Disaster Risk Report 2022

Calgary Emergency Management Agency

July 11, 2022

Acknowledgements

The Calgary Emergency Management Agency (CEMA) would like to thank all stakeholders who provided time, resources, and subject matter expertise to the risk assessment process.

The Disaster Risk Assessment (DRA) methodology utilized for this project was developed based on third-party content from the following organizations, policies, and standards:

- Australian Government Attorney General's Department
- Federal Emergency Management Agency (FEMA)
- ISO 31000:2009 Risk Management
- The City of Calgary Integrated Risk Management Policy and Framework

Disclaimer

Cover photo: Neil Zeller

Chief's Message

Sue Henry
Chief, Calgary Emergency Management Agency

On behalf of the over 60 agency members that make up the Calgary Emergency Management Agency, I am pleased to introduce the 2022 Disaster Risk Report. This report summarizes the results of the 2021 Disaster Risk Assessment and would not be possible without the subject matter expertise of our agency members. I would like to thank all stakeholders who contributed to this report and continue to dedicate themselves to ensuring Calgarians are safe and resilient.

Raising awareness of local risks is critical to ensuring individuals, businesses, and communities are prepared. Calgary is located in a very active area for severe weather and Calgarians have experienced numerous impactful events over the years. Climate change is expected to exacerbate many of these hazards, and more than ever we will need the collective efforts of all community members to remain resilient.

In the four years following the last Disaster Risk Report in 2018, Calgary has endured even greater numbers of catastrophic events and losses from disasters – including the most impactful event since World War II. Now entering its third year, the COVID-19 pandemic has had a significant impact on Calgarians' health and the local economy. The size and scale of the pandemic will have lasting repercussions on local governments and public expectations – many of which we still don't fully understand. The increasingly interconnected and globalized world has made these types of cascading events more likely: hazards that don't adhere to strict geographic boundaries – meaning a risk anywhere becomes a risk everywhere.

Calgary has maintained its role as Canada's disaster hotspot – experiencing one of the worst natural disasters in Canadian history in 2020. The June hailstorm caused widespread and lasting damage to the northeast quadrant of the city. Insured losses were estimated to be over $1.2 billion and total economic losses were orders of magnitude higher. In June 2021, the city endured an historic heat wave with five days in a row above 30°C and two days reaching 36.3°C (the second highest all-time recorded temperature for Calgary). Alberta experienced new summertime highs for energy consumption, water demand spiked, and there were significant public health impacts – including fatalities. These types of events are costing Calgarians over $500 million annually in insured losses.

As we release the 2022 Disaster Risk Report, the case for disaster risk reduction has never been clearer. My hope is that this report serves as a guiding framework to support investment and prioritization of proactive mitigation and preparedness measures to reduce the impacts of disaster events on Calgarians.

Contents

Executive Summary

Disaster losses continue to increase

…Globally

$302 billion

Average economic losses per year for the last 10 years (10% above previous decade) [1]

…Nationally

$2.56 billion

Average insured losses per year for the last 10 years (245% above previous decade) [2]

...and in Calgary

$538 million

Average insured losses per year for the last 10 years (207% above previous decade) [3]

Calgary is Canada's disaster hotspot in both frequency and severity

1 out of 7 catastrophic loss events in Canada since 2010 has impacted Calgary (insured loss >$25 million) [4]

50% of the events with over $500 million in insured losses that have occurred in Canada this century have impacted Calgary [5]

We've assessed our risks

65 local hazards and threats analyzed

16 High Risks identified as priorities for action

Natural: Blizzard, Extreme Cold, Flood (Bow River), Flood (Elbow River), Heavy Rainfall, Hydrological Drought, Pandemic, Tornado, Winter Storm

Technological: Critical Infrastructure Failure, Dam Breach (Bow River), Dam Breach (Elbow River), Rail Incident

Human-induced: Civil Disobedience, Hostage Incident, Mass Casualty Attack

…and understand the risk drivers

Urbanization has increased the exposure of people, property, wealth, and livelihoods to hazards – leading to a substantial rise in disaster losses

New extremes and global Black Swan events challenge traditional conceptions of emergency management and require new methodologies to assess and manage future risk

Climate change creates uncertainty and increases the frequency, variability, and intensity of some hazards

Interconnectivity and interdependency of our modern world leaves systems vulnerable to cyber-attacks, supply chain disruptions, cascading impacts, and systemic risks

Aging infrastructure, outdated building standards, and inadequate investment in resilient mitigation leaves our last line of defence weakened - exacerbating all other risk drivers and leaving us vulnerable to future extremes

Sociodemographic conditions and enduring social inequities increase vulnerability to disasters

We know what works

Up to $6 in savings for every $1 invested in disaster mitigation

Nationwide average benefit-cost ratio for hazard mitigation (US National Institute of Building Sciences, 2021) [6]

…but we still have more to do

58% Insurance protection gap

Average difference between total economic losses and insured losses in the Americas since 2000 [7]

$30 - $60 billion estimated annual damages due to climate change in Canada by 2050s (Public Safety Canada, 2019) [8]

The Case for Disaster Risk Reduction

What can we do today to plan for tomorrow?

The path forward

Canada is a signatory to the United Nations Sendai Framework for Disaster Risk Reduction. This global agreement establishes a shared roadmap to reduce the risk of human-induced, natural, and technological disasters by focusing collective efforts on increasing societal resilience in the areas of capacity, exposure, and vulnerability.

Four priorities have been identified:

- Understanding disaster risk
- Strengthening disaster risk governance
- Investing in disaster risk reduction
- Enhancing disaster preparedness

These priorities provide strategic direction to the work of the Calgary Emergency Management Agency and are embedded in the Comprehensive Emergency Management Model.

Benefits of Disaster Risk Reduction

Disaster Risk Reduction focuses on preventing new risk, reducing existing risk, and managing residual risk in order to increase the resilience of people, communities, infrastructure, natural environments, and systems. At its core, Disaster Risk Reduction is focused on proactively managing risk in all its forms rather than only reactively managing consequences.

Some of the benefits include:

- Saving lives and reducing negative health outcomes
- Reducing economic losses and limiting business interruptions
- Reducing future needs for response and recovery
- Strengthening community partnerships and improving quality of life
- Protecting natural assets and ecological systems
- Fostering economic growth and future-proofing communities (ex. build back better)

Mitigation saves

The US National Institute of Building Sciences conducts one of the most detailed benefit-cost analyses on disaster mitigation. They've found that savings vary depending on the hazard and geographic location but the average benefit-cost ratio across all mitigation types is 6:1. The analysis was organized within four main mitigation strategies: adopting and strengthening building codes; upgrading and retrofitting existing buildings; improving transportation, telecommunications, power, water, and other lifeline utility systems; and public-sector investment in mitigation since 1995. A report from Public Safety Canada (2019) found similar results in Canada. For every $1 invested in flood mitigation efforts, $7 to $10 (CAD) can be saved in post-flood recovery costs.[9]

	Adopt code	Above code	Building retrofit	Lifeline retrofit	Federal grants
Overall benefit-cost ratio	11:1	4:1	4:1	4:1	6:1
Cost ($ billions)	$1/year	$4/year	$520	$0.60	$27
Benefit ($ billions)	$13/year	$16/year	$2,200	$2.5	$160
Riverine flooding	6:1	5:1	6:1	8:1	7:1
Wind	10:1	5:1	6:1	7:1	5:1
Earthquake	12:1	4:1	13:1	3:1	3:1
Wildland urban interface fire	N/A	4:1	2:1	N/A	3:1

**Lifelines are a term used to describe utilities and transportation infrastructure.*

Source: National Institute of Building Sciences 2019 (in USD) [10]

Using Disaster Risk Data to Build Resilience

Identifying, understanding, and raising awareness of disaster risks are fundamental disaster management activities. They are the foundation upon which proactive risk reduction and resilience-building measures are grounded.

How can this report help strengthen resilience?

This report helps quantify and qualify the underlying factors driving disaster risk in Calgary. The analysis in this report can be used as a decision support tool to inform business plans, emergency management strategies, disaster mitigation investment, community preparedness activities, municipal planning processes, and other risk reduction practices.

Identify trends and risk factors

- Explore societal trends contributing to disaster risk in Calgary
- Analyze underlying risk factors in the dimensions of exposure and vulnerability
- Analyze local damage and loss trends
- Understand the influence of climate change and other risk drivers on local hazards

Raise awareness and educate

- Improve understanding of local hazards and threats
- Ensure a common understanding of disaster risks amongst key decision-makers in Calgary
- Support actions taken to prepare individuals, families, and communities

Support investment and planning decisions

- Identify the relative order of priority for the treatment of local risks
- Provide data and analytics to support investment in risk mitigation and adaptation
- Support operational and business continuity planning
- Provide risk analysis to augment planning and development processes

Flood resilience in Calgary

Following the devastating 2013 flood, The City of Calgary formed an independent Expert Management Panel on River Flood Mitigation. The panel was focused on understanding flood risk in Calgary, analyzing the underlying factors that contribute to that risk, and identifying targeted investments to reduce the risk of future events. Recommendations from this panel have been adopted into the Calgary Flood Resilience Plan and are organized into three main focus areas:

- Upstream flood protection
- Community-level flood protection
- Property-level flood protection

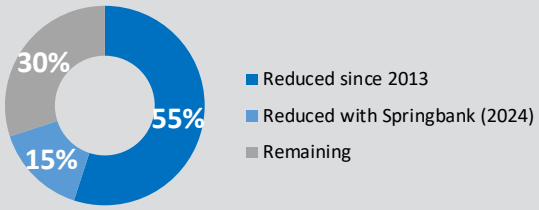
Implementing the plan

Since 2013, The City and Government of Alberta have invested over $150 million in new flood mitigation infrastructure. This has included:

- Flood barriers in vulnerable communities
- Higher gates at the Glenmore Dam
- Seasonal operational agreement with TransAlta to manage flows on the Bow River
- Springbank Off-Stream Reservoir (2024)
- Non-structural measures focused on flood mapping, policy, regulations, forecasting, and emergency response planning

Reducing flood risk

The mitigation measures implemented since 2013 have reduced flood risk by 55 per cent, which equals a reduced risk of flood damages of approximately $93 million every year. Once the Springbank Off-Stream Reservoir is complete, flood risk in Calgary will have been reduced by 70 per cent.



Estimated flood damages with and without mitigation:

	Avg. annual damage	1:100 flood
Current mitigation	$75 million/year	$2.2 billion
Without mitigation	$168 million/year	$3.3 billion
Savings	$93 million/year	$1.1 billion

Average annual damage estimates the costs of flood damage in a given year, based on the probability of different sized floods.

Understanding Risk

Risk is a function of hazard (severity and frequency); exposure (people, assets, and livelihoods); and vulnerability (socioeconomic, demographic, physical, or environmental).

The City of Calgary completes a Disaster Risk Assessment in order to understand local risks and develop strategies to reduce and manage the impact of future events. The assessment is updated annually and a detailed Disaster Risk Report is released every four years in alignment with the municipal budget cycle. The 2022 Disaster Risk Report summarizes the results of the 2021 Disaster Risk Assessment.

Scope

The Disaster Risk Assessment adheres to international risk management principles and standards but is limited in its focus to ***disaster risks***. The results of the Disaster Risk Assessment and other information outlined in this report are not intended to be predictive of future events but they will inform decision-making related to risk treatment, emergency management, planning, research, and investment.

Situation

Due its geographic location in the foothills of the Canadian Rockies, Calgary experiences a range of severe weather phenomena and other natural hazards. It is also the largest metropolitan area in Alberta, which leaves it vulnerable to additional human-caused and technological hazards that exist in modern urban centres. These hazards can cause a range of potential impacts, including:

- Fatalities, injuries, and illness;
- Direct and indirect economic losses;
- Environmental damage;
- Social and cultural losses; and
- Interruptions to the delivery of public services

Assumptions

The Disaster Risk Assessment is based on the following core assumptions:

- The risk assessment is limited to the city of Calgary and based on current data;
- The hazards being assessed are based on input from subject matter experts and include those that have impacted Calgary historically or are possible in the future;
- The hazards assessed are based on their most probable worst-case scenario;
- The risk assessment is a point-in-time measurement based on current conditions;
- The risk assessors only assessed hazards for which they are subject matter experts;
- The risk assessment relied on expertise, knowledge, historical records, future trends, and other data; and
- The risk criteria utilized to assess risk is relevant to the Calgary context (geography, population, infrastructure, environment, economy, etc.).

Risk assessment methodology

The City of Calgary utilizes an industry standard three-step risk assessment methodology to identify, analyze, and evaluate disaster risk (see Figure 1).

Risk Level

Risk Level is assessed by estimating the probable consequences of an event, projecting the current risk trend, and identifying the likelihood of the event occurring with all predicted impacts.

Risk Trend

Risk Trend is a modifier that is built into the risk assessment process in order to account for the dynamic nature of risk. This can include material changes to the specific hazard/threat or the human and natural systems to which they are exposed. Risk Trend can be scored as: Decreasing, Stable, or Increasing.

Likelihood

Likelihood is a measure of the probability that both the emergency event and all of the estimated impacts (e.g. deaths, injuries, costs, damage, etc.) will occur.

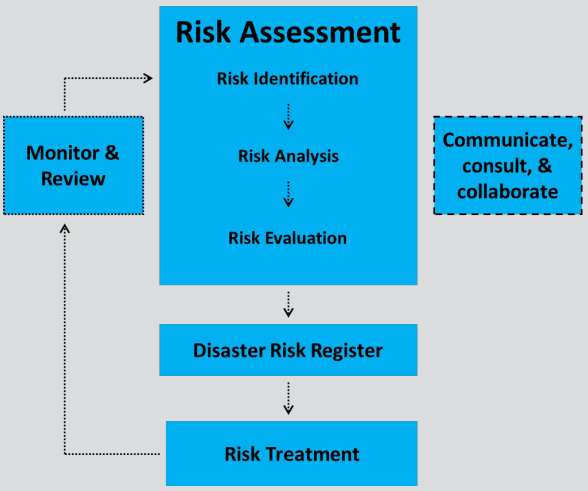
Consequence

Consequence is a measure of the predicted impact to people, economy, natural environment, social environment, and city government & services. It is estimated using the probable worst-case scenario event for the hazard or threat occurring in high-risk areas, during the high-risk season, and with all current controls in place. It subsumes assessment of capacity and vulnerability.

Figure 2: Consequence descriptions

People	Death, injury, or illness
Economy	Impact to economic activity, asset value, important industry, and supply chain
Natural Environment	Impact to ecosystems, species, and environmental values of interest
Social Environment	Impact to social fabric, community services, quality of life, and cultural assets
City Services	Impact to city government and service delivery

Figure 1: Risk assessment model



Roles and Responsibilities
The City of Calgary coordinates the Disaster Risk Assessment process, maintains the Disaster Risk Register, and reports on disaster risk. Subject matter experts and risk owners assess, manage, and treat risks associated to specific hazards and threats under their area of responsibility.

Risk Identification
Describing the hazard characteristics: source, duration, high-risk areas, high-risk seasons, impact, associated emergency events, existing controls, probability of occurrence, and historical events.

Risk Analysis
Identifying the potential consequences, determining the likelihood they will occur, assessing the effectiveness of existing controls, and determining the level of confidence in the analysis.

Risk Evaluation
Categorizing the hazards to determine the order of priority for risk treatment.

Risk Treatment
The partial or complete removal of a risk source or some improvement in the controls to modify the level of risk.

Monitor and Review
Implementing regular monitoring and reviews to account for material changes that affect the evaluation of identified risks as well as to identify the emergence of new risks.

Disaster Risk Register
A central repository and record of information for all significant hazards and threats in Calgary. It captures all of the relevant data, information, and analysis collected during the risk assessment process. It is updated annually.

Disaster Risk Report
A detailed report summarizing results of the risk assessment and identifying underlying risks drivers. It is released every four years in alignment with the municipal budget cycle.

Trends and Risk Drivers

Trends and risk drivers are observable patterns, changes, indicators, and signals that support a deeper understanding of how and why risk is evolving. They are informative rather than predictive. Further research may be required to fully understand their relationship to other contributing factors and influence on specific hazards, locations, and populations. The following represents trends we are monitoring that are anticipated to be the most impactful to Calgary's evolving disaster risk landscape over the next 10-15 years.

Urbanization

Nearly three in four Canadians now live in a large urban centre (population of 100,000 or more).[11] The Calgary Census Metropolitan Area has a population over 1.5 million and had one of the fastest growth rates in Canada between 2010 and 2020 (24 per cent).[12] The city is also expanding in total land area, growing 47 per cent since 2000.[13] The concentration of people, property, wealth, and livelihoods in urban environments increases exposure to hazards. The increasing geographic size of urban areas also makes them a larger target for severe weather systems and can lead to encroachment into new hazardous areas.

New uncharted extremes

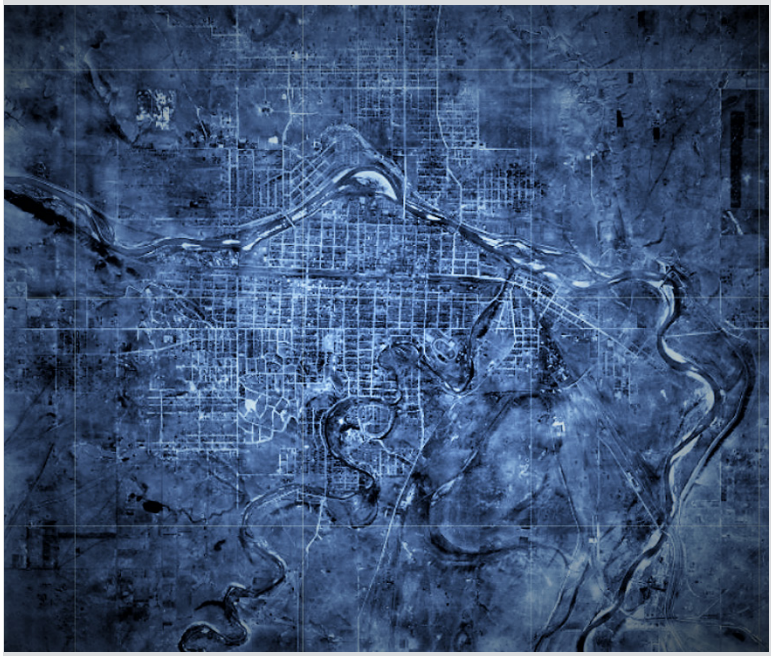
Recent events, such as COVID-19 and the 2011 Japanese earthquake, have taught us that historical antecedents are no longer relevant when assessing the risk and complexity of future disasters. These events can lead to cascading societal impacts that transcend borders and cause ripple effects across global economies. Backward-looking assessment and modeling of risk does not properly account for emerging cascading risk events, Black Swans, or the interconnected nature of the modern world.

Calgary's urban growth and density over time

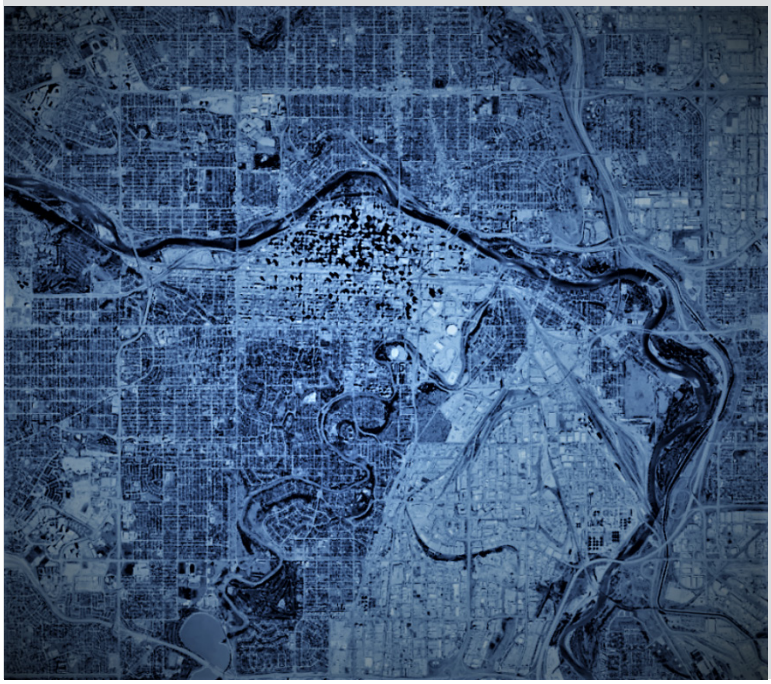
The two aerial photos below illustrate the considerable growth in Calgary's urban area over the last hundred years. This has included significant settlement and development within the floodplain. The river courses and associated flood hazard have remained mostly static over time but the buildup of human populations, livelihoods, and infrastructure exposed in the flood hazard area has dramatically increased the values at-risk to flooding.

The expansion of the city's land area and increased population density means that events experienced today of a similar magnitude and extent as those that may have had a limited impact historically, would now impact thousands of people and cause billions of dollars in direct and indirect damages.

Calgary city centre 1926:



Calgary city centre 2021:



Climate change

Canada is warming at nearly twice the global rate. Increasing global surface temperatures can lead to changes in the frequency, intensity, extent, duration, and timing of weather and climate extremes – resulting in costlier disasters in the future. It is estimated that severe weather insurance claims could more than double over the next 10 years in Canada; increasing from $2.1 billion per year to $5 billion per year.[14] Climatological events are also causing secondary impacts to regions far away from the hazard area. The wildfire activity in western Canada over the last few years has resulted in a significant increase in air quality warnings for Calgary during the summer months.

Interconnectivity

The modern world is increasingly interconnected, interdependent, and reliant on technology - increasing the risk of cascading events, systemic risks, and secondary impacts. The recent increase in cyber-attacks and the widespread disruptions to the global supply chain experienced during COVID-19 will define the borderless nature of risk in the future. Events experienced anywhere in the world can have cascading downstream impacts to Calgary's food systems, critical infrastructure operations, service delivery, and economy.

Aging infrastructure

Studies estimate that 13 per cent of Canada's core municipal infrastructure is in poor or very poor condition.[15] The state of infrastructure can negatively impact the resilience of populations exposed to hazards. A lack of investment in mitigation and resilient design has left communities unprepared. Existing building codes and standards may not provide the protection needed to mitigate future climate extremes. It is estimated that infrastructure failures linked to climate change could cost Canada $300 billion[16] over the next decade if no changes are made to building standards. These numbers could reach as high as $30 to $60 billion in damages annually by mid-century.[17]

Social determinants of health

The underlying sociodemographic factors in a community directly contribute to its vulnerability and capacity to withstand disaster. Income, education, job security, food security, housing, access to services, race, gender, disability, and other social determinants of health all factor into the different levels of resiliency experienced by individuals and communities at any given time.

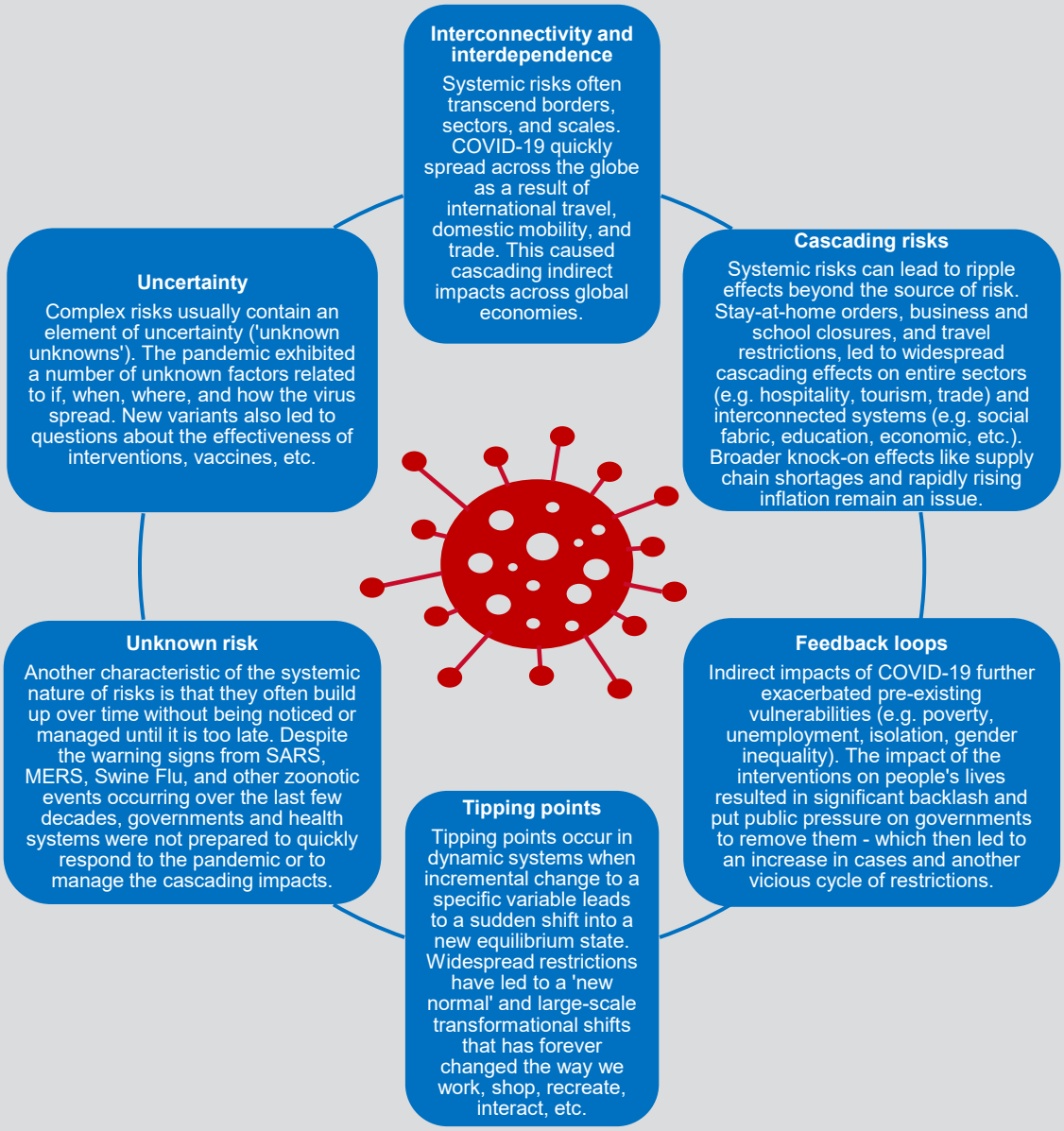
Increasing disaster losses

There has been a steady increase in disaster losses over the last forty years. This has largely been driven by the concentration of people, wealth, and livelihoods in urban centres – i.e. more people, who own more things, who live and work in high-risk areas. These losses are being exacerbated by a changing climate and are expected to increase significantly in the future without proper investment in adaptation and disaster mitigation.

Understanding Systemic Risk

Using the COVID-19 pandemic to illustrate the systemic nature of risk in the modern world

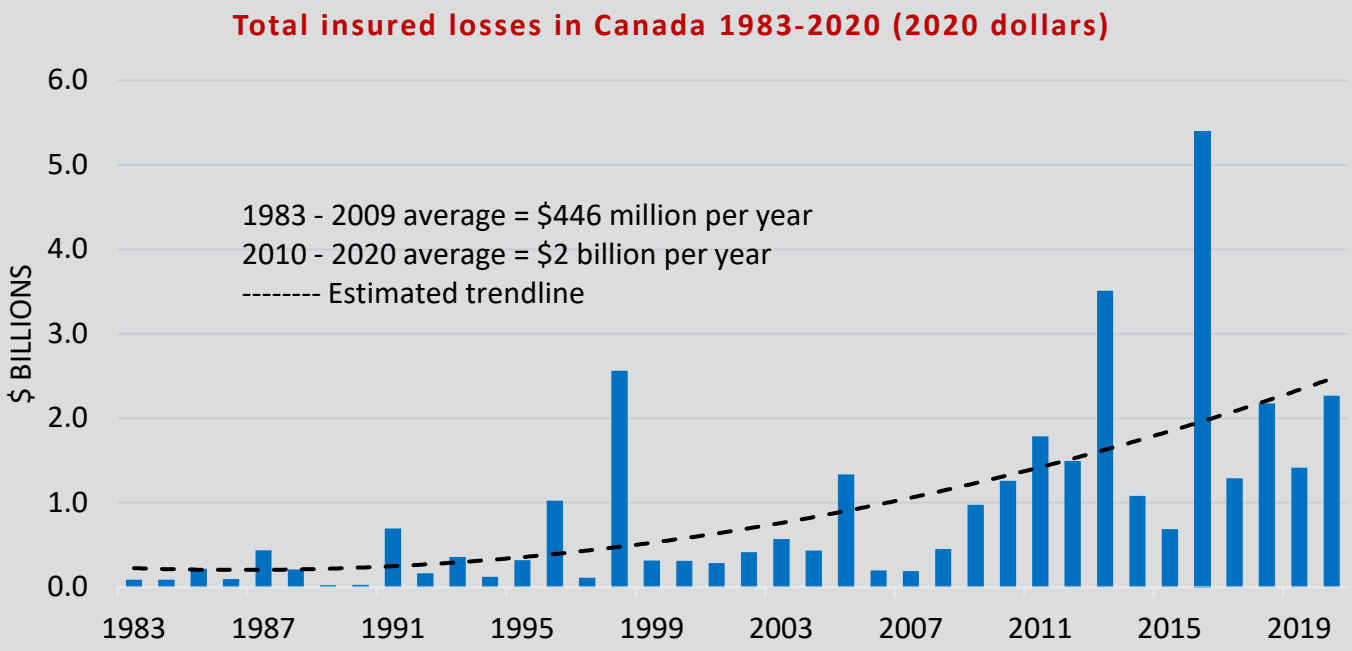
The COVID-19 pandemic exhibited a number of characteristics that are representative of the complexity and systemic nature of risk. As a result of globalization and technological advancements, the world is now an increasingly interconnected system of systems. While offering tremendous societal benefits, these changes also present new risks that need to be actively managed. Understanding the interrelationship between these factors is critical to reducing systemic risk in the future.



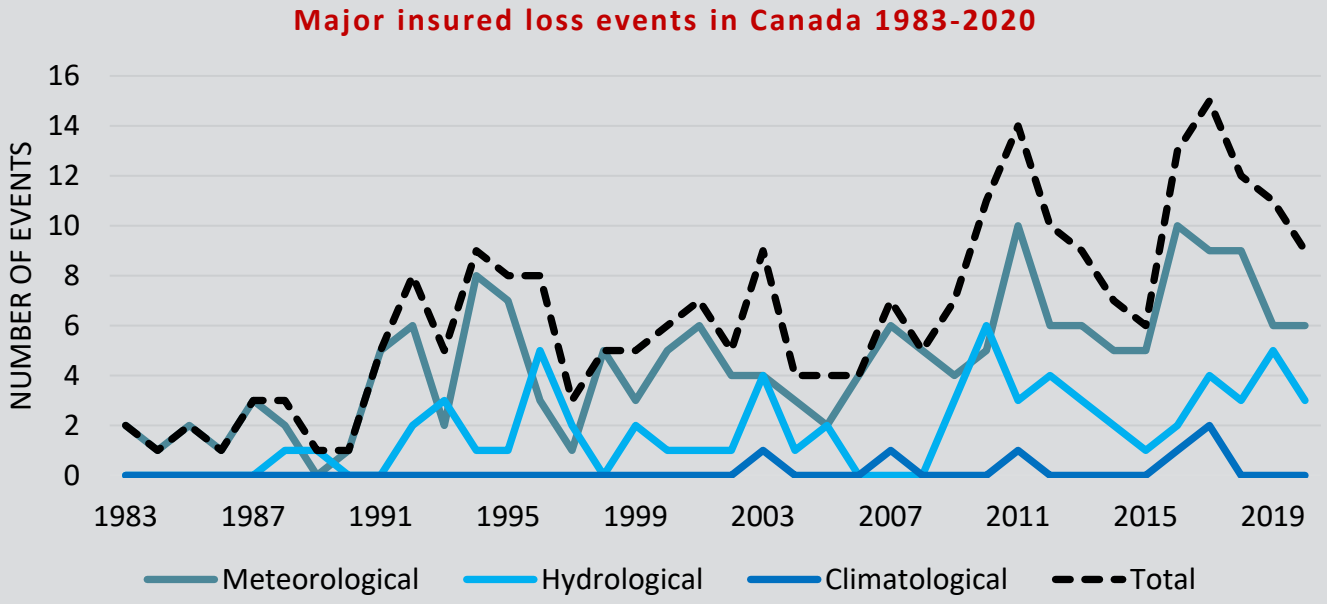
Source: United Nations Office for Disaster Risk Reduction (2022) [18]

Telltale Charts

Disasters are becoming more costly in Canada



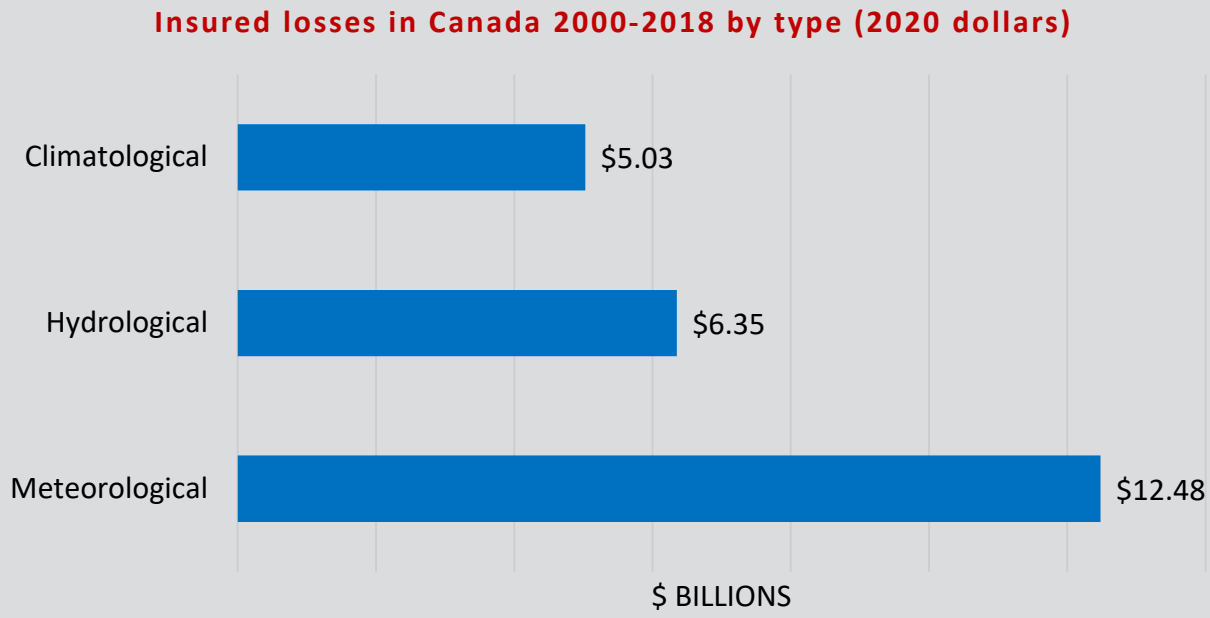
…and more frequent



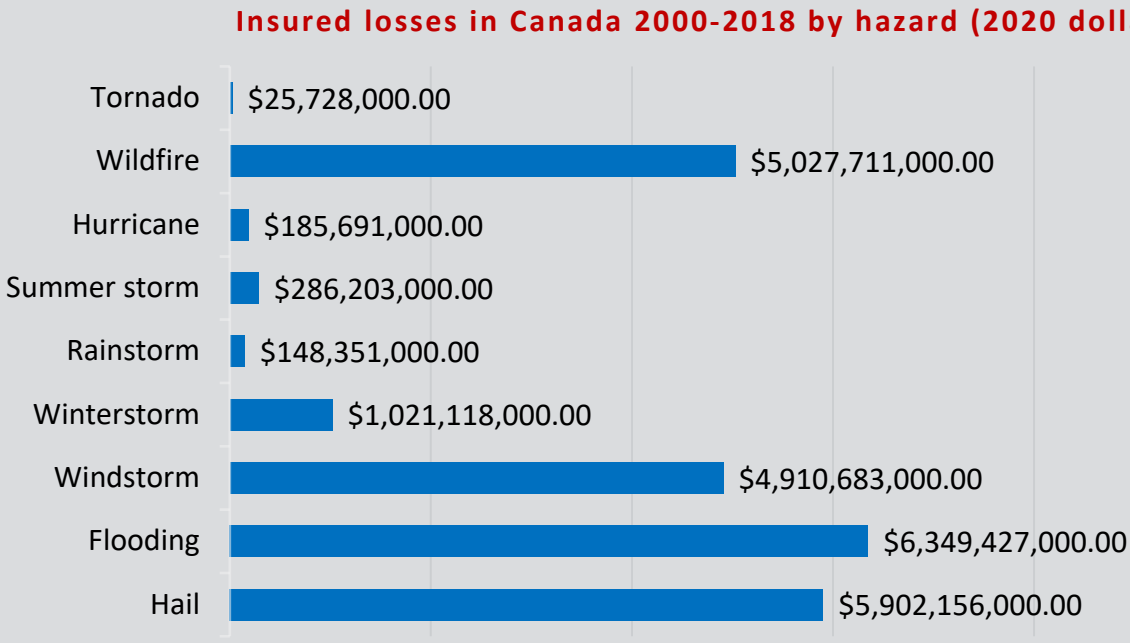
Source: Insurance Bureau of Canada (2021) [19]

Telltale Charts

Meteorological events account for the majority of total insured losses this century



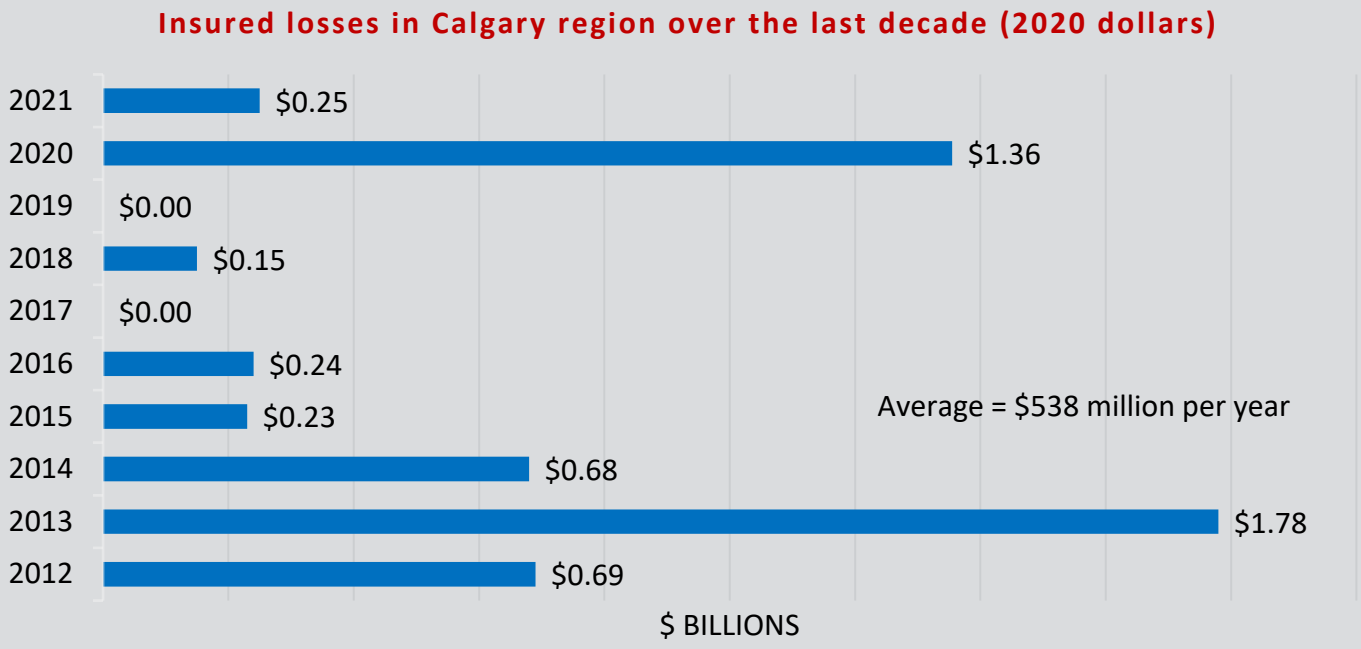
…but flooding remains the single costliest hazard nationally



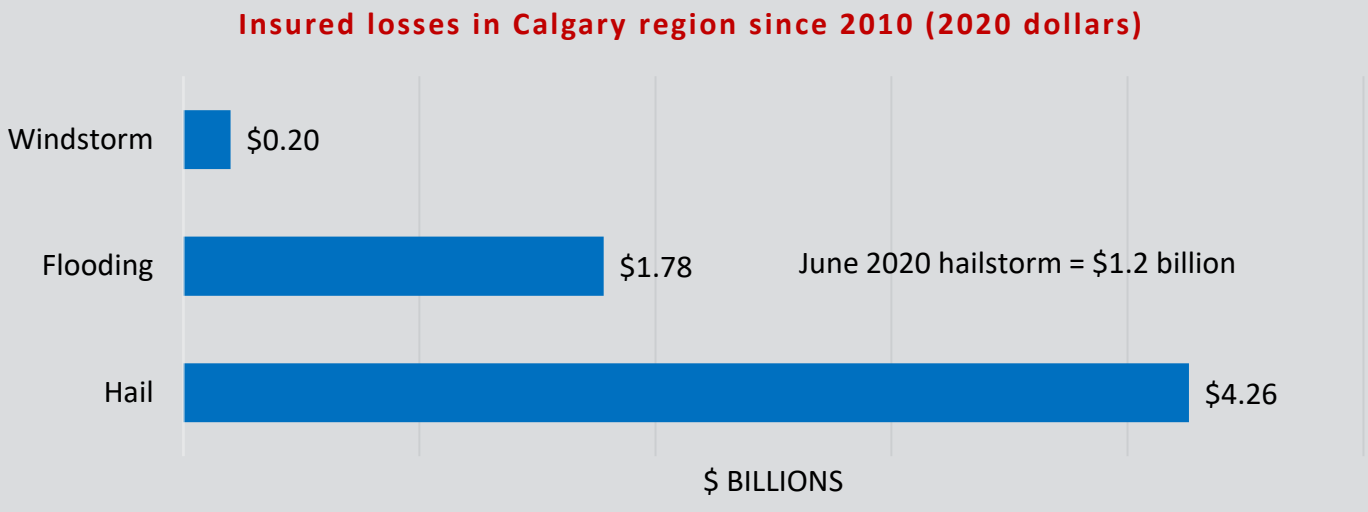
Source: Insurance Bureau of Canada (2021) [20]
**Final insured loss data for the years 2019 through 2021 is currently unavailable*

Telltale Charts

Six of the ten costliest disasters in Canadian history have occurred in Alberta. Calgary is Canada's disaster hotspot with annual losses within the region averaging $538 million over the last decade – approximately 25 per cent of the average annual losses nationally. Insured losses only represent 40-50 per cent of the total economic losses on average – meaning a significant cost is borne by both governments and individuals when a disaster occurs



…the majority of these losses are due to severe thunderstorms that produce damaging hail



Source: Insurance Bureau of Canada (2021) [21]

Climate Trends

How will climate change impact Calgary?

Climate risk assessment

The City of Calgary has undertaken a detailed climate risk assessment focused on identifying and understanding climate change impacts in Calgary. Eight climate hazards have been identified as priorities for action. They include: extreme heat, shifting seasons, drought, wildfire, heavy rainfall, severe storms, river flooding, and heavy snowfall. These hazards have been assessed and projected into the future to better understand the impact of a changing climate on their behaviour. In general, they are all expected to increase in frequency, duration, and severity in a changing climate - except for heavy snowfall, which will decrease as precipitation shifts from snow to rain in winter months. This could result in increased response and recovery costs; frequent interruptions to community services and businesses; impairment of critical infrastructure; environmental degradation; and negative physical and mental health impacts. It should be noted that not all extreme weather and climate events can be attributed to human-caused climate change. In many cases, they are a result of natural climate variability and some hazards simply require further study in order to fully understand the dynamic relationship. Regardless of the contributing factors, actions taken to mitigate and reduce these risks today will be critically important to managing them in the future.

Climate projections for Calgary

The following table provides a summary of the projected climate changes in Calgary for the 2050s and 2080s.

	1981 - 2010	2050s			2080s		
	Average	Low	Average	High	Low	Average	High
Annual maximum temperature	32°C	33°C	34°C	37°C	35°C	37°C	42°C
Growing season	124 days	146 days	154 days	167 days	160 days	174 days	186 days
Frequency of rainfall deficit (< 1mm)	55 years	-	28 years	-	-	18 years	-
% increase in heavy rainfall	-	-	28%	-	-	52%	-
Number of thunderstorms per year	22	29	34	38	30	39	43
Snowfall total	94 cm	58 cm	72 cm	88 cm	47 cm	60 cm	74 cm

Disaster Risk Assessment

A small risk assessment group comprised of subject matter experts applied the standardized risk assessment methodology to assess a total of 65 hazards and threats that have the potential to impact Calgary. The results are catalogued in the disaster risk register and assigned a priority that will assist decision-makers to determine which require immediate action, further analysis, or monitoring. Hazards and threats can be classified as:

Natural - associated with geophysical, meteorological, hydrological, climatological, biological, and extraterrestrial hazards
Technological - originating from technological or industrial conditions, dangerous procedures, infrastructure failures, or specific human activities
Human-induced - associated with police and security incidents

What are the highest risk hazards and threats in Calgary?

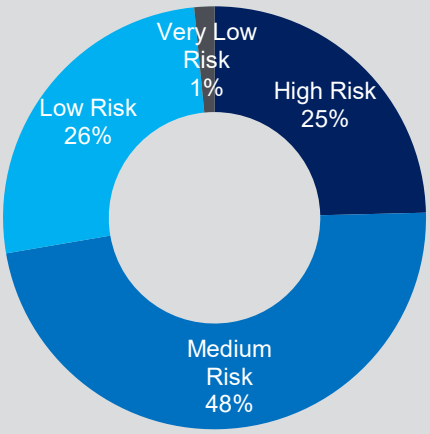
There are 16 hazards and threats assessed as High Risk that currently represent the most significant risk to Calgary and highest disaster management priority:

Natural Hazards		Technological Hazards	Human-induced Threats
Blizzard	Hydrological Drought	Critical Infrastructure Failure	Civil Disobedience
Extreme Cold	Pandemic	Dam Breach (Bow River)	Hostage Incident
Flood (Bow River)	Tornado	Dam Breach (Elbow River)	Mass Casualty Attack
Flood (Elbow River)	Winter Storm	Rail Incident	
Heavy Rainfall			

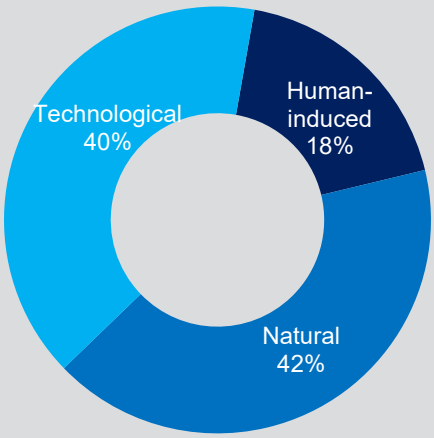
Overall Risk Summary 2022

The 65 hazards and threats assessed broken down by risk level and risk classification.

Risk Level



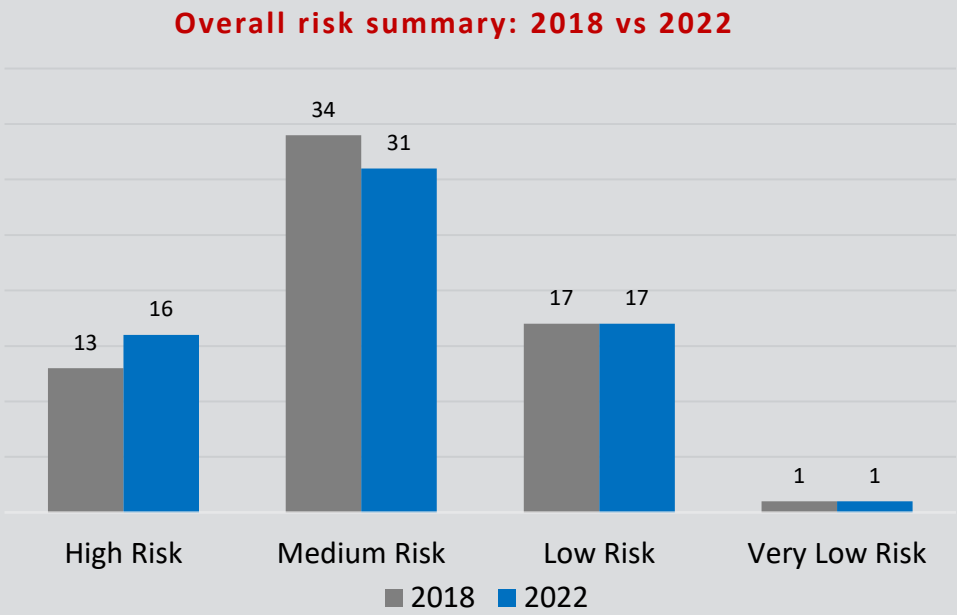
Risk Classification



Disaster Risk Assessment

What's changed since the last report?

The most significant change from the 2018 report is that there are now 16 High Risks versus 13 in 2018. New High Risks include: Civil Disobedience, Dam Breach (Elbow River), and Pandemic. The COVID-19 pandemic and numerous instances of civil disobedience over the last few years has resulted in a reassessment of their risk. Dam Breach (Elbow River) was elevated due to a reassessment of the economic impact of a probable worst-case scenario event. Refer to Appendix 1 for a summary of the assessed risk for all 65 hazards and threats.



What else are we monitoring?

Medium Risks that are currently trending upwards are monitored as they have the potential to become more severe due to a number of contributing factors, including: increased frequency and severity due to climate change; changes to the specific hazard/threat (i.e. volume of hazardous goods shipped by rail); or increased vulnerability within the built, environmental, economic, human, and political systems exposed to the hazard/threat.

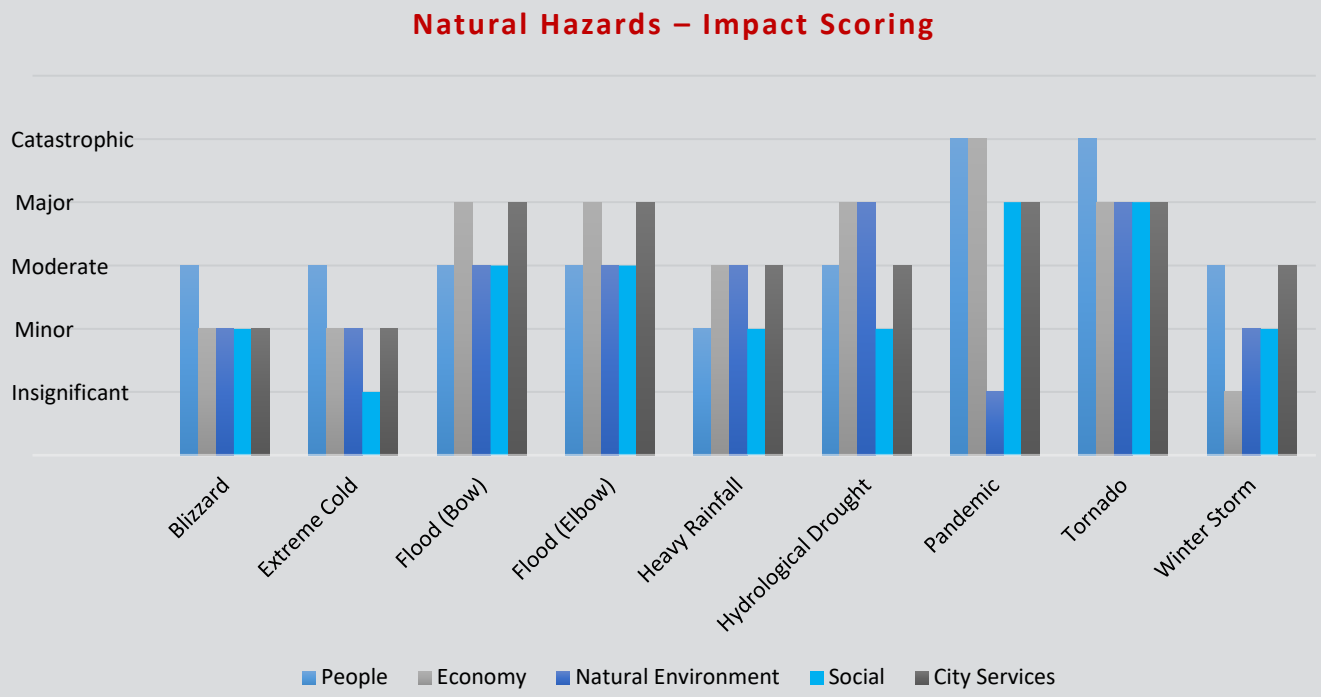
Medium Risks – Trending Upwards

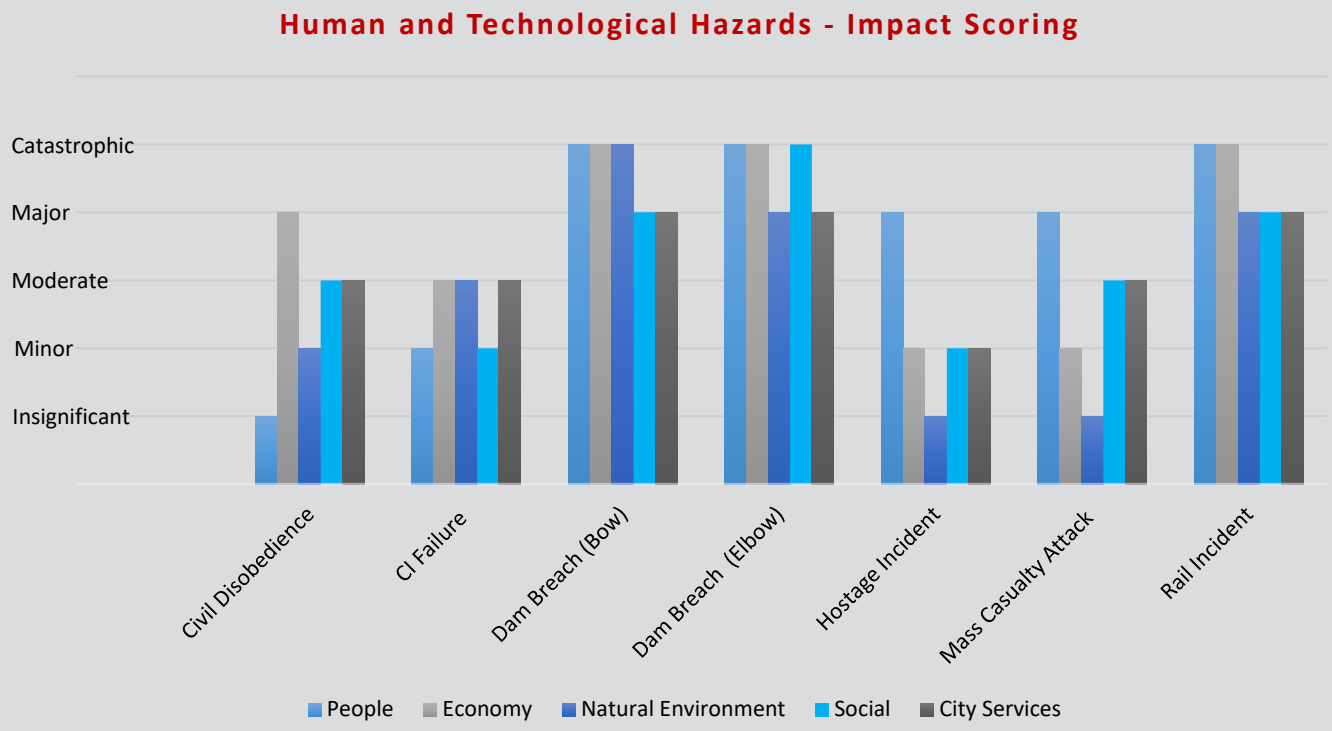
Natural	Basement Seepage Flooding Extreme Heat Extreme Solar Storm Major Solar Storm Poor Air Quality	Water Contamination (Forest Fires) Stormwater Backup Flooding Wildland/Urban Interface Fire Windstorm
Technological	Sanitary Failure (Lift Station) Supply Chain Interruption	Water Contamination (Distribution)
Human-induced	Active Shooter Incident Cyber Attack - Technology	Data Fraud/Theft

Disaster Risk Assessment

Analysis of the 16 High Risks

The following charts summarize the impact scores for the 16 High Risks across the five impact dimensions.





Hazard and Threat Correlation Matrix

The worst catastrophes are combinations of events where a primary trigger event causes secondary cascading effects - resulting in the consequences being worse than if they had happened independently. The potential for one hazard or threat to trigger or exacerbate the effects of another is captured in this matrix. The darker areas (3 and 4) are the most critical as they have the highest potential to induce cascading events. The scoring is based on historical events, expert feedback, and an analysis of plausible future scenarios.

Analysis

The correlation matrix illustrates the significant impact local hazards have on critical infrastructure and its importance to effective risk reduction. Critical infrastructure is the backbone of modern urban centres. Effective disaster response and recovery must be centred on building resilience into these systems, facilities, and services.

Secondary Cascading Impacts

Primary Trigger Event	Blizzard	CI Failure	Civil Disobedience	Dam Breach (Bow)	Dam Breach (Elbow)	Extreme Cold	Rail Incident	Flood (Bow)	Flood (Elbow)	Heavy Rainfall	Hostage Incident	Hydrological Drought	Mass Casualty Attack	Pandemic	Tornado	Winter Storm
Blizzard	1	2	0	0	0	1	2	0	0	0	0	0	0	0	0	1
CI Failure	0	4	0	2	2	1	2	1	1	1	1	0	1	0	1	0
Civil Disobedience	0	0	4	0	0	0	2	0	0	0	1	0	3	0	0	0
Dam Breach (Bow)	0	3	0	4	1	0	3	3	3	1	1	1	1	0	1	0
Dam Breach (Elbow)	0	3	0	1	4	0	3	3	3	1	1	1	1	0	1	0
Extreme Cold	1	3	0	1	1	0	1	1	1	0	0	0	0	0	0	1
Flood (Bow)	0	3	0	3	1	0	3	0	1	1	1	0	1	0	1	0
Flood (Elbow)	0	3	0	1	3	0	3	1	0	1	1	0	1	0	1	0
Heavy Rainfall	0	3	0	3	3	0	3	3	3	0	0	0	0	0	0	0
Rail Incident	0	3	0	2	2	0	4	1	1	0	0	0	1	0	1	0
Hostage Incident	0	1	1	1	1	0	0	1	1	0	1	0	3	0	1	0
Hyrdological Drought	0	2	0	1	1	0	0	0	0	1	0	1	0	0	0	0
Mass Casualty Attack	0	3	1	1	1	0	1	1	1	0	1	0	4	0	1	0
Pandemic	0	2	1	1	1	0	1	1	1	0	1	0	1	1	1	0
Tornado	0	3	0	1	1	0	3	1	1	0	0	0	0	0	1	0
Winter Storm	1	3	0	0	0	1	3	0	0	0	0	0	0	0	0	1

4	***Cascading potential:*** *an event of this type can potentially trigger other sub-category hazards/threats within the same category (i.e. human-induced or natural).*
3	***Strong potential:*** *an event of this type can potentially directly trigger an event of the second type.*
2	***Weak potential:*** *there is some potential for an event to contribute to the causal mechanisms that would trigger the occurrence of an event of the second type.*
1	***Indirect potential:*** *no mechanism to cause an event of the second type but the impact of second event would be worse due to resources already deployed and abilities to respond reduced.*
0	***No potential:*** *the two event types are uncorrelated and if they occurred coincidentally their consequences would be broadly the same as if they occurred independently.*

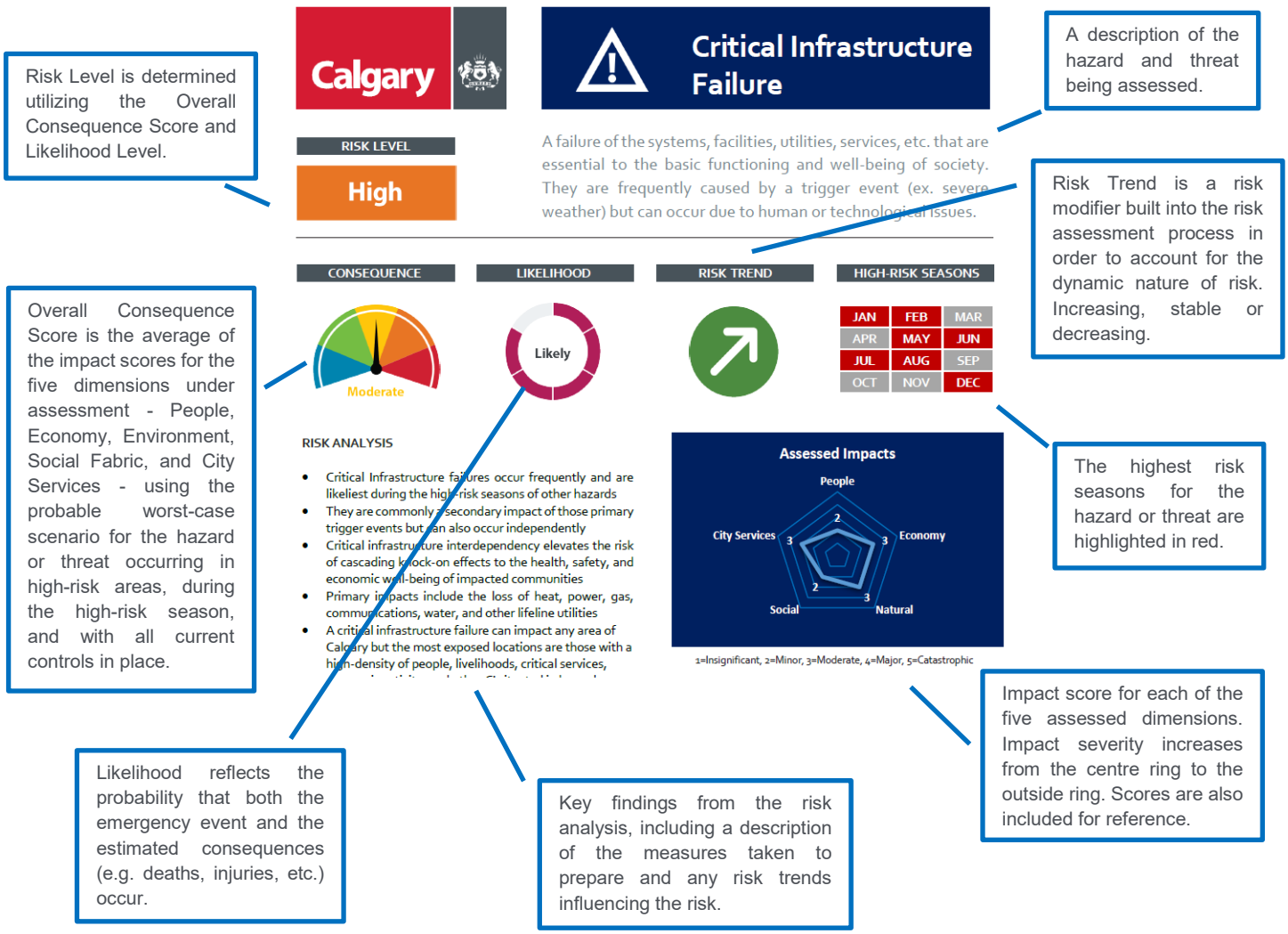
Source: based on work from the University of Cambridge [22]

Disaster Risk Profiles

The following sections provide individual risk profiles for the 16 High Risk hazards and threats that currently represent the most significant risk to Calgary. The Disaster Risk Assessment is a preliminary assessment intended to provide decision-makers with a general idea of the prioritization of risks. Detailed engineered assessments and analysis may be required for some risks prior to making final treatment decisions. Additional hazards and threats not discussed in detail within this document may currently represent less risk but this does not mean they pose zero risk. Please refer to Appendix 1 for a summary of the assessed risk for all 65 hazards and threats.

All hazards and threats have an active suite of controls in place to mitigate their impacts. These have been factored into the risk scoring in order to assess the residual risk of these events. Determining the likelihood of major disaster scenarios involving human actor(s) with malicious intent is very different from other threats/hazards (i.e. weather events). Please refer to the Police and Security section for considerations regarding their risk evaluation.

Reading the risk profiles



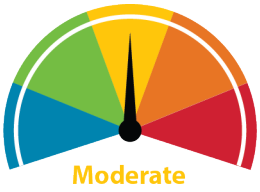
Blizzard

RISK LEVEL

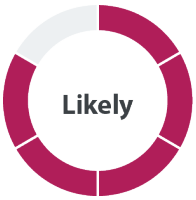
High

A severe winter weather event characterized by strong winds and falling or blowing snow that leads to widespread reductions in visibility. Blizzards can cause extremely hazardous travel conditions and will usually last for a few hours up to one day.

CONSEQUENCE



LIKELIHOOD



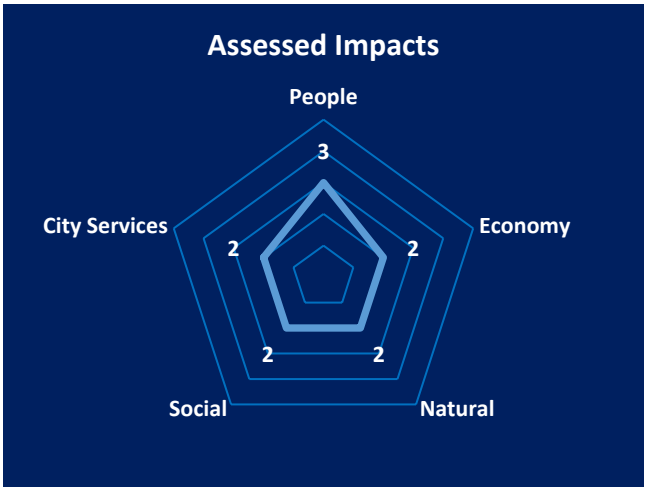
RISK TREND

HIGH-RISK SEASONS

JAN	FEB	MAR
APR	MAY	JUN
JUL	AUG	SEP
OCT	NOV	DEC

RISK ANALYSIS

- Blizzard conditions can form at any time during the winter months and typically occur every five years in Calgary
- Urban municipalities are most likely to be impacted in the transition from the urban environment to semi-rural or rural areas
- Highways and secondary roads represent the highest risk
- The primary impact of winter storms is on the health and safety of affected populations
- Injuries and death may occur from exposure and traffic accidents
- People experiencing homelessness and outside workers are particularly vulnerable as high-winds combined with cold temperatures speeds the rate of heat loss to the body; increasing the risk of serious health issues, such as frostbite and hypothermia
- Secondary knock-on effects include significant travel delays and rerouting



1=Insignificant, 2=Minor, 3=Moderate, 4=Major, 5=Catastrophic

PREPAREDNESS

- Early warning systems are in place to notify the public, emergency response personnel, and health providers in advance of winter storm events
- Agencies responsible for traffic safety have emergency plans and resources in place to respond when these events occur; including designated snow clearing routes

RISK DRIVERS AND TRENDS

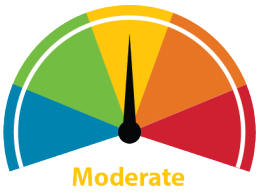
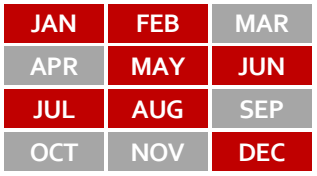
- Winter season will be shorter in the future but Calgary will continue to experience winter storm hazards
- Global warming increases the amount of energy available in the atmosphere to fuel severe storms, which may contribute to increased blizzard frequency and intensity

Critical Infrastructure Failure

RISK LEVEL

High

A failure of the systems, facilities, utilities, services, etc. that are essential to the basic functioning and well-being of society. They are frequently caused by a trigger event (ex. severe weather) but can occur due to human or technological issues.

CONSEQUENCE	LIKELIHOOD	RISK TREND	HIGH-RISK SEASONS
			

RISK ANALYSIS

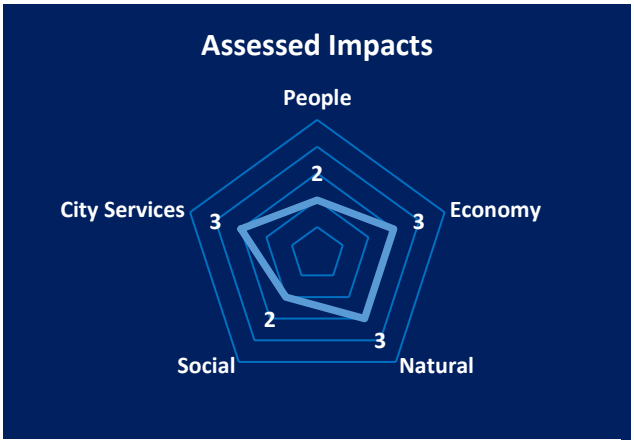
- Critical Infrastructure (CI) failures occur frequently and are likeliest during the high-risk seasons of other hazards
- They are commonly a secondary impact of those primary trigger events but can also occur independently
- CI interdependency elevates the risk of cascading knock-on effects to the health, safety, and economic well-being of impacted communities
- Primary impacts include the loss of heat, power, gas, communications, water, and other lifeline utilities
- A CI failure can impact any area of Calgary but the most exposed locations are those with a high-density of people, livelihoods, critical services, economic activity, and other CI situated in hazard-prone areas (e.g. flood hazard area and downtown core)
- Certain social factors - such as poverty, disability, and age – can increase vulnerability
- Communities serviced by older infrastructure or that lack redundant backup systems are more susceptible

PREPAREDNESS

- Infrastructure operators have continuity strategies and workarounds in place to limit interruptions
- Mitigating trigger events (e.g. flooding) also reduces the risk of secondary critical infrastructure failures

RISK DRIVERS AND TRENDS

- Climate change increases the risk of disruptions due to weathering of assets and infrastructure that may not be built to tolerate new weather extremes
- Increased cyber-attacks on critical infrastructure is an emerging risk with the potential to cause disruptions



1=Insignificant, 2=Minor, 3=Moderate, 4=Major, 5=Catastrophic

Figure 4: Critical Infrastructure sectors

Sector	Examples
Energy and Utilities	Electrical power grids, natural gas pipelines, oil production facilities, power substations, and power lines
Finance	Banks, securities, financial services, and payment systems
Food	Food safety, production facilities, distribution systems, and storage
Government	Government facilities, services (e.g. elections), information networks, assets, and cultural institutions/monuments
Health	Hospitals, healthcare facilities, blood-supply facilities, laboratories, and pharmaceuticals
Information and Communication Technology	Telecommunications (phone, fax, cable, satellites), broadcasting systems, software, hardware, and networks (internet)
Manufacturing	Chemical and strategic manufacturers
Safety	Hazardous substances, explosives, nuclear waste, and emergency services
Transportation	Roads, air, rail, and marine
Water	Drinking water and wastewater management systems

Dam Breach

RISK LEVEL

High

A dam breach is a catastrophic type of dam failure characterized by the sudden, rapid, and uncontrolled release of impounded water. They are usually categorized as structural failures, mechanical failures, or hydraulic failures.

CONSEQUENCE

LIKELIHOOD

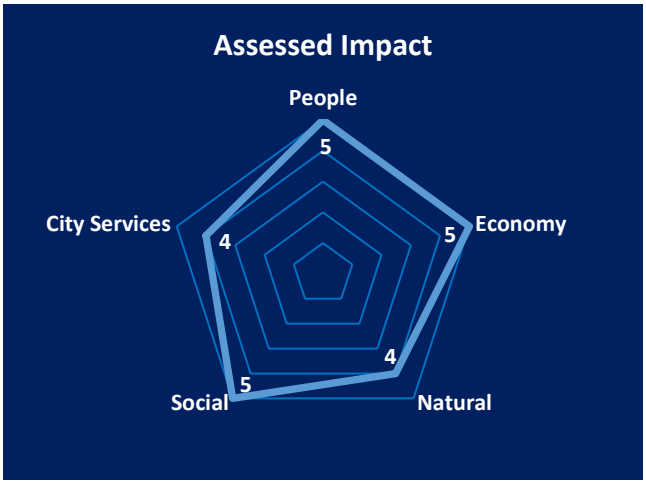
RISK TREND

HIGH-RISK SEASONS

JAN	FEB	MAR
APR	MAY	JUN
JUL	AUG	SEP
OCT	NOV	DEC

RISK ANALYSIS

- Dam breaches occur due to a causal event (e.g. flooding or earthquake), technical issues, or human acts
- There are 11 hydroelectric plants upstream of Calgary along the Bow River and one dam on the Elbow River
- The total number of people, properties, and assets exposed within the potential dam breach inundation area is much greater than a 1:100 year flood event
- Communities along the Bow and Elbow Rivers would experience flooding multiple times worse than the 2013 flood - inundating the entire river valley and reaching areas of the city that have never previously flooded
- A major dam breach on either river would likely result in: significant numbers of fatalities, severe injuries, and psychosocial trauma; billions of dollars in direct and indirect damages; largescale evacuations; catastrophic critical infrastructure and property damage; business and community service disruptions; major bridge and road closures; water supply issues; and other knock-on effects
- Dam breaches can occur at any time during the year



1=Insignificant, 2=Minor, 3=Moderate, 4=Major, 5=Catastrophic

PREPAREDNESS

- Risk treatment focuses on preventing failures and mitigating potential consequences by using built infrastructure, policy, and planning measures
- Dam owners undertake regular risk assessments, inspections, and maintenance of dam facilities while also having prescribed operating procedures in place to dramatically reduce the potential of an event occurring

RISK DRIVERS AND TRENDS

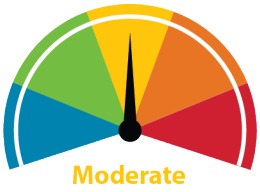
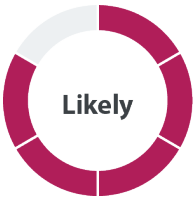
- Future rain and flooding extremes under a changing climate may stress dams but they are built to withstand initiating events greater than 1:10,000 return period

Extreme Cold

RISK LEVEL

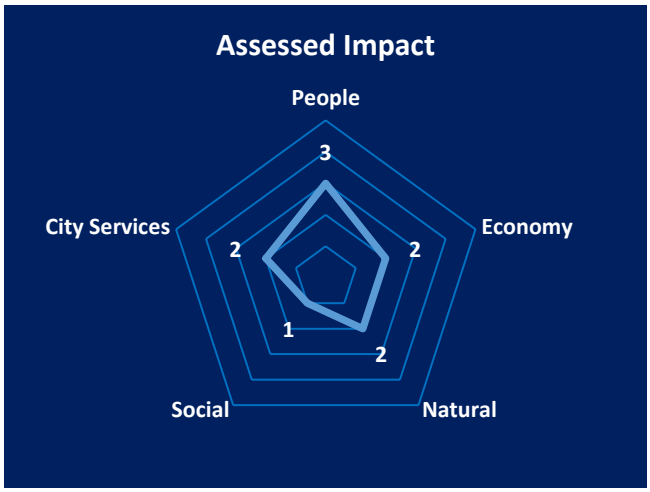
High

Extreme cold events typically occur when an intrusion of cold air from the north causes a dramatic drop in local temperatures below normal. Warnings are issued when temperature or wind chill is expected to reach -40°C for at least two hours.

CONSEQUENCE	LIKELIHOOD	RISK TREND	HIGH-RISK SEASONS
			JAN, FEB, MAR APR, MAY, JUN JUL, AUG, SEP OCT, NOV, DEC

RISK ANALYSIS

- Extreme cold conditions can form at any time during the winter months and impact any community in Calgary
- Calgary typically experiences three days per year of extreme cold temperatures but the number and length of extreme cold events have decreased over the last 30 years
- The primary impact of winter storms is on the health and safety of impacted populations
- High-winds combined with cold temperatures speeds the rate of heat loss to the body; increasing the risk of serious health issues, such as frostbite and hypothermia
- People experiencing homelessness, seniors, and people working outdoors are placed at increased risk
- Secondary knock-on effects can include the loss of heat, power, communications, water, and other lifeline utilities
- Extreme cold events may also increase the demand on healthcare and sheltering services



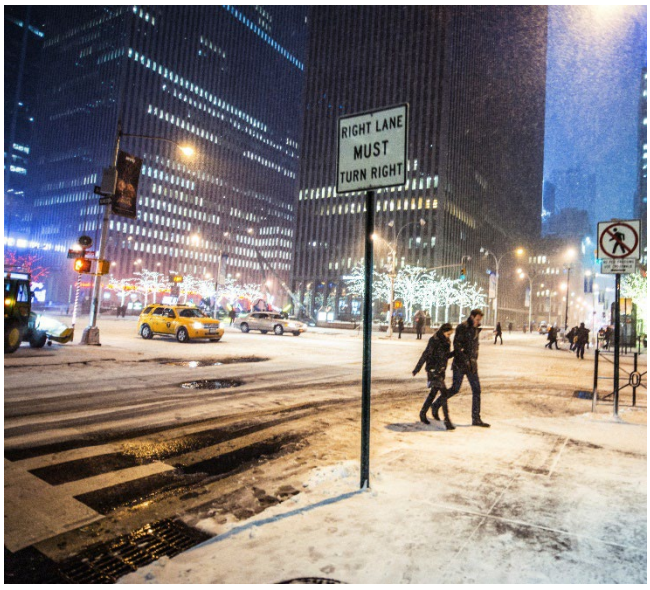
1=Insignificant, 2=Minor, 3=Moderate, 4=Major, 5=Catastrophic

PREPAREDNESS

- Early warning systems are in place to notify the public, emergency response personnel, shelters, and health providers in advance of extreme cold events
- The City and local shelters have plans in place to quickly respond in advance of these types of events

RISK DRIVERS AND TRENDS

- The average number of cold-related hospital visits and hospitalizations has been increasing in Calgary despite the downward trend in extreme cold events
- Calgary is projected to have less extreme cold events in a warming climate



Flooding

RISK LEVEL

High

For the purposes of this assessment, a catastrophic flood is defined as a 1:100 return period event (or greater) caused by a combination of heavy rainfall, moist antecedent soil conditions, and snowmelt.

CONSEQUENCE

LIKELIHOOD

RISK TREND

HIGH-RISK SEASONS

JAN	FEB	MAR
APR	MAY	JUN
JUL	AUG	SEP
OCT	NOV	DEC

RISK ANALYSIS

- A 1:100 year return period means there is a one per cent chance that the area will flood in any given year or a 22 per cent chance of happening during the lifetime of a 25-year mortgage
- With current mitigation in place, $2.2 billion is at-risk under a 1:100 flood scenario, $12.3 billion under a 1:1000 scenario, and $75 million per year in average annual damages (based on probability of different sized floods)
- Approximately 75,000 Calgarians and thousands of buildings with total assessed values close to $100 billion are situated in the floodplain
- A major flood would cause billions of dollars in direct and indirect damages, force the evacuation of tens of thousands of people, disrupt lifeline utilities, interrupt community services, close businesses, damage major bridges and roads, and have cascading societal impacts.
- More flood info available at: www.calgary.ca

PREPAREDNESS

- Current flood mitigation projects have reduced flood risk by 55 per cent and that number will grow to 70 per cent with future projects currently under construction
- Mitigation includes upstream reservoirs to hold back water, community-level flood barriers, land-use policies, improved building regulations, and programs to enhance the resilience of river valley communities

RISK DRIVERS AND TRENDS

- Experts predict the risk of river flooding will increase with climate change. Shifting precipitation patterns will bring warmer springs, earlier melt of mountain snowpack, and more intense storms. High river flow season may shift earlier, resulting in bigger floods occurring more often.

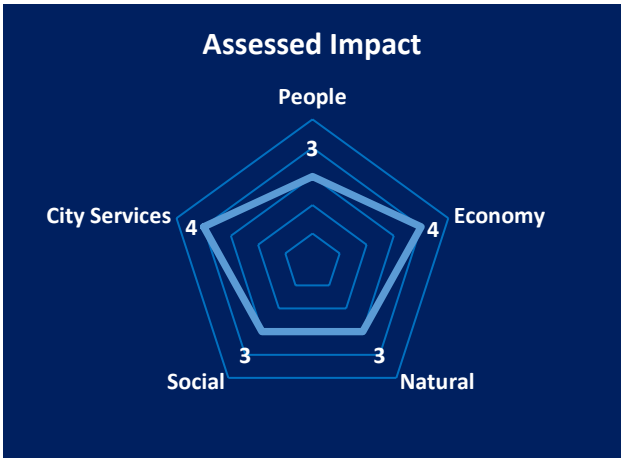


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Figure 5: CI and populations at-risk for flood scenarios

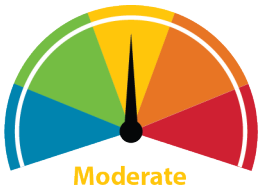
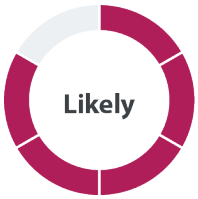
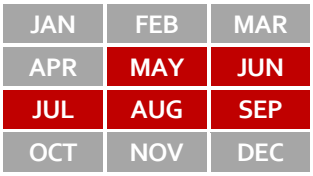
	1:100 Flood	1:200 Flood	1:1000 Flood
After School Programs	11	13	19
Clinics	2	2	2
Community Centres	6	8	9
Cultural Attractions/Resources	16	19	26
Day Cares	27	35	44
EMS Services	5	6	6
ENMAX Substations	3	3	7
Fire Stations	3	4	4
LRT Stations	5	7	16
Municipal Halls	1	1	1
Nursing Homes	6	7	8
Police Stations	0	0	0
Preschools	5	6	12
Recreation Facilities	12	14	16
Schools	18	24	35
Wastewater Treatment Plants	2	2	3
Total Population	30065	42559	76492

Heavy Rainfall

RISK LEVEL

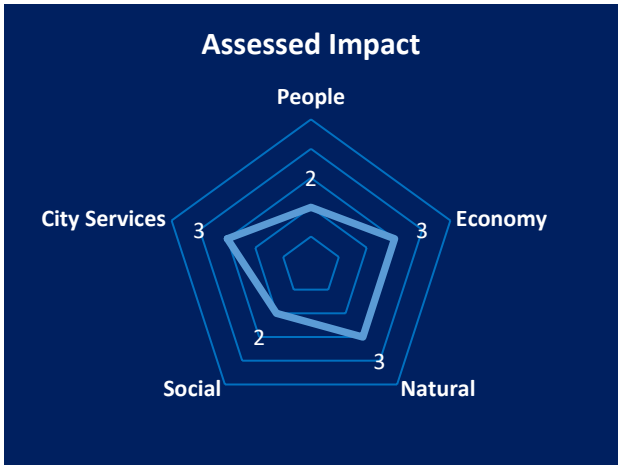
High

Intense rainfall events in Calgary are generally caused by either large-scale weather systems lasting multiple days or short duration high intensity (SDHI) rainfall resulting from severe thunderstorms that last less than 24 hours.

CONSEQUENCE	LIKELIHOOD	RISK TREND	HIGH-RISK SEASONS
			

RISK ANALYSIS

- Calgary receives approximately 326.4 mm of rainfall each year with almost half of this amount in July and August
- On average, Calgary experiences two days per year with rainfall greater than 25 mm
- SDHI rainfall is the main driver of pluvial and stormwater flooding as it overwhelms drainage, leads to sewer backups, flooding, and property damage
- Heavy rainfall is a trigger event for a number of local risks, including critical infrastructure failures, dam breaches, rail incidents, and floods
- Secondary knock-on impacts include power disruptions, traffic re-routing, flooded properties, backed-up storm/sanitary systems, evacuations, stranded motorists, debris removal, and prolonged service interruptions



1=Insignificant, 2=Minor, 3=Moderate, 4=Major, 5=Catastrophic

PREPAREDNESS

- The City of Calgary uses a combination of built infrastructure, emergency response resources, forecasting, and policy to mitigate the risk of heavy rainfall

RISK DRIVERS AND TRENDS

- Over the last 30 years, Calgary has experienced an increase in the intensity and frequency of SDHI rainfall. Climate projections indicate an upward trend in SDHI rainfall totals for Calgary of 28% by the 2050s and 52% by the 2080s
- Climate projections indicate an upward trend of long duration rainfall totals for Calgary of 10-15% by the 2050s and 10-20% by the 2080s

Hydrological Drought

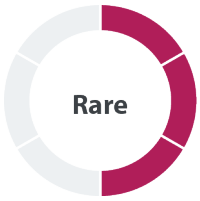
RISK LEVEL

High

A prolonged climatological condition that results in a reduction in the amount of water in the watershed below levels required to sustain human needs.

CONSEQUENCE

LIKELIHOOD



RISK TREND

HIGH-RISK SEASONS

JAN	FEB	MAR
APR	MAY	JUN
JUL	AUG	SEP
OCT	NOV	DEC

RISK ANALYSIS

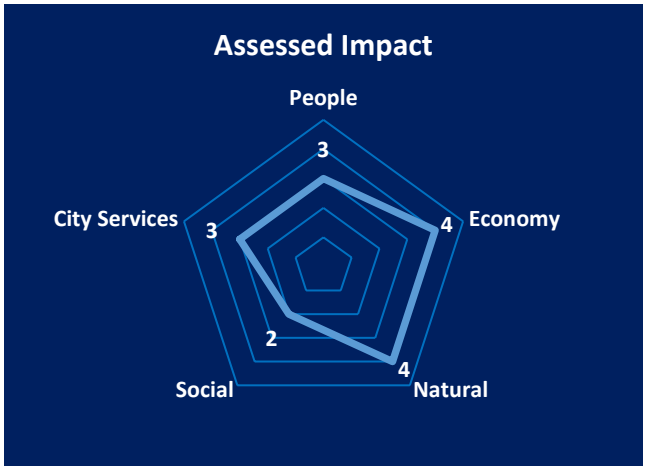
- Calgary is located in a prairie region prone to drought
- Droughts have historically been one of Canada's costliest hazards with numerous events exceeding $500 million
- Although Calgary has not experienced a major drought in recent urban history, the region did experience prolonged and severe droughts in the 18th and 19th centuries
- Hydrological droughts conditions can last for months to years and can be exacerbated by climate change and population growth
- A severe drought event lasting several years in Calgary could have a major impact in the hundreds of millions to local Gross Domestic Product (GDP), cause significant damage to ecosystems, and significantly compromise The City's ability to deliver services.
- Drought can be uniquely challenging since the recognition of onset can be slow and duration unknown

PREPAREDNESS

- The City of Calgary uses a combination of built infrastructure, hydrologic monitoring, strategic supply and demand management, and policy to mitigate the risk of drought
- To manage this risk, regional cooperation and management of water supply are addressed through collaboration of the major water licence holders

RISK DRIVERS AND TRENDS

- Drought risk is expected to become significantly more likely in the future as the climate warms, resulting in lower flows and decreased water quality for the Bow and Elbow Rivers amidst drier, longer, and hotter summers



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Pandemic

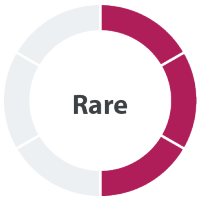
RISK LEVEL

High

Unpredictable but recurring events that occur when a novel virus strain emerges and acquires the ability to cause sustained human-to-human transmission that leads to rapid worldwide spread.

CONSEQUENCE

LIKELIHOOD



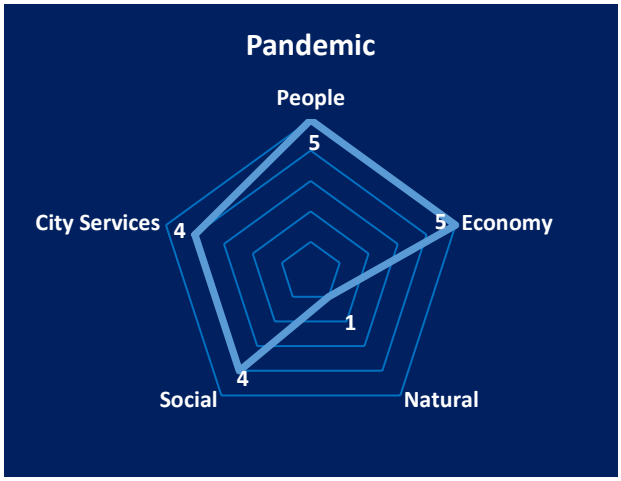
RISK TREND

HIGH-RISK SEASONS

JAN	FEB	MAR
APR	MAY	JUN
JUL	AUG	SEP
OCT	NOV	DEC

RISK ANALYSIS

- The impact of a pandemic is unpredictable in timing, severity of illness, and age groups affected
- Fall and Winter months tend to be the highest-risk seasons for transmission
- As most of the population will have had limited, if any, previous exposure to the virus, everyone is at-risk
- Age and health are two primary determinants of risk
- The primary impact of a pandemic is on the health of people impacted as they can cause significant and widespread illness and death
- Secondary impacts include significant pressure on the healthcare systems, high absenteeism rates, business interruptions, public service reductions, severe supply chain issues, psychosocial trauma, and considerable economic damage



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PREPAREDNESS

- Public health authorities maintain disease surveillance systems to detect outbreaks
- Local response agencies maintain infectious disease plans, Personal Protective Equipment stockpiles, business continuity plans, and other resources required to manage the impact of an epidemic

RISK DRIVERS AND TRENDS

- Global warming and human activities, like deforestation and settlement into previously undeveloped areas, has led to increased contact between humans, wildlife, and livestock – increasing the risk of zoonotic spillover (viruses crossing over from animals to humans)
- Globalization and interconnectedness make it easier for viruses to spread quickly across the globe

Rail Incident

RISK LEVEL

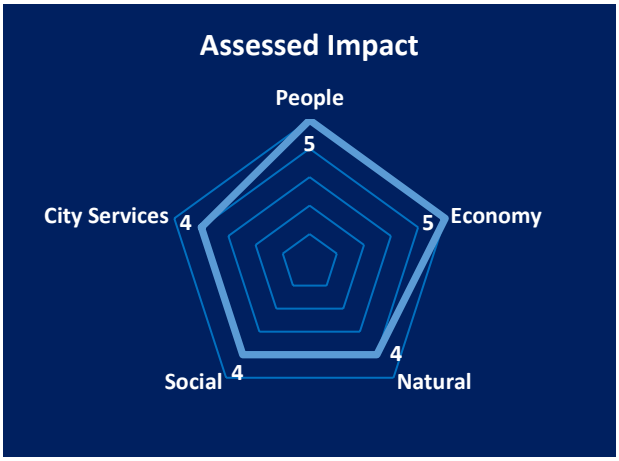
High

Major rail incidents include collision, derailment, fire, explosion, accidental release of dangerous goods, emission of hazardous materials, and rail security incidents. Incidents are rare but have the potential to be catastrophic if they occur in high-risk areas.

CONSEQUENCE	LIKELIHOOD	RISK TREND	HIGH-RISK SEASONS
Catastrophic	Rare	↗	JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC

RISK ANALYSIS

- Calgary is the hub of several major rail networks and has rail lines and facilities spread throughout the city
- Rail risk is attached to a defined geo-based source (i.e. rail line) whose hazard area extends outward from that source
- High-risk areas include communities along the rail corridor, downtown core, and rail lines in the floodplain
- Hazardous materials are frequently carried through Calgary that can be toxic, corrosive, flammable, or explosive
- A probable worst-case scenario would involve a derailment in a high-density urban area that leads to a major spill and fire with cars carrying hazardous materials
- Potential consequences include significant fatalities and injuries, building damage, evacuations, service and utility disruptions, traffic rerouting, and business closures
- Rail is a critical sector in Canada and delays to the rail system could result in significant economic impacts
- There is no distinct high-risk season but flood season, summer event season (e.g. Stampede), daytime hours, and rush hours present increased risk



1=Insignificant, 2=Minor, 3=Moderate, 4=Major, 5=Catastrophic

PREPAREDNESS

- Local response agencies have advanced capabilities to respond to incidents, including plans with rail companies and hazardous materials and technical rescue teams
- The railway sector has significant regulations, standards, and protocols in place to mitigate the risk of an incident

RISK DRIVERS AND TRENDS

- From 2010 through 2019, there was a steady increase in the average length of trains, tonnage of goods, and total number of carloads carrying dangerous goods in Canada
- The shipment of fuel oil and crude oil moved by rail tripled from 2011 to 2019

Tornado

RISK LEVEL

High

A violently rotating column of air extending between a vertically developing cloud and the surface. Wind speeds in most tornadoes are under 130 km/h (EF0) but can exceed 315 km/h (EF5). Made visible by rotating debris or water near the surface.

CONSEQUENCE

LIKELIHOOD

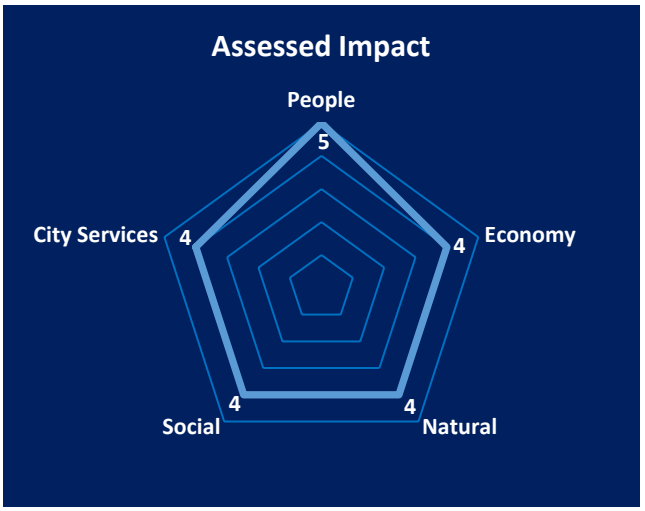
RISK TREND

HIGH-RISK SEASONS

JAN	FEB	MAR
APR	MAY	JUN
JUL	AUG	SEP
OCT	NOV	DEC

RISK ANALYSIS

- Tornadoes are one of nature's most destructive and hazardous phenomena
- Tornadoes are most likely to occur in the afternoon or early evening during summer
- Calgary is located within an area of high-risk for tornadic activity in terms of both frequency and severity
- Alberta averages 15 reported tornadoes per year and Calgary has experienced 18 tornadoes (EF1 and EF0) within 30 km of the city since 1980
- The primary impact of tornadoes is on the health and safety of affected populations
- A severe tornado impacting Calgary could result in significant loss of life and injuries, hundreds of millions of dollars in direct and indirect losses, impairment of lifeline utilities, and the incapacitation of essential services
- Secondary knock-on effects include large-scale evacuations, traffic rerouting, structural collapses, and power outages



1=Insignificant, 2=Minor, 3=Moderate, 4=Major, 5=Catastrophic

PREPAREDNESS

- Early warning systems are in place to notify the public, emergency response personnel, and health providers in advance of summer storm events
- Local agencies maintain capabilities to undertake search and rescue operations, respond to structural collapses, manage debris, and implement mass casualty incident protocols required following a tornado

RISK DRIVERS AND TRENDS

- Although a warming climate will have more moisture and energy available to fuel severe storms, it is unclear how tornado frequency and intensity will be influenced by climate change

Winter Storm

RISK LEVEL

High

Winter storms occur when heavy snowfall combines with freezing rain, strong winds, and/or cold temperatures. They are typically over within hours but can last for days and impact entire regions.

CONSEQUENCE	LIKELIHOOD	RISK TREND	HIGH-RISK SEASONS
Moderate	Likely	↗	JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC

RISK ANALYSIS

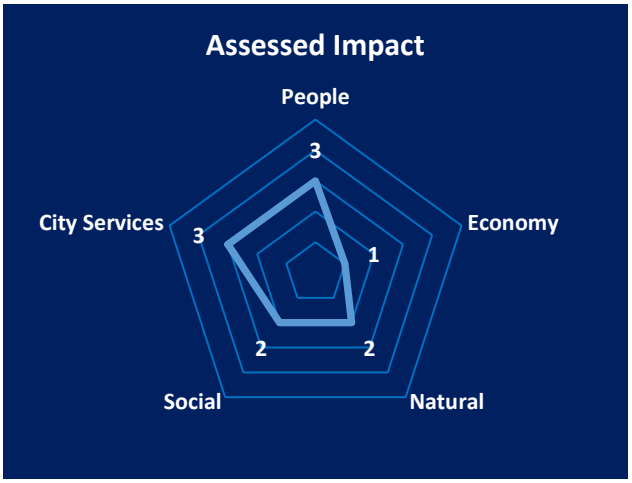
- A single day snowfall event of 20 cm or more occurs in Calgary about once every three years and they have occurred in every month except for July and August
- Winter storms can occur from early Fall through Spring but Calgary has experienced more heavy snowfall events in the winter months over the last 30 years
- The primary impact of winter storms is on the health and safety of impacted populations
- Injuries and death may occur from exposure, dangerous road conditions, heart attacks related to snow clearing, and carbon monoxide poisoning
- These events can place seniors, people experiencing homelessness, and other vulnerable groups at greater risk
- Secondary knock-on effects can include the loss of heat, power, communications services, and other lifeline utilities
- Heavy snowfall can cause hazardous travel conditions and in rare situations, the structural collapse of buildings
- Winter storms can impact any community in Calgary

PREPAREDNESS

- Early warning systems are in place to notify the public, emergency response personnel, and health providers in advance of winter storm events
- Agencies responsible for traffic safety have emergency plans and resources in place to respond when these events occur; including designated snow clearing routes

RISK DRIVERS AND TRENDS

- Winter season will be shorter in the future but Calgary will continue to experience winter storm hazards while spring and fall are expected to have less snow and more rain



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Police and Security Threats

Determining the likelihood of major disaster scenarios involving human actor(s) with malicious intent is very different from other threats/hazards (i.e. weather events). When quantitative data is not available (i.e. historical data, statistical studies), likelihood can instead be determined by qualitative judgments by subject matter experts, while considering the overall capability (technical feasibility) of the malicious actor(s) carrying out the threat. In this type of likelihood analysis, aspects of risk are considered using descriptive scales (i.e. level of knowledge and access to target).

For many of the scenarios assessed in the Disaster Risk Assessment, a disaster of city-wide magnitude has not yet occurred in Calgary. This qualitative assessment of likelihood was drawn from the Federal All-Hazards Risk-Assessment approach to disaster risk assessment. The threats developed for the Disaster Risk Assessment are realistic, worst-case scenarios with city-wide impact. **They are hypothetical and are not based on any specific intelligence.**

Likelihood scoring for Police and Security Threats

Estimating the likelihood of malicious scenarios is considerably different than for other hazards or threats as these estimates must take into account the determined and adaptive nature of an intelligent adversary. Such an adversary will make a choice to carry out an attack based on considerations such as whether mounting an attack is technically feasible, an individual's or organization's intent to carry out an attack, or whether they have the means to carry it out.

The current approach developed by Public Safety Canada (All Hazards Risk Assessment Methodology Guidelines 2012, 2013) and utilized for this assessment relies on judgment from domain experts to assess various components of the technical feasibility of a malicious attack scenario. In this approach, an assessment of the technical feasibility of mounting an attack is used as a proxy for an assessment of likelihood.

While it may be relatively easy for subject matter experts to estimate an expected recurrence interval, frequency, and probability of certain natural hazard events for a specific location based on the historical record and other observable data; for malicious scenarios, this can be quite challenging as likelihood is relative to potential. As recommended by Public Safety Canada, the overall feasibility score for a scenario is based on the principle of the weakest link, meaning that the final rating is determined by selecting the lowest component rating, across all components. A successful adversarial attack cannot occur if one of the elements is absent, lacking, or unobtainable; in other words, an attack is assessed as unlikely if the level for one element of the overall capability of the malicious actor(s) is below a necessary level.

Civil Disobedience

RISK LEVEL

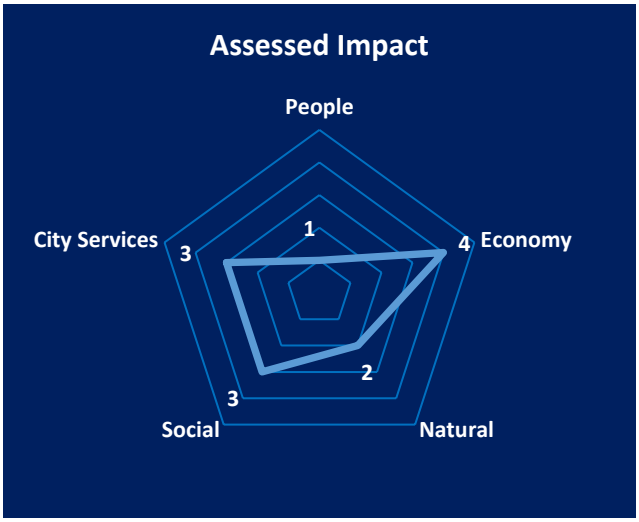
High

A form of non-violent protest that involves the intentional violation of the law and refusal to obey the demands, orders, or commands of a government authority. Often involves unlawfully preventing access and use of a specific location.

CONSEQUENCE	LIKELIHOOD	RISK TREND	HIGH-RISK SEASONS
Moderate	Likely	↗	JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

RISK ANALYSIS

- There has been a dramatic increase in protests and acts of civil disobedience in recent years
- These events have the potential to escalate and cause severe disruptions to the functioning of the impacted community – lasting for weeks to months
- Protests usually target government buildings, major roadways, parks, and locations in the downtown core
- Communities and businesses in the vicinity of these locations are most at-risk to disruptions
- These events are more likely in warmer seasons although they can occur at any time
- Recent events have lasted for days to months



1=Insignificant, 2=Minor, 3=Moderate, 4=Major, 5=Catastrophic

PREPAREDNESS

- Local police and law enforcement agencies have trained personnel, plans, equipment, Standard Operating Procedures, and other resources required to respond to these types of events

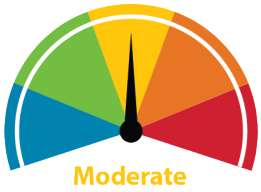
Hostage Incident

A hostage incident involves an assailant entering a building and holding multiple people hostage.

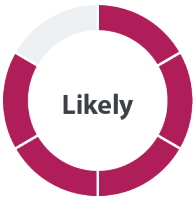
RISK LEVEL

High

CONSEQUENCE



LIKELIHOOD



RISK TREND

HIGH-RISK SEASONS

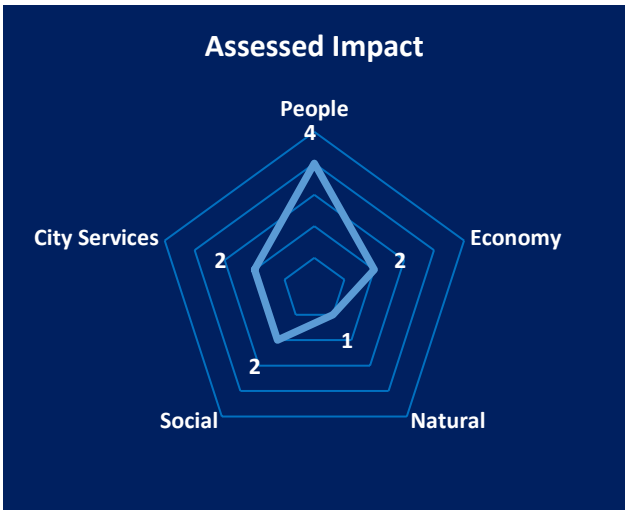
JAN	FEB	MAR
APR	MAY	JUN
JUL	AUG	SEP
OCT	NOV	DEC

RISK ANALYSIS

- Hostage incidents are a risk in modern metropolitan cities – they have occurred in Calgary historically and there is the potential for future incidents
- The primary impact of a hostage incident is the potential for injuries and fatalities
- Secondary impacts to communities in the vicinity can include evacuations, lockdowns, road closures, business interruptions, and traffic rerouting
- There is no high-risk season but these typically occur on weekdays during business hours

PREPAREDNESS

- Local police and law enforcement agencies have trained personnel, plans, equipment, Standard Operating Procedures, and other resources required to respond to these types of events



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Mass Casualty Attack

RISK LEVEL

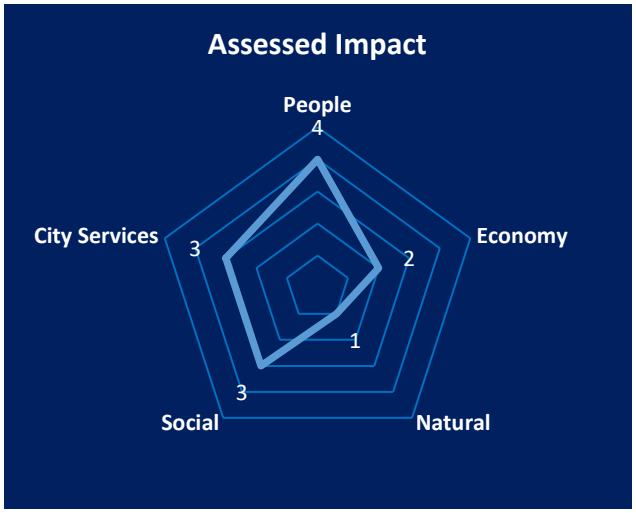
High

An intentional hostile act by an assailant(s) that targets a mass gathering of people and results in a large number of fatalities.

CONSEQUENCE	LIKELIHOOD	RISK TREND	HIGH-RISK SEASONS
Moderate	Likely	→	JAN FEB MAR APR **MAY JUN JUL AUG SEP** OCT NOV DEC

RISK ANALYSIS

- Mass casualty attacks are a risk in modern cities and there is the potential for an incident to occur in Calgary
- The primary impact of a mass casualty incident is the potential for a large number of injuries and fatalities
- Secondary impacts to communities in the vicinity can include property damage, lasting psychosocial trauma, evacuations, lockdowns, road closures, business interruptions, and traffic rerouting
- These events are more likely in warmer seasons during business hours or targeting a major event - although they can occur at any time
- Highly-visited areas and event locations are most at-risk



1=Insignificant, 2=Minor, 3=Moderate, 4=Major, 5=Catastrophic

PREPAREDNESS

- Local police and law enforcement agencies have trained personnel, plans, equipment, Standard Operating Procedures, and other resources required to respond to these types of events

Figure 6: Likelihood Scoring Matrix for Police and Security Threats

	Material	Equipment	Access to Target or System	Technical Expertise	Knowledge
Extremely rare	Extremely difficult to produce or acquire	Custom designed	Almost impossible	Requires controlled advanced specialized technical training	Almost impossible to access required information (e.g., highly classified government information)
Very Rare	Material very difficult to produce or acquire	Manufactured equipment	Extremely difficult	Requires advanced specialized technical training	Extremely difficult to access required information (e.g., closely held military information)
Rare	Material difficult to produce (e.g., synthesis of nine or more steps or tissue culture)	Some specialized equipment	Very difficult	Requires advanced technical training	Very difficult to access required information (e.g., protected or restricted access to information)
Unlikely	Material easily produced	Standard laboratory and dissemination equipment	Difficult	Requires some advanced technical training	Difficult to access required information (e.g., specialized scientific literature or declassified military documents)
Likely	Material readily available (e.g., commercially available product or frequently occurring in nature)	No specialized equipment need, purchased outside the household (i.e., Home Depot)	Accessible	Requires minimal technical training	Required information easily accessible (e.g., standard published literature)
Almost Certain	Material uncontrolled, commercially available	Derived from household products or no equipment needed	Very accessible	Requires no technical training	Required information readily available

Appendix 1: Disaster Risk Summary 2022

Assessed risk for all 65 hazards and threats analyzed in the current Disaster Risk Assessment.

High Risk	Blizzard Civil Disobedience Critical Infrastructure Failure Dam Breach (Bow River) Dam Breach (Elbow River) Extreme Cold Flood (Bow River) Flood (Elbow River)	Heavy Rainfall Hostage Incident Hydrological Drought Mass Casualty Attack Pandemic Rail Incident Winter Storm Tornado
Medium Risk	Active Shooter Incident Basement Seepage Flooding Bomb Threat incident Bridge Failure/Interruption Cyber Attack (Technology as Instrument) Electric Power Blackout Extreme Heat Extreme Solar Storm Hailstorm Hazmat Incident Incident of Data Fraud/Theft Industrial Accident Lightning storm Loss of Major Transportation Corridor Major Solar Storm Mass Gathering Incident	Poor Air Quality Riot Road Accident Sanitary Forcemain Failure (Lift Station) Security Incident at City Facility Stormwater Backup Flooding Structure Fire Supply Chain Interruption Telecommunications Failure Thunderstorm Water Contamination (Distribution) Water Contamination (Forest Fires) Water Distribution (Infrastructure Failure) Wildland / Urban Interface Fire Windstorm
Low Risk	Aircraft Incident Cyber Attack (Technology as Target) Earthquake (Magnitude 4.0+) Flood (Ice Jam) Fog Forcemain Failure (Purple Pipe) Forcemain Failure (Sludge) Gas Main Break Labour Action	Major Ice Accumulation Moderate Pandemic Pipeline Incident (AER lines) Pipeline Incident (TNPL to YYC) Sanitary Failure (Water Body) Transit Rail Incident Water Contamination (Spills) Water Shortage
Very Low Risk	Pump Station Failure (Purple Pipe)	

Appendix 2: References

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