Enclosure 2

Investing in a Climate Resilient Future: Cost of Doing Nothing Report

Strathcona County

APRIL, 2024

ICLEI
Local Governments for Sustainability
Les gouvernements locaux pour le développement durable
CANADA

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EXECUTIVE SUMMARY

As Strathcona County navigates the increasing impacts of climate change, understanding the financial and social ramifications of inaction is paramount. This report serves as a guide for local decision-makers, framing climate data within the broader national and provincial contexts and focusing on the costs and impacts across various climate hazards.

The financial costs of climate-related events are substantial and growing. Wildfire management in Canada has consistently required investments of $800 million to $1.4 billion annually, protecting critical infrastructure but also reflecting just a portion of the overall damages incurred. Locally, Strathcona County witnessed significant wildfire events in 2009 and 2018, with estimated costs of $4.7 million and $1-2 million respectively, highlighting the direct impact on the County's financial resources.

The increasing frequency of extreme heat events is a key concern. Historically, Strathcona County experiences an average of 3 days per year with temperatures exceeding 30°C. Projections indicate a rise to an average of 25 such days annually by the 2051-2080 period, under high emission scenarios. This surge in heat waves corresponds to a higher demand for water, more strain on cooling resources, and additional pressure on County operations.

Extreme weather and precipitation significantly affect Strathcona County's natural ecosystems and infrastructure. For instance, intense rainfalls have contributed to soil saturation and overland flooding, presenting challenges for stormwater management systems and increasing maintenance costs. Additionally, the County's natural asset infrastructure is at risk, with potential losses dwarfing the costs of conserving existing green spaces.

The ramifications on natural systems due to extreme heat and precipitation events cannot be overstated. The loss of natural assets like trees and wetlands impairs ecosystem services crucial for temperature regulation and biodiversity, with replacement and restoration costs being significantly higher than those of man-made infrastructure.

Strathcona County's agriculture sector is also at risk. The 2021 heat dome in BC serves as a warning, where the agriculture sector experienced dramatic losses in revenue. Similarly, significant payouts from the Agriculture Financial Services Corp. in Alberta—totaling $2.1 billion in 2021—underscore the potential financial impact on Strathcona County's agricultural producers.

Health and safety considerations remain an important concern in the County, especially considering recent climate events. For instance, the short- and long-term health repercussions of long-range transport of pollutants and smoke because of ongoing wildfires are wide-ranging. This has led to a surge in respiratory-related hospital admissions and healthcare costs province-wide. Alberta has seen substantial increases in healthcare expenditures during this period, with the province recording a significant spike in emergency room visits and a corresponding rise in medical spending due to the adverse air quality.

As Strathcona County continues to develop its corporate Climate Resilience Plan, *Degrees of Resilience: Our Climate Adaptation Compass*, the insights gained from this report underscore the necessity of proactive adaptation measures to reduce or avoid the impacts of climate change. Through strategic planning and action, we can safeguard our community's future, ensuring a resilient and thriving Strathcona County.

INTRODUCTION

The mounting costs of climate change present a serious fiscal and logistical challenge for municipalities whose budgets and capacities are already stretched. Without immediate action, these costs will only increase and threaten to consume funds and resources needed for maintaining and operating critical services and addressing existing and emerging priorities.

This report is designed to complement Strathcona County's ongoing efforts in developing a Corporate Climate Resilience Plan. The report provides Strathcona County decision-makers with guidance on using locally relevant data to weigh the costs of action vs. inaction. Information presented in the report will also frame Strathcona County climate data within a national and provincial/territorial context and examine the costs and impacts of climate change across several climate change hazards and sectors.

This report was developed in collaboration with ICLEI Canada, leveraging their extensive experience in supporting local governments to address climate change impacts. They support local governments by providing them with the expertise, resources, and capacity needed to take climate action to build more sustainable, low-carbon, biodiverse, and climate-ready communities.

WHY UNDERSTANDING THE COST OF INACTION MATTERS

While climate change-driven consequences are happening throughout Canada, most municipal governments don't have a complete understanding of the local costs (both market and non-market) of climate change. These costs are expected to increase as the climate continues to warm, and municipalities need to rapidly gain a better understanding and prioritize adaptive measures to limit these costs. There is also strong evidence that these will be even greater without rapid decarbonization and adaptive measures that build resilience against mounting risks from climate change.

Further, municipal governments are now responsible for a significantly larger share of infrastructure funding than in the past. For example, according to Alberta Municipal Services Corporation (Alberta Municipalities or AMSC), municipalities own 60% of public infrastructure in Alberta (AMSC, 2023), and in a recent report they state that the provincial government's Budget 2024 is inadequate to keep pace with Alberta's population growth and changes in inflation, nor to make up for the estimated $30 billion municipal infrastructure deficit (AMSC, 2024a; AMSC, 2024b). To ensure that Strathcona County dollars are efficiently and responsibly allocated, investments in municipal assets and infrastructure must keep the effects of climate change in mind. In making investment decisions, the trade-offs, and costs of doing nothing must be properly assessed using national, subnational, and local data available. This report provides a starting point to understanding the local costs of climate change to help Strathcona County decision makers weigh the costs of action vs. inaction.

CONTEXT

SUMMARY OF CLIMATE CHANGE RISKS AND COSTS

The effects of climate change in Canada are already evident. Projections suggest these are *very likely* to worsen in the future including more frequent extreme heat events, more frequent wildfires, reduced air quality, increased coastal erosion, more frequent extreme precipitation resulting in flooding, and more frequent extreme weather events (e.g., windstorms, ice storms, tornadoes) (Bush et al., 2022; IPCC, 2021).

Consequently, Canadian communities are facing a wide range of direct and indirect impacts, with numerous implications for the built, socio-economic, and natural systems. Municipalities are facing increased financial costs that include both direct and indirect economic costs (e.g., costs of repairs, increased operations and maintenance expenses, loss of service delivery and business interruption) (Boyd & Markandya, 2021).

National estimates show climate change is now costing Canada billions of dollars every year. Furthermore, as the trends in extreme weather events have increased, so too have the trends in insured and uninsured losses. A growing body of evidence indicates that uninsured losses are often underestimated and may dwarf insured losses (Boyd & Markandya, 2021; IBC & FCM, 2020; Ness et al., 2021; Sawyer et al., 2020, 2022).

Canada's municipalities are vulnerable

Canada's municipalities are particularly vulnerable and exposed to the impacts of climate change due to a wide range of characteristics including concentrated and growing populations, increasing densification, high concentration of hard surfaces that are prone to flooding and amplified warming, proximity to water, exposure of economically valuable assets, aging infrastructure, and degraded ecosystems that would otherwise reduce these impacts (Brown et al., 2021).

Canada's municipalities are also home to a large proportion of populations who are the most vulnerable to climate impacts due to a variety of circumstances unrelated to the climate hazard directly (e.g., Indigenous populations, elderly people, newcomers, people with existing health conditions, people experiencing homelessness, among others).

Climate change driven natural disasters have continued to cause significant damage to Canadian communities, with evidence supporting projections that their intensity and frequency are increasing. In fact, eight of the top ten costliest natural disasters have occurred over the past decade (Figure 1).

Table 1 highlights extreme weather events over just the last five years (2016-2021), which have resulted in billions of dollars in damages as well as unprecedented human and ecological impacts.

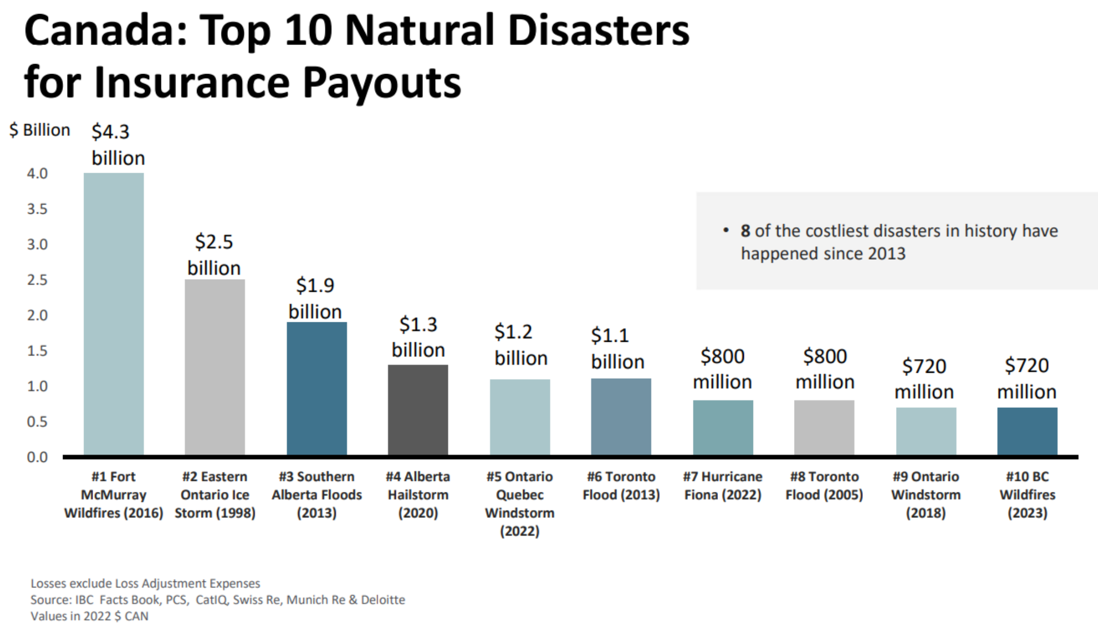


Figure 1: Canada's costliest natural disasters in terms of insurance payouts (in 2022 CAD). Losses exclude Loss Adjustment Expenses (Source: IBC Facts Book, CatIQ, PCS, Swiss Re, Munich Re & Deloitte). (IBC, 2023)

Table 1: The costliest weather events over the period of 2016-2021.

Date	Location	Weather event and cost estimates
2021	South Coast, BC	Multiple atmospheric rivers converged producing record precipitation that led to severe flooding across the region. Early estimates of insured losses are $450 million (IBC, 2021); however, broader estimates suggest billions in damages.
2020	Calgary, AB	Severe hailstorm causing nearly $1.2 billion in damages (IBC, 2020).
2020	Fort MacMurray, AB	Extreme precipitation resulting in $500 million in flood damages.
2018	Eastern ON and Southern QC	Severe thunderstorm which spawned multiple tornados that caused $300 million in damages.
2018	Southern ON and QC	Severe thunderstorms produced hurricane-force gusts that caused over $1 billion in damages (ECCC, 2019).

Date	Location	Weather event and cost estimates
2017	Southern BC	Widespread and long-lasting wildfires caused an estimated $650 million in damages.
2016	Fort MacMurray, AB	Wildfires caused over $4 billion in insured losses and had a broader economic cost of nearly $11 billion (Alam & Islam, 2017).

Implications of climate change costs on the economy

Climate change impacts have serious implications for Canada's economy and economic prosperity of our communities (Sawyer et al., 2022). A recent report by GHD, projects $140 billion (CAD) in economic losses by 2050 (GHD, 2022). Projections of annual climate costs by the end of the century may reach $865 billion under the high emissions scenario (RCP8.5) (Sawyer et al., 2022).

Extreme heat and extended heat waves are going to affect the capacity of people who work outside building and maintaining infrastructure like roads and parks. Extreme weather is going to impact transportation and transit services making commuting, goods distribution, and other transportation services more difficult and unsafe. Changing lake levels, drought, warmer winters, and unpredictable precipitation will impact the tourism industry and communities that rely on it.

A Statistics Canada study analyzing the workplace productivity following the Alberta floods of 2013 found that 7.5 million hours of private sector work were lost in the two weeks after the flood due to workplace closures (IBC & FCM, 2020). Climate driven extreme weather events hinder both the broader economy and put tremendous socio-economic stress on individuals in the community.

RE-DEFINING THE COSTS OF CLIMATE CHANGE

Beyond the clear financial costs associated with extreme weather events, multiple cascading or indirect costs are not accounted for in many climate change cost estimates, including municipal service disruptions, supply chain disruptions, transportation network interruptions, business interruptions, power outages, food/water shortages, as well as other significant non-market costs.

Non-market costs (the costs to human health and well-being and the natural environment) must also be considered to fully understand the breadth of climate impacts, allocate public resources for climate adaptation, and ensure that these resources are directed towards the most efficient actions.

It is important for decision-makers to consider the broader systemic human and environmental costs of climate change as these often have wider spatial and temporal scales than financial costs (Boyd & Markandya, 2021). Similarly, to financial costs, these non-market costs may be incurred directly and indirectly. It is therefore critical to consider the combined direct and indirect financial and non-market costs of climate change. Table 2 lists examples of both types of costs.

Table 2: Examples of direct and indirect costs of climate change.

Examples of direct costs	Examples of indirect costs
• Damage to hard infrastructure and buildings (e.g., repair and replacement costs after a flood event)	• Flood damage to municipal infrastructure causes disruption/interruption of service delivery (e.g., water and waste)
• Increased wear and tear resulting in increased operations and maintenance costs	• Workers not able to get to work due to damaged transportation networks
• Physical and mental health impacts (e.g., costs for medical treatment after an extreme heat event)	• Rising insurance premiums from flooded buildings
• Damage to ecosystems (e.g., damage to tree canopy after a windstorm resulting in loss of ecosystem services)	• Long-term physical and mental health impacts
	• Loss of revenue in businesses who work with directly impacted businesses

Impacts to social systems

The effects of climate change on public health and wellbeing, including increased loss of life and physical and mental health impacts, are becoming increasingly costly and cannot be understated. Extreme heat events are projected to become more common in Canada and are proving to be increasingly dangerous and costly. As these climate hazards become more common, they will have a profound impact on human health and well-being, on our health care systems, our emergency services, and on vulnerable populations. Specific groups, such as those who work outside, low-income and racialized populations, infants and young children, older adults, those with limited mobility and chronic medical conditions, and people experiencing homelessness are particularly at risk (Berry & Schnitter, 2022).

The compounding hazards of extreme heat and higher concentrations of ground level ozone are of particular concern. Ground level ozone, a major component of urban smog, is made more dangerous by interacting with sunlight and warm temperatures. High levels are linked to increased mortality and respiratory illnesses (Berry & Schnitter, 2022; Clark et al., 2021). As Canadian summers get hotter, including more severe and frequent heat waves, poor air quality is expected to increase.

The Canadian Climate Institute projects that by 2080, healthcare costs associated with ground-level ozone could reach $1 billion per year, while the costs of premature deaths from ground-level ozone could exceed $300 billion per year under a high-emissions scenario (Clark et al., 2021). The recent 2021 heat dome event in British Columbia is one such example, where a stagnant air mass and solar radiation contributed to very high ground-level ozone concentrations resulting in 619 deaths and many more heat-related physical and mental morbidities (Henderson et al., 2022).

Data compiled from the Canadian Disaster Database (CDD, 2022) shows that heat events are responsible for the greatest loss of life in terms of weather-related natural disasters. Figure 2 below shows the top seven deadliest weather-related natural disasters across Canada between 1900 and 2021. Importantly, three of the top five deadliest heat events have occurred over the past 15 years.

It should also be noted that climate driven negative health outcomes also bear financial implications for already strained health systems. The cost of heat-related hospital visits is expected to increase 21% by mid-century and 102% by end of century even under a low-emissions scenario. The number of heat-related mortalities is also expected to reach 790 annually (nearly double current value) by the end of century under a high emissions scenario, costing an estimated $8.5 billion annually (Clark et al., 2021).

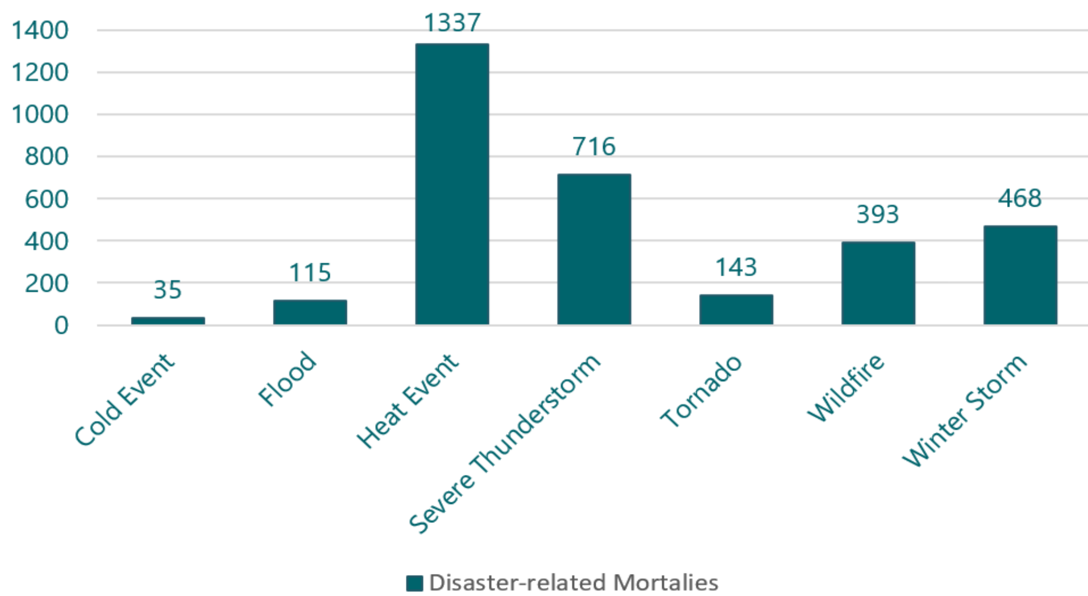


Figure 2: Sum of disaster related mortalities in Canada by category: cold event, drought, flood, heat event, storms and severe thunderstorms, tornados, wildfire, winter storm (Source: CDD, 2022).

Impact to natural systems

Climate change poses a major threat to the natural asset infrastructure (both natural and engineered) in local communities resulting in a loss of inherent and financial value of ecosystem services, and extensive restoration or replacement costs.

The term natural asset infrastructure refers to both naturally occurring and enhanced naturally occurring assets (also called green infrastructure assets) and human-made assets that are designed or engineered to mimic the functions and processes of natural assets (also called grey assets). The list of natural asset infrastructure is long and includes blue spaces such as aquifers, streams, wetlands, ponds and lakes, green spaces such as parks, forests, street trees, cemeteries, and gardens, as well as engineered elements like green roofs, artificial swales, rain gardens and stormwater retention ponds. These assets provide a host of ecosystem services at equivalent or better levels than engineered assets at a fraction of the cost (Table 3).

Ecosystem services delivered by municipal natural asset infrastructure include flood control, stormwater drainage and retention, reduced soil erosion, water purification, cooling of urban space and reducing the urban heat island effect, as well as improved air quality. These co-benefits all complement broader municipal policies while also providing increased access to community amenity space (MNAI, 2019; PCC, 2017). The social benefits of municipal green space are well documented, from reduced mortality and increased mental health benefits, while encouraging stewardship and increased participation and involvement in the planning process (PCC, 2017).

Much of the assessment of the impacts and costs of climate change have focused primarily on human systems and have tended to overlook the damage to natural systems and loss of goods and services ecosystems provide. This is a significant gap because impacts and costs to human systems often result from permanent or temporary loss of ecosystem services caused by climate hazards (van der Geest et al., 2019).

Municipalities must better understand the impacts and costs of losses of ecosystem services to plan interventions that limit these losses and damages, as well as take advantage of the many climate co-benefits ecosystems provided in the form of nature-based solutions.

Table 3: Types and examples of ecosystem services provided by natural asset infrastructure (MEA, 2005).

Type	Ecosystem service
Provisioning services	Goods such as food, water, timber, fuel, and fibers
Regulating services	Climate regulation, flood control, erosion control, water purification, air quality regulation
Cultural services	Non-material assets such cultural/traditional practices, aesthetic or recreational opportunities, health, and well-being benefits
Supporting services	Key underlying process including photosynthesis, nutrient cycling, creation of soils, water cycle

CLIMATE HAZARDS FACING STRATHCONA COUNTY

The following climate hazards were identified as affecting Strathcona County and provide a framework through which to analyze the cost of inaction arising from various impacted sectors. Strathcona County's prioritized list of high-risk local impacts are indicated below underneath each related hazard.

These high-risk local impacts were identified through the Corporate Climate Resilience Plan's Vulnerability and Risk Assessment process. The purpose of the Vulnerability and Risk Assessment process was to prioritize impacts that pose a significant threat to Strathcona County. Those impacts which scored higher in the vulnerability assessment and then in the risk assessment were considered highest priority impacts. These were brought forward into Milestone Three (planning phase) of the BARC Framework, where the County identified adaptive actions to address them.

The information in this report can provide the basis for further exploration by Strathcona County to identify additional local sources of data that can inform decision-making on the appropriate allocation of resources to adapt municipal assets, infrastructure and services to reduce risk and build community resilience.

1. **Extreme Weather and Precipitation**
   i. **Impact #20**: Increased frequency and intensity of precipitation events (especially in, winter and spring), freezing rain events, and ice loading resulting in flooding, leading to damage to County assets and infrastructure (i.e. stormwater management infrastructure and water treatment plants, sports fields, buildings, roads, pavements, bridges, culverts, trees, streetlights, signs, etc.) and associated maintenance requirements.
   ii. **Impact #31:** Increase in extreme weather events resulting in demand for emergency shelters and services (i.e. warming/cooling centres, power generation, responding to injuries, etc.) leading to an increased strain on emergency planning and resources.
   iii. **Impact #17:** Increased frequency and intensity of precipitation events leading to more overland flooding, resulting in greater runoff and sediment loading into streams and rivers and loss of wildlife habitat and ecosystem services.

1. **Extreme Heat**
   i. **Impact #1:** Increase in average annual temperatures and hot days (> 30 C) leading to escalating energy consumption and utility costs, GHG output, potential failures of critical systems (e.g. HVAC) and increased demand on County operations (e.g. increased call volumes to facility managers).
   ii. **Impact #8:** Increased frequency and duration of hot days (> 30 °C) resulting in heatwaves and reduced air quality leading to health and safety risks (e.g. heat stress, domestic violence/violent altercations, cardiovascular disorders, food-borne/water-borne illnesses, etc.) especially to vulnerable populations (e.g. outdoor workers, seniors, women, children, those with chronic health conditions, temporary foreign workers, those without air conditioning, etc.).
   iii. **Impact #4:** Increase in average annual temperatures resulting in an increased spread of invasive species (e.g. zebra & quagga mussels, Prussian carp), pests (e.g. mosquitoes, rodents, etc.), growth/spread of noxious weeds and plants (e.g. absinthe wormwood, hawkweed, giant hogweed) affecting the forestry and agriculture sectors, urban tree canopies, and natural ecosystems (terrestrial and aquatic).
   iv. **Impact #10:** Increased average annual temperatures and increased frequency and duration of hot days (>30 C) resulting in drought events, low

water levels, and low base flow, leading to stress on natural ecosystems (e.g. changing wetland boundaries, species mortality/extinction, biodiversity loss, pollinator impacts, decreased shade canopy) and reduced water quality.

v. **Impact #3:** Increase in average annual temperatures leading to a longer growing season, subsequent drought and increased weed control needs, as well as potential agricultural livestock/crop failure (i.e. disrupted growth cycles and growing regions of temperature- and moisture-sensitive plants/crops, more invasive species, etc.).

2. Wildfires

i. **Impact #23:** Increase in frequency, severity, and length of wildfires leading to damage to County-owned assets and infrastructure, increased water demand for firefighting, and increased administrative strain and demand on emergency response resources and continuity of support (e.g. increased call volumes to staff, evacuations, arranging temporary accommodation, etc.).

ii. **Impact #24:** Increase in frequency, severity, and length of wildfires leading to health and safety concerns for outdoor workers and the public due to poor air quality and poor visibility (e.g. traffic accidents).

EXTREME WEATHER AND PRECIPITATION EVENTS

WHAT TO KNOW ABOUT THESE HAZARDS

Precipitation

The annual mean precipitation in Canada has increased since the mid-20th century and is projected to increase further under both low and high emission scenarios (Bush & Lemmen, 2019). Climate change is also expected to increase the intensity, duration, and frequency of extreme precipitation events. Intensity-duration-frequency (IDF) curves can be used to predict heavy precipitation under a changing climate. For example, IDF curves for Toronto, Edmonton, and Calgary project 100-year flood events are expected to become 6-year events (Ness et al., 2021).

As Canada's climate continues to warm, shoulder seasons will lengthen, and winter months will become milder. Much of Canada is expected to experience an increase in precipitation across all seasons, but this is particularly true for precipitation in winter months. Spring, winter, and autumn precipitation accumulations are projected to increase by the end of the century with spring and winter experiencing the greatest increases. The combination of milder winters and increased precipitation is likely to result in an increase in freezing rain and wet snow events, especially in maritime and southern portions of the country.

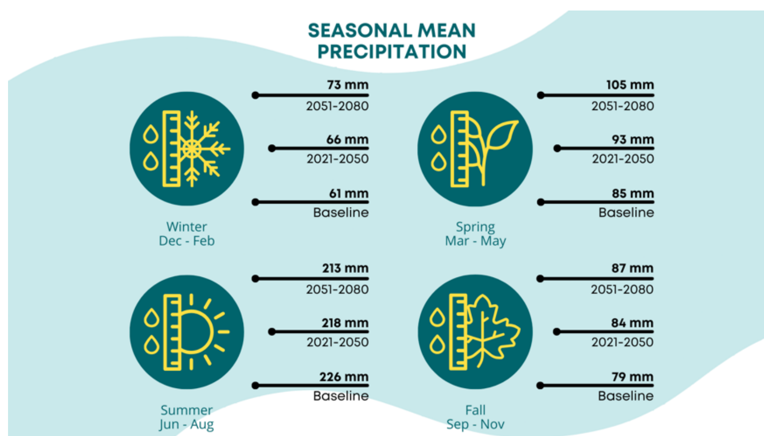


Figure 3: Infographic from the Strathcona County Climate Science Report on projected seasonal mean precipitation (present to 2080).

Cold weather is an important aspect of life in Canada, and many places in Canada are well adapted to very cold winters. While, the frequency and severity of cold days are decreasing across Canada, increases in winter precipitation and the frequency and severity of freezing rain is projected to increase. Projecting the pattern, intensity and frequency of future freezing precipitation events is complex and is difficult to predict given the rise of winter precipitation and shorter cold seasons.

Precipitation across Alberta is expected to increase 12% by the 2080s under a high emissions scenario, but this change will not be felt equally across all seasons. For example, summer precipitation is only expected to increase by 4.5%, where spring, fall, and winter precipitation is expected to increase by 24%, 15%, and 16.6% respectively resulting in wetter spring, fall and winter seasons.

Extreme weather events (i.e. ice storms, wind storms, flooding, thunderstorms, freezing rain, tornadoes, etc.)

Extreme weather events in Canada over the past 50 years are occurring at an unprecedented rate and are expected to become more frequent as the climate continues to warm. The events considered under the umbrella of *extreme weather events* for this report include ice storms, wind storms, flooding, thunderstorms, freezing rain, and tornadoes. In Canada, models show shorter return periods (the estimated interval of time between occurrences) between extreme events in the future (Bush & Lemmen, 2019).

Predicting precisely when extreme weather events will occur is beyond the scope of current climate data modeling, however considerable research has concluded that the probability of extreme weather events has increased 12-fold due to human-influenced climate change (Zhang et al., 2019).

The prairie provinces have been experiencing some of the strongest warming trends across southern Canada, which has been driving some of the most severe weather events. These include six of the top 10 costliest extreme weather events since 2010 (Sauchyn et al., 2020). These events include flooding, drought, hailstorms, and more, and account for billions in losses. 12 out of 20 of the most damaging weather, fire, and flooding events since 1983 occurred in Alberta, and the insured losses in dollar amounts can be seen in Table 4.

Table 4: Most expensive extreme weather, fire, and flooding events in Alberta since 1983 and the associated insured losses in 2018 dollar amounts.

Date	Location	Event type	Losses ($ million*)
May 3–19, 2016	Fort McMurray, AB	Fire	3,899.1
June 19–24, 2013	Southern Alberta	Flooding, water	1,737.4
May 15–16, 2011	Slave Lake, AB	Fire, windstorm	587.6
August 7, 2014	Central Alberta	Hail, lightning, water, windstorm	582.3

Date	Location	Event type	Losses ($ million*)
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
July 31, 1987	Edmonton, AB	Tornado	282.5
July 21, 2015	Central Alberta	Flooding, hail, water, windstorm	273.3

*Losses are in 2018 $

Under a high emissions scenario, extreme weather in Alberta, including convective summer storms (associated with thunder, lightning, heavy rain, hail, strong winds, and summer temperature changes), are expected to become more frequent in the Prairies as fluctuations in temperature and precipitation become more extreme (Sauchyn et al., 2020).

The next section gives a more detailed insight into the various impacts that extreme weather and precipitation events could have towards the infrastructure, either directly and indirectly, on critical services, and on natural systems as well as the associated costs.

Increasing Precipitation and Extreme Weather Events in Strathcona County

Total precipitation

The total annual average precipitation is projected to increase from a baseline of 426 mm to approximately 441 mm between 2021 and 2050, and to 448 mm between 2051 and 2080.

Heavy Precipitation and Intensity-Duration and Frequency of Precipitation Events

Across the County, heavy precipitation days are expected to increase by approximately 2 days for 10 mm day events, and 1 day for 20 mm day events. Maximum 1-day and 5-day events are also expected to increase across the County, with the greatest increase in 5-day events. Specifically, Max 5-day events are projected to increase from a baseline of 58 mm to 63 mm by 2051-2080.

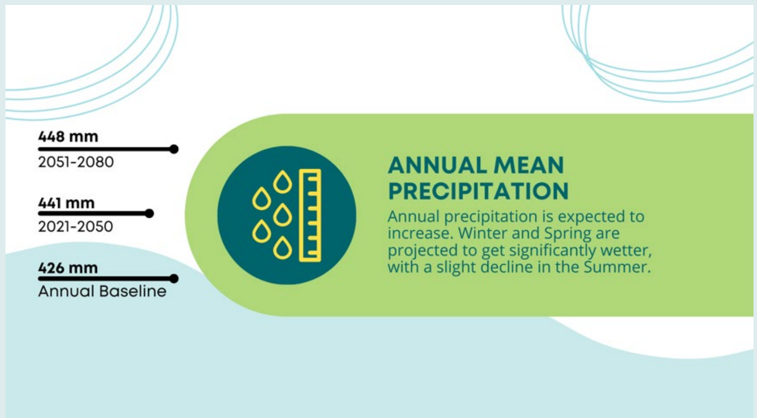
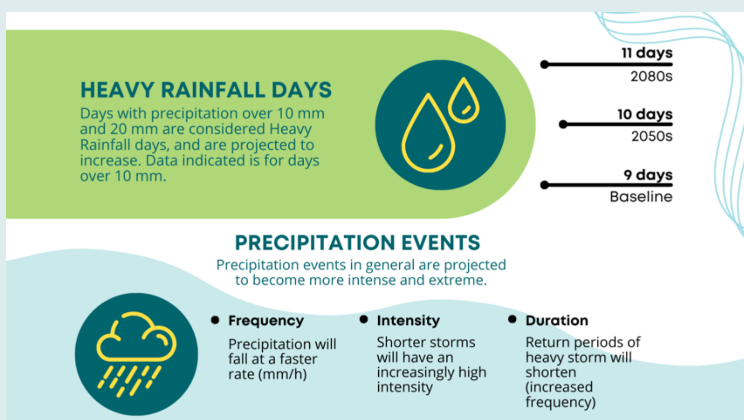


Figure 4: Infographic from the Strathcona County Climate Science Report on projected annual mean precipitation (present to 2080).

The Intensity-Duration-Frequency (IDF) analysis for the County underscores a significant trend toward more intense and frequent rainfall events. While longer, more frequent rainfall events (e.g. a typical rainy day) will bring slightly higher amounts of rain, the intensity of rainfall during more infrequent, extreme storms (i.e. 1 in 20, 25, 50, 100-year storms) is projected to increase by the 2050s and the 2080s.



Hail and Thunderstorms

Figure 5: Infographic from the Strathcona County Climate Science Report on projected heavy rainfall days and precipitation events (present to 2080).

While localized data related to hail projections are largely unavailable and year-to-year variability of hail events can be high, recent studies suggest that the frequency of hailstorms is linked to the increased frequency of severe thunderstorms under future climate projections (Etkin, 2018).

Past significant precipitation and extreme weather events in Strathcona County

SIGNIFICANT FLOODING EVENTS

2013 Sherwood Park Flooding

In July 2013, Sherwood Park experienced significant rainfall, recording over 70 millimeters of rainfall, particularly heavy in eastern parts. This intense rainfall led to localized flooding, including infrastructure challenges such as a dislodged manhole and water ponding at Lakeland Drive, signaling the need for careful stormwater management and maintenance to ensure readiness for such extreme conditions.[1]

2018 Widespread Flooding

In April 2018, Strathcona County faced widespread flooding due to rapid snowmelt, prompting the deployment of over 2,500 sandbags and addressing nearly 70 overland flooding instances, particularly in northeast rural areas. The county's response prioritized protecting homes, roads, and infrastructure from flood damage, utilizing resources like sand, water worms, and active pumps, while the community rallied together to mitigate the immediate impacts and began planning for future flood resilience.[2]

OTHER SIGNIFICANT EXTREME WEATHER EVENTS (I.E. ICE STORMS, WINDSTORMS, THUNDERSTORMS, FREEZING RAIN, TORNADOES, ETC.)

2017 Windstorm

In October 2017, Strathcona County and other regions were struck by an intense low-pressure system, resulting in wind gusts exceeding 100 km/h. This powerful storm led to widespread power outages due to downed wires and damaged equipment, as well as significant environmental disruptions, including fallen trees and disrupted water supply in nearby areas, showcasing the urgent need for robust windstorm preparedness and response strategies.[3]

2018 and 2021 Windstorms

A windstorm in 2018 tore down over 120 traffic signs throughout Strathcona County.[4] In 2021, a windstorm produced gusts over 100 km per hour, causing disruption to roadways and critical infrastructure.[5]

IMPACTS ON INFRASTRUCTURE

Relevant Localized Impact

Impact #20: Increased frequency and intensity of precipitation events (especially in, winter and spring), freezing rain events, and ice loading resulting in flooding, leading to damage to County assets and infrastructure (i.e. Stormwater Management Facility infrastructure and water treatment plants, sports fields, buildings, roads, pavements, bridges, culverts trees, streetlights, signs, etc.) and associated maintenance requirements.

Direct Impact: Buildings and Homes

Flooding due to extreme precipitation is among the most prevalent and costly climate change hazards affecting Canadian municipalities. Intense precipitation combined with lack of permeable surfaces can quickly overwhelm the capacity of drainage systems and lead to flooding, water infiltration and damage to buildings and homes.

Many of Canada's major cities are at risk of flooding with hundreds of thousands of homes and buildings within flood zones. For example, the majority of homes in Edmonton are considered to be susceptible to basement flooding. As projections indicate the amount and intensity of precipitation events is expected to increase (by 54mm by the 2080s), more overland flooding and sewer and stormwater backups are anticipated, causing costly infrastructure and property damage (City of Edmonton, n.d.).

Direct Impact: Transportation Infrastructure

Roads and rail lines are an integral part of Canada's transportation network that facilitates the movement of people, goods, and services across the country and within municipalities.

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[1] Germain, L. (2013, July 18). Park hit by heavy rainfall. *Sherwood Park News*. Retrieved from https://www.sherwoodparknews.com/2013/07/18/park-hit-by-heavy-rainfall

[2] Sherwood Park News. (2018, April 24). County grapples with flooding. Sherwood Park News. Retrieved from https://www.sherwoodparknews.com/2018/04/24/county-grapples-with-flooding

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[4] Sherwood Park News. (2018, June 18). High winds wreak havoc in county. *Sherwood Park News*. https://www.sherwoodparknews.com/2018/06/18/high-winds-wreak-havoc-in-county

[5] Dosser, T. (2021, January 26). Rural home lost to blaze during windstorm. *Sherwood Park News*. https://www.sherwoodparknews.com/news/rural-home-lost-to-blaze-during-windstorm

As the climate continues to warm, increasing intensity and frequency of climate hazards will expedite the degradation of this critical infrastructure.

Asphalt and pavement are susceptible to increased wear and tear due to high temperatures and freeze-thaw events. Erosion from increased precipitation, combined with other climate hazards such as ice storms and windstorms will also lead to increased wear and tear to roads and transportation infrastructure, reducing their lifespan.

This can include blockages from snow, the damage or destruction of roads and railways from washouts, and dangerous travel conditions. Extreme weather like hail, freezing rain and high winds can also damage traffic and rail signals.

Local examples:

A windstorm in 2018 tore down over 120 traffic signs throughout Strathcona County.

The 2018 flooding in Strathcona County resulted in over 515 reports of culvert issues, and had 36 daytime and 18 nighttime workers from Transportation and Agriculture Services working to mitigate the impacts of the flooding ("County", 2018).

Indirect Impacts

While the exact costs related to service loss and disruptions are not yet fully understood, recent reports suggest that the related direct and indirect costs will continue to grow. These include costs related to transportation delays, loss of business income, loss of business value, business disruptions, labour productivity losses, and reduced economic growth due to flooding. (Sawyer et al., 2020)

Research by GHD (2022) suggests flooding due to extreme precipitation will be the most disruptive and costliest to businesses. Two sectors of businesses that will be the most impacted, and are also linked, are manufacturing and distribution and consumer goods and retail (GHD, 2022). Extreme precipitation leading to flooding can cause direct damage to businesses and assets such as buildings, inventory, and machinery. Increased maintenance and replacement costs can result in increased taxes and shipping costs, transport delays and disruptions, increased road and travel-related accidents, risk of injury and death.

Changing winter precipitation patterns and continued freeze-thaw cycles will further deteriorate roads, pavement (including sidewalks), and increase the risk of injury or death from accidents and slips on icy surfaces. The result of these climate-driven hazards will be ever increasing disruption of supply chains, disruption, and delay of services, reduced economic output, increased risk of toxic spills, and increased risk of injury and death from transportation accidents.

As seen with the catastrophic 2021 British Columbia extreme precipitation event, widespread flooding can also cause cascading national disruptions to supply chains through transport infrastructure such as roads and railways and compounding delays in shipping. Far-reaching impacts of this event were not only felt in British Columbia, but in Alberta as well. Disruptions to electronic products and produce supply into Alberta as well as disruptions to oil and other goods out of the province to the west coast was likely experienced. (Gibson, 2021)

During 2013, 14% of Alberta's workforce was unable to work for over two weeks during the 2013 floods which is the equivalent of 5.1 million hours of lost work and $601 million of lost economic output (Sawyer et al., 2020).

IMPACTS ON CRITICAL SERVICES

Relevant Localized Impact

Impact #31: Increase in extreme weather events resulting in demand for emergency shelters and services (i.e. warming/cooling centres, power generation, responding to injuries, etc.) leading to an increased strain on emergency planning and resources

The impacts of climate change such as overland flooding routinely disrupt critical services including public transit, health care and delivery of utilities. For example, flood events are increasingly causing municipal transit agencies to divert services away from flooded areas, requiring contingency routes with reduced service.

Winter precipitation and freezing rain events are among the costliest and disruptive across all built, socio-economic, natural systems, and are also significant in terms of loss of life. Canada's electrical systems are particularly vulnerable to freezing rain damage which could result in billions in repair costs and leave millions of households, businesses, and services without power for often weeks. Ice storms also result in fatalities from fallen power lines, trees, and increased road accidents due to icy driving conditions.

The utilities sector, including telecommunications and electricity systems, are also expected to be impacted by more extreme weather events such as, thunderstorms, hailstorms, extreme wind events, and tornadoes. This can result in increased power demand, more frequent power outages, disruptions to critical services like healthcare and telecommunications, and disruptions to emergency response.

Canada's electricity systems are vulnerable to extreme weather events, most especially freezing windstorms, tornadoes, and freezing rain events that damage transmission lines and transformers and extreme precipitation from thunderstorms that flood electrical infrastructure. Consequently, these events greatly increase the risk of power outages and grid failure and increasing risk of cascading infrastructure failures. Moreover, severe weather events are second only to extreme heat in terms of climate change-linked loss of life. Over the past 100 years, severe weather events have caused over 15 million power outages and over 800 deaths (CDD, 2022).

When climate-related emergencies and disasters like flooding strike, health facilities and services are affected. In some cases, climate-related emergencies force health care centres and hospitals in Canada to close temporarily, evacuate patients, and/or cancel operations and other services. Direct flood damage to healthcare facilities as well as related electrical and water service outages can disrupt medical supply chains and critical public health services while demands for such services are at their highest (Clark et al., 2021). Over 5,000 healthcare centers are at risk of flooding across Canada including 1,072 in Alberta alone (Clark et al., 2021). A similar proportion of other critical public services such as police and fire stations are also at risk of flooding (Clark et al., 2021).

Even if health facilities and services remain operational during a climate-related disaster, they can be pushed beyond their capacity to respond because of injuries, illnesses, and patient transfers due to the disaster. Combined effects of climate change that overlap and interact could lead to cascading effects on several health outcomes simultaneously.

Local example:

An example of this affecting Strathcona County locally is in 2021. Wind gusts from a windstorm in the county exceeded 100km per hour and caused three electrical hazards from downed power lines, a vehicle fire, alarm systems to act up, and multiple EMS-related calls (Dosser, 2021)

Financial Costs – Infrastructure and Critical Services

Statistics Canada estimates Canada's 2.8 million kilometres of roads already cost federal, provincial, territorial, Indigenous, and municipal governments approximately $20.2 billion per year to maintain. This cost is expected to reach $300 billion over the coming decade and is likely to further increase as summers become longer and hotter, and as precipitation events become more frequent and extreme (Ness et al., 2021).

Economic losses associated with congested roadways, transportation system interruptions, and supply chain issues are also expected to increase. In 2017 alone, $2.2 trillion worth of goods were moved on Canadian roads (Ness et al., 2021). Estimated annual costs of road delay across Canada are expected to reach nearly $2 billion by the end of the century if no adaptation measures are implemented, compared to $250 million where proactive adaptation measures are taken (Ness et al., 2021). Poor road conditions also cost Canadian drivers an average of $3 billion per year in higher vehicle operating costs (Ness et al., 2021).

In terms of flooding specifically, since 2010, flooding has accounted for the costliest extreme weather disaster affecting Canadians in the form of insurable and uninsurable losses and disaster-assistance payouts by federal, provincial, and territorial governments (Moudrak & Feltmate, 2020).

Homes and buildings are highly exposed to flood damages. Flood and water-related losses have been trending upwards from 1983-2000 baselines with Disaster Financial Assistance Agreements expected to reach $1 billion per year by 2020 (Moudrak & Feltmate, 2020) and costs in annual damages reaching between $1.3 and $12.4 billion by the end of the century (Ness et al., 2021).

As shown in Figure 6, the costs of flooding damage to households located in flood zones will significantly increase under both low and high emission scenarios as can be seen in the data from six major Canadian cities.

CMA Name	Province	Households in flood zone	Baseline	Mid-century, low-emissions	Mid-century, high-emissions	End of century, low-emissions	End of century, high-emissions
Toronto	Ontario	146,798	$99	$557	$592	$548	$566
Winnipeg	Manitoba	250,918	$54	$285	$239	$259	$325
Calgary	Alberta	105,441	$37	$193	$195	$193	$234
Mississauga	Ontario	38,341	$24	$162	$166	$157	$165
Edmonton	Alberta	108,171	$35	$131	$108	$129	$144
Ottawa	Ontario	75,514	$44	$114	$92	$109	$114

Figure 6: Homes at risk of inland flooding will face more damage more often. Flood damages, millions of dollars (2019 CAD) (Ness et al., 2021).

Canada's private infrastructure was valued at $6.1 trillion in 2019 with privately-owned homes and buildings making up 85% (or $5.18 trillion) of this number (Moudrak & Feltmate, 2020). As extreme events have become more commonplace, home and building owners have historically relied on private insurance and government disaster assistance programs to cover much of these costs, however limits of these supports are being reached. Insurance premiums are rising and limitations on coverage are threatening the viability of protection for many home and business owners at risk of flooding (Ness et al., 2021). Recognizing the increased liability associated with the Disaster Financial Assistance Arrangements (DFAA) program, the Federal government reduced its financial support in 2015 by increasing the thresholds for access to funding (Davies, 2020). This has shifted the burden of costs to recover from natural disasters to municipal, provincial, territorial governments, homeowners, and businesses. For example, industry average premium for homeowner insurance has risen by 20-25% over the past five years in Canada (Moudrak & Feltmate, 2020).

The Insurance Bureau of Canada indicates a substantial increase in property and casualty insurance claims due to extreme weather events since the 1980s, with payouts doubling approximately every decade. From 1983 to 2008, the annual average of such claims was $405 million, but this figure increased dramatically in the following years, with more than $1 billion in payouts annually in 11 out of 12 years before 2020. Over half of this surge can be attributed to water-related damages, highlighting the escalating financial impact of climate-related events. (Moudrak & Feltmate, 2020). Extreme weather events in 2021 alone accounted for over $2 billion in insured losses and ranked sixth in Canada's top 10 highest loss years on record (IBC, 2022). Additionally, it is estimated that insured losses only encapsulate a fraction of the true cost of these events.

Zooming into what this has looked like for Alberta, the Federal Government allocated $13,051,334 to the province in 2023 under the Disaster Financial Assistance Arrangements (DFAA) program to compensate for the severe weather events, including flooding and heavy precipitation, experienced in 2011 and 2013 (Public Safety Canada, 2023).

We can look to Calgary to learn more about these costs. The flooding Calgary experienced in 2013 is estimated to have cost a combined $5 billion in financial loss and property damage, with $409 million in damages to key municipal infrastructure in Calgary alone (City of Calgary, 2021a). A hailstorm that struck Calgary in 2018 caused $80 million in damage, with a significant portion of that to vehicles (Government, n.d).

An extreme weather event experienced by Calgary in June 2020 caused power outages for more than 10,000 residents (ECCC, 2020). Tennis ball-sized hail and 70 km/h winds damaged vehicles and homes, downed trees, flooded streets, and suspended transit services, while outside of the city barley, wheat, and canola crops were ravaged by the event (ECCC, 2020). This event is estimated to have cost approximately $1.3 billion (minus crop losses) and is one of many extremely costly hail events the city has experienced in the last decade. Table 5 provides a summary of the fatalities, financial costs and impacts to utilities of other freezing rain events over a 20-year period between 2001-2021 (CDD, 2022).

Table 5: Fatalities, financial costs and power outages caused by freezing rain events between 2001-2021 (CDD, 2022).

Location	Year	Fatalities	Financial costs	Power outages
Western Canada	2021	—	$155 million	212,000 without power
Eastern Canada	2019	—	$39 million in damages	57,000 without power

Southern Ontario	2016	—	$27 million in damages	300,000 without power
Southern Ontario	2013-14	2	$262 million in damages	2.4 million without power
Prince Edward County	2008	—	$1.5 million in repair costs incurred by utilities	95% of PEI without power
Russell, Ontario	2006	—	—	Entire town lost power and issued state of emergency
Prince Edward Island	2003	—	$1.8 million in damages	—
Quebec	2001	6	$143 million	—

Additionally, in 2016, Fort McMurray received up to 85mm of rain and experienced flash floods that caused over $462 million in damages to personal property and disrupted local traffic and recovery (Public Safety Canada, n.d.). During the past year, spring flooding in 2023 affected homeowners, businesses, non-profits and farms across Edson, Whitecourt, Yellowhead and Woodlands Counties in Alberta, prompting the Alberta government to offer $68 million in support for uninsured losses (Bellefontaine, 2023). Other precipitation events such as hailstorms have resulted in significant damage and losses across Alberta, with three wind/water/hail events in Alberta in 2010, 2012, and 2014 totaling more than $1.66 billion in insured losses alone (Etkin, 2018).

Given these recent events, and the potential risks of future events, municipalities will need to consider adjusting engineering infrastructure requirements to improve the adaptive capacity of the critical services at risk of being impacted and mitigate the long-term risks to people, property, and communities. For example, a recent study showed that power lines aligned west to east, perpendicular to the strongest winds, are most susceptible to the consequences of icing and accretion within both current and future climate projections (Tropea & Stewart, 2021).

IMPACTS ON NATURAL SYSTEMS

Relevant Localized Impact

Impact #17: Increased frequency and intensity of precipitation events leading to more overland flooding, resulting in greater runoff and sediment loading into streams and rivers and loss of wildlife habitat and ecosystem services.

The assessment of impacts and costs of extreme weather have largely focused on loss and damage to 'hard infrastructure' (e.g., buildings, transportation infrastructure, and other hard engineered assets) and the resulting loss of services (e.g., public transportation delays, power outages and water and sewage disruptions). However, municipal 'natural asset infrastructure' is also at risk to extreme weather events, including damage and downed trees, loss of tree canopy, the destruction of urban food crops, damage to grasslands and wetlands, erosion, bank instability, loss of habitat and biodiversity, unsafe conditions in park spaces, lake, and river contamination and more. These impacts significantly disrupt the flow of 'ecosystem goods services' provided by natural asset infrastructure.

The term natural asset infrastructure refers to both naturally occurring and enhanced naturally occurring assets (also called green infrastructure assets) and human-made assets that are designed or engineered to mimic the functions and processes of natural assets (also called grey assets). The list of natural asset infrastructure is long and can include:

- Blue spaces such as aquifers, streams, wetlands, ponds, and lakes
- Green spaces such as parks, forests, street trees, cemeteries, and gardens
- Engineered elements like green roofs, artificial swales, rain gardens and stormwater retention ponds

These assets provide a host of ecosystem services at equivalent or better services than engineered assets at a fraction of the cost.

The term 'ecosystem services' is used to broadly refer to the role that the natural environment plays in providing several key services, including water filtration, pollination, carbon sequestration, stormwater and wastewater management services, green space and access to recreation, air filtration, and can help cool urbanized areas. Additionally, natural assets can increase community resilience to extreme weather events and climate change by reducing the urban heat island effect and soil erosion, flood, and drought mitigation, and managing risks to water quality.

The rise in precipitation and extreme weather events due to climate change is contributing to substantial disruptions to Strathcona County's natural systems, also leading to loss of wildlife habitat and deterioration of vital ecosystem services. Intense rainfall and more frequent overland flooding result in significant habitat displacement for a diverse range of species, disturbing the ecological balance and continuity of life cycles. This increase in water flow also accelerates sediment runoff, which can overload streams and rivers, degrade water quality, and cause the destruction of aquatic ecosystems. The compounded effect of these disturbances extends to the loss of ecosystem services such as water filtration, flood mitigation, and the provision of recreational spaces. These challenges to natural habitats and services highlight the urgency of implementing resilient ecological management and targeted restoration strategies to maintain the biodiversity and ecological functionality within the County in the face of escalating climatic threats.

Local Example:

In Strathcona County, high winds in 2018 resulted in various damages to the natural systems residents rely on. 150 downed trees were reported throughout the County, and 114 reports of storm damage in open spaces and parks were received, not including minor damages such as broken branches or unreported downed trees in forested areas that did not affect public infrastructure. Notably, a large downed tree blocked the entrance of Broadmoor Lake Park (High Winds, 2018), which prevented citizens' access and enjoyment of the park.

Financial Costs

The quantification of climate threats on natural asset infrastructure is challenging, yet is necessary to support decision-making, prioritize adaptation strategies, and increase community resilience. Understanding the costs of extreme weather events on municipal natural asset infrastructure involves assessing the financial and intrinsic value of natural asset infrastructure, the costs associated with the loss of ecosystem services due to damage to natural asset infrastructure (including many climate co-benefits they provide), and the costs associated with restoration and replacement.

In evaluating the value of natural asset infrastructure and costs associated with its restoration and replacement, it is important to note that it takes significantly longer than built assets for the full benefits and flow off ecosystem services to be restored after a disturbance. Moreover, natural assets (e.g., wetlands and forests) also increase in value over time, which is contrary to built assets (City of Calgary, 2021b). Table 6 shows the results of recent valuation studies for various ecosystem services conducted by municipalities across Canada. Table 7 provides a more detailed breakdown of the natural asset valuation conducted by the City of Calgary in 2021 and provides an excellent model for establishing the baseline values needed to assess the consequences of climate change.

Understanding the baseline value of natural asset infrastructure and the ecosystem services they provide helps establish the full costs of their damage due to climatic events, as well as build the case for investments in their management, enhancement, and protection.

Table 6: Examples of valuation studies for various ecosystem services.

Location	Service	Value
City of Edmonton, AB	Urban forest services	$2.7 billion (MNAI, 2022)
City of Calgary, AB	Ecosystem services (includes recreation, amenity and enjoyment, habitat, water retention, urban heat reduction, and carbon storage services)	$2.5 billion per year, $6.9 billion total replacement value (City of Calgary, 2021b)
City of Toronto, ON	Ravine ecosystem services (includes recreation, physical health, mental health, air quality, carbon sequestration, food provision, aesthetic appreciation, and habitat services)	$822 million per year (MNAI, 2022)
City of Saskatoon, SK	Aquatic, grass, forest, and shrubland services	$48.2 million per year (City of Saskatoon, 2020)
Town of Aurora, ON	Natural asset services	$7.4 million per year (Town of Aurora, 2013)

Table 7: Natural asset valuation conducted by the City of Calgary (City of Calgary, 2021b).

Service	Value
Recreation	$899 million annually
Amenity and enjoyment	$50 million annually
Habitat	$33.7 million annually

Water retention	$1.2 billion annually
Urban heat reduction	$381 million annually
Carbon storage	$1.8-7.6 million

The Natural Capital Asset Valuation (NCAV) Pilot Project by the City of Saskatoon highlights key financial cost savings by protecting natural environments (City of Saskatoon, 2020). For example, carbon sequestration services provided by wetlands and grasslands lock away CO_2, thus preventing its release into the atmosphere and providing potential costs savings in carbon offsetting. The study found that 82,904 tonnes of CO_2 is stored in soils of wetlands and grasslands in Area 1 of the site, and 54,081 tonnes of CO_2 in soils and biomass of wetlands, grassland and forests/shrublands. Stormwater management is another key role of wetlands as they act as sponges, controlling flooding and reducing the need for engineered stormwater management systems, which could lead to significant capital and operational cost savings for municipalities (City of Saskatoon, 2020). The total annual value of ecosystem services for all natural areas in Saskatoon are estimated at approximately $48,167,800 highlighted in the NCAV Pilot project (City of Saskatoon, 2020) These examples demonstrate the financial cost savings and broader economic benefits associated with protecting natural environments through the valuation of ecosystem services.

EXTREME HEAT

WHAT TO KNOW ABOUT THIS HAZARD

Under a high emissions scenario, Alberta is expected to warm on average 2.2°C by 2050, and 4.3°C by 2080 and experience up to 12 days of extreme heat days (+32°C). Cities across the southern Prairies are expected to experience maximum temperatures and extreme heat to a greater degree than the rest of the Prairies.

As a result of annual warming, winter seasons are becoming both warmer and shorter. The number of cool days (below 5°C) in Alberta are expected to decrease, resulting in approximately two weeks' fewer cool days per degree of global warming, with most parts of Alberta expected to experience nearly no very cold days (below -30°C) (Hayhoe & Stoner, 2019). Across the southern Prairies, Calgary (22%), Regina (35%), and Winnipeg (36%) are expected to experience a major decrease in the frequency of winter days (-15°C).

In looking at the hazard of extreme heat events further, these are defined as extended spells of high temperatures, often described as days over 30°C. Extreme heat events are projected to be more severe and occur more frequently and for longer periods. These changes become more pronounced as time goes on especially with higher emissions scenarios. For this high emissions scenario in Alberta, it is projected that the number of +30°C days will sharply increase from an annual baseline of 4 days (baseline of 1976-2005) up to 21 days per year by the 2050-2080s.

Increasing Extreme Heat Events in Strathcona County

Temperature Extremes

The baseline average number of days when the maximum temperature (TMax) was greater than or equal to 30°C was 3 days for the County. This is expected to increase to an average of 25 days as seen in Figure 7, with a possible range in any given year of 16-57 days in the 2051-2080 period under the SSP5-8.5 scenario.

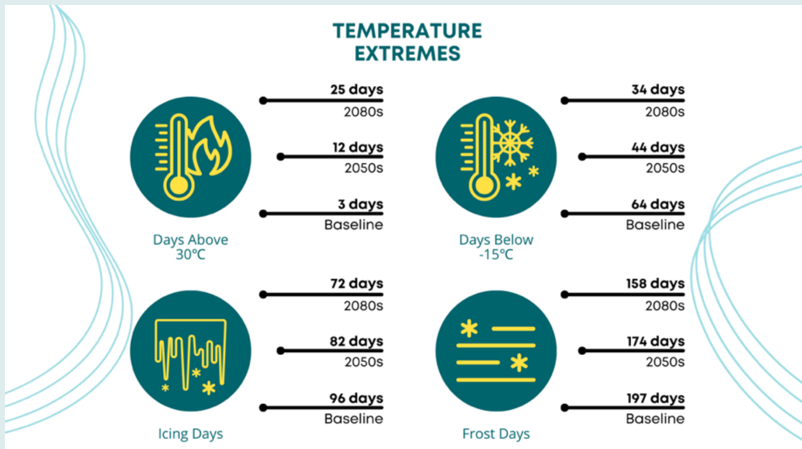

Figure 7: Infographic from the Strathcona County Climate Science Report on projected temperature extremes (present to 2080).

Heat Waves

The Climate Atlas of Canada defines a heat wave as three days in a row that reach or exceed 30°C and considers two variables for heat waves: the annual average length of heat waves, and the annual number of heat waves. The annual number of heat wave events measures the average number of times per year where the temperature reaches or exceeds 30°C. The baseline number of heat waves for Strathcona County is 0.4. In the 2051-2080 period according to RCP8.5, the County can expect to experience over three heat wave events per year.

With regards to the average length of heat waves (in days), the County experienced an average of 1.2 days of heat wave conditions in the baseline period. In the 2051-2080 period, according to RCP8.5, Strathcona County can expect to see an average heat wave event occurring for 5.4 days – over quadruple the current length.

Overall, heat waves are projected to occur more frequently and for longer periods of time, leading to greater occurrences of extreme heat events in Strathcona County. These changes become more pronounced over time, and in response to higher emissions scenarios (Figure 3).

Past significant extreme heat events in Strathcona County

SIGNIFICANT EXTREME HEAT EVENTS

2023 Alberta Heat Wave

Grappling with an unseasonable heat wave, dry conditions, and pre-existing wildfires, Alberta declared a state of emergency during the early summer of 2023. Temperatures were forecasted to exceed 30ºC in many regions around Alberta and special air quality advisories were issued, endangering those that were already forced from their homes due to rampaging wildfires. Specifically, the City of Edmonton was projected to reach 31ºC due to a "blocking pattern" that prevents the influx of cooler northern air to cool extreme temperatures.[6]

2022 Alberta Heat Wave

Large swaths of the province were under heat warnings during the summer of 2022. The City of Calgary and its surrounding regions faced extended stretches of extreme heat reaching anywhere from 30 to 32ºC. As this event occurred during the Stampede, many were at risk due to peak temperatures in the high-20s to low-30s in Calgary and peaks above 30ºC in Medicine Hat. Edmonton also experienced highs of 32ºC which lasted multiple days.[7]

2021 Strathcona County Heat Wave Event

Due to extreme heat and lack of rain with monthly peaks reaching 35ºC, Strathcona County implemented a voluntary water restriction in July 2021. These climatic conditions resulted in regional water reserves falling below typical levels for several days. Consequently, residents in the communities of Sherwood Park, Ardrossan, Josephburg, Half Moon Lake, Collingwood Cove, Antler Lake, and Fultonvale were encouraged to conscientiously manage their water consumption to help mitigate the strain on the water supply.[8]

2021 Alberta Heat Wave

During June of 2021, temperatures climbed above 30ºC across the entire province and peaked near 40ºC in some areas, including Edmonton. Alberta even broke its all-time summertime electricity demand record, hitting 11,414 megawatts – which surpasses the previous record of 11,169 megawatts from 2018. The heat warning in Edmonton persisted throughout a week and continued even longer in other regions, causing air quality concerns due to built up pollutants at the surface.[9]

2015 Strathcona County Heat Wave

In regions surrounding Strathcona County, a record high for July 9 of 34.1°C was reached in the City of Edmonton, with the previous record being 32.6°C. Many surrounding rivers such as the North Saskatchewan River also saw the effects of the heat wave, demonstrating the lowest flow rates in years.[10]

IMPACTS ON INFRASTRUCTURE

Relevant Localized Impact

Impact #1: Increase in average annual temperatures leading to an increased need to cool County facilities, escalating energy consumption and GHG output, and utility costs. Increased frequency and duration of hot days (>30 C), resulting in potential failures of critical systems (e.g. HVAC) and reduced access to cooling resources leading to increased demand on County operations (e.g. increased call volumes to facility managers, etc.).

The effects of climate change on infrastructure are subject to a range of local variables, leading to distinct challenges in different communities. As the intensity, duration, and frequency of heat events escalate, they are expected to exert additional pressure on infrastructure and building assets, accelerating damage and wear. This acceleration is likely to lead to rising costs in repairs, replacements, operations, and maintenance. Furthermore, the surge in extreme temperatures boosts the demand for cooling in buildings. Cooling accounts for approximately 10% of global electricity demand, and this figure is set to climb, potentially overburdening electrical systems with the increased use of air conditioning (Howarth, 2023).

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[6] The Canadian Press. (2023, May 10). Western Canada braces for early heat wave, raising wildfire risk in Alberta and B.C. Edmonton. https://edmonton.ctvnews.ca/western-canada-braces-for-early-heat-wave-raising-wildfire-risk-in-alberta-and-b-c-1.6393356

[7] https://globalnews.ca/news/8984127/calgary-and-area-eastern-alberta-heat-warnings/

[8] https://www.strathcona.ca/council-county/news/news/2021/6/28/water-restriction21/

[9] https://edmontonjournal.com/news/local-news/alberta-breaks-summer-record-for-electricity-demand-monday-amid-heat-wave

[10] https://globalnews.ca/news/2103672/strathcona-county-asks-residents-to-reduce-water-use-as-temperatures-soar/

Similarly, a rise in average summer temperatures and the number of extreme heat days are anticipated to significantly affect transportation infrastructure. This includes an uptick in both frequency and severity of damage, reduced service life of transportation assets (particularly asphalt and pavement), and subsequent delays across the transportation network (Ness et al., 2021).

The sensitivity of paved surfaces and transportation infrastructure is mainly affected by three factors: age, composition, and design (City of Windsor, 2019). The average lifespan of roadways varies by province but generally local, collector, and arterial roads have a lifespan of anywhere from 20 to 39 years (Government of Canada, 2022); however, high temperatures can significantly reduce this lifespan. Table 8 shows some of the impacts that extreme heat has on road infrastructure (City of Windsor, 2019).

Table 8: Examples of impacts on various types of infrastructure due to high temperatures (City of Windsor, 2019). Note that this table is not an exhaustive list of impact.

Highway roads	Bridges	Buildings
Pavement softening causing rutting	Cracking of bridge decks due to limits of expansion joints being exceeded	Building damage has been observed when clay soils dry out
Increased flushing and bleeding of older pavement	Drier conditions can affect the life cycle of bridges and culverts	Premature weathering
Reduction in maximum loads that can safely be transported		Increased indoor air temperature and reliance of cooling systems
Buckling of roads and sidewalks		
Shortened life expectancy of highways, roads, and rail		

The escalating challenges outlined—ranging from the strain on infrastructure due to rising temperatures to the increased demand for cooling—were starkly exemplified by the heat dome event of 2021 in British Columbia. This unprecedented climatic occurrence led to record-breaking temperatures across the province, with Lytton registering peak temperatures of 49.6°C, setting a new national high. The impact of such extreme heat was immediate and severe: power grids were overwhelmed and failed, roads and pavements buckled under the sweltering conditions, and rail lines deformed, vividly illustrating the tangible risks that lie ahead for communities and their infrastructure (Howarth, 2023; Ness et al., 2021).

Indirect Impacts

Increased temperatures as well as precipitation are expected to impact the dependability of transportation networks, leading to longer transit times for freight services and amplifying the costs associated with lost time and missed economic opportunities. Temperature increase contributes to accelerated surface wear and tear, experienced as greater roughness, thermal cracking, and rutting of roads. This deterioration requires more frequent maintenance and repairs, inflating associated expenses. Furthermore, such conditions compromise the quality-of-service delivery and can result in significant economic losses due to less efficient transportation systems.

Financial Costs

The Canadian Climate Institute has identified extreme heat as the principal factor in the escalating costs of road damage due to climate change. This includes not only the direct expenses for maintenance and repairs but also the wider economic repercussions such as transport delays, compromised service delivery, and the hindered movement of goods and services. Forecasts suggest temperature-related road damage could represent a staggering 87% of all climate-related road repair costs. Localized financial projections warn that, by 2050, municipalities could face an added burden of approximately $3.1 billion annually for road maintenance and repairs due to climate change (Ness et al., 2021).

Currently, Statistics Canada estimates that the upkeep of Canada's extensive 2.8 million kilometers of road infrastructure demands an annual outlay of $20.2 billion from various levels of government, from federal to municipal. This figure is on a trajectory to surpass $300 billion over the next ten years, largely attributable to increasingly prolonged and intense summer heat, coupled with more severe and frequent precipitation events, both of which are expected to exacerbate roadway deterioration (Ness et al., 2021).

In British Columbia, a practical illustration of these costs emerged in the aftermath of the 2021 heat dome event. The Ministry of Transportation and Infrastructure documented numerous instances of heat-related damage. Busy roadways buckled, forming deep ruts as asphalt softened under the extreme heat, while bridges sustained joint damage from thermal expansion. The financial toll of these damages on B.C.'s road and bridge infrastructure soared into the tens of millions, underscoring the substantial economic strain that extreme weather events can impose on government resources (Government of British Columbia 2022d; B.C. Ministry of Transport and Infrastructure 2022)."

IMPACTS ON HEALTH AND SAFETY

Relevant Localized Impact

Impact #8: Increase in hot days over 30°C causing heatwaves & reduced air quality leading to health and safety risks (e.g. heat stress, domestic violence/violent altercations, cardiovascular disorders, food-borne/water-borne illnesses, etc.) especially to vulnerable populations (e.g. outdoor workers, seniors, women, children, those with chronic health conditions, temporary foreign workers, those without AC, etc.)

The connection between climate change and health outcomes can be multifaceted – with direct impacts experienced through loss of life, injuries, and a surge in cases of mental health disorders (e.g., PTSD, climate-anxiety). Indirectly, health can be affected though social, environmental, cultural, and economic pathways (Berry & Schnitter, 2022). The toll of extreme heat events on physical and mental well-being is multi-dimensional and increasing.

Impacts on Physical Health

Traditionally, the relief provided by cooler nights has helped mitigate the effects of daytime heat. Yet, during extreme heat alerts, communities may face prolonged exposure to heat, particularly during 'tropical nights' where temperatures remain above 20°C. The rise in the intensity, duration, and frequency of heat events can have immediate and long-term consequences, and in extreme cases, lead to loss of life. In 2019, heat-related incidents were responsible for over 356,000 deaths globally, making it one of the deadliest climate-driven hazards (The Lancet, 2021). The vulnerability is especially acute for children, the elderly, outdoor workers, and those engaging in outdoor activities.

Heatwaves in Quebec such as those in 2010 and 2018 – resulted in 291 deaths and 86 deaths, respectively. More recently, the 2021 heat dome in British Columbia, which set temperature records and claimed 619 lives, exemplifies the devastating potential of extreme heat (British Columbia Coroner Service, 2022). Research suggests that the increased risk of heat-related mortality in the 2021 heat dome event was associated with socio-economic factors, including lack of access to green spaces, older age, and sex (Henderson et al., 2022).

Additionally, extreme heat exacerbates air pollution, aggravating conditions for those with respiratory or cardiovascular diseases, and can lead to an increase in hospital admissions for cardiovascular issues and pregnancy complications.

Vector-borne Diseases

Understanding the link between climate change and disease proliferation requires understanding the interactions among human populations and behavior, geography climate, vectors, and transmission dynamics. As climate change continues to drive temperature rises and precipitation increases, we can expect direct and indirect upticks in infectious and vector-borne diseases.

Milder winters and longer shoulder seasons will allow vectors such as ticks to survive historically unfavorable conditions, prolong their life cycles, expand their range, and lengthen transmission seasons. Furthermore, wetter conditions, coupled with milder off-peak seasons, will foster mosquito population growth, raising the risk of diseases like West Nile virus and other mosquito-borne infections (e.g., Eastern Equine Encephalitis, Jamestown Canyon virus, snowshoe hare virus).

Disease carrying tick populations have been expanding northward into southwestern, south central, and southeastern Canada and are expected to continue expanding northward as winters become increasingly milder. West Nile vectors are already established in both eastern and western Canada and will continue to expand their range northward as long-term warming is observed and shoulder seasons lengthen.

Ice days, when the daily maximum temperature is at or below 0°C, can help understand freeze and thaw patterns and document risks relating to the spread of vector borne diseases. A reduction in days with maximum temperatures below 0°C could have an impact on the survival and spread of ticks and Lyme disease, as ticks can be active in temperatures above 4°C (Alberta Health, 2019). While deer ticks are most active in spring and fall, warmer winters could extend their window of activity.

Canada is already experiencing a rapid increase in Lyme infections directly linked to climate change and is more vulnerable to this over time. This could have especially severe implications for vulnerable populations such as: immunocompromised individuals, seniors, low-income and marginalized populations, children, and more. Understandably, this may lead to further stress to healthcare facilities, increased worker absenteeism, and financial implications for governments, health services, employers, and employees.

Impacts on Mental Health

Mental health risks are compounded by climate change, aggravating existing conditions and precipitating new mental health issues. The strain on Canadian healthcare systems due to mental health costs is set to increase without adequate adaptation interventions (Berry & Schnitter, 2022). Moreover, climate change intensifies stressors such as grief, anxiety, and vicarious trauma. Certain psychiatric medications can heighten heat sensitivity, further elevating the risk during extreme heat events (Berry & Schnitter, 2022).

Indirect Impacts

Climate change is anticipated to exert significant pressure on workforce productivity due to environmental conditions, illness, or premature death, all contributing to lost productivity. Temperature stress can lead to diminished work output, service disruption, and job loss. It affects workers both physically and psychologically, impairing their productivity and economic output (Henderson et al., 2022). Such reductions in labor productivity have the potential to impact national economic growth and incomes (Clark et al., 2021).

Financial Costs

The Health of Canadians in a Changing Climate report by Health Canada (Berry & Schnitter, 2022) brings to the forefront the escalating costs to physical and mental health attributed to climate-related events like heatwaves.

The Climate Risk Institute estimates a sobering financial forecast: that under low- and high-emissions scenarios, the annual national health-related expenditures linked to climate change by the mid-century are projected at $3.0 billion and $3.9 billion, respectively. When comparing these to the end of the century, these costs could soar to $5.2 billion and $8.5 billion annually, highlighting the economic repercussions of inaction on emissions (CICC, 2021).

A case in point is the 2021 heat dome in British Columbia, where severe heat-related health complications led to 530 additional hospital admissions, amounting to an estimated healthcare expenditure of $8 million (based on Figure 8, below). Additionally, the immediate healthcare costs, including emergency response for the 619 deaths amount to approximately $4 million, or $7,028 per person (Beugin et al., 2023).

Illness	Per cent change from baseline (number of excess hospitalizations for B.C.)	Average acute bed length of stay (days)	Average cost of hospitalization per patient
Dehydration	136% increase (88)	3.8	$4,892
Acute kidney failure	45% increase (147)	6.4	$9,183
Diabetic ketoacidosis with coma	285% increase (4)	5.3	$5,739
Neurocognitive disorders*[11]	33% increase (94)	12.7	$14,513
Pneumonia	25% increase (40)	6.0	$8,718
Hepatorenal syndrome	170% increase (5)	7.9	$10,458
Heatstroke	16,876% increase (511)	5.8	$10,317

Figure 8: Illnesses requiring hospitalization that increased during the heat wave. (Beugin et al., 2023)

In terms of labour productivity, projections by the Climate Risk Institute (Clark et al., 2021) suggest that by mid-century, the annual cost of lost productivity could be up to $5.4 billion, ballooning to $14.8 billion by the end of the century under a high emissions scenario. This translates to 128 million hours, or 62,000 full-time workers, in lost productivity annually nationwide. Estimates are also made for Alberta, as seen in Figure 9 below.

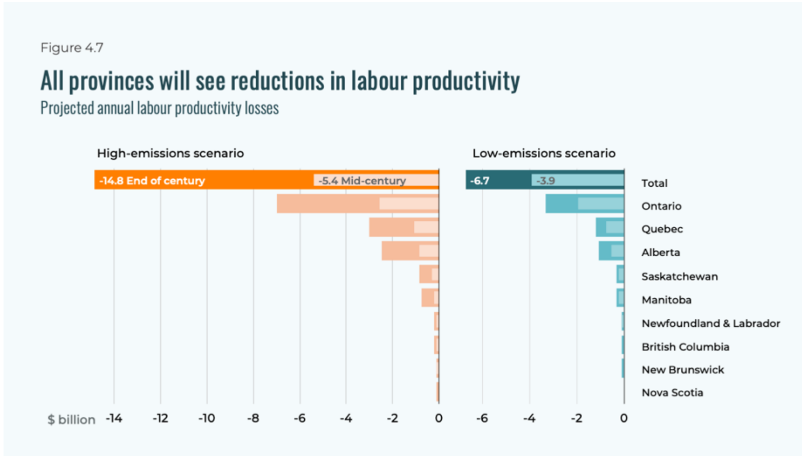

Figure 9: Provincial labour productivity reductions in low- and high-emissions scenario. (CICC, 2021)

Quantifying the impact of vector-borne and emerging infectious diseases is complex. several studies indicate that costs fluctuate by disease and individual but at the population level, average healthcare costs provide a measurable metric. These costs encompass emergency and doctor clinic visits, hospitalizations, laboratory testing, and the time investment of physicians and administrative personnel. In terms of broader socio-economic impacts, factors like absenteeism, diminished productivity, extended illness, and mortality are significant. Research by Shing et al. (2019) revealed that over one year, a patient with West Nile Virus might generate $13,648 in direct healthcare costs, while Lyme disease costs average $832 per patient.

IMPACTS ON NATURAL SYSTEMS

Relevant Localized Impact

Impact #10: Increased average annual temperatures and increased frequency and duration of hot days (>30 C) resulting in drought events, low water levels, and low base flow, leading to stress on natural ecosystems (e.g. changing wetland boundaries, species mortality/extinction, biodiversity loss, pollinator impacts, decreased shade canopy) and reduce water quality.

Strathcona County's natural habitats and ecosystems are increasingly vulnerable to the ramifications of climate change, particularly rising extreme heat events. As mentioned in the previous section of this Report on *Extreme Weather and Precipitation*, such events pose risks to our 'natural asset infrastructure,' threatening wildlife habitats and undermining the critical ecosystem services they provide. Extreme weather events, inclusive of intense heat, have been known to cause significant harm, leading to damage of trees, degradation of green spaces, and a cascade of detrimental effects ranging from wildlife habitat loss to park safety issues, and from water body contamination to the interruption of natural ecosystem goods and services.

The consequences of extreme heat on fauna are significant, altering their behaviors, health, and survival rates, with certain species more susceptible than others. Notably, the 2021 heat dome event in British Columbia may have led to a tragic marine die-off, where over a billion seashore animals succumbed to the scorching temperatures, as reported by UBC researchers. Further, warmer surface water temperatures and decreasing water quality pose fatal threats to aquatic life, especially to species like salmon and trout, and can trigger harmful algal blooms (Migdal, 2021).

Catastrophic losses of vegetation and canopy can also result from the coupling of extreme heat, drought, and fire (Eyquem & Feltmate, 2022). The degradation of urban tree canopy not only impacts biodiversity but also intensifies the urban heat island effect, wherein urban regions experience temperatures 1-3°C higher than their rural counterparts due to impermeable surfaces like concrete and asphalt (Buse, et al., 2022).

Moreover, extended periods of drought, compounded by extreme heat, bear direct implications on both natural asset infrastructure and municipal water resources vital for sustaining such infrastructure. Drought conditions may result when dry periods are long-lasting (i.e., more than five consecutive days when daily precipitation totals are less than 1mm) (Alberta Water Portal Society, 2024).

Financial Costs

The costs of losing natural assets can be severe. In the City of Calgary, for instance, natural assets are believed to contribute an estimated annual value of $381 million by mitigating the urban heat island effect. These natural systems provide invaluable temperature regulation services in urban environments prone to excessive heat due to man-made surfaces. By lowering surface air temperatures, natural areas and street trees play a part in preventing an estimated 46 deaths annually, equating to a financial value of $381 million.

Similarly, the conservation of various habitats—including forests, wetlands, grasslands, and shrublands—is estimated to have a value of $33.7 million annually, averaging a value of $2,930 per hectare each year. These ecosystems are pivotal, offering services like water retention and carbon sequestration that, while challenging to quantify, are indispensable. The annual economic benefit of these services is valued at $1.2 billion for water retention and between $1.8 to $7.6 million for carbon capture (City of Calgary, 2021b). It is to be noted that European researchers suggest that increasing urban canopy up to 30%, could reduce heat-related fatalities in cities by one-third (Lungman et al., 2023).

IMPACTS ON AGRICULTURE

Relevant Localized Impact

Impact #4: Increase in average annual temperatures resulting in an increased spread of invasive species (e.g. zebra & quagga mussels, prussian carp), pests (e.g. mosquitoes, rodents, etc.), growth/spread of noxious weeds and plants (e.g. absinthe wormwood, hawkweed, giant hogweed) affecting the agriculture sectors, urban tree canopies, and natural ecosystems (terrestrial and aquatic).

Relevant Localized Impact

Impact #3: Increase in average annual temperatures leading to a longer growing season, subsequent drought and increased weed control needs, as well as potential agricultural livestock/crop failure (i.e. disrupted growth cycles and growing regions of temperature- and moisture-sensitive plants/crops, more invasive species, etc.)

The escalation of heat extremes precipitates widespread disruptions in plant and animal physiology, directly impacting food systems (Beugin et al., 2023). Prolonged or repeated droughts exacerbate these disruptions, impairing agricultural productivity and water supply. Impacts manifest both directly, through crop and livestock losses, and indirectly, by aggravating issues related to pests, diseases, soil degradation, weeds, and the health of humans and livestock. The economic ramifications of these impacts are projected to incur billions in costs across Canada (Wheaton & Barrow, n.d.).

Anticipated more intense and expansive droughts, despite predictions of increased overall precipitation, pose significant risks. Due to the increasing variability of precipitation, drying trends may deepen by the 2050s, surpassing the severity of historically notorious droughts in the Prairies. The droughts from the 1930s, the 1960s, the 1980s and early 2000s are likely to be nowhere near as severe as future projections. Such conditions foreshadow not only diminished yields and potential crop failures but also diminishing water supplies (Wheaton & Barrow, n.d.).

In the case of the 2021 BC heat dome, food systems faced a variety of challenges. Livestock and shellfish sectors suffered notable setbacks, while fruit and vegetable yields and quality saw marked declines, translating to substantial financial burdens for producers and significant insurance payouts by the Canadian government, particularly given the subsidies in place for certain crops. Indigenous communities' traditional food sources were also acutely affected due to their intrinsic ties to the land and natural world (Beugin et al., 2023).

Past significant drought events in Strathcona County

SIGNIFICANT DROUGHT EVENTS

2024 Alberta Drought

Due to low snowpack, low precipitation and El Niño conditions in 2022-2023, Alberta is currently experiencing drought in a large portion of the province. As the season progresses, this will likely result in water shortages and agricultural disasters in much of the province.[11]

2021 Alberta Drought

The drought experienced in 2021 is thought to be worse than the infamous "Dirty Thirties" drought and was considered the worst drought Alberta has faced in 60 years. With almost all regions of Alberta subject to drought conditions, agricultural production was in danger, and it was clear that climate change and rising temperatures profoundly affected Alberta's water supply.[12]

2010 Alberta Drought

2010 brought along a devastating drought in central and northern Alberta, affecting the counties of Grand Prairie, Saddle Hills and Birch Hills, as well as the Municipal Districts of Big Lakes, Northern Sunrise, Spirit River, Fairview, Clear Hills, Smoky River and Greenview. All of these communities declared agricultural disaster zones.[11]

2009 Alberta Drought

In 2009, central Alberta, primarily "Palliser's Triangle" region, was affected by a severe drought as they received the smallest amount of precipitation recorded in the past fifty years. Due to this, ten counties declared states of emergency.[11]

2002-2004 Alberta Drought

The 2001-2002 drought in Alberta was particularly disastrous, costing the Canadian economy $5.8 billion. Net farm income amounted to zero in Alberta in 2002, resulting in 41,000 lost jobs across the country and many farmers abandoning their farms completely.[11]

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[11] Alberta Water Portal Society. (2024, May 25). *Drought in 21st Century Alberta*. Alberta WaterPortal. https://albertawater.com/history-of-drought-in-alberta/drought-in-21st-century-alberta/#_edn9
[12] Climenhaga, C. (2022, March 28). *Severity and sweep of Prairie droughts could spiral as climate changes*. CBC. https://www.cbc.ca/news/canada/edmonton/severity-and-sweep-of-prairie-droughts-could-spiral-as-climate-changes-1.6391982

Financial Costs

The fiscal implications for agricultural systems are starkly illustrated by the payouts of the Agriculture Financial Services Corp. (AFSC) in Alberta, which disbursed $2.1 billion in 2021 and $552 million in 2022 due to drought-induced crop failures. These massive insurance claims have led to a forecast of increased crop insurance premiums for the 2024 crop year (Stephenson, 2024).

The 2021 BC heat dome event exacted a heavy toll on livestock and shellfish, with poultry losses alone leading to over $5 million in revenue deficits, exclusive of the decline in egg and dairy production. The mussel farming sector also took a hit, with a 40% revenue reduction from the prior five-year average due to the heatwave and other compounding factors. Individual operators reported substantial financial losses, with two farmers reporting $30,000 and $70,000 in losses respectively after having lost up to 80% of their stock. (Beugin et al., 2023).

Fruit growers, too, grappled with considerable losses. The heatwave caused the tree fruit industry to forfeit over $17 million in potential revenue, equating to 17% of the industry’s annual revenue potential. Raspberry and cherry farmers faced sales reductions of 35% and 19%, respectively. In response to the heat wave, the provincial government's subsidized crop insurance payouts for fruit trees totaled nearly $12 million, marking a record-breaking expense in the face of heat-induced payouts according to the BC Ministry of Agriculture (Beugin et al., 2023).

WILDFIRES

WHAT TO KNOW ABOUT THIS HAZARD

Wildfires

Wildfires are caused by three main factors: fuel (type, structure, amount, and moisture), ignition (natural or human-caused), and fire-conductive weather (hot, dry, and windy) (Sauchyn et al., 2020). Wildfire activity in Canada has already worsened due to anthropogenic warming, causing the area of forest burned per year in Canada to increase. Warmer temperatures result in lengthier fire seasons, are associated with increased lighting strikes, and lead to drier conditions that cause fuels to become more flammable and harder to extinguish (i.e. moisture is transferred from plants and soil to the atmosphere) (Sauchyn et al., 2020).

The annual average surface air temperature over land in Canada has warmed by approximately 1.7ºC since 1958, with greater temperature increases across the Prairies in particular. In the Prairies, annual mean temperature has increased by 1.9ºC from 1958–2016 and is projected to increase by 2.3ºC by 2050 and by 6.5ºC by 2100 in a high emission scenario (RCP8.5) (Cohen et al., 2019).

Periodic droughts and soil moisture deficits are common in the Canadian Prairies and are expected to become more frequent and intense during the summer, particularly within the south. Due to the vast size of the Prairie provinces and their hydroclimatic diversity, many communities are likely experiencing drought and wildfire simultaneously while others experience flooding. Even though annual precipitation is projected to increase in Alberta's future climate scenarios, it is expected to be insufficient to compensate for the drying effect of warmer temperatures that exacerbate wildfires (Sauchyn et al., 2020).

Seasonal trends, including relatively unchanged summer rainfall amounts paired with the projected increases in temperatures and heatwave lengths, may lead to increased instances of dry weather and extended drought periods. This results in conditions ripe for wildfires throughout the spring, summer, and fall seasons within many parts of western Canada. As a result, it is projected that the occurrence of wildfires within Alberta will increase significantly as the climate continues to change. This can have profound impacts on social, natural, and economic systems.

Extreme weather such as wildfire will impact varying communities and social groups differently based on their livelihoods, their social and economic status, their access to natural capital, the ability to evacuate, ignition fuels available, the amount of damage and disruption caused, and more (Sauchyn et al., 2020; Evans et al., 2023).

Although wildfires can be beneficial to natural systems in some circumstances (vegetation regeneration, soil nutrient dynamics, hydrology, etc.), if exacerbated by human interference and or the changing climate, their impacts can be catastrophic for the affected ecosystem. Vegetation loss can be severe and is increasing as wildfire frequency increases due to climate change, resulting in increased greenhouse gas emissions, native habitat destruction, wildlife mortality, and other disturbances such as insect outbreaks. According to Hope et al. (2016), over the past 25 years, the quantity of fires per year has decreased, but the area burned has doubled, resulting in an average of 2.3 million hectares burnt per year. This number is projected to increase to four times this amount by 2100. 2023 wildfires burnt an estimated 18.5 million hectares, breaking the previous record from 1995 for area burned in one year which was less than half this value at 7.1 million hectares (Evans et al., 2023).

Increased flood risk is also a detrimental impact caused by wildfire events. This increase in flood risk is due to the consumption of flammable materials which leaves behind burnt and water-repellent soil which in turn, increases the chances of landslides and floods for up to five years after the wildfire event (Evans et al., 2023). British Columbia experienced destroyed highways and submerged homes in 2021 due to devastating floods after their fourth worst wildfire season to date. In 2023, Edson, Alberta, experienced flash flooding one week after wildfire evacuation orders were lifted, leading to a state of emergency declaration for flooding (CBC News, 2023).

Past Significant Wildfire Events in Alberta

SIGNIFICANT WILDFIRE EVENTS

2023 Wildfire Season

Wildfires in 2023 burned 10 times more hectares than the five-year average (226,000 ha), burning roughly 2.2 million hectares and breaking previous records. Due to dry conditions, droughts, and record heat waves, fires burned throughout the summer all the way into January, causing a devastating wildfire season in Alberta, British Columbia, Northwest Territories, Quebec, and Nova Scotia. More than 60 percent of these fires were caused by people, 35 percent were caused by lightning, and 4 percent are still being investigated.[13]

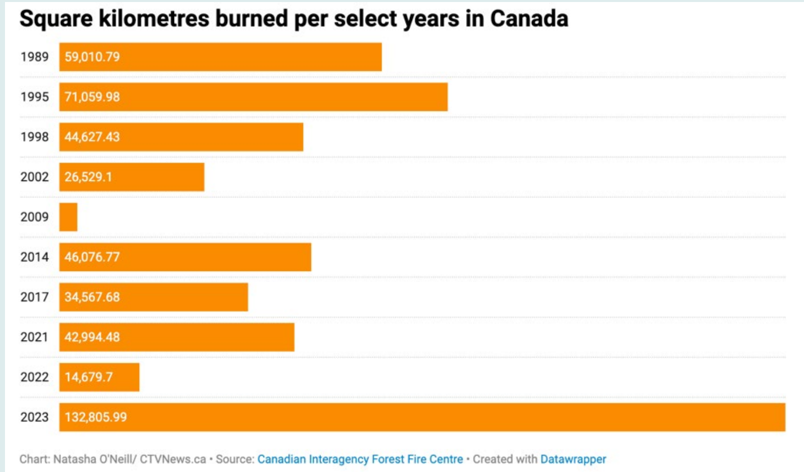

Figure 10: Square kilometres burned per select years in Canada. Sourced from Natasha O'Neill, CTVNews. (O'Neill, 2023)

2019 Wildfire Season

Likely started by a lightning strike on May 10th, but exacerbated by persistent drought conditions in northwestern Alberta, this wildfire was discovered near High Level, Alberta. Soon after on May 17th high winds caused the spread of the fire and it was deemed out of control burning 3,501 km^2 and causing more than 3,000 High Level, Mackenzie County, and Dene Tha' First Nation residents to be evacuated for almost a month. Additional fires – the McMillian and Battle fires – occurred during the same season, affecting a total of 15,000 individuals due to evacuations.[14]

2016 Fort McMurray Wildfire

In May 2016, 600,000 hectares of northern Alberta were burnt in a large wildfire and resulted in the massive evacuation of all residents of Fort McMurray (more than 90,000 people). As the most expensive natural disaster in Canadian history, the fires destroyed 2,400 homes and businesses, and damaged 530 other buildings[14]. This catastrophic event caused emotional and economic distress, destroyed homes, buildings, and other infrastructure, halted production in the oil sands, and caused an estimated $3.5 billion in insured losses alone (Evans et al., 2023; Zhang et al., 2019). Total costs were estimated to be at least $8.8 billion (Mahajan & Kim, 2020).

[13] Derworiz, C. (2024, January 5). *Wildfires in Alberta burned 10 times more area in 2023 than the five-year average*. CBC. https://www.cbc.ca/news/canada/edmonton/wildfires-in-alberta-burned-10-times-more-area-in-2023-than-the-five-year-average-1.7075263

[14] D'Andrea, A. (2023, May 5). *Alberta wildfires: A look at past blazes that caused billions in damages | Globalnews.ca*. Global News. https://globalnews.ca/news/9676356/alberta-wildfires-timeline/

2012 Lethbridge and Coalhurst Wildfires

These two grass fires lead to local states of emergency and evacuations of approximately 2,200 residents in Coalhurst and Lethbridge and 800 in Milk River. The fires damaged private property (sheds, outbuildings, houses) and caused one fire-related injury.[14]

2011 Slave Lake Wildfire

In May of 2011, forty-nine wildfires in north-central Alberta burned, causing more than $500 million in damages. 735 Slave Lake residents and families lost their homes and 7,000 were evacuated. 433 buildings in total were destroyed and 84 were damaged by the flames.[14]

Increasing wildfire events in Strathcona County

Changing Climatic Factors Causing Increased Frequency of Wildfires

Wildfires are caused by a multitude of factors including temperature, precipitation, wind, and human influence (i.e. improper fire management practices, illegal or unattended burning of debris, negligent discarding of cigarettes, etc.) Any combination of these factors can cause a wildfire and consequently affect the severity, intensity, and longevity of the event. As the climate changes due to global warming, consequent environmental, social, and economic impacts are expected to be exacerbated. (BC Wildfire Service, 2023a; BC Wildfire Service, 2023b)

Concurrent changes in temperature and precipitation across Canada due to climate change exacerbate climate impacts across many sectors, with one of the most prevalent being fire weather. Changing precipitation, temperature, and wind can create hot, dry, and windy conditions that alter the risk of extreme wildfires (Zhang et al., 2019). Alongside increased occurrence of drought and extreme heat, these concurrent conditions create an environment where evaporation and transpiration exceed precipitation, giving rise to dry conditions, flammable fuel, and an increased likelihood and increased severity of extreme fire weather (Cohen et al., 2019).

Projections for the Prairie Provinces

Predicting precisely when extreme weather events will occur is beyond the scope of current climate data modeling, however research shows that extreme wildfire risk in western Canada has increased by a factor of 1.5 to 6 due to climate change. Warmer temperatures lengthen the fire season and are associated with increased lightning strikes. More large and high-intensity wildfires, such as that experienced in Fort McMurray in 2016, are expected under current climate change projections.

Figure 11: Infographic from the Strathcona County Climate Science Report on projected temperature extremes (present to 2080).

Preparing for 2024 wildfire season

Declaring an early start to wildfire season on February 20th, 2024, the Government of Alberta is attempting to ensure proper preparation and control over the 2024 wildfire season. After the disastrous fires in 2023, Alberta Wildfire will be utilizing permits, 100 newly hired firefighters, fire bans, and restrictions to reduce the possibility of human-caused wildfires.[15]

IMPACTS ON INFRASTRUCTURE

Relevant Localized Impact

Impact #23: Increase in frequency, severity, and length of wildfires leading to damage to County-owned assets and infrastructure, increased water demand for firefighting, and increased administrative strain and demand on emergency response resources and continuity of support (e.g. increased call volumes to staff, evacuations, arranging temp accommodation, etc.)

Direct Impact: Buildings and Homes

Wildfire events routinely impact communities through the destruction and damage of built infrastructure such as buildings, private businesses, and homes. With the 2023 wildfire season being the worst seen to date, Alberta alone saw 1,022 wildfires and many Canadians faced unequivocal displacement and destruction. Final reports have yet to release the total infrastructure damage dealt by the fires, however as of May 20th, 2023 approximately 275 structures had already burned down in Alberta (Earl, 2023). Continual destruction of buildings and homes is resulting in the worsening of Canada's ongoing housing crisis, construction labour shortages, and increased reconstruction times (Stober, 2023).

In 2019, approximately 15,000 Albertans were displaced from their homes due to the threat of wildfire from Chuckegg Creek, Battle, and/or McMillan. The Paddle Prairie Métis Settlement (PPMS) suffered significant loss with the fires destroying 16 out of

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[15] Sandy Erni, Lynn Johnston, Yan Boulanger, Francis Manka, Pierre Bernier, Brian Eddy, Amy Christianson, Tom Swystun, and Sylvie Gauthier. 2021. Exposure of the Canadian wildland–human interface and population to wildland fire, under current and future climate conditions. Canadian Journal of Forest Research. 51(9): 1357-1367. https://doi.org/10.1139/cjfr-2020-0422

approximately 250 homes in the community. In addition to this, 9 homes were damaged, and several outbuildings were lost to the fire. (MNP LLP, 2020)

In 2016, the Fort McMurray wildfire was one of the most devastating and costly extreme weather events in Canadian history and is intimately linked to climate change. Costing the country more than $4 billion in losses, the fire destroyed 2,400 buildings, and caused over 80,000 people to be evacuated (CICC, 2020). Other similar extreme fire events and their impacts on buildings and homes are shown in Figure 10 below.

Year	Wildfire/Event	Comments
2015	**2015 Fire Season**	Early spring fire season. One of the highest number of wildfires on record. Evacuations in Northwestern Alberta.
2011	**Flat Top Wildfire Complex**	Early spring fire season. Wildfires burned into the Town of Slave Lake and nearby communities. A total of 510 homes and non-residential buildings were destroyed. Estimated insurable losses of over $700 million.
2001	**Chisholm Wildfire**	Spring fire season. One of the most intense wildfires recorded world-wide, in terms of energy release. The fire destroyed 10 homes, a trapper cabin, and 48 outbuildings.
1998	**1998 Fire Season, Virginia Hills and Mitsue Wildfires**	Early spring fire season experienced, similar to the 2015 fire season. Extensive loss of productive forest and oil/gas production. Evacuations in central Alberta.

Figure 12: Summary of Previous Spring Wildfires and Events in Alberta, Canada. (MNP LLP, 2017)

Local example

Recently in 2023, Strathcona County saw two simultaneous emergency evacuation notices with a fire burning along Township Road 534, and a second fire just south of Township Road 520. Residents were evacuated overnight and came back the next day to an estimated 1,700 metres by 800 metres burned in the first fire and 2,900 metres by 800 metres burned in the second. 18 properties reported damages such as the loss of two sheds, as well as damages to four holiday trailers, a Quonset, two cube vans, five vehicles, and two quads front entry gates, fences, and vinyl siding of structures.[15]

Direct Impact: Power and Communication Infrastructure

The physical impacts of wildfires can be severe, resulting in critical infrastructure and property damage as well as disrupted essential services. Power lines and transmission towers may be toppled during wildfires, causing power outages to essential infrastructure (e.g. hospitals or water treatment plants) and safety hazards that could cause more fires. These fallen power lines may hinder emergency services and firefighters' access to affected areas as well as their ability to access necessary resources during times of emergency.

Power may also be intentionally cut off as a precautionary measure but may result in a variety of unintended consequences for affected populations, particularly vulnerable populations (e.g. the elderly, medically dependent individuals, low-income individuals, etc.). (Evans et al., 2023)

In turn, telecommunications could be halted due to power outages, potentially causing evacuation complications, and leaving the community disconnected and unable to access the internet. For example, in 2017, a cellphone tower near Ashcroft Indian Band, British Columbia was damaged by wildfires, causing evacuation plans and missing person search efforts to be complicated and severely disrupted (Evans et al., 2023).

Direct Impact: Transportation Infrastructure

Despite their vital role in wildfire response, roads and other transportation routes may be forcefully closed during wildfire events, impeding evacuation, emergency services, and firefighting operations. There may also be an increased risk of landslides and flooding post-fire, potentially restricting road access further. This occurred in 2021, following the wildfires in Lytton, BC when a segment of the Trans-Canada Highway was temporarily closed due to landslides (Evans et al., 2023).

During the same event in Lytton, CN and CP rail lines were temporarily shut down and suffered disruptions as the fire spread close to the rail lines. Rail lines that transport goods between the Port of Vancouver and the interior of BC were also operating at reduced capacity resulting in a reduction in critical transport links for these materials (Sexton, 2021). CN has identified wildfires as a major climate-related concern for the railroad industry due to such service disruptions as well as damage to wooden bridges (Andrey et al., 2014).

Indirect Impacts

The increasing frequency of forest fires will pose a variety of risks to the forest industry and subsequent industry offshoots, buyers, and consumers. Forestry operations will be severely disrupted in affected areas and the amount of timber supply available will decrease, affecting forest-dependent workers, economies, and sawmills. This in turn is expected to cause lumber prices to increase, affecting the construction industry, homebuilding, and housing affordability. This inflation has already occurred in June and July of 2023 during the extensive wildfire season, where Canadians saw an increase of nearly 20 percent in the price of lumber futures. Not only will it cause prices for homeowners to increase, but trade companies as well, creating supply chain issues and transportation disruptions of forest products. For example, in the second quarter of 2023, Canfor reported losing $44 million partly due to wildfires (Lindsay & Pelai, 2024).

Following wildfire events, runoff carries natural and unnatural contaminants into the water such as ash, debris, phosphorous, or carbon, resulting in challenging and costly water treatment processes. For example, Fort McMurray's water treatment costs approximately doubled after the 2016 wildfire due to increased contamination in the Athabasca River. The contaminants pose a strain on the infrastructure and water supply quantity (Hantiuk, 2023). If such extreme weather events occur back-to-back, frequent periods of high demand will stress water treatment infrastructure and systems may not be able to sufficiently replenish depleted water in the reservoir (Warren & Lemmen, 2014). Wildfires also reduce the amount of water transported from upstream forests and seasonal water flows, thus affecting water allocation and the amount of usable water available to the public during periods of high demand (Robinne et al., 2020).

Contaminants may also threaten the health of surrounding ecosystems due to cascading effects such as algae blooms that can contaminate water further and even pose health risks (Hantiuk, 2023). Overall indirect effects can last for several decades and include drinking water pollution, reservoir sedimentation, flash floods, and reduced recreational benefits from rivers (Robinne et al., 2020).

Financial Costs

Over the previous 10 years, Canadian wildland fire management agencies have routinely invested between $800 million to $1.4 billion every year to protect critical infrastructure. However, these costs pale in comparison to damages incurred by wildfires (Natural Resources Canada, 2024). This has resulted in an average of $1 billion spent annually on fire suppression from 2010-2020. If total fire damage and indirect environmental, social, and economic costs are included in this summation, this number rises significantly to $2 - $30 billion every year, nationally.

In the near future, Canada's fire suppression budget will need to be doubled by 2040 to ensure the same amount of protection as the frequency and severity of wildfires are projected to increase. In contrast to suppression costs, proactive, preventative wildfire risk reduction and emergency preparedness measures often constitute less than 10% of total fire management costs (Evans et al., 2023).

It is also to be noted that water treatment complications may also arise following wildfire activity, causing costly, difficult, and lengthy disruptions that can last for decades. Water treatment costs will increase (e.g. increased use of chemicals) even if existing systems can handle the impacts of extreme weather events, however, some infrastructure may also need to be upgraded if water treatment systems are not capable of handling the effects of wildfires. For example, in Canada, one large, severe wildfire event might cause drinking water production costs to increase by $13 million to nearly $140 million (Robinne et al., 2020; Warren & Lemmen, 2014).

The Fort McMurray wildfire of 2016 resulted in roughly $4 billion in insured losses and has since been considered the largest and most costly extreme weather event in Canadian history (CICC, 2020). If indirect factors are included such as total property and infrastructure damage ($3.7 billion), business disruption ($458 million), lost oil sands production ($1 billion), provincial disaster recovery efforts ($647 million)[16], lost provincial royalties and taxes ($300 million), and other economic losses ($1 billion), total losses have been estimated to be nearly $11 billion. This amount equates to 3.5% of Alberta's GDP or approximately 1.5 years of lost provincial economic growth (CICC, 2020).

Local examples:

At a local level, in 2018, fires blazed in Strathcona County during the summer months and destroyed roughly 680 hectares of land. In total, the fires are estimated to have cost the county between $1 million and $2 million. Although no homes were lost, other infrastructure and utilities were affected such as power lines.[1] Additionally, on the afternoon of May 3, 2009, Strathcona County Emergency Services responded to a major fire in north Strathcona. In total, the fire is estimated to have impacted an area of over 8,500 acres of land; 14 times the size of the fire which occurred in 2008. It briefly crossed the North Saskatchewan River into Sturgeon County and incurred a total cost to Strathcona County of approximately $4.7 million (Strathcona County, 2010).

IMPACTS ON HEALTH AND SAFETY

Relevant Localized Impact

Impact #24: Increase in frequency, severity, and length of wildfires leading to health and safety concerns for outdoor workers and the public due to poor air quality, poor visibility (i.e. traffic accidents)

Direct Impact: Physical Health

Wildfires can significantly impact air quality in surrounding communities affected by the fires, as well as cause long-range transport of pollutants and smoke (Warren & Lemmen, 2014). As wildfire smoke is composed of fine particulate matter and toxic gases, inhalation of smoke allows these particles to enter the lungs and bloodstream, leading to various respiratory impacts such as shortness of breath, respiratory tract burns, increased infant mortality, worsening of chronic diseases (e.g. asthma, chronic obstructive pulmonary disease (COPD), ischemic heart disease, etc.), and increased risk of cardiovascular diseases.

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[16] Press, T. C. (2017, January 17). Costs of Alberta wildfire reach $9.5 billion: Study - BNN Bloomberg. BNN. https://www.bnnbloomberg.ca/costs-of-alberta-wildfire-reaches-9-5-billion-study-1.652292

Other health impacts have been reported such as radiant heat injury, dehydration, and heat exhaustion (Warren & Lemmen, 2014; CICC, 2021).

Additionally, these toxic smoke and ash particles may enter surface waters, thus contaminating local drinking water sources which can increase the risk of cancer. According to Health Canada, short-term exposure to wildfire smoke between 2013 to 2018 can be linked to approximately 240 premature deaths each year, while long-term exposure may have contributed to up to 2,500 premature deaths per year (Evans et al., 2023).

Burns, physical trauma, motor vehicle crashes, and asphyxiation may also occur due to exposure to flames and heat, falling infrastructure and trees, and emergency evacuations and response. Studies have also shown that extreme weather events and natural disasters, such as wildfires, may also lead to an increase in domestic violence and risk of assault (CICC, 2021).

Direct Impact: Mental Health and Wellbeing

Natural disasters such as wildfires can be traumatic and may cause mid- to long-term impacts such as mental exhaustion, anxiety, depression and post-traumatic stress disorder (PTSD), and, in some cases, suicidal thoughts. This can be largely due to the destruction and loss of personal property, friends, relatives, homes and livelihoods, the transformation of familiar places and ecosystems, the threat to the community's safety, and alterations to one's economic security. These physical and mental health challenges are particularly felt by firefighters who are exposed to such risks exceedingly more so than the general population (Warren & Lemmen, 2014; CICC, 2021).

During such events, individuals may face anxiety and PTSD during evacuation, particularly if extreme fire weather events have impacted them in the past or if community members are separated by significant distances and lengthy time frames. Particularly, evacuations may adversely affect Indigenous Peoples, bringing back historical trauma originating from past interference from the Canadian government and forced relocations (Evans et al., 2023). In Alberta, recent research has demonstrated significant cumulative mental health impacts suffered by residents exposed to multiple natural disasters (e.g., fire, flood) in Fort McMurray, who experienced elevated and compounding instances of increased anxiety, depression and post-traumatic stress disorder (Agyapong et al., 2022). Concerningly, mental health impacts were especially high and worsened over time in young people who experienced one or more of these events (Brown et al., 2021).

Indirect Impacts

The County may experience significant administrative strain due to wildfire events and the subsequent demand on health and emergency services. Furthermore, when whole communities need to be evacuated and require post-event support, resources, and services, municipalities will likely experience a surge of appeals, demands, and departmental strain (Warren & Lemmen, 2014).

Water service and source water quality may be negatively impacted by the spread of wildfires as increased turbidity in surface water may complicate and compromise disinfection processes and produce trihalomethanes which is a disinfection by-product that is proven to cause cancer (Patrick, 2018). In addition to turbidity, ash, nutrients, heavy metals and toxins, and sediments may be washed into streams and pose problems for drinking water production. Mercury contamination is a particular concern after wildfires as it may be re-emitted in large amounts from plants and leaves when deposited in nearby bodies of water. This mercury-rich plant matter is then bio-accumulated in the food web, thus exposing humans to higher-than-normal mercury levels through fish consumption (Robinne et al., 2019). In addition to natural materials, human-made materials may be washed into nearby bodies of water, and when burned, the chemicals in this ash can be transported into the water and can cause serious health problems (Climate Atlas of Canada, 2019a).

Food and water security may be severely impacted by wildfires through the contamination of drinking water sources and devastation of wild plants, animals, and crops that certain communities rely on for sustenance (CICC, 2021). In particular, Indigenous communities are disproportionally impacted by these effects, as extended summers and increased wildfires alter feeding grounds, shift the distribution and abundance of caribou populations, and thus reduce one of the community's vital traditional food sources (Warren & Lemmen, 2014). Indigenous communities are also 30% more likely to be evacuated during wildfires than other non-Indigenous communities (Evans et al., 2023).

Financial Costs

Extreme fire weather can result in significant public health costs and impacts, including direct medical expenses, or indirect costs such as lost productivity. Acute, short-term impacts such as medical treatments or reduced productivity may cost anywhere from approximately $410 million to $1.8 billion annually in Canada. Long-term, chronic impacts, however, can raise this estimate substantially to $4.3 billion to $19 billion per year. These estimates are based off observed decreased air quality (wildfire-$PM_{2.5}$) health impacts but may be greater if mortalities and other health afflictions are considered financially (Matz et al., 2020; Sawyer et al., 2023). From 2013-2015 and 2017-2018, wildfire-$PM_{2.5}$ health impacts for Edmonton, Alberta specifically are valued at $350 million (Matz, 2022). By the year 2090, Neumann et al. (2021) estimate that wildfire-attributable $PM_{2.5}$-related mortality costs could increase from $29 billion to $36 billion (2015 USD) which is nearly $38 billion to $46 billion (2015 CAD) (Grant & Runkle, 2022).

For example, Chisholm, Alberta suffered from a wildfire in 2001, destroying 116,000 hectares of land and burning several buildings for a week straight. The blaze caused significant long-distance smoke transport, and PM levels well exceeded Canada's air quality guidelines, causing a variety of health risks for many regions throughout Alberta. A study estimates that the health impacts of the fire and smoke cost the province between $9 million and $12 million due to increased mortality risk, lost wages and productivity, restricted activity days, and short-term respiratory issues experienced by those who were affected by the reduced air quality (University of Alberta, 2006).

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