climate change and the success of adaptation measures. Such measures include planting tree species that are adapted to dry conditions and removing human-caused barriers to range shifts, such as those caused by industrial and urban development. Some species may be lost as ecosystems transition, while in the mountains, entire ecosystems could disappear as their climate envelopes rise to higher elevations. On the other hand, the climate associated with grasslands is expected to expand, suggesting that the many at-risk species in this region could benefit, with appropriate protection and restoration of grassland habitat.

4.2.1 Ecosystem shifts

Over the long term, plants respond to climatic changes by shifting their ranges. These shifts are mediated through competition and other interspecific interactions (Hargreaves et al., 2014; HilleRisLambers et al., 2013). Competition ensures that the plants that exist in any particular area are those best adapted to the local climate and site conditions. When the climate regime changes, the competitive balance is disrupted and must be re-established (Wiens et al., 2010; Martinez-Meyer et al., 2004). At the macro scale, this manifests as a slow directional shift in the distribution of plant communities along the prevailing climatic gradient (Kelly and Goulden, 2008). This is often described as plants "tracking" their climatic envelope, although it is actually a process driven by competition (*see* Ecosystem Services chapter and Box 4.1).

Box 4.1: Transitional mechanisms

Species range shifts will lag significantly behind changes in climate (Gray and Hamann, 2013). This is because ecological systems have inertia, largely an effect of "priority of place" (HilleRisLambers et al., 2013; Suttle et al., 2007). Established plants are not easily displaced by new arrivals, even if the climate has become suboptimal for them (Urban et al., 2012). Superior competitors will eventually prevail, but may need to wait for a window of opportunity to be provided by the mortality of existing plants; this transition can take decades in forest ecosystems.

Aspen provide a useful example. Surveys along the eastern slopes of the Rocky Mountains have identified aspen seedlings growing at an elevation as high as 1500 m, which is 200 m higher than previously recorded (Landhäusser et al., 2010). All of these seedlings were growing within forestry cutblocks, which provided the conditions needed for aspen establishment. Aspen was unable to establish within adjacent mature forest stands, even though climatic conditions were similar. The implication is that the potential range of aspen has already expanded as a result of the warming that has occurred in recent decades; however, the utilization of this new range is being impeded by the presence of existing vegetation. Most species are likely to experience these sorts of lag effects (Gray and Hamann, 2013; Bedford et al., 2012).

The aspen example demonstrates that disturbance rates will be a key factor governing the rate of ecological transition (Stralberg et al., 2018; Schneider et al., 2009; Hogg et al., 2008). Anything that kills or seriously weakens existing vegetation—including disturbances such as fire, severe drought, insect outbreaks or wind-throw—provides an opportunity for competitive rebalancing and range shifts. Conversely, areas that remain undisturbed will transition much more slowly, despite progressive changes in climate. The rate of natural disturbances is expected to increase under climate change, potentially hastening the rate of ecological transition (Boucher et al., 2018; Stralberg et al., 2018; Wotton et al., 2017).

Given the role played by disturbances in these ecological transitions, ecosystem boundaries will not shift as a solid front. Instead, ecological transitions are likely to be widely distributed and patchy, reflecting the scattered distribution of natural disturbances (Schneider et al., 2009). The types of transitions that occur within disturbed sites will depend on the degree of climatic warming that has occurred up to that point, and on local factors such as soil moisture and nutrient levels at the time of the disturbance and the availability of seed sources.

Dispersal ability is another factor limiting vegetation responses to climate change (Urban et al., 2012). The rate at which plants can invade new landscapes—given suitable conditions—depends on the distance that their seeds can travel and the time required for seedlings to mature and produce seed. Potential for the disruption of co-dependent relationships between species (e.g., pollinators and flowering plants) could also affect seed germination and dispersal patterns. Given the rapid rate at which the climate is warming, many species will be unable to disperse fast enough to keep pace with the leading edge of their preferred climatic conditions (Corlett and Westcott, 2013). The ones that do are likely to be pioneer species, like fireweed, with the ability to exploit new and potentially distant habitats. A corollary is that climate change is expected to lead to the expansion of native species and the arrival of new invasive species (Walther et al., 2009).

Because dispersal ability varies among species, their ranges will shift at different rates. This means that we can expect novel combinations of species to occur within ecosystems during the transitional period (Urban et al., 2012). The movement of intact ecological units, as predicted by simple bioclimatic models, is an oversimplification (Schneider et al., 2015).

Soil moisture levels control the broad-scale vegetation patterns in the Prairie provinces (Hogg and Hurdle, 1995; Hogg, 1994). A mixed-grass prairie occupies the driest areas of the region, transitioning to taller grasses, aspen parkland, closed aspen forests and boreal forest as moisture levels increase (Schneider, 2013; Thorpe, 2011). Warmer temperatures will increase evaporation and transpiration during the growing season, resulting in lower soil moisture unless it is offset by increases in seasonal precipitation. While annual precipitation is projected to increase across most of the region, much of this will occur early in the calendar year and is likely to be insufficient for preventing soil moisture decreases by late summer (Bonsal et al., 2019).

The northern forests of the Prairie provinces receive much less precipitation than do most forests in British Columbia and eastern Canada (Hogg and Hurdle, 1995). Lower mean temperatures and rates of evaporation explain the positive water balance and forest vegetation. However, as temperatures rise and soil moisture declines, the forest will transition to a more open ecosystem type. There is a strong likelihood that large areas of boreal forest will eventually transition to aspen parkland and grassland, even under the lowest warming scenarios (Stralberg et al., 2018; Ireson et al., 2015; Schneider et al., 2015; Hogg and Hurdle, 1995).

Vegetation communities will track their preferred climatic envelopes as they shift northward and upslope as a result of progressive warming. The rate and spatial pattern of vegetation transitions depend largely on warming rates, natural disturbance rates and the individual species' dispersal rates *(see* Box 4.1). Ecosystem transitions are expected to be dramatic in Alberta *(see* Figure 4.4), reflecting the fact that most low-elevation areas in northern Alberta are already near the climatic threshold between forest and grassland. Open prairie and farming communities already exist along the Peace River in northern Alberta. Northern Saskatchewan and Manitoba receive more precipitation than northern Alberta, and are therefore less likely to undergo similar transitions. However, the southern fringe of the boreal forest will move substantially northward, and island forests in the southern parts of these provinces are unlikely to remain forested (Ireson et al., 2015; Hogg and Bernier, 2005; Henderson et al., 2002). As the climate warms, southern parts of the Prairie provinces will remain as grassland ecosystems, but the species composition will shift in areas that have not been converted to agriculture. Under a low emissions scenario, the grassland ecosystems in this region may eventually resemble the grassland communities of Montana and North Dakota (Thorpe, 2011). Higher levels of warming may result in an influx of species that are not native to Canada *(see* International Dimensions chapter; Thorpe, 2011).

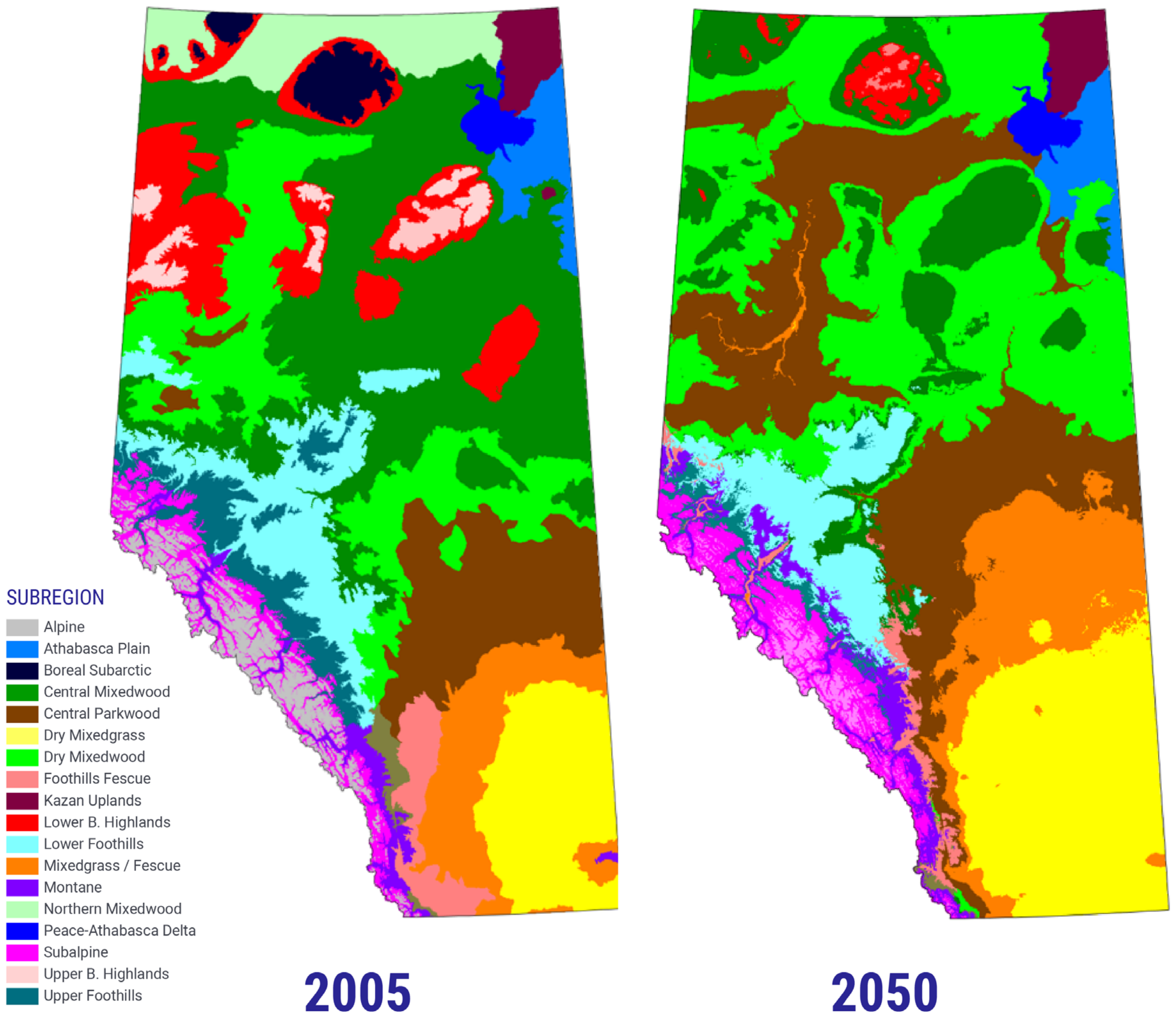

Figure 4.4: The distribution of Alberta's major ecosystem types in 2005 (left) and bioclimatic envelope model projections of these ecosystems for the 2050s (right), under a medium emissions scenario (ECHAM5-A2). Source: Adapted from Schneider and Bayne, 2015.

Bioclimatic envelope model projections, such as those presented in Figure 4.4, predict the equilibrium redistribution of ecosystems under future climatic conditions for a medium emissions scenario. However, since the climate is expected to continue changing until at least well into the next century, we can expect a prolonged period of transition. Ecosystems will be complex mixtures of old and new elements, blurring ecosystem boundaries and increasing habitat diversity in most regions (Savage and Vellend, 2015; Berteaux et al., 2010).

Increased evaporation and a longer snow-free period will reduce the average water levels of wetlands and increase the amount of time that seasonal wetlands are dry (Johnson et al., 2010; Larson, 1995). These changes will be most pronounced in the southern grasslands, where summer moisture deficits are already the norm. In northern areas, peatlands predominate and have considerable resistance to evaporation losses (Kettridge and Waddington, 2014). Nevertheless, the overall area of peatlands will slowly contract (Schneider et al., 2015). In all areas, the amount of change will be proportional to the amount of warming.

4.2.2 Animal responses

Climate influences animal distributions both directly and indirectly, with impacts differing between habitat generalists and habitat specialists. For generalists, the direct effects of warming are likely to be most important. For example, white-tailed deer are found across many Prairie biomes, from boreal forests to grasslands. The northern extent of their range is thought to be determined mainly by winter severity, which affects survival and fecundity (Dawe and Boutin, 2016). Thus, warmer winters are likely to lead to range expansion long before vegetative communities have responded. Evidence of such climate-induced range expansion is already accumulating in the Prairie provinces and in adjacent regions to the north (Veitch, 2001; Dawe and Boutin, 2016).

For other animal species, habitat suitability is the key factor governing range shifts (Kissling et al., 2010; Nixon et al., 2016). For example, the climate envelope for the burrowing owl—an endangered grassland species at the northern extent of its range in the Prairie provinces—is projected to move northward fairly rapidly (Fisher and Bayne, 2014). However, the owls will not be able to utilize this expanded potential range until entire grassland ecosystems—including appropriate vegetation and prey species—are in place. As such, despite their high mobility, many animal species will be unable to respond to climate any faster than the plant species they ultimately depend upon (Nixon et al., 2016).

4.2.3 Biodiversity implications and adaptation strategies

Species diversity in Canada declines with increasing latitude and is, on the whole, relatively low compared to many other countries (Willig et al., 2003). A northward movement of climate envelopes is expected to boost biotic productivity and species richness at all latitudes (Jia et al., 2009; Savage and Vellend, 2015). However, not all ecosystems and species will benefit. For example, alpine ecosystems in the Rocky Mountains will be compressed as suitable climate conditions rise in elevation towards the summits of the mountain peaks. The grassland ecosystems, with the largest number of species at risk in the Prairie provinces, will benefit as they expand into the southern boreal region (Hogg and Hurdle, 1995; Ireson et al., 2015).

These expectations of biodiversity patterns are subject to a major caveat. Individual species must have the ability to keep pace with climatic and ecological changes as they occur; otherwise, warming may result in the loss of species rather than a reshuffling of species. Although Canadian species have demonstrated the ability to adapt to dramatic climate changes in the past, the current unprecedented rate of change may result in some species being unable to adapt quickly enough, especially those with low dispersal ability, low rates of reproduction and low levels of genetic variation (Pearson et al., 2014).

The landscapes of the Prairie provinces are also greatly impacted by human activities, which limit the ability of species to adapt. Concern is greatest for species at risk, which are already struggling to remain viable under current conditions. The added stress imposed by rapidly changing climatic conditions exacerbates other anthropogenic impacts on species habitats (Hof et al., 2011). For example, the burrowing owl is currently declining in abundance as its habitat is contracting southward towards the core of its range in the US (COSEWIC, 2006), despite the fact that changing climate conditions suggest it should be able to expand along the northern edge of its range as conditions become suitable. Moreover, its small remnant populations in Canada may lack the resilience needed to withstand extreme weather events (Oliver et al., 2013; Fisher et al., 2015).

Species also face physical barriers that impede range shifts (Hof et al., 2011; Melles et al., 2011). Habitat deterioration presents the most widespread barrier and, while not completely blocking movement, slows the pace of adaptation. For example, the ability of grassland species to track their preferred climate is likely to be hindered by the presence of intensively managed agricultural land (Nixon et al., 2016). For fish, stream fragmentation may reduce access into climatically optimal watercourses (Park et al., 2008).

With appropriate management support, the proportion of species that are “left behind” may be relatively small under low emission scenarios. However, widespread adaptation failure is a real possibility under high emission scenarios, which will result in unprecedented changes (Corlett and Westcott, 2013). Available adaptation measures are, for the most part, components of the standard conservation toolkit (Heller and Zavaleta, 2009; Schneider, 2014). A key approach is to reduce anthropogenic stressors—such as habitat loss—to improve the general vitality and resilience of species, thereby enhancing their adaptive capacity.

Management strategies designed to minimize the impacts of human disturbances are paramount. In managing forest and grassland ecosystems, it is important that conservation objectives be dynamic, rather than planned based on historical conditions. The challenge is to develop a planning system that embraces flexibility, while safeguarding against activities that are inconsistent with the aims of conservation. There is also a need to incorporate climate change into the regulatory and policy frameworks supporting conservation. The Canadian Council of Forest Ministers developed a toolbox to assist forest managers in determining the vulnerability of their forest management systems to climate change. The centrepiece of the toolbox is a guidebook (Edwards et al., 2015) that walks forest managers through vulnerability assessment and adaptation planning.

Another important strategy is to remove or minimize barriers to movement, such as by restoring previously disturbed landscapes. Strategically placed protected areas can also facilitate species movements (Nantel et al., 2014; Nunez et al., 2013). Species that are unable to effectively track climatic changes may require active support in the form of assisted migration (Gallagher et al., 2015; Warren and Lemmen, 2014). Assisted migration is a feasible adaptation option that can be implemented now in preparation for future impacts—such as drought or warmer temperatures—and resulting changes in habitat (Ste-Marie et al., 2011; Warren and Lemmen, 2014). This form of migration can comprise the following: i) assisted population expansion, by moving populations (i.e., seed) from other locations to sites within the current species range to improve productivity and health as the climate changes; ii) assisted range expansion, by moving seed to locations somewhat beyond the species’ current distribution, where the climate in the near future is expected to be suitable for the growth of the species; and iii) translocation of exotics, by moving a species far beyond its current distribution to a location in which it has not been established in the past (e.g., to a new ecoregion or a different continent) (*see* Ste-Marie, et al., 2011 for a comprehensive review of assisted migration in the Canadian context).

4.3 Floods, drought and wildfires are getting worse

Extreme weather events of amplified severity will likely be the most challenging consequence of climate change in the Prairie Provinces. The impacts of flooding, drought and wildfire in recent years are unprecedented, and climate models suggest an increased risk of these events in the future. Provincial and municipal governments have responded by proposing policies, structures and practices to reduce the impacts of future extreme weather events.

Recent extreme weather events in the Prairie provinces—including flooding, drought and wildfire—have been the costliest natural disasters in Canadian history. This includes record dry months and historically high water levels. An increased frequency and severity of extreme weather events will be superimposed upon a more gradual change in average conditions, requiring adaptation to prepare for a wider range of weather conditions and to shifts in the distribution of water resources. Ultimately, water shortages would be the most damaging, resulting in social and environmental impacts, along with economic losses from lost productivity in the agriculture, forestry, energy and mining sectors (i.e., extraction of oil sands and solution potash mining).

4.3.1 Weather hazards

Extreme weather presents the most immediate climate risk for the Prairie provinces, as is evident from the catastrophic events that have taken place over the past 10 years (*see* Figure 4.2). Extremes in precipitation and temperature lead to impacts, such as flooding, drought and wildfire (*see* Box 4.2). Given the vast size and hydroclimatic diversity of the Prairie provinces, it is not unusual for parts of the region to be experiencing drought and wildfire at the same time, while other communities are being flooded (Brimelow et al., 2014). Extreme weather events superimposed on longer-term trends of changing average climate conditions have significant social and economic impacts, challenging the sustainable management of water, forests and soil.

Climate warming may have profound and immediate impacts on wildfire activity. The area of forest burned in Canada has already increased, mainly due to human-caused warming (Gillett et al., 2004). Warmer temperatures lengthen the fire season (Albert-Green et al., 2013) and are associated with increased lightning strikes (Romps et al., 2014). More importantly, higher temperatures lead to drier fuels, as moisture is lost from soil and plants to the warmer atmosphere (Flannigan et al., 2016). The amount of moisture held by the atmosphere increases almost exponentially as the temperature rises. Almost none of the future scenarios include sufficient increases in precipitation to compensate for the drying effect of warmer temperatures. Drier fuels make it easier for fires to start, spread and burn more intensely, making them more difficult to extinguish *(see* Video 4.1).

Video 4.1: Métis wildland firefighters are deeply connected to the land, their culture, and the impacts of climate change across the Canadian prairies. Source: Métis National Council and Prairie Climate Centre, 2020. https://youtu.be/Px4eDr8ozys

Box 4.2: Assessing the risk of flooding and other natural hazards in Saskatchewan

The province of Saskatchewan completed a comprehensive assessment of natural hazards in 2018 (Wittrock et al., 2018). Aggregate risk—the combination of likelihood and impact—was evaluated for ten climate-related hazards *(see* Table 4.2). Likelihood was based on the analysis of weather records and climate model projections, while the impact level was estimated using data about past weather events and information obtained from consultations with stakeholders and sector experts.

Table 4.2: Degree of aggregate risk in Saskatchewan from climate-related natural hazards

NATURAL HAZARD	CURRENT RISK[1]	MID-CENTURY RISK[2]
Drought	High	High to extreme
Convective summer storms	High	High to extreme
Forest fire	Moderate to high	Moderate to high
Winter storms	Moderate to high	Moderate to high
Overland flooding	Moderate	Moderate to high
Grass fire	Moderate	Moderate to high
Plains runoff flooding	Moderate	Moderate
Lake flooding	Moderate	Moderate
Mountain runoff flooding	Low to moderate	Low to moderate
Groundwater flooding	Low	Low

1 Plausible worst-case scenario based on historic events

2 Risk under projected mid-21st century climatic conditions

SOURCE: WITTROCK ET AL., 2018.

This analysis indicates that future risk of drought and summer convective storms rises to "extreme" as warming amplifies the severity of these weather events. This effect is also seen in the increased risk from overland flooding as rainfall becomes more intense. Floods will increasingly be generated by heavy rain or rain on snow, in contrast to the historical prevalence of flooding being the result of spring snowmelt runoff (Pomeroy et al., 2015).

This risk assessment applies to the neighbouring Prairie provinces with two notable exceptions. The risk of mountain runoff flooding is much higher for Alberta's urban centres, given their greater proximity to the Rocky Mountains. In Manitoba, the risk from plains runoff flooding is higher than in Saskatchewan, specifically in the Red River and Assiniboine River basins. Otherwise, the Prairie provinces experience similar exposure to and consequences from drought, wildfire and storms—the weather-related hazards that represent the greatest near-term risk in the region.

4.3.2 Hydrological hazards

Large interannual variability and extreme hydroclimatic events are characteristic of the Prairie provinces. Simultaneous wet and dry conditions across the region are not uncommon; they occur, for example, when high pressure in the western Prairies diverts moist air masses towards the east (e.g., Liu et al., 2004; Rannie, 2006; Szeto et al., 2011).

Both gradual, long-term changes in water levels and extreme fluctuations around the changing baseline will have impacts and require adaptation. Water allocation and the design of storage and conveyance structures—such as reservoir and irrigation pipes—are based mainly on average seasonal water levels. Otherwise, water resources are managed to prevent the adverse impacts of flooding and drought.

There has been much analysis of the most recent multi-year drought in the Prairie provinces, which spanned the period from 1999–2004 (e.g., Hanesiak et al., 2011; Bonsal et al., 2011; Wheaton et al., 2008). This was followed by a period of relatively wet conditions from 2005–2019, with the exception of some intense droughts of seasonal duration, including from summer 2008 to winter of 2009–2010 (Wittrock et al., 2010), summer 2015 (Szeto et al., 2016), spring/summer 2017 (Jencso et al., 2019), and spring/summer 2019 (Agriculture and Agri-Food Canada, 2019). While drought and flooding are difficult to predict, their probability is strongly linked to periodic fluctuations in sea surface temperatures in the Pacific Ocean, known as the Pacific Decadal Oscillation (PDO) and the El Niño Southern Oscillation (ENSO) (*see* Box 2.5 in Bush et al., 2019). Uncertainty in projected future precipitation amounts and extremes depends largely on the ability of the models to simulate the internal variability of the regional climate—such as changes in the teleconnections between ocean–atmosphere oscillations (i.e., the ENSO and PDO) and in the regional hydroclimate (Barrow and Sauchyn, 2019)—and, to a lesser extent, on the use of different models and greenhouse gas emissions scenarios.

The impacts of water excesses and deficits differ with respect to the timing, duration, intensity and extent of flood and drought events. Meteorological drought (lack of rain) can immediately affect dryland farming, while hydrological drought (low water levels) affects irrigation, municipal and industrial water supplies. The cumulative impacts of a long period of low water levels contrast with the effect of short, intense drought. Flooding has been most damaging along the Red River in Manitoba and the rivers flowing from the Rocky Mountains, where population centres are concentrated. In the Prairies, however, inundation of agricultural land is common given the large area of depression storage (including sloughs and wetlands). A torrential rainstorm near Vanguard, SK on July 3, 2000, saw 375 mm of rain fall in 8 hours, with an estimated 62% of that water retained on the landscape (Hunter et al., 2002). While drought results in crop losses over large areas, flooding can prevent the sowing of crops, as occurred in 2011 over 5.5 million hectares, mostly in Manitoba (Brimelow et al., 2014). The Quill Lakes of east-central Saskatchewan have risen to such an extent that they are now one large lake inundating thousands of hectares of farmland, railroads and provincial highways (Water Security Agency, 2016).

Studies of the 2015 drought (Szeto et al., 2016), 2013 floods in southwestern Alberta (Teufel et al., 2017; Pomeroy et al., 2015) and of the Assiniboine River Basin in Saskatchewan and Manitoba in 2014 (Szeto et al., 2016) concluded that these naturally occurring events were intensified by human-caused climate change. The analysis of rainfall data generated by climate models indicates that a warming climate will cause a significant shift from historical values in the intensity, duration and frequency of rainfall events (Bonsal et al., 2019). For example, climate projections for Saskatoon reveal an increase in the intensity of short-duration extreme precipitation events and a decrease in the length of the return period between these events, with the most intense precipitation occurring towards the end of the 21st century under the RCP8.5 high emissions scenario (Alam and Elshorbagy, 2015).

An increase in rainfall intensity is one of the most consistent changes projected globally (IPCC, 2014), nationally (Zhang et al., 2019) and regionally (Gizaw and Gan, 2015). In the Prairies, farmland and infrastructure could be periodically inundated by excess precipitation in winter, which in future decades is increasingly likely to fall as rain. This excess water will occur as the warmer climate converges with the wet phase of the PDO and ENSO. Similarly, the amplitude of dry phases will likewise increase when there is an absence of rain, but also with higher temperatures than in the past (Tan et al., 2019). Climate projections suggest an increasing risk of drought in the Prairies, specifically in summer and fall (Bonsal et al., 2019). The worst-case future scenario for the Prairie provinces is the reoccurrence of consecutive years of severe drought, such as those that occurred in the 1930s and in preceding centuries (Sauchyn et al., 2015).

4.3.3 Societal impacts

The 2013 flooding in Calgary and the 2016 wildfire in Fort McMurray represent two of the costliest natural disasters in Canadian history, and provide dramatic examples of societal impacts arising from extreme weather. They also provide insight into actions being taken to reduce such impacts in the future (*see* Case Story 4.1), and highlight the linkages between climate change and natural disasters (*see* Case Story 4.2).

Case Story 4.1: Policies and measures for reducing flood risk in the City of Calgary

In 2013, Calgary experienced its largest flood since the turn of the 19th century (City of Calgary, 2017). Homes and businesses located in historic neighbourhoods and in the downtown core experienced devastating damage from riverine and stormwater flooding (*see* Figure 4.5). Traffic was disrupted, businesses were closed and community services were impacted. The resulting damage totalled $6 billion, including over $400 million to City of Calgary infrastructure (City of Calgary, 2017). The downtown core, in particular, was overwhelmed as power was lost and many businesses were not accessible for at least six days. Increased flood protection in this area is critical, especially considering that 124 corporate head offices are located there and provide more than 99,000 jobs—approximately 20% of the total number of jobs in Calgary (City of Calgary, 2019a).

Figure 4.5: Damage and recovery from flooding in Calgary in June 2013: a) near record-high water levels on the Bow River, b) disrupted urban transportation, c) flooded City Centre, and d) West Eau Claire flood wall.Photos courtesy of: Shutterstock.

Building flood resiliency is a top priority for the City of Calgary (City of Calgary, 2017). The City has taken a holistic approach to flood reduction, employing multiple lines of defence at the watershed, community and property levels. A comprehensive Flood Mitigation Measures Assessment, for example, identified the need for a combination of upstream, local and property-level adaptation measures, along with planning and policy to reduce flood risk and potential damages (*see* Figure 4.6; City of Calgary, 2017).

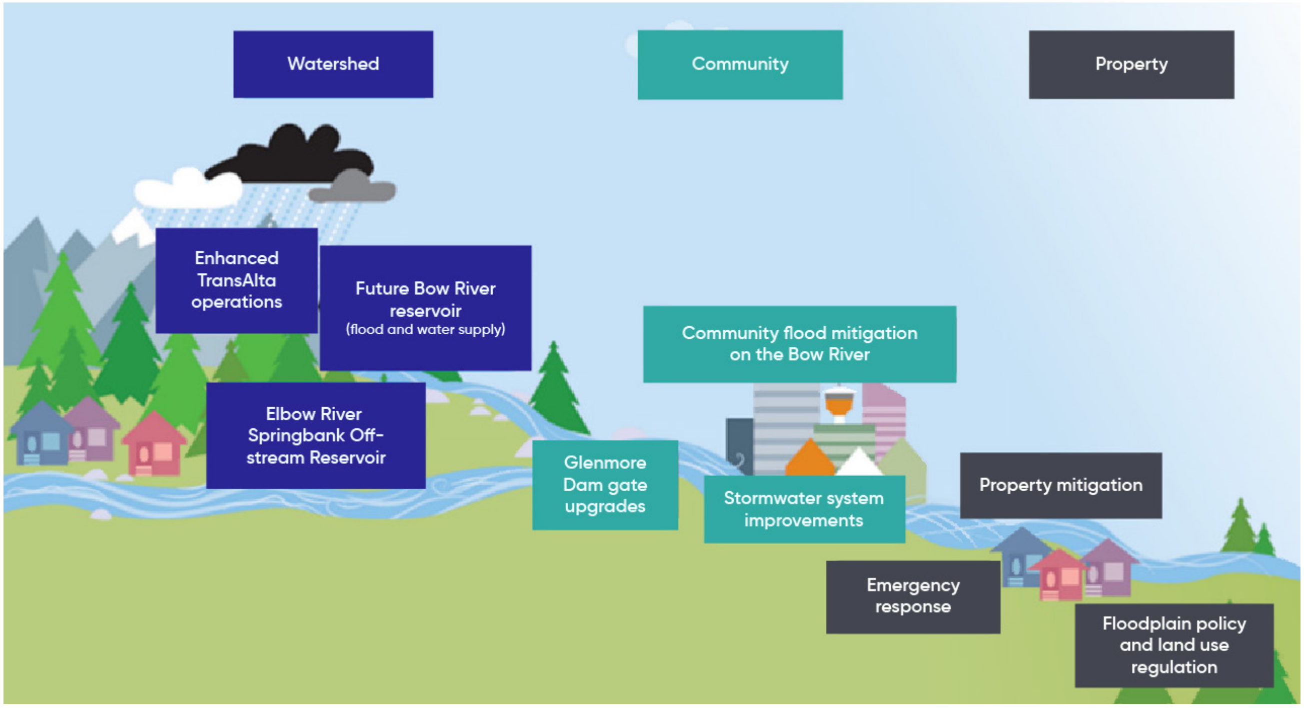

Figure 4.6: Visual representation of key adaptation measures from Calgary's Flood Resilience Plan. The plan uses a three-layered approach: 1) Upstream flood protection on the Bow and Elbow Rivers to increase water storage and help slow larger flows from the mountains, 2) Community-level flood protection through the installation and upgrading of permanent infrastructure, and 3) Property-level flood protection through changes to building regulations and bylaws, limiting types of development in flood-prone areas and public education. Source: City of Calgary, 2019b.

The City's Flood Mitigation Measures Assessment Report (City of Calgary, 2017) focused on protection against an event similar to the one experienced in 2013, with increased protection in critical areas such as the downtown and neighbourhoods at highest risk. A combination of barriers and flood-control operation protocols at existing reservoirs support the plan, although its success is also dependent on the ability of upstream reservoirs to provide a high level of protection, so as to avoid relocating communities. Stormwater flooding and a number of projects aimed at reducing stormwater back-up from flooded rivers have also been considered in the City's flood mitigation planning. In 2015, the Government of Alberta earmarked $150 million over 10 years for the City of Calgary to implement projects that reduce flood risk through the Alberta Community Resilience Program (Government of Alberta, 2015).

Case Story 4.2: The 2016 Fort McMurray wildfire

Wildfire is the keystone process responsible for shaping landscape diversity in the forests of the Canadian Prairies. However, wildfire can also be a threat to human life, communities and valuable commercial and industrial activities. A human-caused wildfire was discovered on May 1, 2016 about 7 km west of Fort McMurray, Alberta. This high-intensity, fast-moving wildfire spread into the town two days later *(see* Figure 4.7). The fire necessitated the evacuation of around 90,000 people, destroyed 2,800 structures and burned an area of 590,000 ha (slightly larger than Prince Edward Island) (Kochtubajda et al., 2017). The Fort McMurray fire was the costliest natural disaster in Canadian history, leading to insurable losses of just under $4 billion dollars and a negative impact on the national GDP *(see* Sector Impacts and Adaptation chapter).

Figure 4.7: The 2016 Fort McMurray wildfire. Source: Shutterstock.

Three factors influence wildfire activity: fuel (type, structure, amount and moisture), ignition (humans or lightning) and fire-conducive weather (typically hot, dry and windy) (Wotton et al., 2017). These three factors came together for the Fort McMurray fire with exceedingly dry fuel, human ignition and hot, dry and windy conditions.

More large and high-intensity wildfires, such as that experienced in Fort McMurray, are expected under current climate change projections (Flannigan et al., 2009; Zhang et al., 2019). Recent research suggests that the risk of extreme fires in western Canada has increased by a factor of 1.5 to 6 due to human-caused climate change (Kirchmeier-Young et al., 2017; Zheng et al., 2019), and that extreme springtime fire weather across western Canada is very likely an effect of human-caused warming (Tan et al., 2019).

The potential for interactions between society and fire will increase in a warmer world, requiring that people adapt to living alongside wildfire, while working to reduce its likelihood of threatening communities and other assets. Impacts from wildfires are a result of a warming climate and more development in forests. The number of days each year in which there is the potential for unmanageable fire is projected to more than double (between the periods 1971–2000 and 2081–2099) in some parts of the northern boreal forest in the Prairies (Wotton et al., 2017). Wildfire hazard can be reduced at the community level through actions such as reducing risks associated with vegetation located near structures and reducing the use of flammable building components (FireSmart Canada, 2020). FireSmart recommendations can be applied at the landscape level by using timber harvest and reforestation practices to break up large contiguous areas of conifer cover and to establish areas of low flammability with deciduous species such as aspen (Volney and Hirsch, 2005). Detailed reviews of adaptation options for forest management are available *(see* Sector Impacts and Adaptation chapter; Ogden and Innes, 2007, 2009; Gauthier et al., 2014).

4.4 Collaborative water management reduces negative impacts

Regional land-use policy and planning, as well as emergency preparedness, are critical for reducing the impacts of flooding and drought in the Prairie provinces. Collaboration is needed among all levels of government, and with stakeholders such as watershed stewardship groups, rural municipalities and conservation districts, to implement these adaptation measures and to promote practices that prevent or minimize adverse effects of water excesses and shortages.

The Prairie provinces have extensive experience dealing with water excesses and shortages, and have developed important mechanisms for adapting to climate variability. While many of these mechanisms are tailored to drought, some also address flooding and excessive moisture. The extensive management of water flows through dams, diversions and withdrawals on the Prairies makes it difficult to discern climate-related changes; adaptive management of water resources can help to compensate for changes in the availability of water supplies, while also reducing the impacts of flooding and drought.

4.4.1 Institutional mechanisms

Interprovincial level

Canada's decentralized approach to water governance provides the provinces with considerable autonomy over water-related decisions (Heinmiller, 2018). The Prairie Provinces Water Board (PPWB) is an enduring institution established in 1948 to foster water management cooperation among the provinces of Alberta, Saskatchewan and Manitoba. The Master Agreement on Apportionment (MAA) was created by the PPWB in 1969 (Heinmiller, 2018) and states that in any given year, each province is entitled to half of the natural flows of interprovincial rivers, as measured at the provincial boundary (Prairie Provinces Water Board, 2015). The MAA thereby removes potential uncertainties associated with interprovincial politics when dealing with water scarcity. It provides water managers in each province with a clear quota of the amount of available water that they will manage, even if the actual amount of water in the river is uncertain or highly variable.

While the PPWB and MAA provide this important mechanism to address hydroclimate extremes, particularly drought, they can also be inflexible under changing climate conditions, given the strictly defined apportionment of surface water among the Prairie Provinces. The PPWB has been examining the issue of the MAA's resilience under various climate scenarios (Prairie Provinces Water Board, 2014). This type of strategic exercise demonstrates one benefit of the PPWB and the interprovincial governance networks that it fosters.

Provincial level

The individual Prairie provinces have differing approaches to coping with hydroclimatic extremes. For example, Alberta uses a cap-and-trade system for reallocating water licences during times of water scarcity, whereas Saskatchewan and Manitoba take a more centralized approach with strong government oversight (Heinmiller, 2018; Government of Manitoba, 2018). Alberta allows for the creation of water markets at the regional level to reallocate water from low-valued to high-valued uses when drought threatens the status quo. While this is a potentially useful institutional mechanism, concerns have been raised about fairness and equity issues that could emerge (Hurlbert and Gupta, 2017). For example, declining summer river flows from the Rocky Mountains could affect water allocations in southern Alberta, especially for junior licence holders, since the major irrigation districts hold the senior licences. The effect of low water levels in the South Saskatchewan River Basin (SSRB) was ameliorated somewhat following the drought of 2001–2002, when the transfer of water rights was introduced and the Government of Alberta closed much of the SSRB to new surface water allocations (Government of Alberta, 2006). Saskatchewan's more centralized approach may limit opportunities among affected stakeholders for sharing and learning about drought response mechanisms and other adaptation challenges (Hurlbert and Gupta, 2017).

The previous experiences of the Prairie provinces with water and weather extremes have led to the development of important mechanisms for adapting to climate variability. All three provinces have a plan for drought—the region's worst threat (*see* Table 4.3)—, and Alberta's plan also addresses the risks of excessive moisture, demonstrating how some mechanisms tailored to drought could be repurposed to address concerns about flooding and excessive moisture. The Saskatchewan plan is mostly focused on agricultural risks, as drought planning is part of the Water Security Agency's broader mandate and 25-year plan.

Manitoba's drought planning appears to recognize the wider environmental, economic and societal impacts. All of the plans consider climate change to some extent.

Table 4.3: Provincial drought planning: Some characteristics and status

PROVINCE	MOST RECENT REPORT	LEAD MINISTRY/ MINISTRIES	CLIMATE CHANGE ADDRESSED?	NEXT STEPS? (EXAMPLES)	CURRENT IMPLEMENTATION STAGE? (EXAMPLES)
Alberta	Alberta's Agriculture Drought and Excess Moisture Risk Management Plan (2016)	Alberta Agriculture and Forestry	Yes	Continued improvement is envisioned	Drought and excess moisture advisory group
Saskatchewan	25 Year Saskatchewan Water Security Plan (2012)*	Ministry of Agriculture; Water Security Agency	Yes	Several listed (e.g., coordination of moisture monitoring, new infrastructure)	Moisture monitoring committee meets as needed
Manitoba	A Made-in-Manitoba Climate and Green Plan (2017)	Manitoba Sustainable Development and Stewardship (now the Ministry of Conservation and Climate)	Yes	Evaluate the strategy and update; determine drought preparedness levels	Evaluate and update the strategy; status of action items are reported (2017)

** The plan includes drought response actions.*

Watershed or regional level

Across the Prairie provinces, watershed-based organizations have become an effective mechanism for local climate change adaptation planning and soil water protection. In Manitoba, the Watershed Districts Program (formerly Conservation District Program) is a partnership between the province, which provides most of the funding, and more than 130 municipalities that develop and administer soil and water conservation programs. The Watershed Districts Act, proclaimed on January 1, 2020, transitioned 18 conservation districts to 14 new watershed districts, with boundaries based on drainage divides (Government of Manitoba, 2020). Integrated watershed management plans were among 30 municipal planning documents reviewed in a report commissioned by Manitoba Sustainable Development (now the Ministry of Conservation and Climate) (International Institute for Sustainable Development, 2019). Only five of the 30 documents explicitly referred to the need to adapt to climate change, and none included climate projections, nor committed to taking further actions to assess the climate change risks to their communities. Saskatchewan established local Watershed Stewardship Groups to work in collaboration with the provincial government to address a broad range of water quality-related issues. These groups constitute forums for multiple stakeholders to discuss local water issues and design locally appropriate solutions. They typically include participants from municipalities, agricultural producers, environmental NGOS and other industries in the respective watershed. While initially focusing on water quality, these groups have since branched out to tackle other water-related issues, including drought and flooding (Pittman et al., 2016). Many groups have been involved in climate change adaptation projects, including the development of extreme hydroclimate scenarios and action plans to provide watershed-specific solutions (Pittman et al., 2016). In Alberta, eleven Watershed Planning and Advisory Councils (WPACs) are independent, non-profit organizations designated by Alberta Environment and Parks to report on the health of their watersheds, lead collaborative planning, and facilitate education and stewardship activities. Each WPAC engages key stakeholders in their watershed, seeking consensus on land and water management strategies to achieve shared environmental, social and economic goals (*see* Case Story 4.3).

Case Story 4.3: Collaborative adaptation planning in Alberta watersheds

With Alberta's long history of great variability in river flow volumes and recent experience with flood and drought, water experts, managers and users across the province have recognized the importance of collaborative and proactive adaptation planning. Since 2010, a series of projects have brought together municipalities, industry, government, watershed groups, environmental groups, Indigenous groups and academics to explore the implications of climate change for water supplies and to develop strategies to support sustainable and resilient water management. Working groups have developed and used interactive water balance models to simulate flows and operations based on historic records and future climate change scenarios (Sauchyn et al., 2016).

The Bow River Basin (BRB) Working Group considered the alternative use of reservoirs to augment low river flows and improve ecosystem health. Reservoirs are often filled during low-flow periods in the late summer, coinciding with warm air temperatures; these two factors together strain both the quantity and the quality of water in downstream rivers. One potential adaptive strategy is the use of a "water bank", which would hold a specific amount of water in the upper BRB reservoirs to be released as dictated by low flow conditions downstream. Following severe flooding in 2013, the working group examined options for using existing and new reservoirs in the upper Bow River system to reduce peak flood flows through urban and rural communities (*see* Figure 4.8). The resulting report put forward 12 recommendations, including feasibility studies for three potential flood mitigation structures and for a series of smaller projects to maintain a balance between flood and drought resilience (Bow River Water Management Project, 2017).

Flood mitigation in the Bow River Basin

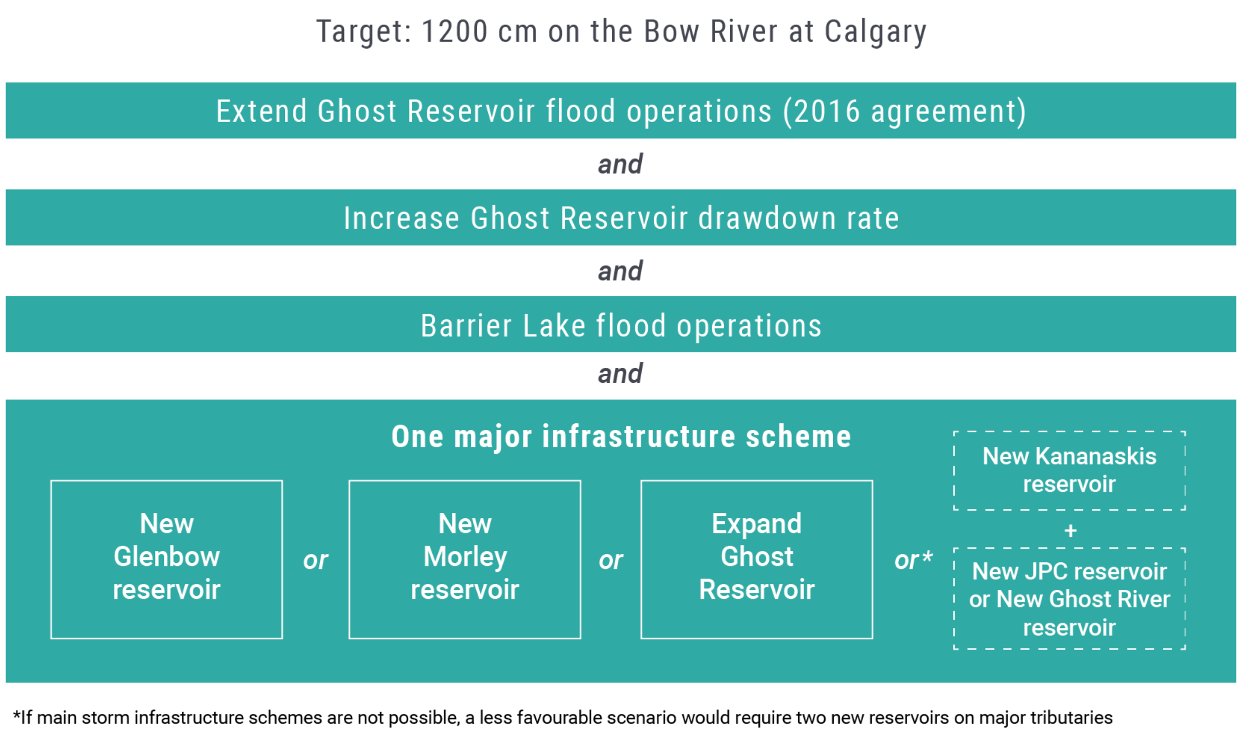

Figure 4.8: Approaches considered by the Bow River Basin Working Group for reducing flood impacts. Source: Bow River Water Management Project, 2017.

The Athabasca River Basin (ARB) Working Group linked a physically-based hydrological model of the watershed to data on water use and allocations to better understand the role of land-use policy and practices in adapting to changing water supply and demand. The working group followed a structured process (*see*

Figure 4.9) that identified 12 broad strategies and six recommendations to support sustainable water management into the future (WaterSMART Solutions Ltd., 2018). These recommendations included land-use planning to maintain natural hydrological functions, sharing and applying Indigenous knowledge, and establishing environmental flow needs.

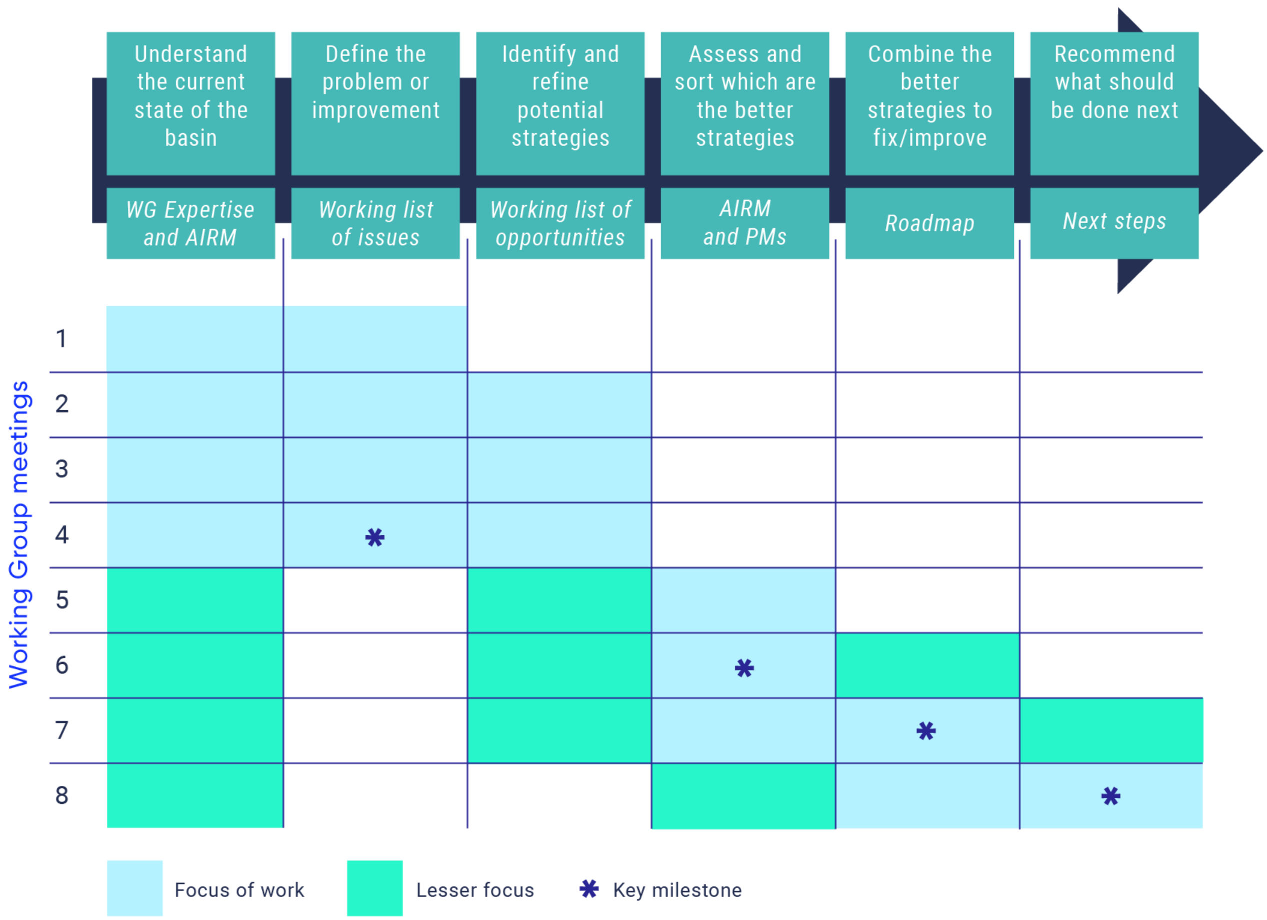

Figure 4.9: The process used by the Athabasca River Basin Working Group to move from increasing understanding of the Athabasca River basin to developing a roadmap for sustainable water management (AIRM: Athabasca Integrated River Model; PM: Performance Measures). Source: WaterSMART Solutions Ltd., 2018.

Both collaborative projects supported institutional resilience in Alberta by bringing together water managers and stakeholders to build a common understanding of climate change impacts on the balance between basin water supply and demand. Participants were able to identify and test adaptation strategies and scenarios, and collectively identify practical options to increase resilience in the watershed.

Irrigation districts across the Prairie provinces are another type of local stakeholder group that helps to manage hydroclimate extremes. While initially developed to manage local water for irrigation, they are now engaged in a broader range of issues. For example, during the 2001-2002 drought, the water markets referred to previously were coordinated by the local irrigation district in the Oldman River Basin of Alberta. Irrigation districts provide a locally-rooted mechanism for building trust and fostering collective action in the face of water-related adversity. They have been involved in participatory scenario exercises to prepare for drought (Hadarits et al., 2017) and have also voluntarily taken on new roles addressing adaptation to excessive moisture. The infrastructure managed by the irrigation districts to enhance agricultural production has also proven useful in recent years for dealing with excessively wet conditions (Hadarits et al., 2017).

4.5 Climate change brings both benefits and threats to agriculture

Prairie agriculture, particularly crop production, may benefit from higher temperatures and a longer growing season. Achieving net benefits will require adaptation to limit the impacts of climate extremes, including on water availability, and the increased risk of pests, vector-borne diseases and invasive species. Although agricultural producers are highly adaptable to fluctuations in weather and climate, barriers to adaptation include limited information and awareness of climate change impacts, combined with limited financial resources and institutional support.

Agriculture is a key employer and a major driver of the economy in the Prairies. Climate change brings both opportunities for and threats to agriculture. Direct impacts include changes in growing season length, timing and quantity of precipitation, heat units, extreme events—such as heat, hail and windstorms, flooding and drought. Indirect climate change impacts include effects on weeds, diseases, insects and soil characteristics, as well as on socio-economic factors influenced by global-scale changes in climate. These factors include effects on global food security, and trade and relations with supply industries for agricultural production and food processing. Assessing the convergence of these direct and indirect impacts is a major challenge. The overall impacts of climate change will depend on the effectiveness of adaptation not only in the Prairie provinces, but in Canada more generally and in other countries as well.

4.5.1 Impacts

Climate change has both direct and indirect impacts on agriculture in the Prairie provinces, resulting in both risks and opportunities (Kulshreshtha and Wheaton, 2013). Changing precipitation, temperatures, carbon dioxide levels and other variables will affect the following: crop and pasture productivity, quality and nutrient cycling; weeds, insects and diseases; and livestock production and reproductive rates (Sudmeyer et al., 2016). Projected biophysical impacts include increased water scarcity, more frequent extreme precipitation events, shifting and variable precipitation patterns, longer growing seasons, increasing heat units (i.e., a measure of crop development in relation to temperature), and more frequent and intense droughts (e.g., Bonsal et al., 2019; Kulshreshtha and Wheaton, 2013).

Certain crop yields and hay productivity may increase in the near term in response to climate factors, such as longer growing seasons and increased heat units (*see* Box 4.3). However, high temperatures, droughts and more variable precipitation negatively affect crop yields, particularly for canola and wheat (Meng et al., 2017; Qian et al., 2018). Increased exposure to high temperatures (e.g., over 30°C), especially at critical times, may also reduce yields of corn, soybean, canola and wheat (Schauberger et al., 2017; Meng et al., 2017).

Box 4.3: Climate change impacts on future crop yields

Much of the historical variation in annual crop yields is attributable to climatic variability (Qian et al., 2009; Wittrock et al., 2014). For example, in Saskatchewan's Swift Current River Basin, the water balance index and the departure of spring wheat yields from expected values have a strong correlation with negative anomalies in drought years and higher than expected yields in years with positive water balances (*see* Figure 4.10; Wittrock et al., 2014). Yields have generally increased over time thanks to improved management and new technology. The yield data were detrended to remove the influence of farming practices, so that the effects of climate variability are the primary focus. However, technology advances are important adaptation measures that continue to improve agricultural production.

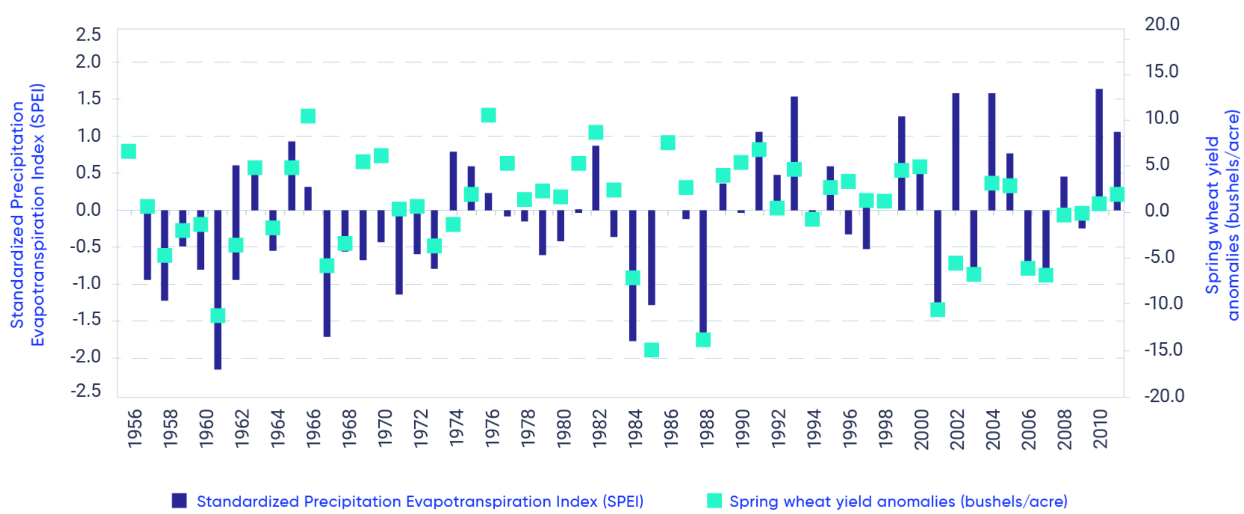

Figure 4.10: Comparison between spring wheat yield anomalies (e.g., departures from the trend) and growing season Standardized Precipitation Evapotranspiration Index (SPEI) for the Swift Current Creek Watershed in Saskatchewan. Source: Wittrock et al., 2014.

Projections of changes in crop yields in the Prairie provinces are limited, uncertain and largely only available for a few main crops (*see* Table 4.4). Spring wheat yields are projected to increase by 8–37% and higher by the 2050s under medium and high emissions scenarios (He et al., 2018; Qian et al., 2015, 2016; Smith et al., 2013). A large proportion of this increase is due to the direct effect of increasing carbon dioxide levels. For example, increases in the simulated average wheat yield range from 26% to 37% of the baseline yield when the effects of elevated carbon dioxide are included, but reach only 15% when carbon dioxide effects are excluded (Qian et al., 2016). Estimates for other main crops are limited. Increased heat and water stress on current crop cultivars may reduce canola yields (Qian et al., 2018). Examples of agriculture-specific adaptations include irrigation, use of cultivars with greater tolerance to heat and drought stress, and earlier seeding dates and fertilization (e.g., Qian et al., 2016). Some of these adaptation strategies were considered in the model simulations referred to in Table 4.4. Information and support from agriculture ministries, the agricultural industry and producer groups will help to enable crop producers to adapt to climate change, thereby ensuring that these simulated yield increases are practical and attainable.

Table 4.4: Simulations of changes in future crop yields in the Canadian Prairies (Qian, 2018)

LOCATIONS	CROP	YIELD CHANGE AND TIME PERIOD	CLIMATE SCENARIO	CROP MODEL	REFERENCE
Swift Current, SK	Spring wheat	8–11% (2041–2070) 8–15% (2071–2100)	CanRCM4 RCP4.5 and RCP8.5	DSSAT	He et al., 2018
Brandon, MB	Canola	-21% to -44% (2041–2070) -23% to -74% (2071–2100)	CanRCM4 RCP4.5 and RCP8.5	DSSAT	Qian et al., 2018
13 locations across the Prairies	Spring wheat	15–25% (2041–2070)	CanESM2 and CanRCM4 RCP4.5 and RCP8.5	DSSAT	Qian et al., 2016
11 locations across the Prairies	Spring wheat	26–37% (2041–2070)	CGCM3 and HadCM3 IPCC SRES A2	DSSAT	Qian et al., 2015

LOCATIONS	CROP	YIELD CHANGE AND TIME PERIOD	CLIMATE SCENARIO	CROP MODEL	REFERENCE
Dauphin, MB; Melfort, SK; Edmonton, AB; Fort Vermilion, AB	Timothy	>24% for first cut and <-31% for second cut (2040–2069)	CGCM3 and HadGEM1 SRES A1B and A2	CATIMO	Jing et al., 2013
Swift Current, SK	Spring wheat (Biofuel cultivar)	41–74% (2040–2069)	CGCM3 SRES A1B, A2, B1	DSSAT	Wang et al., 2012
Swift Current, SK; Melfort, SK; Lethbridge, AB	Spring wheat	~37% (2040–2069)	CCGCM3 SRES A1B A2, B1	DNDC	Smith et al., 2013

Extreme events, particularly droughts, negatively affect crops, livestock and forage production, causing financial losses such as those that occurred in 2001–2002, when drought resulted in a more than $2.97 billion reduction in agricultural production in the three Prairie provinces (Wheaton et al., 2008). Such impacts require further assessment and documentation (Craft et al., 2017), including an examination of the social aspects (*see* Section 4.6). Climate change extremes also affect soil and water quality through increased risk of soil erosion, soil salinization, desertification and soil degradation (Wheaton and Kulshreshtha, 2017). For example, flooding of agricultural lands due to precipitation extremes caused $1 billion in damages in the southeastern Prairies in 2014 (Szeto et al., 2014) and almost $700 million in 2011 in Manitoba alone (Public Safety Canada, 2019).

Future surface and soil water deficits (Bonsal et al., 2019) will have profound effects on the quantity and quality of surface water and on groundwater supplies. Decreased availability of river water is a concern for all producers, particularly those irrigating crops. Plant germination and reproduction are highly sensitive to moisture and heat stress corresponding with the timing for these stages in the life cycle of plants (Champagne et al., 2012). Negative impacts on water quality also result from extreme rainfall events, generating runoff with heavy nutrient loads, and from longer periods of low flow in streams and rivers (Venema et al., 2010).

4.5.2 Adaptation

While agricultural producers can benefit from longer and warmer growing seasons and increasing carbon dioxide levels, other climate change impacts, such as water scarcity, and excess moisture and heat, may be very challenging. Existing adaptive practices include the use of zero-till agriculture, feed stockpiling, increasing farm size, beneficial management practices, insurance, large-scale infrastructure such as dams (e.g., Smit and Skinner, 2002; McMartin and Hernani Merino, 2014; Warren, 2016a), earlier seeding dates, mixed farming and changes in crop varieties. Beneficial management practices include the use of methods, policies, programs and tools for improving the environmental and economic positioning of agriculture (McMartin and Hernani Merino, 2014). Unexpected social, economic and environmental consequences of adaptive practices could render some strategies maladaptive, meaning that despite attempting to reduce risk to climate change, they inadvertently increase vulnerability (Müller et al., 2017).

Agricultural systems need to adapt to a suite of climate change impacts that interact with other factors, such as economic pressures, opportunities related to an increasing global population, changing human dietary preferences, increased input costs and energy prices, competing land-use pressures and policy-related economic pressures. Agricultural producers have access to various types of adaptation options, ranging from relatively minor measures, such as growing drought-tolerant crop varieties, to more substantial or even transformative changes (i.e., major, purposeful actions at the farm level or higher), such as policies that remove obstacles to climate change adaptation or changes from dryland cropping to irrigation (Rickards and Howden, 2012). However, the cumulative impacts associated with multiple drivers of change will test overall capacity to adapt. Economics is a major motivation in the adoption of new practices (*see* Sector Impacts and Adaptation chapter), and the most appropriate adaptation measures will depend on a large number of factors, including capacity (*see* Case Story 4.4).

Case Story 4.4: Building adaptive capacity in Indigenous communities through agriculture

Although farming operations in any given region will likely experience similar biophysical climate change impacts, differences in vulnerability and adaptive capacity may result in very different experiences, especially between Indigenous and non-Indigenous communities. Social factors such as culture, socio-economic status and historical experience with agriculture will influence how farmers adapt. Factors such as the low socio-economic status in many First Nations communities exacerbate vulnerability and negatively affect resilience to climate extremes. While federal legislation has historically inhibited many First Nations from participating in agriculture (Tang, 2003), today there are several examples of successful agricultural initiatives undertaken by First Nations in the Prairie region. Examples include the Blood Tribe Agricultural Producers in southern Alberta (Kulshreshtha et al., 2011), whose operations are vulnerable to periodic flooding (Magzul, 2009) and the Muskoday First Nation in Saskatchewan, which has operated a successful organic agriculture co-operative for over a decade (Martens, 2016). The use by First Nations of alternative agricultural practices (e.g., organics) may have higher resilience in terms of ecological and market diversity, and could include the harvesting of native plants and traditional foods. Two consultation sessions between the federal government and First Nations representatives in Alberta and Quebec revealed obstacles and opportunities facing the participation of First Nations in agriculture (Agriculture and Agri-Food Canada, 2017). Access to capital, support programs and extension services (e.g., mentoring, information sharing) were identified as needs. While climate change adaptation was not mentioned explicitly in the consultation report (Agriculture and Agri-Food Canada, 2017), access to related resources could enhance the participation of First Nations in agriculture, thereby enhancing their adaptive capacity.

Mixed farms with both crops and livestock have advantages for adaptation. Drought response practices for mixed farms may include purchasing feed when necessary and early weaning of calves, combined with feeding strategies aimed at reducing both feed demand and the producer's financial burden during drought periods (Poudel and Kulshreshtha, 2016; Poudel et al., 2017). Options that are more specific to rangeland and livestock production include herd management, raising alternative breeds and species, pest management, and changes in enterprises and geographic locations (Joyce et al., 2013).

Current barriers to adaptation include a lack of awareness of options, inadequate financial resources and institutional support mechanisms, insufficient preparation, and political resistance (e.g., Lilliston, 2018). The development of irrigated areas—a logical adaptation to increased water stress in agricultural systems—involves building dams and distribution channels, and is therefore highly capital intensive (Warren, 2016a). Water availability for irrigation may also be a limitation, as stream flows are reduced during severe droughts (*see* Section 4.4; Wheaton et al., 2008). Existing irrigation systems may not be able to cope with the water demands of a multi-year drought. Observed trends toward increasing farm debt (Statistics Canada, 2017b) may severely impede the ability to undertake adaptive actions.

Increases in heat units and longer growing seasons will affect agronomic management practices such as seeding dates. Heat stress may result in a shorter growing season for some crops, such as soybeans (Jing et al., 2017). For crops like canola, earlier seeding and increased fertilization are limited options because of increased heat and water stresses, which are important limiting factors for crop yields. Key adaptation measures include new heat- and drought-tolerant cultivars (Qian et al., 2018). Higher temperatures could lessen the limitations imposed by a short growing season along the northern margins of the agricultural zone. However, extending agriculture into this region will require adaptation of farming practices to yield crops in nutrient-poor forest soils.

Governance institutions play important roles in adaptation and can improve the adaptive capacity of producers and other rural residents (Hurlbert et al., 2009). However, capacity constraints and isolation exacerbate the vulnerability of many rural communities (Hanna, 2011; Lal et al., 2011; Garschagen, 2013). Institutions that deal with water management and development, including the former Prairie Farm Rehabilitation Administration, water-user groups, watershed stewards and irrigation project associations (Marchildon, 2009; McLeman et al., 2014; Hurlbert and Gupta, 2017) are instrumental in facilitating adaptation actions (*see* Section 4.4.1).

Farmers have relied on their understanding of local climate regimes to manage risk, and may not consider alternative farming practices without evidence of economic benefits (Heal and Millner, 2014; Convery and Wagner, 2015; Yusa et al., 2015; Wood et al., 2016). While the impacts of drought have been the subject of previous studies, impact assessments of flood, extreme heat and winter thaw events are more limited.

4.6 Social groups have unique vulnerabilities and strengths

The impacts of climate change may exacerbate existing societal inequities, especially among Indigenous peoples, women, people of low socio-economic status, youth and the elderly. Public policy and adaptation planning should consider the unique vulnerabilities and strengths of these social groups, and also the means by which race, age, gender and poverty amplify vulnerability or resilience to climate hazards.

Climate impacts interact with existing social inequalities, which are influenced by histories of oppression and/or colonization affecting different groups of people in different ways. Indigenous peoples, people of low socio-economic status, ethnic minorities, youth and elders all have unique strengths and vulnerabilities when adapting to climate change. Social inequality shapes social roles, access to resources and decision-making power. Multiple forms of inequality can intersect to create different experiences, even within certain groups; this is known as intersectionality. Social inequality and marginalization also shape people's access to social infrastructure, such as services and facilities, and to physical infrastructure; this in turn affects their ability to cope with and adapt to climate change. By considering these interrelated social factors, we can plan for climate hazards more effectively and ensure that responses and infrastructure are inclusive and beneficial for all.

4.6.1 Introduction

Climate change impacts will have widely divergent effects on Prairie economies and communities. The capacity to adapt to these impacts also varies widely. Although reliance on natural resources remains important for the economies of all three provinces, the business and service sectors are also important. The Prairie population is increasingly urbanized (Statistics Canada 2011b), with a small number of medium and large cities, combined with numerous rural communities of relatively low, and in many cases, ageing populations that are reliant on climate-sensitive sectors such as agriculture, forestry and tourism (*see* Rural and Remote Communities chapter).

The following analysis combines information available on the status of vulnerable social groups in the Prairie provinces. Due to limited data on how climate change affects vulnerable groups in the Prairies specifically, this section also presents a broader review of the literature on climate impacts and adaptation by drawing on research conducted in other regions. It also benefits from new conceptual frameworks that provide insights into understanding vulnerability (*see* Box 4.4).

Box 4.4: Understanding vulnerability

Technical approaches to vulnerability assessment tend to employ common metrics of exposure, sensitivity and adaptive capacity, and to characterize large groups of people as collectively experiencing the same forms of vulnerability. This approach has several limitations, including the inappropriate categorization of groups as equally vulnerable and as passive victims (Arora-Jonsson, 2011; Cameron, 2012), an inability to accommodate cultural understandings of values, risk (Adger et al., 2012; Wolf et al., 2013; Reid et al., 2014), local knowledge and other context-specific features of social systems (Adger et al., 2012; Ford, 2012), and the exclusion of certain sources of inequality and oppression (Iniesta-Arandia et al., 2016), such as colonialism (Cameron, 2012). Some of these limitations can be overcome through the inclusion of intersectionality and social infrastructure approaches, which help to identify not only intersecting sources of vulnerability, but also unique adaptive capacities among marginalized groups.

Intersectionality

An intersectionality approach considers how multiple attributes and identities can intersect to affect vulnerability and adaptive capacity (Kaijser and Kronsell, 2014; Moosa and Tuana, 2014; Iniesta-Arandia et al., 2016). It acknowledges that individuals' experiences of climate change are shaped by power systems that intersect with the ability to empower or marginalize people based on sex/gender, race, socio-economic status, age, location, sexual identity and other factors. For example, although there are gendered trends in the experience of climate extremes, not all women will experience an extreme in the same way because gender combines with other factors, such as high/low income or Indigeneity, to create different experiences amongst women. In climate change research, intersectionality is useful in acknowledging that: (a) group vulnerability to climate change is a product of social relations that include power and privilege, and it is not inherent or immutable; and (b) not all members of a group will have the same experience, as a result of inter-group differences and contexts. This approach also recognizes agency, including contributions and insights that stem from marginalized perspectives, such as Indigenous knowledge and women's experiences.

Social infrastructure

The concept of social infrastructure refers to the collective capabilities of institutions, communities or organizations to provide or take advantage of opportunities that enhance their economic and social well-being. Social infrastructure encompasses "the social environment [facilities and infrastructure], services and programs that support the accumulation and enhancement of human capital" and quality of life, including the sense of belonging that is fundamental to healthy and sustainable communities (Teriman and Yigitcanlar, 2011). Focusing on social infrastructure can draw attention to existing practices, and whether or how they can be retained or revised for positive adaptation to climate change.

4.6.2 Vulnerable social groups

While there is value in understanding which factors render various social groups (e.g., women, Indigenous people) more or less vulnerable to climate change, it is important to avoid portraying all members of such groups as inherently and consistently vulnerable and lacking the ability to respond to risks (e.g., Arora-Jonsson, 2011; O'Shaughnessy and Krogman, 2011; Cameron, 2012; Moosa and Tuana, 2014). The main elements of these vulnerabilities are described below, noting that unique strengths can advance adaptation action.

Indigenous peoples

Many Indigenous peoples are disproportionately exposed to the impacts of climate change (Parlee and Furgal, 2012). Furthermore, Indigenous peoples experience significantly higher rates of poverty and unemployment, and lower average rates of income than the non-Indigenous population (*see* Table 4.5), while having less access to many services. Table 4.5 demonstrates income inequality at the intersection of gender and Indigeneity, showing notable income differentials not only between Indigenous women and non-Indigenous women, but also between Indigenous women and Indigenous men. Research on Indigenous vulnerability to climate change in the Prairies (Wittrock et al., 2011; Christianson et al., 2012; Mottershead, 2017; Patrick, 2018a,b) has identified how these and other interacting social factors exacerbate the impacts of climate change and compromise adaptation. Importantly, however, Indigenous communities are also leading their own climate change studies—for example, through federal programs such as the First Nation Adapt Program and the Indigenous Community-Based Climate Monitoring Program, among others.

Table 4.5: Selected socio-economic metrics for Indigenous and non-Indigenous populations in the Prairie provinces and Canada

GROUP	CANADA	SK	AB	MB
Median annual after-tax individual income, 2016				
Male, non-Aboriginal	$36,267	$42,483	$47,723	$36,826
Female, non-Aboriginal	$26,811	$30,528	$30,903	$27,430
Male, Aboriginal	$26,507	$22,297	$34,122	$22,673
Female, Aboriginal	$22,799	$23,231	$24,414	$22,206
Unemployment rate, 2018				
Aboriginal population over 15, all education levels	10.1%	11.5%		

Non-Aboriginal population over 15, all education levels	5.7%	6.1%

SOURCES: STATISTICS CANADA DATA TABLES #98-400-X2016171 AND #14-10-0359-0

Note: Census data still refers to "indigenous" peoples as "aboriginal"

Existing Canadian studies have shown that legacies of historic colonialism and its persistence today manifest in numerous ways, from poverty and poor living conditions, to substance abuse (Cameron, 2012; Veland et al., 2013; Williams, 2018). These conditions multiply the effects of risk, with particular implications for health status (Ford et al., 2010), and can result in reduced coping capacities during extreme events (Mottershead, 2017). The effects of the 2013 flood in the Siksika First Nation reserve in Alberta were more severe than in other communities, with one quarter of residents evacuated, 134 homes destroyed (which constituted approximately 9% of all homes in the Nation, according to 2011 Census figures), and loss of water supply to 62% of the remaining homes, despite which they were forced to wait longer than residents in other regions for recovery assistance (Patrick, 2018a). Studies of the severe flooding experienced in 2011 in the Lake St. Martin community and nearby First Nations communities in Manitoba highlight a lack of warning, forced evacuation on short notice, inadequate recovery efforts (some families remained displaced at the time of this chapter being written) and consistent lack of communication between emergency agencies and residents (e.g., Martin et al., 2017; Thompson, 2015).

Indigenous peoples rely to a greater—though varying—extent on local foods, with the result that shifts in availability of and access to those sources can directly affect food security and livelihoods. Limitations on the ability to participate in traditional land-based activities because of changes in species distributions and wildfires, as well as non-climate factors, can also affect mental well-being and can increase dependence on the cash-based economy (Bunce et al., 2016).

Treaty rights and other regulations may restrict Indigenous peoples' access to their territories and/or constrain land-based adaptation strategies by specifying the types of activities in which Indigenous peoples can and cannot engage (Wittrock et al., 2011; Natcher et al., 2016; McNeeley et al., 2018). In addition, the remote location of some communities translates into acute risk to extreme events, such as floods and wildfires (Christianson et al., 2012), which can be exacerbated due to lack of early warning systems (Ford et al., 2010), and transportation networks (Tam et al., 2013) that are compromised or non-redundant (i.e., lacking alternative routes). For many communities in Northern Manitoba, for instance, mobility in winter via ice roads is jeopardized by a warming climate (Blair and Sauchyn, 2010; Taylor and Parry, 2014).

Research in regions outside of the Prairie provinces has found that food-sharing networks and other local institutions in Indigenous communities serve as important contributors to adaptive capacity (Baggio et al., 2016; Ready, 2018). Compromises in traditional sharing practices as a result of increased involvement in wage labour, for example, can affect food security to an even greater extent than declines in the availability of traditional foodstuffs (Baggio et al., 2016). Indigenous community residents living in their traditional homes also express high levels of place attachment, which can foster commitment to adaptation (Cunsolo Willox et al., 2012). However, this attachment to place may also interact with the acute personal and cultural consequences of both climate and non-climate impacts, affecting their ability to engage with the local landscape (Cunsolo Willox et al., 2012) or resulting in their forced relocation.

Indigenous peoples also have several unique sources of adaptive capacity. Culturally appropriate forms of community inclusion in adaptation planning, specifically those including women and youth (Pennesi et al., 2012; Reid et al., 2014; Whyte, 2014), allow for the identification and prioritization of locally determined values (Christianson et al., 2012; Veland et al., 2013). Indigenous knowledge is of tremendous value to climate science and adaptation planning (Ingty, 2017; Rosales and Chapman, 2015; Reid et al., 2014; Ignatowski and Rosales, 2013; Veland et al., 2013; Leonard et al., 2013; Pennesi et al., 2012; Downing and Cuerrier, 2011). It encompasses detailed local and historical observations of changes associated with climate (Chisholm Hatfield et al., 2018) and is noted for being more inclusive of social elements than is Western science (Ignatowski and Rosales, 2013). Many Indigenous peoples are accustomed and adaptive to environmental change, with Indigenous knowledge providing important perspectives on the relationship between human activity and the environment (*see* Video 4.2; Leonard et al., 2013; Veland et al., 2013). As noted in Section 4.7.2, Indigenous communities are actively building adaptation strategies based on Indigenous Knowledge systems.

Video 4.2: Elder Dave Courchene is a respected Knowledge Keeper of the Anishinaabe Nation and founder of the Turtle Lodge. In this video, he shares his views on climate change, stewardship and Indigenous wisdom. Source: The Turtle Lodge and Prairie Climate Centre, 2017. https://youtu.be/nMt5l9gpWTk

Women

While gender analysis of climate change vulnerability and adaptation has increased substantially over the past decade, studies specific to the Prairie provinces remain limited. Existing literature from other contexts acknowledges that, in general, gender inequality produces different experiences of climate impacts between women and men (Jerneck, 2018). For example, women's vulnerability to climate change is affected by lower average incomes (Perkins, 2017); gendered divisions of labour—especially in natural resources contexts and rural communities (Alston, 2013; Reed et al., 2014; Vasseur et al., 2015; Fletcher and Knuttila, 2016); unequal access to or control over land, technology and information (Seager, 2014); cultural norms and gender ideologies (Alston and Whittenbury, 2013; Reed et al., 2014); and less decision-making power (2014; Vasseur et al., 2015; Fletcher and Knuttila, 2016; Pearse, 2017).

The intersection of gender roles and low socio-economic status, for example, may increase vulnerability for women. Income affects people's ability to cope and adapt to climate extremes. Women across Canada continue to experience a pay gap compared to men, partly attributable to women's disproportionate participation in part-time employment (Statistics Canada, 2018b), which itself is due in part to women's ongoing and disproportionate responsibility for caregiving and domestic work (Moyser and Burlock, 2018). Even among full-time workers, statistics show provincial pay gaps of 24.6% in Alberta, 21.6% in Saskatchewan and 13.2% in Manitoba (Conference Board of Canada, 2017). Another major factor influencing this pay gap is the occupational division of labour, in which sectors with a larger representation of women tend to have lower pay levels than male-dominated sectors (Vincent, 2013). Women are also less likely than men to be employed. The three Prairie provinces (plus Ontario) show the highest male-to-female employment gaps in Canada, with 11.3 percentage points for Alberta, 8.8 in Manitoba, and 8.2 in Saskatchewan (Statistics Canada, 2018b).

The percentage of women living in poverty across Canada is consistently higher than the percentage of men in poverty. Of low-wage earners in Alberta, 59.6% are female. In Saskatchewan, 16.9% of women over 65 are in the low-income category, compared to 11.1% of women in the 18–64 age category and 14.5% of men who are 65 and over (Statistics Canada, 2016). Single mothers, lesbian women, women with disabilities, Indigenous women, women of colour, and women who have been incarcerated often experience more severe financial challenges than other people living in Canada (The Women's Centre of Calgary, 2017). Transgender people may also experience additional barriers to finding paid work (Trans PULSE, 2011), which could increase their vulnerability. No literature exists on transgender people's experiences of climate change in the Prairie region; however, research is beginning to explore the challenges faced by lesbian, gay and transgender people experiencing climate disasters elsewhere (e.g., Balgos et al., 2012; Dominey-Howes et al., 2014; Gorman-Murray et al., 2017).

In the Prairie region, available research suggests that rigid gender roles in agriculture, forestry and other resource contexts create different experiences for women and men. Women in agriculture may have less influence over on-farm adaptation decisions, including the use of technologies like drought-resistant seed (Fletcher and Knuttila, 2016). In forestry, women and Indigenous people's low decision-making power over natural resource management may extend to adaptation strategies (Reed and Davidson, 2011; Reed et al., 2014). Although women are more likely to experience inequality, research in the Prairies (Fletcher and Knuttila, 2016) and elsewhere (e.g., Alston, 2012) has shown that men may experience particular physical and psychological risks due to expectations of masculinity during climate disasters.

The knowledge and capacities of women and other marginalized groups (Moosa and Tuana, 2014) can be valuable contributions to adaptation. Women often play an active, but overlooked role on farms, in households and communities, and during disaster response. The particular roles played by women may give them a different level or type of environmental awareness from men (MacGregor, 2010; Bunce et al., 2016; Fletcher, 2017), yet they continue to be underrepresented in climate governance (MacGregor, 2010; Pearse, 2017; Williams, 2018).

Rural communities

The general trend of depopulation and urbanization in the Prairie provinces has resulted in reductions in available funding for rural municipalities (Canadian Rural Revitalization Foundation, 2015), and the significant growth in farm size over the past two decades (Statistics Canada, 2007, 2011a, 2017a) has resulted in reductions in social capital and local services that are key elements of adaptive capacity (McLeman, 2010; Desmarais et al., 2015). Dependence on declining water resources for agriculture increases the risk of water conflict between industrial (e.g., oil, gas and mining), agricultural and rural household users (Clark et al., 2017). Financial precarity is an additional vulnerability factor in agriculture (Patiño and Gauthier, 2009; Pittman et al., 2011; Wittrock et al., 2011; Fletcher and Knuttila, 2016), along with lack of institutional support, including federal divestment from drought infrastructure (Marchildon, 2009; Shuba et al., 2016); fragmented flood policy instruments and planning that fails to consider climate projections (Hurlbert, 2018); and volatile markets (O'Brien and Leichenko, 2000; Patiño and Gauthier, 2009; Diaz et al., 2016).

Despite these vulnerabilities, rural residents often have significant adaptive capacity. Rural residents may be more equipped to cope with extreme events than urban residents (McLeman, 2010), and a culture of innovation has helped Prairie farmers adapt to drought over the past century (Warren, 2016a). Strong social capital exists in many rural communities across the Prairies, including cultural norms of mutual assistance during crises (Shuba et al., 2016). As noted in Section 4.7.2, some rural municipalities are carrying out their own adaptation planning processes. Priorities in adaptation planning include participatory planning with increased stakeholder involvement (Lal et al., 2011; Hurlbert, 2018); stable, coherent and consistent policy regimes (Pittman et al., 2011; Hurlbert, 2018); and consideration of climate scenarios in future planning (Hurlbert, 2018).

Low-income families

Prairie residents living in poverty may be more sensitive to climate extremes as a result of insecure sources of employment, poor quality housing, lack of insurance, lack of financial resources for adaptation and lower representation in decision-making forums. The vulnerability and adaptive capacity of people living in poverty in the Prairies has not yet been the subject of research attention; however, information on poverty in the Prairie provinces can inform consideration of the vulnerability of this group to climate change. Youth, women, racialized and Indigenous people are more likely to hold low-wage, part-time and insecure jobs, accounting for a large proportion of the working poor. Standard poverty rates vary between 9–14% across the prairies, but a more informed measure is the prevalence of low incomes based on low-income measure after tax, which is 13.6% in Alberta, 18.1% in Saskatchewan and 20.7% in Manitoba (Statistics Canada, 2016).

Poverty tends to be concentrated in certain rural communities and also in inner cities, which in certain cases may be more exposed to climate-induced hazards than other regions; for example, when poor housing is associated with inner-city neighbourhoods or when economically depressed rural communities lack the capacity to maintain infrastructure. Lone parent families also make up a large proportion of this group, particularly female-headed households. By extension, rates of child poverty are significantly higher than poverty rates for the population as a whole. The percentage of children living in poverty is 15.7% in Alberta (Edmonton Social Planning Council, 2017a), 24% in Saskatchewan (Hunter and Sanchez, 2017) and 27.5% in Manitoba (Campaign 2000, 2017). The elderly and people with pre-existing health conditions are especially susceptible to heat waves and other climate extremes (Rapaport et al., 2015), and those with lower incomes often have no access to air conditioners (Gronlund, 2014).

Recent immigrants

Recent immigrants are rarely studied in climate change research; however, they represent a significant number of residents in many Prairie communities and can be subject to multiple sources of vulnerability. The lack of resources and the language barriers faced by some immigrants can limit adaptive capacity (Burke et al., 2012). Seasonal migrant workers not only experience the vulnerabilities of the average migrant, but also the precarity of work in the agricultural sector under climate change. Refugees in particular may be suffering from trauma due to experiences in their native countries, and many are visible minorities who may be subject to racial discrimination; even children experience this range of effects (Oxman-Martinez et al., 2012). Many recent immigrants are unfamiliar with the sources of social support that may be available. Each of these factors enhances vulnerability to climate change, particularly extreme events.

This group is expected to grow, in part due to increases in out-migration in response to climate change impacts in other parts of the world (*see* International Dimensions chapter). Alberta, in particular, is becoming a preferred destination for immigrants, after Ontario and British Columbia, with landed immigrants currently making up 23.6% of the working population (Government of Alberta, 2018). In 2015, 16,739 immigrants and refugees settled in Edmonton, compared to 6,016 in 2005 (Edmonton Social Planning Council, 2017b).

4.6.3 Sources of social vulnerability

Consideration of vulnerability that focuses exclusively on exposure, sensitivity and adaptive capacity may perpetuate disempowerment rather than enabling capacity building (Veland et al., 2013). For example, depictions of Indigenous peoples as highly vulnerable may serve to reproduce the paternalistic relations reflected in colonialism (Klenk et al., 2013; Veland et al., 2013). GHG emissions reduction and adaptation strategies can reinforce Western, masculine and/or technocratic approaches and male-dominant economic sectors (Williams, 2018). For example, the dominant approach to climate change adaptation favours infrastructure and technological solutions, like dams and zero-till agriculture, over more socially integrative approaches that attend to structural inequalities, social vulnerabilities and institutional barriers (VandenBygaart, 2016; Zeitoun et al., 2016).

Intersectional analysis (*see* Box 4.4) draws attention to the fact that nearly 80% of single parents in Canada are female (Statistics Canada, 2015). When combined with the gender pay gap, the intersection of gender and single-parent status may also affect vulnerability and contribute to child poverty. Similarly, although older adults in general are more likely than other age categories to be low-income (Hunter, 2011), the incomes of older men (65 and over) are still 1.5 times that of older women (Statistics Canada, 2018b), and more than 30% of older women live alone compared to 16% of older men (Statistics Canada, 2018b). In the Prairie region, intersectional analysis reveals particular issues experienced by low-income Indigenous women living on reserve, as compared to their non-Indigenous, male, off-reserve counterparts: Indigenous women are more likely to be lone parents and less likely to be employed than men and non-Indigenous women; they are more likely to live in poor housing on reserve and are self-reporting worse health conditions than Indigenous men (Arriagada, 2016).

Individuals characterized by intersecting causes of vulnerability also have important knowledge to contribute to climate change adaptation because of their perspectives and experience (Whyte, 2014). Both Indigenous women and men may possess unique knowledge about the environment and climatic change (Dowsley et al., 2010), generated through their traditional gender roles and responsibilities. Indigenous women's roles as water protectors, for example, may provide insights into climate change (Whyte, 2014). Older individuals, including male and female Indigenous Elders, hold important knowledge that corroborates and expands upon scientific climate records. The knowledge and contributions of socially marginalized groups can provide crucial insight for more effective and inclusive climate change adaptation moving forward. Furthermore, socially equitable adaptation policies and processes can go beyond inclusion, reducing the root causes of vulnerability and potentially increasing equality over time.

4.7 Adaptation planning helps to reduce climate risks

Cities are at the forefront of adaptation and resilience planning in the Prairie provinces. Governments and businesses have begun to assess climate risks and develop adaptation strategies, but few sector-specific plans and policies consider future climate risks, leaving some firms, governments and sectors unprepared. Assessing the effectiveness of adaptation measures andmeaningful reporting of progress would help achieve climate-resilient communities and local economies.

Governments, industry, businesses, Indigenous communities and civil society across the Prairie provinces are slowly embracing adaptation planning. Leadership is particularly evident from municipalities in the region, while provincial governments are in the early stages. Governments and corporations have begun to assess and disclose climate risks facing public and private assets. Continuous improvement through the evaluation of progress is not common. Another limitation is the continued reliance on recent historic climate conditions for defining climate variability and extremes, rather than referring to future climate projections.

4.7.1 Introduction

Climate change considerations are increasingly included in planning and management processes in municipalities, governments and businesses with diverse operational and management objectives (EPCOR, 2017; TransAlta Corporation, 2018; City of Regina, 2018). Ongoing adaptation projects and initiatives include fostering engagement and raising awareness, research and planning, training and skills development, and infrastructure design and construction from a climate perspective (Zizzo, 2014; Austin, 2015; Bruised Head, 2018; Blackfeet Nation, 2018).

Saskatchewan and Manitoba have climate change plans that include adaptation, reducing GHG emissions and building climate resilience. Saskatchewan's climate change strategy (Government of Saskatchewan, 2017) emphasizes existing government practices (e.g., research to support the adoption of new crop varieties) and commits to new strategies to enhance climate resilience within the province (e.g., improving understanding of future climate trends). Manitoba's Climate and Green Plan (Manitoba Sustainable Development, 2017) is based on four pillars: climate, jobs, water and nature. Adaptation strategies in the plan focus on climate knowledge, sustainable climate-resilient communities and sustainable agriculture.

4.7.2 Community-based adaptation planning and action

Under provincial legislation, Alberta's two largest cities are required to develop climate change plans (*see* Case Story 4.5; Government of Alberta, 2018). Thirteen other municipalities in Alberta have adopted adaptation plans that were developed using the Climate Resilience Express process (Boyd et al., 2016). This streamlined adaptation planning process is based on a one-day workshop that explores climate risks to municipal assets and operations. Rather than presenting a detailed quantitative analysis, the high-level screening approach is meant to be simple and accessible to communities with limited capacity. The output is an action plan for communities that requires implementation, review and updates. The process has been used to produce plans for numerous cities, towns and counties.

Case Story 4.5: Adaptation planning in Edmonton and Calgary

To support their adaptation planning, the cities of Edmonton and Calgary commissioned a series of white papers on building a climate-resilient city in the Prairies (Venema et al., 2017). The papers focused on economics and finance, agriculture and food security, urban ecosystems, transformational adaptation, transportation infrastructure, water supply and sanitation systems, infrastructure for electricity, information and communication technology, the built environment, and disaster preparedness and emergency management. These papers helped to inform climate change plans developed by the two cities.

Calgary launched its Climate Program in 2017 to facilitate GHG emissions reduction and climate change adaptation by the city and its residents and businesses (*see* Figure 4.11; City of Calgary, 2018). Adaptation initiatives include flood planning, water conservation efforts, waste management planning, urban forest management and parks planning to support biodiversity and ecological resilience, naturalization of urban landscapes, green building and low-impact development, and upgrading of wastewater treatment facilities.

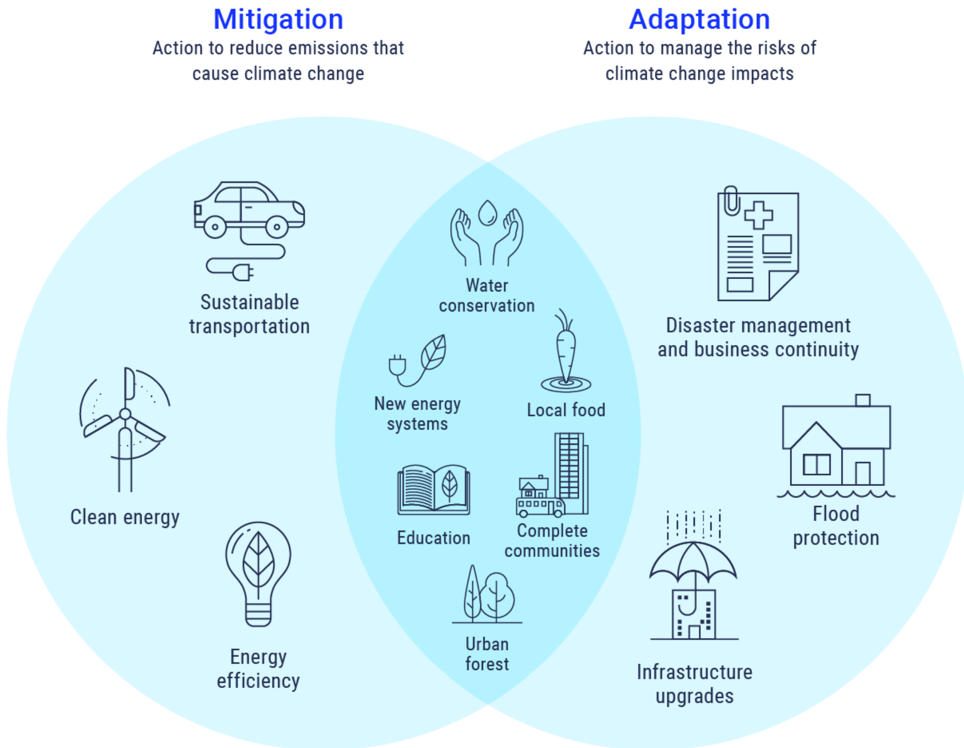

Figure 4.11: Considerations in building climate resilience in the City of Calgary. This figure has been used to build climate literacy with multiple stakeholders. Source: City of Calgary, 2018.

Calgary's Climate Resilience Plan (City of Calgary, 2018) describes what the city is doing to reduce GHG emissions and adapt to climate change. The plan identifies risks and vulnerabilities that city services and operations face as a result of extreme weather events and the business units responsible for implementing actions to reduce those risks. It is structured around five best practices for municipalities: government leadership; capacity building; integrated long-term climate planning; alignment with other initiatives (e.g., 100 Resilient Cities, 2020); and raising public awareness through education and outreach. In March 2018, the City began a series of Climate Change Symposiums to support a climate change conversation with Calgarians, community and youth leaders, entrepreneurs, climate experts and City staff.

The City of Edmonton took a phased approach to developing its climate change adaptation strategy (City of Edmonton, 2018a), starting with an assessment of risk under current climate conditions, examining climate change over the past century and projections of future change, and preparing an economic analysis of the costs of inaction and a review of case studies. A strategic climate change risk and vulnerability assessment used quantitative models to identify physical damages and potential loss of services associated with a variety of climate impacts. Thematic stakeholder workshops involving over 100 participants were held to validate the risk analysis and prioritization. Graphic summaries from these workshops capture the participants' conversations and ideas (Hester, 2018).

Actions to manage climate risks were evaluated using five criteria: sustainability, effectiveness, risk and uncertainty, opportunity and implementation. They were also condensed into five potential pathways for managing risks, comprising science- and evidence-based decisions and preparatory actions for addressing changing temperatures, precipitation, weather extremes and ecosystems.

A summit of city mayors from around the world was held on March 6, 2018, and resulted in the Edmonton Declaration: a call-to-action for mayors to take leadership on climate change. Developed with input from the Federation of Canadian Municipalities, United Cities and Local Governments, C40 and ICLEI – Local Governments for Sustainability in advance of the IPCC Cities and Climate Change Science Conference, the Declaration commits local governments to undertake climate risk and vulnerability assessments to guide their planning and investment decisions, increase climate resilience and minimize the exposure of people and assets to the impacts of climate change (City of Edmonton, 2018b). It has been signed by over 3,000 cities globally. Edmonton's strategy has been designed to deliver on adaptation commitments from the Edmonton Declaration (City of Edmonton, 2018a).

The City of Saskatoon's Climate Action Plan, which includes its Corporate Climate Adaptation Strategy, was released in 2019 (City of Saskatoon, 2019). It undertook an engagement process—focus groups, surveys, pop-up community events and expert workshops—with local businesses, not-for-profit organizations, residents and subject matter experts to inform their Climate Change Business Mitigation Plan (Lura Consulting, 2018). Stakeholders identified climate change activities of interest and potential risks of concern, as well as potential benefits. Upfront costs, lack of infrastructure or services, and lack of responsibility and support were identified as the largest barriers to greater action.

The City of Selkirk, Manitoba, developed its climate change adaptation strategy by considering the seasonal impacts of climate change on municipal assets, local services, and human health and well-being, and by prioritizing risks and associated adaptation actions. Actions were ranked for their efficacy, and costs were calculated and integrated into the City's annual tactical budgeting process to support implementation. The City won the 2019 Tereo Award from the Canadian Network of Asset Managers in recognition of their innovative approach and commitment to climate action (City of Selkirk, 2019).

Indigenous communities in the Prairie provinces are also very active in adaptation planning (Crown-Indigenous Relations and Northern Affairs Canada, 2019). Common areas of focus among adaptation projects include food security and access to traditional foods, safety while on the land, water monitoring, and physical and mental impacts of climate change (Myers et al., 2017).

Adaptation planning in Prairie Indigenous communities often considers Indigenous and local knowledge, along with climate change science and projections (Bruised Head, 2018; Okorosobo, 2018; Patrick, 2018a). For example, the Blackfeet Climate Change Adaptation Plan (Blackfeet Nation, 2018) is informed by cultural observations of climate change impacts and Amskapi Piikani records kept through oral tradition and history. Stories of seasonal hunts, warrior activities, social obligations, gatherings of nations and many other important events have been maintained through oral retellings over hundreds of generations. Climate change is now emerging in these stories as they advance into the present and future. Science-based climate trends and projections were also used to develop the plan, which is built around sector-specific vulnerabilities and impacts. Goals, strategies and actions for climate change adaptation in eight sectors—including agriculture, water and forestry—are based on the Blackfeet understanding that people and nature are one, and that people can only be healthy if the health of the environment is also ensured. A dynamic view of the natural world and recognition of its reciprocal relationship with the Blackfeet is considered necessary to balance the needs of all (*see* Case Story 4.5).

Models are emerging for braiding together Indigenous knowledge and climate science in climate change adaptation planning. For example, Lynes and Boyd (2018) describe a planning process to develop a Local Early Action Plan, comprising strategies and actions to cope with and adapt to immediate priorities identified by Indigenous communities. The process includes a series of educational workshops and community dialogues, followed by an adaptation workshop. Climate change experts and local knowledge holders deliver joint workshops and dialogues with concepts translated into local oral and written language.

4.7.3 Adaptation mainstreaming

Mainstreaming is the systematic analysis of climate risk and inclusion of adaptation in decision-making and planning processes. Government staff in Manitoba and Saskatchewan assessed the adaptability of provincial policies to climate change and their ability to support sectoral adaptation. Participants identified opportunities to build the policy flexibility needed in an uncertain future climate (Bizikova, 2018). Assessments were most useful when climate change response was articulated as a policy goal, either during initial policy design or after policies had been in effect for some time, so that there was some evidence of their effectiveness.

Analysis and planning for water use and management in the Prairie provinces increasingly examine the implications of climate change (TransAlta Corporation, 2018; Patrick, 2018b). For example, a collaborative exploration of water management in the Oldman and South Saskatchewan river basins examined streamflow scenarios for the period of 2025 to 2054 (Sauchyn et al., 2016). Potential adaptation strategies, such as modifying existing infrastructure, building new infrastructure, changing operations to supplement environmental flows, reducing demand and sharing supply, were assessed in interactive modelling sessions. Findings indicate that forecast-based rationing, together with new expanded storage, could dramatically reduce water shortages. Similarly, Manitoba Hydro's climate change strategy (Manitoba Hydro, 2014) is informed by climate change projections and numerous studies across the Nelson-Churchill Watershed that highlight important spatial and temporal patterns in how climate change may affect its core business.

Governments and corporations are also starting to disclose climate risks to public and private assets (*see* Climate Disclosure, Litigation and Finance chapter). For example, Suncor (Suncor Energy Inc., 2018) reported that it is managing climate risks through facility design, operational procedures and insurance for damage to, or loss of, assets, as well as production interruption. TransAlta Corporation (2018) similarly notes that it has experienced negative financial impacts from extreme climate events and is using insurance, retirement of older facilities, improved drainage infrastructure and the stockpiling of supplies to address risks. The company has used climate modelling and past costs to estimate possible future financial implications of the reduction or disruption of production capacity in a changing climate, as well as potential positive financial benefits (TransAlta Corporation, 2018). Risk controls include using dams for flood and drought control, capital maintenance, monitoring weather patterns and adjusting site operations.

4.7.4 Limitations of current adaptation and resilience planning

While most policies currently in place do not take future climate into account, adaptive management—an iterative approach to decision-making in the face of uncertainty—provides flexibility and potential for learning as climate conditions in the Prairies change. Adaptive management is designed to be more flexible and responsive to changing local conditions, and is centered on evidence-based decision-making that aims to reduce uncertainty through monitoring, experimentation and learning (Holling, 1978). For example, several energy and environmental policies governing the oil and gas sector in Alberta reflect adaptive management principles, which could allow operators to adjust as climatic conditions change (Cobb et al., 2015). However, a lack of attention to experimental design and vague or unenforceable reporting requirements can limit actual learning, and undermine the adaptive nature of this approach (Olszynski, 2017). Furthermore, widely varying opinions about climate change and its impacts on the oil and gas sector in western Canada (Wiensczyk, 2014) suggest that some firms, governments and sectors will rely on reactive adaptation measures, and may not be preparing for rapid climate change or environmental and socio-economic tipping points—which cause changes into new or different states (e.g. water for irrigation agriculture became unreliable after three dry decades, as described in Warren, 2016b).

A lack of determination or motivation to address climate change can also limit opportunities for institutional learning. An examination of the evolution of Manitoba's emergency and disaster management system found that, while extreme events generated opportunities for significant learning, policy changes were largely reactive initiatives driven by top-down decision-making, with reduced institutional evolution relative to other policy issues (Haque et al., 2018). Moreover, certain organizations may be reluctant to disclose climate risks due to concerns about company stock value or legal liability *(see* Climate Disclosure, Litigation, and Finance chapter). Some industry reporting may even conceal climate change impacts, lessening incentive for a better understanding or management of climate risks (Quest, 2015).

To enhance adaptation overall, adaptation planning requires regular evaluation of effectiveness, revision based on learnings, and enhanced progress reporting of what is being learned about climate change and adaptation in the Prairies. However, the limited reporting on progress delivered thus far has primarily focused on actions taken. For example, in Manitoba, provincial reporting on climate change and independent reporting from various government departments spoke to climate change risks and adaptation activity, but did not address the extent to which actions were successful at reducing or minimizing the most significant risks (Manitoba's Auditor General, 2017).

While adaptation-related performance metrics and the measurement of adaptation goal achievement are not yet common (Auditors General, 2018; Government of Saskatchewan, 2018), Saskatchewan has developed a framework for measuring progress achieved in making the province more resilient to climate change. Saskatchewan's Climate Change Strategy (Government of Saskatchewan, 2017) describes climate resilience and focuses on the principles of readiness, with a commitment to annual assessment and reporting. The strategy consists of 25 indicators of climate change in five key areas: natural systems, physical infrastructure, economic sustainability, community preparedness and human well-being (Government of Saskatchewan, 2018). This framework will enable the provincial government to track and report on progress in building resilience to climate change.

Another limitation of adaptation planning is the continued reliance on recent historic climate conditions to define future climate variability and extremes. Risk assessments often do not consider extremes outside the range of recorded observation (Sauchyn et al., 2014). Prolonged droughts, such as those that occurred during the period from the 1920s to the early 1940s, are a common feature of climate history in the Prairies, but predate such major industrial allocation of surface water as is used in oil and gas extraction. Taking such extremes into account in planning processes can help in identifying adaptation measures that may be robust enough to address low-probability, high-impact climate change scenarios that would have profound implications for water users (e.g., Sauchyn et al., 2015; EPCOR, 2017).

4.8 Moving forward

4.8.1 Knowledge gaps and research needs

The assessment of current knowledge presented in this chapter reveals gaps and needs for further research. Foremost among these are indicators and methodologies for assessing the effectiveness of strategies and actions that have been implemented. Other key knowledge gaps and needs include:

Best practices and guidance for:

- Incorporating model projections of future climate scenarios into adaptation planning. Many risk assessment processes are based on the analysis of recent historical climate scenarios. Without efforts to consider future climate projections in decision-making—as well as uncertainty in the projections of future climate—some firms, governments and sectors may not be sufficiently prepared; and
- Establishing, implementing, measuring and modifying the monitoring and evaluation of progress towards achieving climate resilience goals.

Improved understanding of:

- New opportunities arising from climate change;
- How agriculture could expand beyond the margins of the Prairie Ecozone and into treed zones of nutrient-poor forest soils;
- The social, environmental and economic impacts of sustained (multi-year) drought and of prolonged inundation of land under excessive wet conditions;
- The vulnerability and adaptive capacity of specific social groups, including low-income families and recent immigrants, and in particular differences between urban Indigenous populations and those in remote and rural communities; and
- How Indigenous knowledge can enhance adaptation and sustainable practices, and how to integrate Indigenous knowledge into adaptation planning processes.

4.8.2 Emerging issues

This assessment of the current knowledge of climate change impacts and adaptation in the Prairie provinces indicates the following emerging issues:

Transformational adaptation

As a warming climate amplifies regional weather extremes, the severity of floods, storms and droughts will exceed the historical experience of Prairie communities. Incremental adjustments made to historical practices and policies are unlikely to deliver adequate adaptation to the evolving hydroclimate and could potentially be maladaptive over time. Therefore, a significant emerging issue is the need for transformational adaptation that challenges existing policies, structures and systems.

Adaptation in rural communities

Recent rural social and economic trends, rural depopulation and increasing farm size, in particular, are factors that undermine the adaptive capacity of rural communities. Extension services in rural areas, previously provided by Prairie universities and government agencies, have diminished. Watershed stewardship groups and rural municipalities now provide these services to some extent, but lack the resources for adaptation planning.

Social and cultural considerations in adaptation decisions

Conventional approaches to evaluating the vulnerability of social groups based on indicators of exposure and adaptive capacity do not take into account cultural understandings of values and risk, local knowledge, certain causal factors of inequality and oppression, and unique capacities for agency, including contributions and insights derived from marginalized perspectives such as Indigenous knowledge and women's experiences.

Intersectionality perspectives

Positive emerging trends include an emphasis on climate policy and planning, and innovative approaches to accessing and interpreting knowledge to inform these processes, including integrating Indigenous understanding of climate change and adaptation (Myers et al., 2017; Lynes and Boyd, 2018). The emerging intersectionality perspective recognizes how multiple attributes and identities can intersect to affect vulnerability and adaptive capacity, while a focus on social infrastructure can draw attention to whether and how existing practices can be retained or revised for positive adaptation.

4.9 Conclusion

In the Prairie provinces, climate change is resulting in a redistribution of natural capital. It is transforming the seasons towards wetter winters and drier summers, and requiring changes to water resource management. The transition to a new distribution of water supplies and new regional ecosystems will be punctuated by phases of change as global warming interacts with regional variability and weather events. Collaboration among governments, municipalities and Indigenous communities is required to deal with the geographic shifts in the availability of water and ecological resources.

As climate change alters the frequency and intensity of extreme weather, the longer-term risks posed by climate change will include an amplified range of water levels and associated consequences: flooding, fire, water supply deficits, disturbance to ecosystems, and more variable forest and farm productivity. The increasing intensity of weather events represents an expanding deviation from a baseline climate, recognizing that the baseline, meanwhile, is also shifting. This ongoing state of change may ultimately be the most challenging scenario. Eventually temperature, precipitation and water levels will cross a threshold beyond which impacts will abruptly become more severe. Examples include the permanent loss of water stored as snow and ice, rainfall intensity that exceeds the watershed and storage capacity of infrastructure, and the loss of low temperatures that inhibit many pest and disease vectors from proliferating in agricultural and forested regions.

The response to climate change in the Prairie provinces has transitioned from recognizing to responding to potential impacts. Government agencies, private industry, Indigenous communities, municipalities and regional community organizations (e.g., watershed stewardship agencies, irrigation districts) are now engaged in resilience and adaptation planning. The net impacts of regional climate change will depend on the success, extent and scope of adaptation planning and its effective implementation. Plans have emerged in the past decade, and adaptation planning is on the agenda of many municipalities, corporations, industry associations and civic organizations. Each of the provincial governments in the Prairies has a climate strategy that incorporates adaptation, and most of the major cities are engaged in resilience planning, although implementation is in the early stages.

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