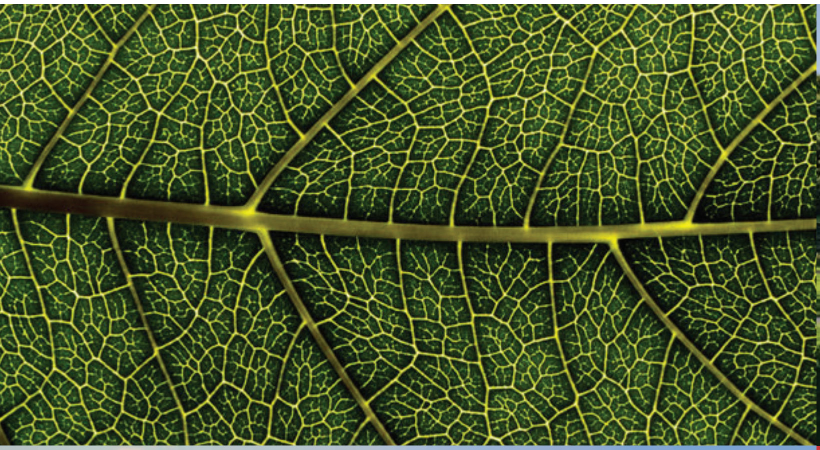
2024

Carleton University
Climate Adaptation Plan




Carleton University

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“Working on this report has not only deepened my understanding of the complexities and challenges of managing a large-scale university infrastructure but also filled me with immense hope for the future. By anticipating and preparing for tomorrow’s challenges today, we ensure that Carleton University remains a beacon of resilience and innovation in an ever-changing climate landscape. This experience has been invaluable, reinforcing my belief in our collective ability to adapt and thrive in the face of adversity.”

Ayo Onakoya, Project Coordinator:
Emergency Management & Climate Change Adaptation (Co-op)

Introduction

Why climate adaptation is important for Carleton University.

Carleton University is not immune to the impacts of rapid climate change. The increased frequency and intensity of Ottawa's heatwaves, heavy precipitation, and frigid cold spells create infrastructure, safety, and operational challenges.

Overview of methodology

- Ministry of Environment and Climate Change Strategy (2019). *Preliminary Strategic Climate Risk Assessment for British Columbia. Report prepared for the Government of British Columbia*, Victoria, BC. Accessible at: https://www2.gov.bc.ca/gov/content/environment/climate-change/adaptation/riskassessment
- *Adapting to Climate Change*. (2020, June). NCC- CCN. https://ncc-ccn.gc.ca/our-plans/climate-change-adaptation

They also present opportunities for leadership in sustainability and resilience.

Recognizing the urgent need for a strategic response, the Facilities Management and Planning (FMP) department hosted weeks of workshops that brought together collective wisdom and decades of lived experience from across our community.

The result of these sessions is this Climate Adaptation Plan.

Properly funded, this plan will safeguard our campus, enhance our preparedness, and ensure the continuity of our educational mission.

Overview of methodology

Our approach was methodical and collaborative, and it drew on proven risk assessment frameworks adapted from the 2019 Province of British Columbia's risk assessment process, and the National Capital Commission's climate adaptation efforts, tailored to meet the specific needs and circumstances of our university.

Risk assessment

Context: Step 1 was to engage a broad range of stakeholders across the FMP department to clearly define the scope and objectives of the adaptation efforts. This was critical for aligning stakeholders, and it set the stage for detailed examinations of potential risks and the development of a targeted action plan.

Identifying relevant risk events: Through a series of eight 1-hour workshops with key personnel (like the Associate Vice President of FMP, the Directors of Operations and Maintenance, Energy, and Sustainability, and managers from critical sections like electrical, building operations, and mechanical), we delved deep into the potential climate-related events that could impact our campus.

To ensure a robust foundation for our risk analysis, our discussions were informed by historical climate data and predictive models. We also made use of tools like the CGR foundation software's dynamic visual overview that helped with seeing and prioritizing risk factors.

Risk analysis: We evaluated the likelihood and potential consequences of each identified risk by considering current conditions and future projections. This helped us prioritize risks based on their potential to disrupt campus operations, damage infrastructure, impact financial resources, affect reputation, and/or compromise health and safety.

Additionally, for a comprehensive understanding of the changing climate's full impact, we explored its nuances in 15+ hours of additional small-group meetings by department. We also dug deeper into departmental subsections because electrical and mechanical managers, for example, are in the same department but face different climate-related challenges.

Risk evaluation: Identified risks were assessed to determine how prepared we are to handle each and where we might be deficient. This was critical in determining where to focus our efforts and how to shape the adaptation plan to align with current needs and future projections.

Transition risks

Transition risks are the potential events out of our control (e.g., legislation changes, technology shifts, and market fluctuations) that can cause financial, operational, and strategic challenges.

We identified and addressed transition risks as part of preparing this adaptation strategy. That extra effort helps us navigate uncertainties effectively, maintain compliance with new regulations, capitalize on emerging technologies, and align with global sustainability trends — all of which further secures the university's reputation as a leader in climate adaptation and resilience.

Mitigation strategies

Mitigation strategies lessen the intensity and potential damage of climate impacts, protect our infrastructure, safeguard the wellbeing of our community, and ensure the continuity of our operations.

By implementing these targeted mitigation measures, we can prevent significant financial losses and enhance the resilience and sustainability of our campus environment.

Implementation and monitoring

The implementation phase involves practical application of strategies across the university's infrastructure and operations, coordinated to minimize disruption and maximize efficiency.

Following implementation, ongoing monitoring assesses the effectiveness, and allows for timely adjustments and refinements.

This continuous feedback loop helps us adapt to new challenges and opportunities as they arise. It ensures our adaptation efforts are responsive to the dynamic nature of climate change. And it safeguards the university's assets, community, and reputation.

Necessity and expected outcomes

The goal of this Climate Adaptation Plan is to kickstart a campus-wide conversation about resilience and proactive planning. And it is an invitation for every member of the Carleton community to engage in these vital efforts.

Through this plan, we aim to mitigate immediate impacts of climate change and foster a resilient, adaptive campus environment for generations to come.

With adequate funding and university-wide cooperation, we are well-positioned to lead Carleton toward becoming a model of sustainability and climate readiness.

Assessing our risks

Our four-step risk assessment process was informed by and adapted from British Columbia's 2019 risk assessment framework for a similar effort:

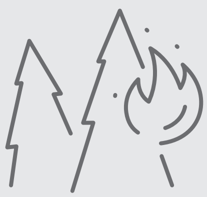
The goal of this Climate Adaptation Plan is to kickstart a campus-wide conversation about resilience and proactive planning. And it is an invitation for every member of the Carleton community to engage in these vital efforts.

Assessing our risks

- Ministry of Environment and Climate Change Strategy (2019). *Preliminary Strategic Climate Risk Assessment for British Columbia. Report prepared for the Government of British Columbia*, Victoria, BC. Accessible at: https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/prelim-strat-climate-risk-assessment.pdf

RISK EVENTS

Rideau River and overland flooding



Wildfire smoke

Heat waves

Extreme cold

Major winter snow and ice storms

Major wind events

Understanding the context

If we thought we would be immune to the effects of climate change in Ottawa, we were wrong. Anyone who has lived here for more than 20 years has watched the weather patterns change in real time. Trends indicate more rapid change and rising threats of risk events that could devastate the campus and the budget. That is why the time is now to invest in mitigation measures.

Selecting risk events

We identified six significant risks and a specific event resulting from each:

- **Rideau River and overland flooding:** A one-in-100-years' flood.
- **Wildfire smoke:** An air quality health index in Ottawa surpassing 10+.
- **Heat waves:** Over 35°C humidex for at least 3+ consecutive days.
- **Extreme cold:** Intense sub-zero temperatures (below –25°C).
- **Major winter snow and ice storms:** Something similar to the 1998 Ice Storm.
- **Major wind events:** Increased frequency/intensity of thunderstorms, derechos and tornadoes.

Risk events analysis

Likelihood

We evaluated the likelihood of each scenario occurring in the present day and also in 2050. This helped with understanding how quickly the effects of climate change are escalating.

- Present-day refers to the weather-related events occurring in Ottawa over the 25-year time period (1998 to 2023).
- 2050 refers to the 20-year time period centred around 2050 (2040 to 2059).
- Climate change projections are primarily sourced from the National Capital Commission's 2020 climate projections that explores high emissions scenarios into the 2080s.
- **In each scenario, we identified climate-related indicators and evaluated the best available projections of how those indicators may change from the present day to 2050. We applied the likelihood rating scale from the framework, shown below:**

Appendix A: Timeline of Ottawa Weather events

Likelihood	R	Criteria
Almost Certain	5	At least once every two years
Likely	4	Every 3 to 10 years
Possible	3	Every 11 to 50 years
Unlikely	2	Every 11 to 50 years
Almost certain not to happen	1	Less once every 100 years

Consequences

We evaluated the potential consequences of the scenario along five dimensions:

- **Infrastructure Damage:** Physical damage to buildings and infrastructure.
- **Operational Disruption:** Interference with teaching, research and/or administrative functions.
- **Health and Safety:** Risks to students, staff and visitors.
- **Financial Implications:** Costs associated with damage and disruption.
- **Reputational Impact:** Costs associated with unwanted attention.

Based on available data for each consequence, we used the framework to create a consequence rating scale:

	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Infrastructure Damage	Negligible damage, minimal repairs. <$1M	Slight, easily repairable damage to facilities. $1M–$10M	Noticeable damage requiring professional repairs. $10M–$50M	Significant damage to buildings' infrastructure. $50M–$100M	Severe damage requiring reconstruction/ replacement. >$100M
Operational Disruption	Minimal disruptions, resolvable within hours to days.	Minor disruptions, resolvable within days to a couple of weeks.	Noticeable disruption for many weeks that requires a coordinated response.	Significant disruptions for weeks to months that require recovery actions.	Severe disruptions for many months that require long-term management.
Health and Safety Risks	Easily manageable within routine procedures.	Minor concerns that can be easily addressed.	Concerns that may require temporary routine changes.	Serious concerns that require immediate and potentially long-term responses.	Extreme life-threatening concerns necessitating extensive emergency measures.
Financial Implications	Zero or minimal financial loss.	Minor financial loss covered by regular budgets.	Moderate financial loss potentially affecting departmental budgets.	Significant financial loss impacting wider university budgets.	Severe financial loss, requiring external funding or insurance claims.
Reputational Impact	No noticeable effect on the university's public image or the public's confidence in us.	Small neutral or non-critical coverage in the media with low potential for erosion of public confidence.	Moderate public/media scrutiny with some negative coverage that leads to minor erosions of public confidence.	High levels of negative public or media attention with moderate erosions in public confidence.	Widespread national or global negative publicity with severe erosions of public confidence.

** Consequences can be interrelated. For example, infrastructure damage and health risks will both often cause operational disruption.*
** Ratings are kept separate to help with understanding the consequences at play and how to mitigate them.*

Evidence base

To determine the likelihood and consequence ratings, we gathered evidence through a combination of risk assessment workshops and desk research.

Where possible, we relied on peer-reviewed literature, grey literature (government reports), expert judgment from workshop participants, and trusted new research, in that order.

Our desk research consisted of conducting targeted internet searches for resources using keywords such as the risk event type and a specific consequence category. We also reviewed resources provided by FMP stakeholders, the project advisory committee, and expert consultations.

Risk evaluation

To determine the final risk score, the project team multiplied the likelihood rating by the average consequence rating. Based on the total score, we categorized risk as extreme, high, medium, or low.

Risk Rating Matrix

5	LOW	MED	HIGH	EXT	EXT
4	LOW	MED	HIGH	HIGH	EXT
3	LOW	MED	MED	HIGH	HIGH
2	LOW	LOW	MED	MED	MED
1	LOW	LOW	LOW	LOW	LOW
Likelihood	1	2	3	4	5

Consequence

Likelihood x Consequence

Score 0 - 5.9 = Low

Score 6 - 11.9 = Medium

Score 12 - 19.9 = High

Score 20 - 25 = Extreme

The table below summarizes the overall results showing risks based on the 2050 likelihood of each scenario, in order of risk score:

Risk Event	Present-Day Likelihood	2050 Likelihood	Average	Risk Score	Risk Rating
Major Wind Events (Thunderstorms, Derecho, Tornadoes)	3	4	3.8	15.2	High
Heat Wave	3	4	2.6	10.4	Medium
Wildfire Smoke	5	5	2	10	Medium
Major Winter Precipitation Events (Snow and Ice Storms)	3	4	1.8	7.2	Medium
100-Year Flood	1	2	2.8	5.6	Low
Extreme Cold Events	4	3	1.4	4.2	Low

• Page 6 and 7 tables: Ministry of Environment and Climate Change Strategy (2019). *Preliminary Strategic Climate Risk Assessment for British Columbia. Report prepared for the Government of British Columbia*, Victoria, BC. Accessible at: https://www2.gov.bc.ca/gov/content/environment/climate-change/adaptation/riskassessment

What to expect on campus as the climate changes

Risk Assessment Findings

As you read through the evidence presented below, you will see encouraging downgrades in some areas of risk, and you will notice that these come at the expense of growing concerns in other areas.

You will also read about the work that has already been done to mitigate some effects of climate change. It is indeed a good start. Trends indicate that more must be done.

100-year flood (Rideau River and overland flooding)

The specific scenario analyzed is 2020's review of the "100-year flood" of the Rideau River, affecting Carleton University.

In this scenario, flood depths could exceed 3m in some locations across campus and last up to two weeks. The flood would most likely be caused by rapid spring snowmelt combined with heavy rainfall.

Summary of findings

This would result in extensive flooding (3m of water) to the National Wildlife Research Centre (NWRC), P14 (Off Raven Road), portions of P5 (Off Stadium Way), and the Bronson Substation. Pigiarvik (formerly Robertson Hall), Richcraft Hall, and Steacie Building are identified as vulnerable structures.

Recent evidence (August 2023) suggests that flooding of this magnitude would threaten the integrity of existing stormwater management systems.

If this event occurred today, it would be the costliest natural disaster in the university's history in terms of consequences and damage.

Climate projections predict we will see the annual precipitation increase by 8%. Though this is a low-likelihood, high-consequence event, climate change will make 2020's assessment of the 100-year Rideau River flood more likely by 2050.

A long-term solution to mitigate the river flooding and a swift adoption of the changes recommended by the stormwater assessment project is needed.

Flood summary

- *Adapting to Climate Change*. (2020, June). NCC-CCN. https://ncc-ccn.gc.ca/our-plans/climate-change-adaptation
- Rideau Valley Conservation Authority. (2020). *Map created: Brewer Park / Carleton University (100 YR Flood Extent)*. https://www.rvca.ca/images/hydrometric/06_BrewerPark_FloodExtent_Combined_Optimized.pdf
- Rideau Valley Conservation Authority (RVCA). (2020). *Brewer Park Neighborhood Flood Maps*. https://www.rvca.ca/watershed-conditions/neighbourhood-flood-maps?highlight=WyJmbG9vZCIsIm1hcCIsImZsb29kIG1hcCJd

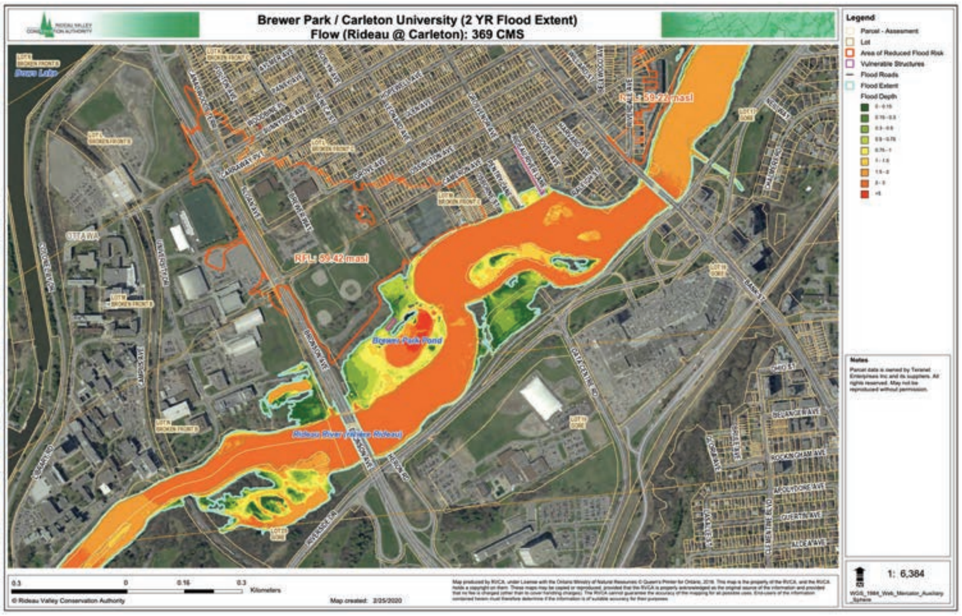


Figure: https://www.rvca.ca/images/hydrometric/06_BrewerPark_FloodExtent_Combined_Optimized.pdf

Likelihood			
Current Rating	**Justification**	**2050 Rating**	**Justification**
1	The “100-year flood” has a 1% chance of occurring in any year.	2	Climate-Related Causes: Flooding driven by periods of hot weather, heavy rain, snowpack melting, etc. 2050 and beyond projections: NCC projects an 8% increase in precipitation and an annual average temperature increase of 3.2C°.

Consequence			
Category	**Rating**	**Justification**	
Infrastructure Damage	3	Significant risk of structural and utility damage, and preventative maintenance improvements are not 100% effective.	
Operational Disruption	4	Extended campus closures or restricted access.	
Health and Safety Risks	1	Risk significantly decreases when the flooded area is secured.	
Financial Implications	4	Extensive damage and the consequential disruption to operations is anticipated to pose the largest financial burden on the university.	
Reputational Impact	2	Risk of potential mishandling of crisis response and long-term recovery efforts.	
Overall Risk		Current	Low (2.8)
		2050	Low (5.6)

Risk Rating Evaluation for 1-in-100 Year Flood (Rideau River and Overland Flooding) Scenario

The present-day risk rating is low (2.8 out of 25).
The 2050 risk rating is also low (5.6 out of 25).

Risk Calculation Risk = Likelihood x Average Consequence

- Present Risk = 1 x 2.8 = 2.8 (Low)
- 2050 Risk = 2 x 2.8 = 5.6 (Low)

Consequence Calculation Overall Consequence

- = Average of Individual Consequence Ratings Overall Consequence
- = (3+4+1+4+2)/5 Overall Consequence = 2.8

Likelihood

• Appendix A: Timeline of Ottawa Events

Likelihood

The present-day likelihood of this scenario is 1 and the 2050 and beyond likelihood is 2. By definition, a 100-year event currently has a 1% annual chance of occurring. To determine the likelihood of this flood event by 2050 and beyond, we relied on climate change-influenced projections published by the National Capital Commission in June 2020:

- Annual precipitation (spring, fall, winter) will increase by 8%.
- The maximum daily precipitation will increase by 14%.
- The annual average temperature will increase by 3.2°C.
- Warming will create favourable conditions for storms, tornadoes, and wildfires.

We also relied on historic summaries of:

- 1998 Flood
- May 2017 Flood
- October 2017
- Spring 2019 Flood
- Effects of August 2023 Flooding on Carleton University

Evaluation of implemented mitigation strategies for a 100-Year Flood

- Better preventative maintenance in buildings and tunnels:
  - More frequent testing and inspections of sump pumps and sump pit conditions, with plans of adding this to the BAS.
  - Spare sump pumps have been obtained to minimize downtime if/when faults are discovered.
  - Portable gas pumps are on a maintenance schedule, with the automotive team ensuring easy and reliable starts when needed.
  - Inspection of catch basins for debris buildup and frequent cleaning to ensure proper flow.
  - Studies conducted on the exterior storm piping:
    - All the mains and laterals were cleaned, and video inspected. Recommendation from the studies included maintenance schedule for cleaning and inspection.
    - Repair work was conducted on areas that were considered critically damaged/degraded with plans to address other areas of concern.
- Completion of the asset-tagging project, currently awaiting integration into the Maximo system for easy access by field staff.
- Creation of a stormwater pond as part of the expansion of P7 (Off University Drive).
- Installation of leak sensors for critical infrastructure in some buildings that trigger emails from the BAS to necessary parties.
- Creation of a weather station that can measure wind, rain, humidity, and temperature, with plans to be added to the BAS for automatic updates at a cost of $2K.

Flooding is anticipated to levy a substantial financial burden onto the university due to the extensive direct damage to infrastructure and the consequential disruptions to operations.

Consequence Ratings

- Appendix D: August 2023 Flooding

Wildfire Smoke Summary

- *Adapting to Climate Change*. (2020, June). NCC-CCN. https://ncc-ccn.gc.ca/our-plans/climate-change-adaptation
- Appendix A: Timeline of Ottawa Weather Events
- Appendix E: June 2023 Wildfire Event

Consequence ratings

Based on these findings, the project team rated the overall consequence of this scenario as **2.8** out of 5.

Infrastructure damage: 3
Despite improvements in preventative maintenance, these fixes are not 100% effective. Additionally, the university could experience substantial losses, including severe interior water damage, because the stormwater infrastructure is inadequate for such events. Ongoing assessments suggest a need for significant upgrades.

Moreover, architectural choices and value engineering affect the accessibility and functionality of critical infrastructure components, potentially aggravating the situation during severe weather events.

Operational disruption: 4
Extended campus closures or restricted access are expected to significantly disrupt academic and administrative operations. The August 2023 flooding demonstrated this impact, as external events were cancelled due to inaccessible tunnels.

Additionally, OC Transpo will lose road access, further complicating campus connectivity and operations.

Health and safety risks: 1
The health and safety risks associated with flooding are initially heightened. However, once the flooded area is secured and cordoned off, the risk significantly decreases.

Financial implications: 4
Flooding is anticipated to levy a substantial financial burden onto the university due to the extensive direct damage to infrastructure and the consequential disruptions to operations. These impacts include repair costs for damaged buildings and facilities and potential revenue losses from halted academic and administrative activities.

Reputational impact: 2
The university's reputation could be significantly impacted by the potential mishandling of crisis response and long-term recovery efforts. If the flood map's indications are accurate and the NWRC building is affected, the decision to build on a floodplain may lead to heightened scrutiny and criticism, further exacerbating reputational damage.

Wildfire Smoke

The specific scenario analyzed is a severe wildfire season in rural areas of Ontario and Quebec.

In this scenario, the byproduct of ash and smoke sends the air quality health index in Ottawa past 10+, indicating very poor air quality.

Summary of findings

Wildfires used to mostly happen in Western Canada or in rural Ontario, and their effects were not explicitly felt in Ottawa. This changed in 2023, as wildfire smoke did affect Ottawa and pushed air quality to hazardous levels.

Climate projections suggest no significant changes in average wind and humidity; however, the frequency of conditions conducive to wildfires is expected to increase due to rising temperatures and changes in precipitation patterns. In 2023, we created Carleton's Wildfire Smoke Readiness Plan that reduces the health and safety risks, but we could still see operational disruption.

Figure: June 2023 - https://www.rvca.ca/images/hydrometric/06_BrewerPark_FloodExtent_Combined_Optimized.pdf

Risk Rating Evaluation for Wildfire Smoke Scenario

Likelihood			
Current Rating	**Justification**	**2050 Rating**	**Justification**
5	Based on 2024 being the driest year on record, and on recent trends in climate variability.	5	Climate-Related Causes: Higher temperatures and low precipitation. 2050 and beyond projections: Projected changes in precipitation and temperature may create conditions more conducive for wildfires.

Consequence			
Category	**Rating**	**Justification**	
Infrastructure Damage	1	No infrastructure damage expected.	
Operational Disruption	3	A wildfire in Algonquin Park could lead to disruptions for weeks. We would anticipate a decrease in outdoor and lab activities due to air flow restrictions.	
Health and Safety Risks	2	Temporary changes in routines or access to facilities will need to be managed effectively, which, while generally under control, still pose a cause for concern.	
Financial Implications	3	The recommended ASHRAE standard of switching MERV 13 filters after every wildfire adds up quickly if not properly accounted in budgets.	
Reputational Impact	1	The reputational impact on the university will depend on its response and communication during events. Additionally, this would not be an isolated incident but part of a broader climate event affecting the entire Ottawa area.	
Overall Risk		Current	Medium (10)
		2050	Medium (10)

The present-day risk rating is low (10 out of 25).
The 2050 risk rating is also low (10 out of 25).

- Risk Calculation Risk = Likelihood x Average Consequence
  - Present Risk = 5 x 2 = 10 (Medium)
  - 2050 Risk = 5 x 2 = 10 (Medium)
- Consequence Calculation Overall Consequence
  - = Average of Individual Consequence Ratings Overall Consequence
  - = (1+3+2+3+1)/5 Overall Consequence = 2

Likelihood

In addition to reviewing historic summaries of the 2018 and 2023 wildfires, we consulted other expert sources.

Environment and Climate Change Canada found the beginning of this year to be drier than normal, charting below-average precipitation in January (down 16%), February (down 71%), and March (down 39%). April has seen 16.9 millimeters of rain and 19.6 centimeters of snow. And while Environment Canada shows higher than average precipitation in Ontario this summer, removing the July 16th rain event and the remnants of Hurricane Beryl would cut the total significantly. This shows both a disturbing trend and more climate volatility.

And while the National Capital Commission reported no changes to trends in average winds and humidity, they expect occurrences of high wind chill to decrease while high humidex days increase in frequency. And they expect conditions favourable to extreme weather (such as freezing rain, tornadoes, lightning, hurricanes, and wildfires) to be more common.

Evaluation of implemented mitigation strategies for extreme wildfire smoke

The majority of these strategies were implemented after August 2023:

- MERV 13 filters were installed in HVAC systems. This is the primary mitigation measure but is not currently accounted for in the budget.
- The Building Operations Team created a process that can be initiated from the BAS. This process is tailored to each building type's air handling characteristics to reduce indoor smoke levels.
- Weather is monitored using Environment Canada and Ventusky as air quality readings are usually consistent across most of Ottawa.
- We offer the FMP ground crews the opportunity to work inside and take frequent breaks during the event.

Consequence ratings

Based on these findings, the project team rated the overall consequence of this scenario as **2** out of 5.

Infrastructure damage: 1
No infrastructure damage expected.

Operational disruption: 3
We should anticipate a decrease in outdoor and lab activities due to air flow restrictions. Although the changing wind conditions might prevent a complete disruption, the impact will still be noticeable.

Health and safety risks: 2
Temporary changes in routines or access to facilities will need to be managed to reduce causes for concern. In June 2023, numerous work orders related to shortness of breath, itchy eyes, etc.

Financial implications: 3
Beyond the costs of meeting recommended ASHRAE standards of switching MERV 13 filters after every wildfire smoke event are the potential disruptions to income-generating activities, like third-party softball and volleyball leagues affected in 2023.

Reputational impact: 1
This will depend on response and communication. Additionally, this would not be an isolated incident but part of a broader climate event affecting the entire Ottawa area.

Heat wave

The specific scenario analyzed is a heat wave where it feels like +35°C for at least three days in a row resulting in significant consequences to human health.

Likelihood

- Wildfire season: What can Ottawa expect? (2024, April 11). Ottawa. https://ottawa.ctvnews.ca/wildfire-season-what-can-ottawa-expect-1.6842270
- *Adapting to Climate Change*. (2020, June). NCC-CCN. https://ncc-ccn.gc.ca/our-plans/climate-change-adaptation
- Appendix A: Timeline of Ottawa Weather Events
- Appendix E: June 2023 Wildfire Event

Consequence Ratings

- Appendix E: June 2023 Wildfire Event

Heat wave

- Bustinza, R., Lebel, G., Gosselin, P., Bélanger, D., & Chebana, F. (2013). Health impacts of the July 2010 heat wave in Québec, Canada. BMC Public Health, 13(1). https://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-13-56#:~:text=During%20the%20heat%20wave%2C%20the,over%20a%2060%2Dday%20horizon.
- Appendix A: Timeline of Ottawa Weather Events

Summary of findings

A significant heat wave would have severe negative outcomes for human health. In July 2010, a heat wave in Ontario and Quebec disrupted operations and led to an increase in paramedic calls. Climate projections suggest that we can expect four times as many days over 30C°.

Our cooling infrastructure is not big enough to manage extreme prolonged heat. In 2024, we have been making unprecedented use of our cooling equipment. We operate at full capacity just to maintain comfortable temperatures. One failed chiller could disrupt cooling in multiple buildings, and our redundancy options are lacking.

Improving and expanding our cooling and electrical infrastructure will give our system more resiliency in a hotter future.

Risk Rating Evaluation for Heat Wave Scenario

Likelihood			
Current Rating	**Justification**	**2050 Rating**	**Justification**
3	Expected to happen every 11 to 50 years.	4	Climate-Related Causes: Increase in average and extreme temperatures. 2050 and beyond projections: Extreme heat days (particularly days above 30C°) are expected to quadruple.

Consequence			
Category	**Rating**	**Justification**	
Infrastructure Damage	2	The increased load on cooling systems damaged chiller plants in the past.	
Operational Disruption	3	Increased likelihoods of a power outage or system breakdowns in certain buildings due to overuse.	
Health and Safety Risks	3	Heat-related illness increases have caused temporary changes in routines or access to facilities.	
Financial Implications	3	Emergency repair costs. More energy use. Losses from disruptions due to heat-related site/office closures.	
Reputational Impact	2	Higher likelihoods of safety risk and operational disruption will see a negative internal effect on reputation.	
Overall Risk		Current	Medium (7.8)
		2050	Medium (10.4)

The present-day risk rating is low (7.8 out of 25).

- Risk Calculation Risk = Likelihood x Average Consequence
  - Present Risk = 3 x 2.6 = 7.8 (Medium)
  - 2050 Risk = 4 x 2.6 = 10.4 (Medium)

The 2050 risk rating is also low (10.4 out of 25).

- Consequence Calculation Overall Consequence
  - = Average of Individual Consequence Ratings Overall Consequence
  - = (2+3+3+3+2)/5 Overall Consequence = 2.6

Costs associated with emergency repairs, increased energy use, and temporary closures add up. Mobilizing of rental chillers for Pigiarvik cost the university $100,000 in 2019. A rental for a larger plant will be significantly more. Additionally, there could be losses from disruptions to income-generating activities.

Likelihood

- *Adapting to Climate Change*. (2020, June). NCC-CCN. https://ncc-ccn.gc.ca/our-plans/climate-change-adaptation
- Appendix A: Timeline of Ottawa Weather Events

Extreme Cold Summary

- *Adapting to Climate Change*. (2020, June). NCC-CCN. https://ncc-ccn.gc.ca/our-plans/climate-change-adaptation

Likelihood

Extended periods of high temperatures have historically led to increased health emergencies and operational disruptions in urban settings. Heat waves in 2010, 2020, 2022, and 2023 show growing intensity and frequency of these extreme weather conditions.

Supporting evidence includes:

- Specifics from NCC report: in a high emissions scenario, by the 2050s we can expect that there will be four times as many days over 30°C.
    - 2010 Heat Event
    - 2020 Heat Event
    - 2022 Heat Event
    - 2023 Hottest Summer on Earth and Canada

Evaluation of implemented mitigation strategies for extreme heat waves

- Our cooling infrastructure is prepared to operate continuously during extreme heat events. The buildings are cooled overnight due to the lack of capacity, in some cases, in the cooling system to maintain comfortable indoor environments during the hottest parts of the day.
- Our system maintenance includes:
    - Pre-season equipment and cooling tower cleaning.
    - Annual chiller cleaning
    - Planned maintenance to rebuild chillers every 10 years
    - Monthly testing and analysis of oil, tube thickness, and motors
    - Water treatments
    - Vibration testing
- Each department and third-party contractors will take the necessary precautions in a heat wave. Like wildfire smoke, ground workers work inside and take frequent breaks when working outside.

Consequence ratings

Based on these findings, the project team rated the overall consequence of this scenario as **2.6** out of 5.

Infrastructure damage: 2
Carleton's buried utility infrastructure protects most equipment from heat damage. However, the increased load on cooling systems has caused damage to chiller plants in the past.

Operational disruption: 3
Risk is reduced significantly by our ability to mobilize emergency rentals and repair services. And it's reduced further by us being on the priority power loop with the Ottawa Hospital.

Health and safety risks: 3
Work-from-home advisories and relocation of events can mitigate some of the risk.

Financial implications: 3
Costs associated with emergency repairs, increased energy use, and temporary closures add up. Mobilizing of rental chillers for Pigiarvik cost the university $100,000 in 2019. A rental for a larger plant will be significantly more. Additionally, there could be losses from disruptions to income-generating activities.

Reputational impact: 2
The higher likelihood of damage, operational disruption, and safety risks will see a negative internal effect on reputation.

Extreme Cold

The specific scenario analyzed is a prolonged period of temperatures in the Ottawa area that feel like –25°C. These events often bring additional challenges like high winds and freezing rain, which compound impacts on our operations and infrastructure.

Summary of findings

Notable cold events in recent years (including cold snaps in 2017 and 2018, and the record cold in 2020 and 2022) underscored the challenges posed by extreme cold of maintaining safe and comfortable indoor environments. We can maintain comfortable indoor temperatures up until a certain threshold during such events. Then, vulnerabilities appear first in lab buildings requiring 100% outdoor air flow in and out due to the chemicals used. Below certain temperatures (which changes from building to building), the ability to maintain comfortable temperatures falters.

Also, power outages are likely to occur due to increased demand for heating nearby homes and emergency facilities. However, we benefit from buried utility infrastructure.

Climate projections suggest that we can expect 35% fewer extreme cold days (particularly days below -10°C). A better electrical infrastructure that reduces our reliance on city utilities is recommended.

While predicted to be less frequent, the recommendations outlined contribute to building our resilience against more dire climate risks.

Risk Rating Evaluation for Extreme Cold Events Scenario

Likelihood			
Current Rating	**Justification**	**2050 Rating**	**Justification**
4	Frequent occurrences historically, with significant impact.	3	Climate-Related Causes: Increase in average and extreme hot temperatures. 2050 and beyond projections: Extreme cold days (particularly days below -10 degrees) are expected to drop 35%. Making an extreme cold event less likely.

Consequence			
Category	**Rating**	**Justification**	
Infrastructure Damage	1	Due to redundancy, any damage will be more localized to weaker points of the infrastructure due to age.	
Operational Disruption	2	Power outages and HVAC infrastructure failure are possibilities.	
Health and Safety Risks	1	The risk of cold-related illness increases but is easily manageable with routine procedures.	
Financial Implications	2	Costs associated with emergency repairs, increased energy use, temporary closures, and/or disruptions to income-generating activities.	
Reputational Impact	1	The low likelihood of damage and safety risks will see little to no effect reputationally unless the aftermath is mishandled.	
Overall Risk		Current	Low (5.6)
		2050	Low (4.2)

The present-day risk rating is low (5.6 out of 25).

- Risk Calculation Risk = Likelihood x Average Consequence
  - Present Risk = 4 x 1.4 = 5.6 (Low)
  - 2050 Risk = 3 x 1.4 = 4.2 (Low)

The 2050 risk rating is also low (4.2 out of 25).

- Consequence Calculation Overall Consequence
  - = Average of Individual Consequence Ratings Overall Consequence
  - = (1+2+1+2+1)/5 Overall Consequence = 1.4

Likelihood

- *Adapting to Climate Change*. (2020, June). NCC-CCN. https://ncc-ccn.gc.ca/our-plans/climate-change-adaptation
- Appendix A: Timeline of Ottawa Weather Events

Major Winter Precipitation

- *Adapting to Climate Change*. (2020, June). NCC-CCN. https://ncc-ccn.gc.ca/our-plans/climate-change-adaptation
- Appendix A: Timeline of Ottawa Weather Events

Likelihood

In addition to reviewing summaries of 2022's extreme cold event and the 2017, 2018, and 2023 cold snaps, we consulted with experts at the National Capital Commission. They predict 35% fewer days below -10°C, thus reducing the likelihood overall of extreme cold events. They also report an expectation of shorter winters (by five weeks), 20% less snowfall, and most likely more freezing rain.

Evaluation of implemented mitigation strategies for extreme cold events

- Buried infrastructure mitigates the impact of power outages or any full utility loss.
- A large amount of redundancy is built into most buildings. For example, Steacie is 100% outside air so the coil is sized for low temperatures.
- Ongoing assessments were conducted by external consultants. They recommend enhancements to building redundancies, along with regular maintenance checks on critical heating components.
- Some newer installations (like in Nicol Building) include coils with antifreeze solutions capable of withstanding temperatures of -40°C without freezing.
- Enhanced safety measures were implemented for outdoor workers, including PPE and adherence to cold weather working standards.
- Power outage precautionary measures have been implemented. The BAS is being moved to emergency power, with efforts to switch all heating pumps to emergency power.
    - We are currently in the process of recovering unused loads on emergency generators so they can be reallocated in the event of an outage.
    - Currently enhancing and refining emergency response plans to handle prolonged outages and ensure continuity of operations during extreme cold events.

Consequence ratings

Based on these findings, the project team rated the overall consequence of this scenario as **1.4** out of 5.

Infrastructure damage: 1
Redundancy will limit damage to weaker/aged points of the infrastructure. An increased risk of frozen pipes exists but can be fixed easily because of the experience at FMP.

Operational disruption: 2
Beyond power outages, limitations in HVAC infrastructure (specifically in lab buildings with outdoor air intake requirements) pose a risk. But it is reduced significantly by our ability to mobilize emergency rentals and repair services. As well as Carleton being on the priority power loop with the Ottawa Hospital.

Health and safety risks: 1
The risk of cold-related illness increases but is easily manageable with routine procedures.

Financial implications: 2
Costs associated with emergency repairs, increased energy use, temporary closures, and/or losses from disruptions to income-generating activities.

Reputational impact: 1
The low likelihood of damage and safety risks will see little to no effect reputationally unless the aftermath is mishandled.

Major Winter Precipitation (ice and snowstorms)

The specific scenario analyzed is a major winter precipitation event likened to the effects of the 1998 Ice Storm when a powerful low-pressure system stalled across the Great Lakes. Many power lines broke and over 1,000 transmission towers collapsed in chain reactions under the weight of the ice, leaving more than 4M people without electricity; most in southern Quebec, western New Brunswick, and eastern Ontario, and some for an entire month.

Summary of findings

The winter storms of 1998, 1999, 2016, 2018, and 2023 highlighted vulnerabilities, infrastructure damage, and operational disruptions.

The unique designs of buildings on campus could cause health and safety risk related to falling ice. The 1998 Ice Storm saw a giant piece of ice slide down from the side of Dunton Tower. And while intentionally burying utility infrastructure prevents damage to utilities or buildings, we could expect prolonged power outages from effects of the storm.

According to the National Capital Commission's climate projections, we can expect shorter winters with less snow and fewer cold days, but the conditions are favourable for more freezing rain. An improved electrical infrastructure is recommended to reduce reliance on city utilities and mitigate the impact of power-related risks.

Risk Rating Evaluation for Major Winter Precipitation Event Scenario

Likelihood			
Current Rating	**Justification**	**2050 Rating**	**Justification**
3	Given the historical frequency and impact of winter storms in the region.	4	Climate-Related Causes: Increased occurrences of near freezing temperatures and precipitation in the winter. 2050 and beyond projections: Projected changes in precipitation and temperature may create conditions more conducive for ice storms.

Consequence			
Category	**Rating**	**Justification**	
Infrastructure Damage	1	Due to redundancy, any damage will be more localized to weaker points of the infrastructure due to age.	
Operational Disruption	2	Citywide power outages are likely to occur in these events, causing disruptions to classes and events. We benefit from being on a priority loop with the Ottawa hospital, but this is not a guarantee for faster restoration.	
Health and Safety Risks	2	The unique design of a few buildings can pose a safety risk of falling ice and snow. We proactively barrier off problem areas to reduce the risk.	
Financial Implications	3	Costs associated with cleanup, repairs, temporary closures, and/or losses from disruptions to income-generating activities.	
Reputational Impact	1	The low likelihood of damage and safety risks will see little to no effect reputationally unless the aftermath is mishandled.	
Overall Risk		Current	Low (5.4)
		2050	Medium (7.2)

The present-day risk rating is low (5.4 out of 25).

- Risk Calculation Risk = Likelihood x Average Consequence
  - Present Risk = 3 x 1.8 = 5.4 (Low)
  - 2050 Risk = 4 x 1.8 = 7.2 (Medium)

The 2050 risk rating is also low (7.2 out of 25).

- Consequence Calculation Overall Consequence
  - = Average of Individual Consequence Ratings Overall Consequence
  - = (1+2+2+3+1)/5 Overall Consequence = 1.8

Likelihood

In addition to reviewing summaries of 2022's extreme cold event and the 2017, 2018, and 2023 cold snaps, we consulted with experts at the National Capital Commission. They predict 35% fewer days below -10°C, thus reducing the likelihood overall of extreme cold events. They also report an expectation of shorter winters (by five weeks), 20% less snowfall, and most likely more freezing rain.

Evaluation of implemented mitigation strategies for extreme cold events

- Buried infrastructure mitigates the impact of power outages or any full utility loss.
- Precautionary measures have been implemented in response to recent power outages. BAS is being moved to emergency power, with efforts to switch all heating pumps to emergency power.
- We are also currently in the process of recovering unused loads on emergency generators so they can be reallocated in the event of an outage. And we are enhancing and refining emergency response plans to handle prolonged outages and ensure continuity of operations during major winter storms.
- We proactively barrier off areas identified as being a danger due to falling snow or ice. We also regularly salt roadways and walkways, but salt becomes less effective as the temperature drops.
- We have implemented enhanced safety measures for outdoor workers, including PPE and adherence to cold weather working standards.
- FMP Electrical Services has rigorous preventative maintenance protocols to ensure the ongoing health and efficiency of the campus's electrical infrastructure. These include inspections of the switchgears and circuit breakers.
- FMP Electrical Services collaborates with Carleton Electric, a primary contractor responsible for managing the high voltage equipment network across the campus. This equipment is crucial for converting power received from the two Hydro Ottawa loops that supply the university. Typically, maintenance of such high voltage equipment is recommended every five years. However, given the aging infrastructure at Carleton, maintenance intervals have been adjusted to a more frequent schedule of every two to three years to preemptively address potential failures and ensure continuous operation. This readiness is particularly valuable given the increasing frequency of climate-related events that can stress electrical systems.

Consequence ratings

Based on these findings, the project team rated the overall consequence of this scenario as **1.8** out of 5.

Infrastructure damage: 1
The redundancy that Canadian buildings have by law and preference allows them to be resilient in these events. As a result, it ensures the damage if any will likely be localized to weaker infrastructure points.

Operational disruption: 2
Carleton benefits from being on a priority loop with the Ottawa hospital. However, this does not guarantee faster restoration.

Health and safety risks: 2
A few buildings pose a safety risk of falling ice and snow, as does the ever-present risk of slip and falls on ice. We proactively barrier off and/or salt problem areas.

Financial implications: 3
Costs associated with cleanup, repairs, temporary closures, and/or losses from disruptions to income-generating activities.

Reputational impact: 1
The low likelihood of damage and safety risks will see little to no effect reputationally unless the aftermath is mishandled.

Major Wind Events (thunderstorms, derechos, and tornadoes)

The scenario analyzed evaluates the impact of major wind events, including thunderstorms, derechos, and tornadoes. These are characterized by strong winds, heavy precipitation, and the potential to significantly damage the university. Historic events and projected changes in climate patterns suggest increased frequency and intensity.

Figure: 2023 Thunderstorms: https://www.theweathernetwork.com/en/news/weather/forecasts/searing-heat-humidity-fuels-growing-storm-risk-in-ontario-and-quebec

Likelihood

- *Adapting to Climate Change*. (2020, June). NCC-CCN. https://ncc-ccn.gc.ca/our-plans/climate-change-adaptation
- Appendix A: Timeline of Ottawa Weather Events

Major Wind Events

- *Adapting to Climate Change*. (2020, June). NCC-CCN. https://ncc-ccn.gc.ca/our-plans/climate-change-adaptation
- Appendix A: Timeline of Ottawa Weather Events

Summary of findings

Extended periods of major wind events have historically led to increased health emergencies, operational disruptions, and electrical infrastructure in urban settings like Ottawa. Major wind events result in widespread power outages due to downed power lines. The EF-3 tornado in 2018 in the Ottawa region caused extensive damage to infrastructure and power systems, as did severe thunderstorms across Ontario and Quebec in 2006. These events demonstrate growing intensity and frequency of these extreme weather conditions.

Unlike other analyzed risks, the university has not been directly impacted by major wind events that can be used as a point of reference. Standard assumptions made are that buildings with large surface areas would be prone to wind damage, and that flying debris could pose a health and safety risk.

Climate projections suggest no significant changes in average wind and humidity; however, the frequency of conditions conducive to thunderstorms and tornadoes are expected to increase due to rising temperatures and changes in precipitation patterns.

Improvement to our electrical infrastructure is recommended to reduce reliance on city utilities and mitigate the impacts of this risk.

Risk Rating Evaluation for Major Wind Event Scenario

Likelihood			
Current Rating	**Justification**	**2050 Rating**	**Justification**
3	Given the historical frequency and impact of wind events in the region.	4	Climate-Related Causes: Increase in temperatures. 2050 and beyond projections: Atmospheric conditions are expected to be favourable for any one of the wind events in this category.

Consequence			
Category	**Rating**	**Justification**	
Infrastructure Damage	3	We can expect total or partial damage to roofing, windows, landscaping, building envelopes, etc. Loss of equipment is expected in large surface area assets like parking lots, exposed structures, etc.	
Operational Disruption	5	Partial to full closure of buildings affected, power outages, and disruption to access routes is expected.	
Health and Safety Risks	4	A real risk of harm from flying debris and structural failures. And with little-to-no warning, it renders ORM's emergency protocols ineffective at removing this risk.	
Financial Implications	4	Costs associated with cleanup, repairs, temporary closures, and/or disruptions to income-generating activities.	
Reputational Impact	2	A neutral outlook reputationally unless the aftermath is mishandled.	
Overall Risk		Current	Medium (11.4)
		2050	High (15.2)

The present-day risk rating is low (11.4 out of 25).

- Risk Calculation Risk = Likelihood x Average Consequence
  - Present Risk = 3 x 3.8 = 11.4 (Medium)
  - 2050 Risk = 4 x 3.8 = 15.2 (High)

The 2050 risk rating is also low (15.2 out of 25).

- Consequence Calculation Overall Consequence
  - = Average of Individual Consequence Ratings Overall Consequence
  - = (3+4+5+5+2)/5 Overall Consequence = 3.8

Major Wind Events

- *Adapting to Climate Change*. (2020, June). NCC-CCN. https://ncc-ccn.gc.ca/our-plans/climate-change-adaptation
- Appendix A: Timeline of Ottawa Weather Events

Likelihood

Extended periods of major wind events lead to increased health emergencies, operational disruptions, and electrical infrastructure in urban settings like Ottawa. Events like 2018's EF-3 tornado demonstrate the growing intensity and frequency of such extreme weather conditions. We looked at this and historical accounts of storms from 2006, 2009, 2012, and 2023.

We also consulted the National Capital Commission climate projections. These pointed to a warmer and wetter climate with annual precipitation (spring, fall, winter) increases of 8%, maximum daily precipitation increases of 14%, and annual average temperature increases of 3.2°C. These are favourable conditions for storms, tornadoes, and wildfires.

Appendix A: Timeline of Ottawa Events

Evaluation of implemented mitigation strategies for major wind events

- Continued reliance on buried infrastructure to mitigate the impact of power outages or any full utility loss.
- Regular building assessments to ensure structural integrity and readiness to withstand high winds.
- Routine maintenance and checks of building envelopes and critical components vulnerable to wind damage.
- Precautionary measures in response to power outages and a transition of the Building Automation System (BAS) to emergency power.
- We are currently recovering unused loads on emergency generators so they can be reallocated in the event of an outage.
- We are also enhancing and refining emergency response plans to handle prolonged outages, ensure continuity during major wind events, and mitigate health/safety risks.

Consequence ratings

Based on these findings, the project team rated the overall consequence of this scenario as **3.8** out of 5.

Infrastructure damage: 3
We can expect total or partial damage to roofing, windows, landscaping, building envelopes, etc. Loss of equipment is expected in large surface area assets like parking lots, exposed structures, etc.

Operational disruption: 4
Depending on the extent of damage, we can expect the partial or full closure of buildings affected, power outages, and disruption to access routes. While our risk is reduced by our ability to mobilize quickly, restoring to operational standard could take time. Portions of one lab were closed for months after the 2019 Steacie fire.

Health and safety risks: 5
The rating is directly caused by the increased risk of harm from flying debris and structural failures, especially if people are outside in seating areas or walking between buildings.

Financial implications: 5
Costs associated with cleanup, repairs, temporary closures, and/or losses from disruptions to income-generating activities.

Reputational impact: 2
The nature of such an event that had little to no warning will result in a neutral outlook reputationally unless the aftermath is mishandled.

As an educational institution, we are expected to be a leader in sustainability efforts. Failure to effectively manage climate risks or adapt to new environmental standards could diminish the university's reputation among key stakeholders, including students, faculty, staff, and the broader community.

Transition risks

Transition risks are associated with the extent an organization adapts to reducing greenhouse gas emissions and transitioning to renewable energy.

In the context of this plan, the transition risks of adapting our infrastructure are as follows:

Compliance costs

As environmental regulations evolve and impending mandates from the Canadian Sustainability Standards Board are introduced within the next three to five years, we may face significant compliance expenses. These could look like the need to invest in cleaner technologies or to retrofit existing infrastructure to meet stringent new environmental standards.

Adaptation requirements

New policies could require substantial operational changes like modifications to energy consumption patterns or updates to building codes. These changes could negatively impact the university's day-to-day functions and long-term sustainability goals if they are not managed carefully.

Increased reliance

An increased reliance on digital platforms intensifies the expectation that Information Technology Services (ITS) maintain robust online campus operations, especially if severe climate events compel a swift pivot to virtual environments.

Obsolescence

Current technologies, particularly those related to energy production and waste management, may soon become outdated. As new, more efficient alternatives become available, the university faces the dual challenge of capital investment and potential disruption during the onboarding phase.

Implementation challenges

Integrating advanced technologies like renewable energy systems or enhancements to the Building Automation System (BAS) presents complexities that could cause early day interferences with campus operations. Meticulous planning and phased implementation should minimize disruptions.

Funding volatility

Economic fluctuations could impact funding for public institutions and directly affect the availability of resources for climate-related projects. The reliance on external funding sources for sustainability initiatives introduces a layer of uncertainty in planning and execution. Like the COVID-19 pandemic, which saw a dramatic decrease in funding to post-secondary institutions, we can expect similar ramifications when climate events increase in the coming years.

Insurance costs

Increases in climate-related events could lead to rises in insurance premiums, especially for assets in high-risk areas. Our position near water could lead to higher water damage insurance premiums.

Stakeholder expectations

As an educational institution, we are expected to be a leader in sustainability efforts. Failure to effectively manage climate risks or adapt to new environmental standards could diminish the university's reputation among key stakeholders, including students, faculty, staff, and the broader community.

Public perception

Public sensitivity to environmental issues is high. Any perceived delays or missteps in addressing transition risks or implementing sustainable practices could attract negative publicity, which could potentially reduce student enrollment and weaken community support.

By identifying and addressing transition risks comprehensively, we can safeguard our infrastructure, community, and academic integrity against the backdrop of a changing climate and evolving regulatory environment.

This proactive approach in the CCAP is intended to align with best practices in sustainability and resilience, ensuring the university not only adapts to but thrives in the face of these challenges.

Transition Risks

- Climate Risks and opportunities defined | US EPA. (2024, March 8). US EPA. https://www.epa.gov/climateleadership/climate-risks-and-opportunities-defined
- Government of Canada, Statistics Canada. (2022, December 7). The Daily — The impact of the COVID-19 pandemic on college finances for the 2020/2021 fiscal year. https://www150.statcan.gc.ca/n1/daily-quotidien/221207/dq221207a-eng.htm
- Henne, D. Dickson, B. (2024, March 27). *New Sustainability Financial Reporting Requirements- Implementation Toolkit* [PowerPoint Slides]. Canadian Association of University Business Officers (CAUBO). https://www.caubo.ca/knowledge-centre/learningevents/webinars/#squelch-taas-accordion-shortcode-content-SustainabilityToolkit

Where our discussions should be if we want to make a concerted effort

Recommended mitigation strategies by risk event

The “Evaluation of Implemented Mitigation Strategies” section in each risk assessment section above reflects what we have done so far.

This section of the report will explore the long-term, capital-intensive projects that come next; those within our current capabilities and that require external consultation and contractors.

These projects are designed to bolster our resilience to the specific climate risks anticipated in our region, reflecting a strategic approach to building sustainable and robust infrastructure.

Mitigation Strategies - Flood

- Campus Master Plan 2023 - Finance and Administration. (2024, June 6). Finance and Administration. https://carleton.ca/finance-admin/campus-master-plan-2023/
- Stormwater Details can be found in Mitigation Strategies sections and Appendix
- Ontario Building Code Act, 1992, O. Reg. 350/06, s. 1.1 https://www.ontario.ca/laws/regulation/060350/v13
- About green roofs — Green roofs for healthy cities. (n.d.). Green Roofs for Healthy Cities. https://greenroofs.org/about-green-roofs
- TrapBag. (2023, August 30). How to build a water retaining wall for flood control. TrapBag. https://trapbag.com/water-retaining-wall-flood-control/#:~:text=A%20water%20retaining%20wall%20can,at%20the%20beach%20or%20embankment.
- Hershfield, M. (2020, July 16). Improving Community Safety with the Rideau River Multi-Use Pathway. Morrison Hershfield. https://blog.morrisonhershfield.com/improving-community-safety-with-the-rideau-river-multi-use-pathway

100-Year Flood

Act on the stormwater master plan assessment.

While some past flooding incidents were due to natural causes beyond our control, the majority were attributed to the inadequate capacity of our existing stormwater system.

In response, Morrison Hershfield has been commissioned to develop a new Stormwater Master Plan. This plan is tasked with assessing the current capacity of our stormwater drainage system and recommending a mix of short-term and long-term solutions:

- **Capacity assessment:** Identify bottlenecks and areas lacking sufficient capacity to handle significant rainfall events.
- **Climate change resiliency:** Ensure the stormwater system can handle increased frequency and intensity of rainfall expected in future scenarios.
- **Capital works program:** Outline a series of capital-intensive projects aimed at expanding and upgrading the stormwater infrastructure to meet current and future needs.
- **Updating the 2008 Master Plan:** Revise and update the existing plan to reflect new insights, support future applications, and ensure compliance with modern standards and regulations.

We strongly advocate for the full implementation of Morrison Hershfield's recommendations, for recognizing the importance of these upgrades to prevent future flooding, and for committing to these enhancements.

The 2008 Master Plan found that 39% of "Network 1" (that drains most of the campus) has insufficient capacity to convey run-off from a one-in-five-year rainfall event. The scope of that assessment did not originally consider the potential flooding from overland flow or the impacts of more intense rainfall (e.g., 100-year events). The new stormwater plan will assess these concerns and more with solutions to fix them.

Explore commonly used mitigation strategies

In addition, the project team explored commonly used mitigation strategies at other institutions that could be phased into the plan. These include:

- **Rainwater Holding Tanks:** 2010 Ontario provincial codes permit the use of rainwater for non-potable purposes like toilets and below-ground irrigation. The tanks could significantly reduce pressure on the stormwater infrastructure concurrently with other strategies.
- **Green Roofs:** A green roof system is an extension of the existing roof. It offers high-quality waterproofing, and at a minimum includes a root repellent system, a drainage system, a filter cloth, a lightweight growing medium, and plants. Green roofs reduce the amount of stormwater runoff and delay runoff times. This decreases stress on sewer systems at peak flow periods.
- **Riparian Zones:** Riparian corridors sit between land and waterways and are made up of plants that help with soil conservation, habitat biodiversity, and the influence they have on fauna and aquatic ecosystems. The Riparian Zone proposed by the 2023 Campus Master Plan Update (CMPU) would act as an additional line of defense against high water levels.
- **Cameras:** The use of cameras atop Dunton Tower to monitor water levels on roofs in an intense rain event.
- **River Wall:** A water retaining wall can prevent significant damage by preventing flooding waters from overflowing and keeping erosion from eating away at embankments. In 2014, the RVCA banned the construction of retaining walls due to environmental concerns. A case can be made with Morrison Hershfield's help. They designed the newly completed Eastern Rideau River Pathway.

Integrate Mechanical Equipment to the BAS

Adding leak sensors and the sump pump network to the BAS would allow for earlier detection and mitigation.

Note that the financial implications of this risk identify the replacement of the MERV 13 filters as an unpredictable cost, and the budget should be given leniency to grow as needed.

Mitigation Strategies - Wildfire Smoke

• Appendix E: June 2023 Wildfire Event

Wildfire Smoke

Keep pursuing the already implemented strategy

The FMP Building Operations team has developed and implemented a comprehensive wildfire smoke readiness plan that leverages the BAS to initiate tailored procedures for managing indoor air quality during smoke events.

The mitigation strategy is designed to address the unique air handling characteristics of different buildings on campus, ensure indoor smoke levels are minimized, and mitigate health risks without causing significant operational disruptions:

- **Lab buildings (Steacie, Nesbitt, NWRC, etc.):** These buildings operate with 100% outdoor air, which is a requirement due to the chemicals used in these facilities. During wildfire smoke events, pre-installed MERV 13 filters are used to remove particulate matter, though they do not eliminate odours. This approach addresses health risks but could lead to potential operational disruptions due to odour persistence.
- **Academic buildings:** These buildings generally recirculate a portion of the outside air for energy efficiency. In the event of wildfire smoke, the system minimizes the intake of outdoor air and aids filtration efforts to reduce indoor smoke levels effectively.
- **Residence buildings:** Each room or unit in residence buildings has its own heating and cooling system that recirculates air within the space. Hallway systems, which take in outdoor air to create a positively pressurized environment, are shut off during smoke events to prevent smoke infiltration, thereby reducing exposure to harmful particulates.

To maintain optimal air quality and system efficiency, regular inspections and replacements of MERV 13 filters are essential, especially following wildfire smoke events as per ASHRAE standards. This ensures filters continue to perform effectively, thus protecting the health of building occupants.

Note that the financial implications of this risk identify the replacement of the MERV 13 filters as an unpredictable cost, and the budget should be given leniency to grow as needed.

In addition, the existing processes need ongoing maintenance and potential upgrades to enhance efficiency. This includes revisiting and optimizing the settings and operations within the BAS to respond more effectively during various air quality emergencies.

While it is impossible to guarantee 100% clean air during intense wildfire smoke events, our proactive and tailored approach aims to significantly mitigate the impact on indoor air quality and ensure the safety and comfort of all campus users.

By continuously improving the efficiency of these systems and processes, we remain committed to protecting our school community from the adverse effects of wildfire smoke.

Heat Wave

Improving electrical infrastructure

Reducing our reliance on city power will mitigate our exposure to power outages, a known effect of heat waves.

Improving cooling infrastructure

Rising global temperatures and more frequent heat waves highlight the urgent need to upgrade the university's cooling infrastructure to ensure the comfort and safety on campus. Outlined below are key components/actions to enhance the resilience and efficiency of the university's cooling systems, particularly focusing on extending operational capacity and addressing redundancy issues.

A main goal is to increase our cooling systems' capacity to operate continuously for over two weeks without interruption in concurrent heat waves. This is crucial as buildings struggle to maintain comfortable temperatures if turned off overnight during heat waves. The following steps will be implemented with appropriate financial backing:

- **Infrastructure replacement:** Begin a phased replacement of aging cooling infrastructure with more efficient and robust systems. This includes upgrading HVAC systems and chillers that are beyond their effective operational life; e.g., Tory Chiller replacement.
- **Preventative maintenance:** Intensify the frequency and scope of preventative maintenance routines to ensure our cooling systems operate at peak efficiency, especially during high temperatures. This includes regular checks and servicing of all components to prevent breakdowns during heatwaves.

Currently, the lack of redundancy in cooling systems that serve multiple buildings, particularly in critical buildings such as Tory and Steacie, poses a significant risk during prolonged high-temperature events. To address this vulnerability, we plan to:

- **Install multiple chillers:** Our strategy is to install larger and more reliable chillers that can service multiple buildings simultaneously. This approach enhances the resilience of our cooling infrastructure and ensures that cooling is not disrupted in critical research and academic buildings. This strategy will reduce maintenance costs as bigger chillers require the same maintenance as smaller units. And a less decentralized network of chillers allows for faster service by FMP.
- **Alternative Cooling:** Explore and invest in solutions to provide backup during failures or maintenance of primary systems. This includes using temporary rental chillers, which, while expensive, are necessary for ensuring continuity during emergency repairs or system failures.

Extreme Cold Events

Replace of aging infrastructure
Refer to Recommended Multipurpose Mitigation Strategies

Improve electrical infrastructure
Refer to Recommended Multipurpose Mitigation Strategies

Make Design Guideline updates
Refer to Recommended Multipurpose Mitigation Strategies

Major Winter Precipitation Events (ice and snowstorms)

Replace of aging infrastructure
Refer to Recommended Multipurpose Mitigation Strategies

Make Design Guideline updates
Refer to Recommended Multipurpose Mitigation Strategies

Improve electrical infrastructure
Refer to Recommended Multipurpose Mitigation Strategies

Major Wind Events (thunderstorms, derechos, and tornadoes)

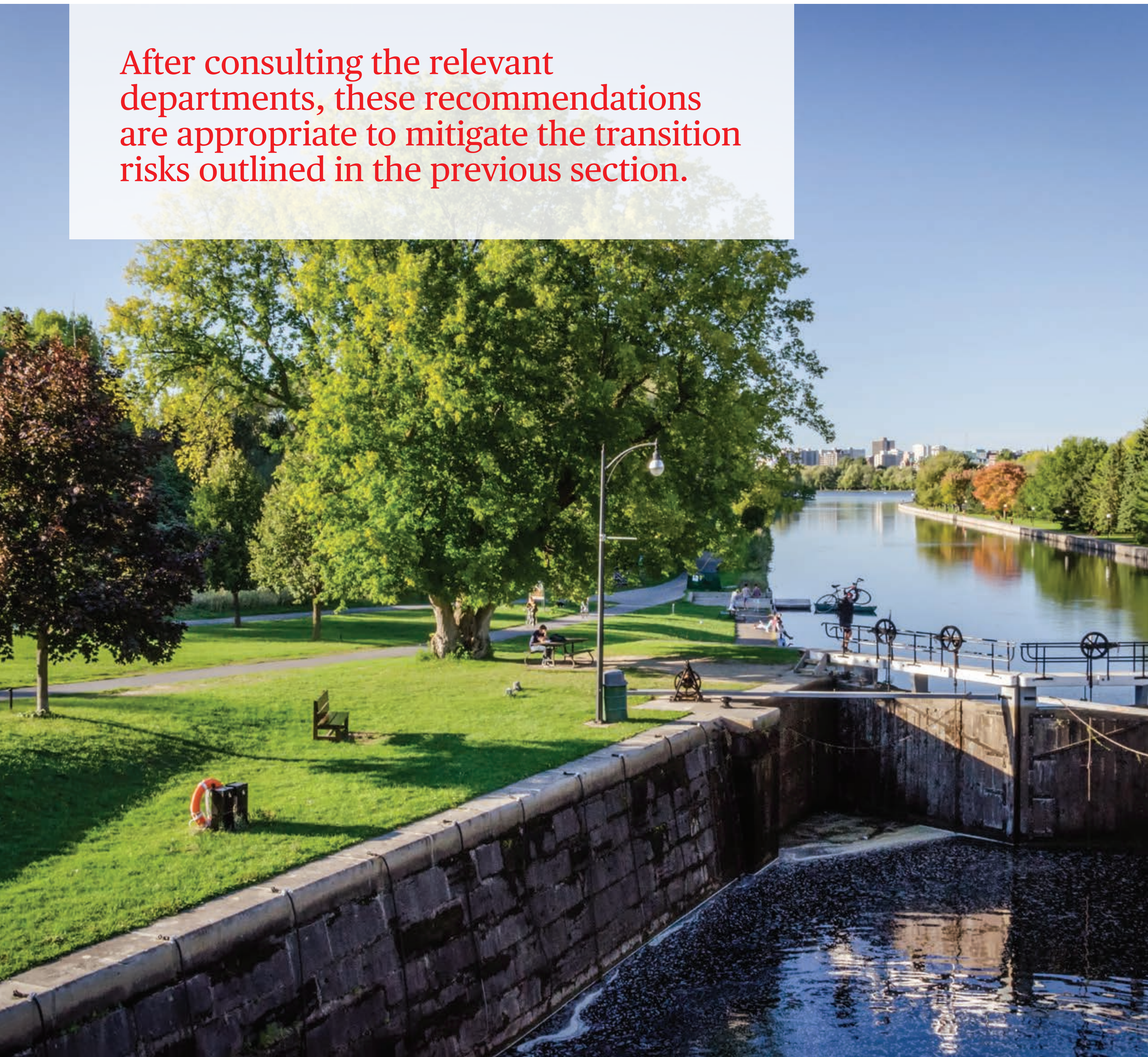
Replace of aging infrastructure
Refer to Recommended Multipurpose Mitigation Strategies

Make Design Guideline updates
Refer to Recommended Multipurpose Mitigation Strategies

Improve electrical infrastructure
Refer to Recommended Multipurpose Mitigation Strategies

Adaptation strategies for transition risks

After consulting the relevant departments, these recommendations are appropriate to mitigate the transition risks outlined in the previous section.



A clear crisis communication strategy will be established to address issues swiftly and transparently, ensuring that accurate and consistent information is provided during incidents or emergencies. Emergency response upgrade plans are explained further in the following section.

Regulatory and policy changes

The university must establish a dedicated team to continuously monitor changes in environmental, safety, and building regulations that impact university operations. This team will ensure Carleton remains in front of new regulations. The first of many Environment, Social, and Governance (ESG) meetings were held in June 2024 to kickstart the process.

In addition, regular assessments should be conducted to keep us compliant and ahead of regulatory curves, and so that we understand how new regulations could impact university facilities and operations. This includes analyzing potential costs, required changes in operational procedures, and impacts on ongoing and planned projects.

Technological risks

To safeguard critical IT infrastructure against climate risks, we will continue our collaboration with Information Technology Services (ITS) to ensure systems like data centres are equipped with adequate cooling and robust backup power systems for handling extreme weather events and power disruptions. ITS has indicated they are equipped to weather run-of-the mill emergencies like brief power loss with their uninterruptible power supply (UPS). The concern lies with more catastrophic loss of physical infrastructure from climate events like floods or tornadoes and cybersecurity threats. They have since began migrating their assets to the cloud.

In addition, before adopting any new technology, ITS (with us in a supporting role) will conduct a thorough due diligence assessment to evaluate reliability, requirements, and compatibility with existing systems. This includes pilot testing and vendor assessments to mitigate the risk of obsolescence.

To address implementation challenges, ITS will work with us to equip the BAS with smart technologies. This includes deploying IoT sensors to monitor energy usage, detect water leaks, and assess structural health, enhancing the university's capability to manage resources efficiently and respond to issues proactively.

Market risks

Strategic financial planning is essential for ensuring that investments in climate resilience are prioritized and managed effectively within the university's broader budget framework.

To address funding volatility, FMP recommends budgeting for sustainability. In collaboration with the finance department, we hope to secure budgets specifically allocated for sustainability projects. Together, we will conduct cost-benefit analyses for proposed projects to assess the long-term savings and benefits of investing in climate resilience measures. This will ensure the investments are sustainable and economically advantageous. In addition, in collaboration with the Office of Risk Management (ORM), we plan to record information helpful for insurance claims, like pre-flood rain data.

Reputational risks

To mitigate the reputational risks, we will continue to ensure all facility services are reliable and in line with the high standards expected by university stakeholders. This involves regular maintenance, prompt repairs, and adherence to quality standards in construction and facility management.

Training for staff will also be enhanced to ensure excellent service. This will involve collaboration with Campus Safety to align emergency response plans and radio protocols, and will complement an already well-equipped and award-winning team.

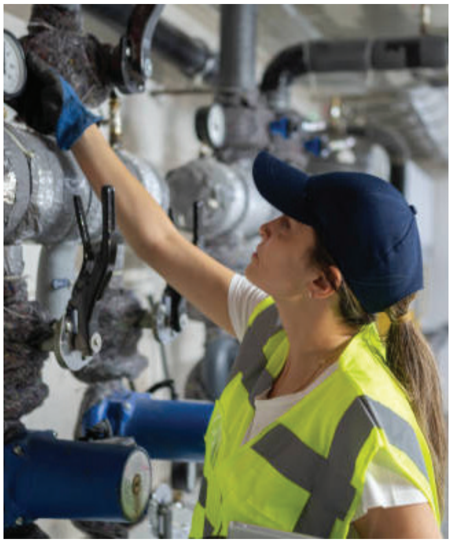
To ensure transparent operations and crisis communication, we will continue working closely with the Department of University Communications (DUC) to maintain transparent operations. A variety of communication channels will be used to keep the community well-informed about ongoing projects, potential disruptions, and improvements.

Additionally, a clear crisis communication strategy will be established to address issues swiftly and transparently, ensuring that accurate and consistent information is provided during incidents or emergencies. Emergency response upgrade plans are explained further in the following section.

Recommended multipurpose mitigation strategies

What our next steps should be if we want to get ahead of climate change.

We identified the following strategies that apply to multiple risks identified above.



BAS integrations and enhancements

The BAS monitors and controls heating, cooling, and air flow in all buildings. In some buildings with animals or research, it monitors CO_2, ammonia, humidity, and temperature levels.

The capabilities of the system are limitless in reducing the impact of climate events, which can include diagnosis of problems, early detection, and automatic protocols, etc.

Projects discussed with the FMP Building Operations team have included:

- **BAS:** The BAS is currently divided between a modern remotely accessible system and an older standalone system that lacks emergency alert capabilities and can only be accessed on campus. FMP has been able to migrate all but three buildings (in progress) and two housing buildings, with plans to complete the integration. The athletics buildings have yet to be migrated due to the lack of budget allocation to the project.

  The need to unify the system has never been more important as it reduces the effectiveness of any modifications proposed.

  The FMP Building Operations team estimates the full migration at $100,000.

- **Weather station integration:** 2023's flooding highlighted the need for localized weather monitoring. Our Building Operations team established a weather station capable of tracking wind, rain, humidity, and temperature, which proved essential given the discrepancies in rainfall measurements between the university and the nearest weather station — the closest weather station less than 10 km away only recorded 30 mm of rain on August 10th, 2023, while Carleton received 100 mm in under two hours.

  In its current state, the weather station can only send a rain alert to one central location once the forecast or current measurements go above an identified threshold. The plan for this fiscal year includes integrating the weather station with the BAS to trigger alerts to relevant parties when rainfall or other weather thresholds are exceeded.

  This integration will enable proactive management of flood risks and other weather-related emergencies.

- **Flood detection assistance:** Discussions are underway to expand the BAS's flood detection capabilities. This includes integrating the campus's sump pump inventory into the BAS, which will facilitate early detection of operational issues with sump pumps; the 2023 flood revealed that several pumps were not operational or were not serviced appropriately.

  In addition, enhancing the leak sensor network in critical infrastructure areas will improve our response to potential flooding and help mitigate water damage.

- **Integration of electrical infrastructure:** We can integrate electrical equipment to the BAS system with our capabilities; specifically, high voltage transfer switches would improve activation of emergency generators during outages. It would allow for comprehensive monitoring and management of electrical redundancies, particularly beneficial during power outages.

  Currently, identifying faults in the system requires time-consuming manual checks by FMP electricians, as some emergency generators have 10+ switches connected to multiple buildings across campus.

  The proposed integration would enable instant fault detection and quicker resolution, significantly reducing downtime and enhancing safety during emergency situations.

  This project is currently under discussion, and similar plans of this nature should be considered and implemented.

Replacing aging infrastructure

Carleton was established in 1942. At an average building age of over 40 years, a recurring theme for discussion and time-sensitive intervention is the replacement of aging infrastructure.

Our adaptation loop culture revealed numerous deficiencies across campus. If provided with adequate financial support, we plan to implement the following strategy to address the need for change to combat the effects of extreme cold, major winter precipitation events, and major wind events.

- Assessment and planning: The university regularly assesses the condition of its infrastructure, based on this new information about specific climate risks to campus. The request to internal teams and external consultants would be to focus on:
  - Extreme Cold Events: Components most vulnerable to failure during extreme cold, such as heating systems, pipes, and insulation.
  - Major Winter Precipitation Events: Detailed assessments of structural elements and drainage systems that must withstand heavy snow and ice accumulation.
  - Major Wind Events: Detailed assessments of all structural vulnerabilities that could be compromised by wind events, such as roofing, windows, and external facades.
- **Enhanced building standards:** Replacement of identified aging infrastructure will adhere to updated building codes and standards to withstand:
  - Extreme Cold Events: This could include upgrading HVAC systems, improving building insulation, and replacing old pipes.
  - Major Winter Precipitation Events: This could include strengthening roof structures and enhancing water drainage systems to manage snow and ice melt effectively.
  - Major Wind Events: This could include installing impact-resistant windows, reinforced roofing materials, and stronger facade elements to protect against flying debris and direct wind force.
- **Enhancing redundancy:** In addition to replacing outdated components, the strategy involves increasing the redundancy of critical systems to mitigate:
  - Extreme Cold Events: Installing multiple sources of heat and backup power supplies to ensure essential services remain operational, even if one component fails.
  - Major Winter Precipitation Events: Redundant water management systems to prevent flooding from snow and ice melt.
  - Major Wind Events: Enhancing system redundancies in the two data centres, laboratories, etc. This includes securing backup power systems and communication networks to ensure they remain operational during and after wind events.

By investing in modern, reliable, and redundant systems, resilience will be enhanced and we can ensure our campus remains a safe, comfortable, and energy-efficient environment.

The 2024 updates to our design guidelines reflect a strategic approach to building resilience against the impacts of climate change and extreme weather events. By incorporating these specific features into new constructions, Carleton is addressing immediate infrastructure vulnerabilities and setting a standard for future developments that prioritize safety, sustainability, and operational continuity.

Design Guideline updates

To enhance resilience and adaptability across its campus, we are committed to updating design guidelines in 2024. These updates are driven by a proactive assessment of pain points in existing infrastructure, and the analysis of climate events impacting the campus.

By integrating new guidelines into the design process, the department aims to mitigate risks associated with extreme weather events and ensure the long-term sustainability of its new facilities. The new additions include:

- **Antifreeze coils:** Antifreeze coils will be suggested in all new building projects to prevent the freezing of heating systems, a common issue during severe cold spells that can lead to significant damage and disruption. This suggestion will be included in the specifications for HVAC systems in all future constructions and major renovations, ensuring that all new facilities have built-in protection against freezing temperatures.
- **Teck cables:** Teck cables address challenges posed by flooding and will be suggested for all new constructions to safeguard electrical systems from water damage and enhance the overall resilience and set performance expectations for new constructions. Known for their durability and resistance to environmental factors, they provide a robust solution to electrical wiring needs, particularly in flood-prone areas, as they do not rust. They will be incorporated into the electrical design guidelines for new buildings.
- **Emergency generators:** To improve resilience in the event of prolonged power outages, the installation of natural gas emergency generators will be suggested for new buildings that cannot be connected to existing generator networks. This guideline will ensure that all new buildings have a reliable on-site power generation capacity, allowing them to remain operational during extensive utility failures. This strategy not only ensures safety and continuity, but also reduces dependency on external power supplies.
- **Intentional portable generator hookups:** Enhancing the flexibility and responsiveness of the university's power supply systems during emergencies, intentional rental or portable generator hookups will be incorporated into the design of new buildings. These hookups allow quick connection to portable or rental generators, facilitating faster restoration of power and continuity of operations in case of an outage. This feature will be particularly valuable in critical areas such as research labs, data centres, and health services.

The 2024 updates to our design guidelines reflect a strategic approach to building resilience against the impacts of climate change and extreme weather events. By incorporating these specific features into new constructions, Carleton is addressing immediate infrastructure vulnerabilities and setting a standard for future developments that prioritize safety, sustainability, and operational continuity.

These guideline updates will play a crucial role in ensuring that the university's facilities are equipped to handle the challenges posed by an evolving climate landscape.

The CCAP underscores the expectation of increased frequency of climate-related events, transitioning what were once considered extraordinary emergencies into anticipated and planned-for occurrences. This shift highlights the urgent need for robust adaptation strategies that prepare the university for what may soon become the new normal.

Emergency management plan (EMP) updates

In addition to the work done on this plan, the project team reviewed and updated the current FMP emergency management plans to better address the impacts of climate events and common emergencies.

The updates to the EMP are designed to integrate seamlessly with the broader objectives of the Climate Change Adaptation Plan (CCAP), emphasizing the need for proactive adaptation and preparedness. The key components of the updated plan include:

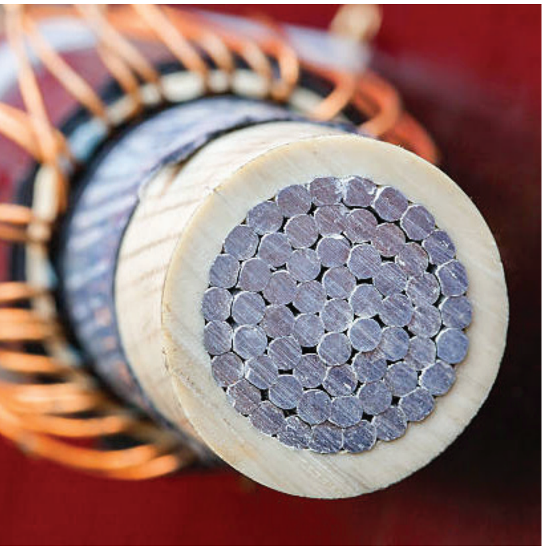
- **Guiding checklists:** Clear, actionable steps for responding to common emergencies that align with Carleton's guiding priorities: Life Safety, Infrastructure, and Operation. Each checklist outlines less prescriptive actions to guide us during emergencies. These checklists ensure swift, coordinated, and effective response efforts that minimize impact and restore normal operations quickly.
- **FMP communication channel:** Access to streamlined, up-to-date communication during emergencies so stakeholders can efficiently coordinate responses. The channel will host supporting documents critical for emergency response, and will be crucial for maintaining clarity and direction during chaotic situations.
- **Standard operating procedures:** A standardized reference that outlines the procedures to be followed during specific emergencies. These documents are intended for both internal use and external reference, particularly by other university departments.

As of August 2024, the FMP project team has developed specific EMPs for the following critical scenarios:

- Building Control Fault EMP
- Central Heating Plant (CHP) EMP
- Loss of Safety Valve EMP
- High Voltage Power Outage EMP
- Watermain Break EMP
- Flood EMP
- Fire EMP

Working on the EMPs in tandem with the CCAP has allowed for alignment between strategies developed for immediate emergencies and longer-term adaptation goals.

The CCAP underscores the expectation of increased frequency of climate-related events, transitioning what were once considered extraordinary emergencies into anticipated and planned-for occurrences. This shift highlights the urgent need for robust adaptation strategies that prepare the university for what may soon become the new normal.



Improve the electrical infrastructure

An uncontrollable reality of the effects of climate change is the increased likelihood of power outages due to strain on the city grid during heat waves, ice accumulation, and/or unpredictable wind events that can damage power infrastructure.

We adopted a proactive approach to upgrade the aging electrical infrastructure, ensuring resilience and continuity during extreme weather events.

Carleton is at an important crossroads with aging infrastructure reaching or exceeding their life cycle. This provides an opportunity for an adequately and financially backed push for adaptation. It is important to note that the values below are finalized once they are sent out for tender; it could come back as lower or higher than the in-house estimates.

As part of our renewed and aggressive approach to climate adaptation, the following projects have begun or are in the design phase:

- **Black start ($830,000):** This project is designed to let the university disconnect from the city grid during city-wide power outages and switch to an independent power source. It involves installing a natural gas generator linked to a Cogen system installed in 2021, capable of powering about one-third of the campus. This setup enables the university to function as a safe haven during severe climate events, reducing reliance on city power.
- **Retesting ($800,000**): Standard practice requires all electrical equipment be retested every five years. However, much of our equipment has never been tested. The project includes testing breakers, cleaning fuses, and more; and it requires building shutdowns during weekends. The tests have produced a deficiency list, prioritizing repairs based on urgency and available resources. So far, half of the campus has been retested. The resulting projects include:
  - Nideyinàn transformer replacement ($2,300,000): Testing revealed that the transformer in Nideyinàn (formerly University Centre) is in most urgent need of replacement because of (a) its age and (b) changed standards of PCBs as a sealant.
  - Bronson substation redesign ($5,000,000): Reconstructing two of the three buses that form the Bronson Substation to ensure continuous power supply during the upgrade. This project aims to modernize the infrastructure while maintaining operational continuity, with three buses always being active during the work. The two buses have not been redone since their installation in the early 1960s.
- **Battery farm (free installation):** This project involves implementing a battery storage system to reduce electricity costs and provide backup power during outages. A company offers free installation with a 10-year contract where savings are shared. This system will help manage peak usage periods and provide emergency power. This project is under design review in collaboration with procurement and FMP.
- **High voltage cables ($5,000,000):** The high voltage cable network dates back to the 1950s and, like the Nideyinàn transformer, it needs to be replaced due to lack of effectiveness and use of PCBs as a sealant. Thirty percent of the network has been replaced, and the project hinges on the availability of specific splice kits, which take time to deliver.

Carleton is at an important crossroads with aging infrastructure reaching or exceeding their life cycle. This provides an opportunity for an adequately and financially backed push for adaptation.

- **Tory Building chiller and emergency generator replacement ($6,000,000):** The combined replacement of the Tory chiller and emergency generator will help reduce energy consumption. After completion, the Dunton Tower chiller plant will be removed and added to the Tory network, which currently provides cooling to five buildings. Ultimately, the centralization and redundancy of the chiller will reduce energy consumption.

- **Miscellaneous:** In addition to the major projects to rehabilitate electrical infrastructure, the following are actions being taken simultaneously if possible:

- **Updating electrical plans:** All electrical plans are updated before and after major projects to ensure all modifications are accurately reflected in university records.

- **Switching to natural gas generators:** As diesel generators reach the end of their lifecycle, we plan to replace them with natural gas generators, leveraging Carleton's uninterrupted natural gas service from Enbridge. This transition will enhance the reliability of emergency power supplies. Currently only 3/11 generators are natural gas.

Implementation plan

Our climate adaptation strategies target various aspects of campus infrastructure and operations.

The implementation of these strategies considers the unique nature of each, and prioritizes them based on their potential impact and the frequency of related climate events as detailed in the risk assessment phase.

Below is an overview of which strategies apply to specific climate events, indicated by checkmarks in the corresponding boxes:

Implementation Considerations

Given the overlapping nature of the strategies, nearly all involve some form of infrastructure replacement due to the age of the university.

We have prioritized long-term solutions for managing flooding and enhancing electrical resilience. The placement of flooding in the 5th position on the risk rating scale is due to the likelihood of a 100-year flood event; however, the likelihood of smaller-scale floods is expected to increase. These events have slightly more predictable consequences such as overwhelming the storm system and flooding buildings near the river.

The need for electrical resilience is underscored by four out of six risks identifying power outages as a side effect of the event. These two areas are the cornerstone of operations and wellbeing on campus. At a high level, we plan to accomplish the following:

Phased implementation

- **Initial phase:** Focus on critical infrastructures like electrical systems and flood defenses. This includes:
  - Expediting the Black start project and other related electrical upgrades to enhance the campus's ability to maintain power during grid failures, which are increasingly likely due to climate events.
  - Scheduling comprehensive updates to the stormwater management (SWM) systems and ensure all new constructions are built with elevated flood resilience standards to handle severe precipitation.
- **Subsequent phases:** Gradually address less critical but equally important areas such as cooling systems, and update design guidelines to incorporate advanced mitigation technologies and materials.

Stakeholder engagement

- **Internal collaboration:** Consulting regularly with various university departments, including academic units and student services, to ensure the planned measures align with all campus needs and activities.
- **Community involvement:** Engaging with local government, emergency services and the surrounding community to ensure our plans complement regional climate adaptation efforts.

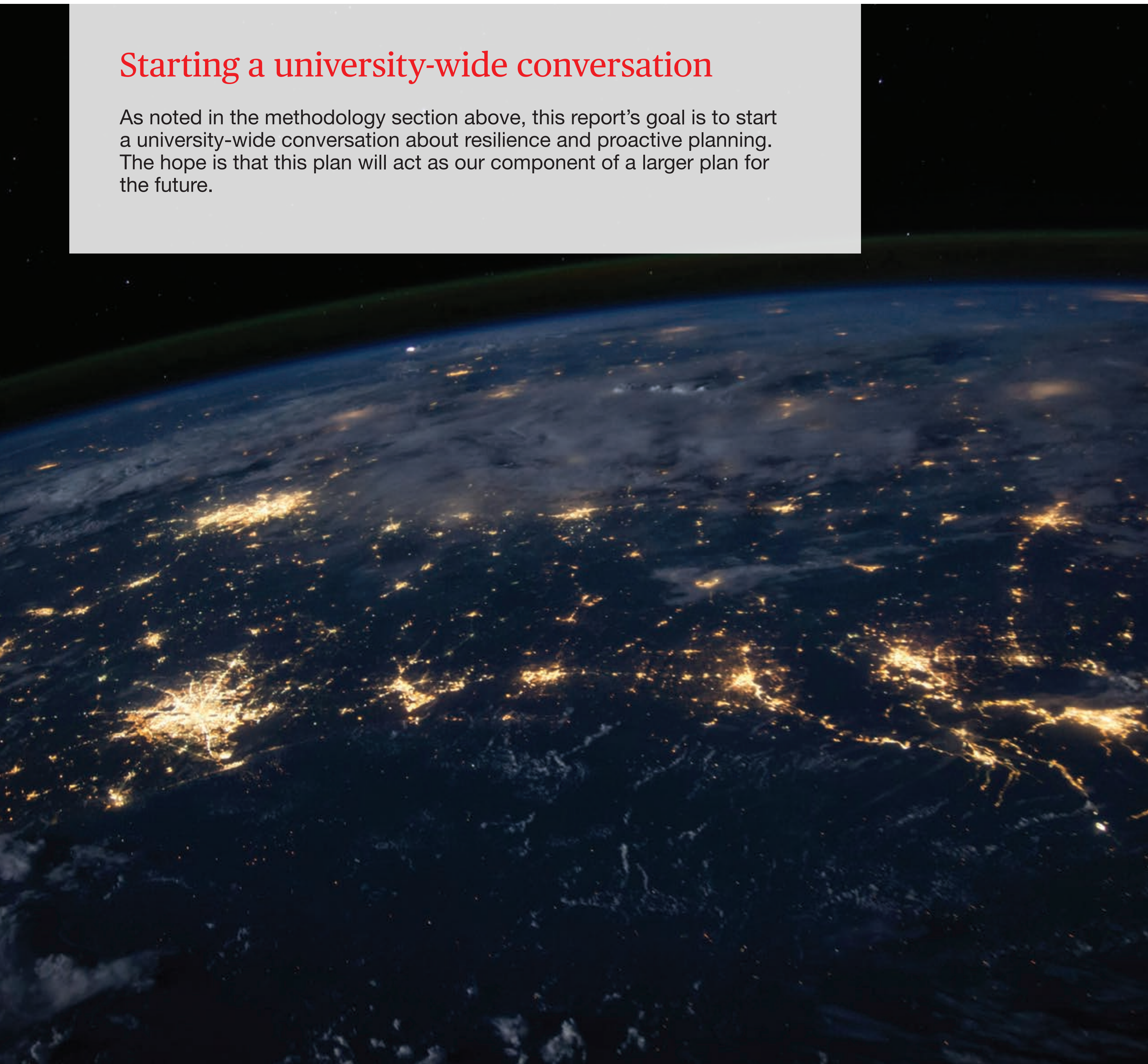
The implementation plan for FMP's climate adaptation strategies is designed to be dynamic, allowing for adjustments as new information and technologies become available. By prioritizing actions based on risk assessments and integrating feedback from across the university community, we ensure a resilient and sustainable campus environment for the future.

	SWM Recs	Commonly used mitigation strategies	Maintenance of Implemented strategy	Improving Electrical Infrastructure	Improving Cooling Infrastructure	Replacement of Aging Infrastructure	Design Guidelines
1-in-100 Year Flood	✓	✓					
Wildfire Smoke		✓	✓	✓	✓		✓
Heat Wave		✓		✓		✓	✓
Extreme Cold Events		✓		✓		✓	✓
Major Wind Events		✓		✓		✓	✓
Total	1	6	1	4	1	3	4

Monitoring and evaluation

Starting a university-wide conversation

As noted in the methodology section above, this report’s goal is to start a university-wide conversation about resilience and proactive planning. The hope is that this plan will act as our component of a larger plan for the future.



To ensure the effectiveness of a university-wide Climate Change Adaptation Plan (CCAP) and to facilitate ongoing improvement, a robust Monitoring and Evaluation (M&E) framework is essential. This framework will help track the progress of implementation, assess the effectiveness of adaptation measures, and provide data-driven insights to inform future actions.

Objectives of monitoring and evaluation

- **Assess effectiveness:** Evaluate how well the adaptation strategies are performing against set goals and objectives in reducing vulnerabilities and enhancing resilience.
- **Inform decisions:** Provide actionable data to decision-makers to improve, scale, or modify adaptation strategies based on observed outcomes and emerging trends.
- Enhance transparency and accountability: Keep stakeholders informed about the progress and impacts of the adaptation efforts, ensuring accountability for the commitments made.

Components of the monitoring and evaluation framework

- **Indicator development:** Clear, measurable KPIs for each adaptation strategy implemented. These indicators should cover key aspects such as infrastructure resilience, operational continuity, community wellbeing, and environmental impact. Examples of indicators could include:
  - Reduction in downtime due to climate-related disruptions.
  - Decrease in maintenance and repair costs due to improved infrastructure resilience.
  - Levels of stakeholder satisfaction with implemented changes.
- **Data collection methods:** A mix of quantitative and qualitative methods. Quantitative data might include system performance metrics, while qualitative data could come from surveys, interviews, focus groups with affected stakeholders, IoT sensors, and other technology-based solutions to continuously monitor environmental conditions and infrastructure performance in real-time — similar to the requirements for green globe certifications.
- **Evaluation schedule:** This includes regular evaluation that aligns with the university's academic and fiscal calendars, and interim assessments for specific high-priority or high-risk areas. It also includes major evaluative reviews every five years in advance of comprehensive assessments that align with larger strategic reviews of the university's overall climate readiness.
- Reporting mechanisms: A standardized reporting format to present findings to various stakeholders, including university leadership, students, staff, and external partners; and digital dashboards where real-time data can be accessed and analyzed by relevant stakeholders to ensure transparency and facilitate quick decision-making.

Feedback: Formal mechanisms for integrating feedback from the M&E process into current and future adaptation planning. This might involve regular workshops or meetings with stakeholders to discuss evaluation findings and possible strategy adjustments. Ensure that there is a clear process for stakeholders to contribute their observations and concerns about the adaptation strategies' performance.

By systematically tracking performance, engaging stakeholders, and integrating feedback into adaptation strategies, the university can dynamically respond to changing climate conditions and enhance its resilience for the future.

Challenges and Solutions

As we get into implementation, we know we will face challenges that require solutions. While we cannot predict what they will be, we are confident that these two will come up:

- **Data overload:** Managing and making sense of vast amounts of data collected through various methods.
  - **Solution:** Implement advanced data management and analysis systems, use AI and machine learning tools to help sift through data and highlight actionable insights. This can be achieved in collaboration with ITS and academic labs wherever possible.
- **Stakeholder engagement:** Ensuring continued stakeholder involvement in the M&E process.
  - **Solution:** Maintain clear communication channels, provide regular updates, and actively solicit stakeholder feedback through user-friendly platforms.

By systematically tracking performance, engaging stakeholders, and integrating feedback into adaptation strategies, the university can dynamically respond to changing climate conditions and enhance its resilience for the future.

As more come up, our commitments to stakeholders are to be transparent about the challenge and comprehensive in devising a solution.

Conclusion

Carleton University stands at a pivotal moment. We must respond to our rapidly changing climate or risk the damaging and expensive consequences. This plan addresses those risks and acts as a proactive strategy for long-term sustainability and resilience.

Success hinges on collective action and commitment.

We believe every member of the Carleton community—students, faculty, staff, and stakeholders—have a role to play and it is important to actively engage in these vital initiatives. Your participation, whether through supporting sustainability projects, adhering to new protocols, or contributing ideas, is crucial.

With adequate funding, university-wide cooperation and your active involvement, we can transform Carleton into a model of climate resilience and sustainability. Let's work towards ensuring a safer, more sustainable future for generations to come.

Join us in this critical mission to make Carleton a beacon of climate adaptation and environmental stewardship.

APPENDIX

APPENDIX A: TIMELINE OF OTTAWA WEATHER EVENTS

One of the first tasks the project team embarked on was creating a timeline of Ottawa weather events. The goal was to highlight either the reduced or increased frequency of certain events in the Ottawa area so that it can influence our present-day ratings. The project team used two main resources to document the timeline:

- For the years between 1998-2020 the project team used the Canadian Disaster Database. Last updated in 2020, the resource provided specific dates, location, and short comments on the impact of the event type mentioned including estimated financial losses.

- For the years 2020-2023 the project used Canada's top ten weather stories that has delivered narratives of each year since 1996 developed by Environment and Climate Change Canada (ECCC).

The combination of these resources presents the following events referenced throughout the plan above (Infographic):

Winter Storm 1998

- Ontario, Quebec and New Brunswick, January 4-10, 1998. Freezing rain (50 to >100mm) fell in a corridor extending from Kingston to Ottawa to Montreal to the Monteregie area south and east of Montreal, and on into New Brunswick, caused massive power outages.

- The power line triangles were toppled by the weight of the ice.

- Overall, Environment Canada estimates "the storm claims as many as 35 lives, downs millions of trees, 1,000 transmission towers, 30,000 utility poles and enough wires and cable to stretch around the world three times. - https://hydroottawa.com/en/about-us/our-company/our-history

Flood 1998

- Eastern Ontario and Quebec, March 28-April 15, 1998. Warm weather and thunderstorms caused spring flooding. In Ontario, the Clyde River, Ottawa River, Mississippi River, and rivers feeding Lake Nipissing overflowed.

Winter Storm 1999

- Southern Ontario, January 3, 1999. Eleven people died January 3 while shovelling heavy wet snow from one of the fiercest storms to hit southern and central Ontario in years. Cities were buried under 40 cm of snow. The storm, which also packed powerful wind gusts up to 70 km/h, ice pellets and freezing rain, moved in a line from Windsor northeast to Ottawa and Quebec. Many airports, including Pearson International in Toronto were closed.

2003 Power Outage

- On August 14, 2003, a transmission line fault in Ohio caused by contact with a tree cascaded into what would become one of the largest outages in North American history plunging more than 50 million people in eight states and Ontario into darkness.

2006 Severe Thunderstorms

- Ontario and Quebec, October 29, 2006. A storm that blew in from the United States left about 49,000 Quebec and 30,000 Ontario residents without power (approximately 240,000 individuals). High winds felled lines in a broad band across central Ontario, while in Quebec, the Laurentians region, north of Montreal, and the Gasp were particularly hard hit.

2009 Severe Thunderstorms

- Ottawa, Toronto, and Windsor ON, April 25, 2009. A spate of fierce thunderstorms broke out across southwestern, southcentral, and eastern Ontario.

- Winds at Toronto Pearson International Airport gusted to 115 km/h, the strongest wind gusts reported since January 1978.

- Power lines and trees came down across the province, knocking out power to 100,000 customers (300,000 individuals).

- Embedded in the thunderstorm cluster were marble-sized hail near Parry Sound, waterspouts in the Ottawa River, straight-line winds and weak tornados in Windsor and Ottawa.

- In Windsor, the roof was ripped off a union hall building with chunks of roofing and shards of glass littering the lawn and front steps.

- At Ottawa's Rockcliffe Flying Club, winds damaged 18 planes. Both tornados were F0 in intensity with winds of up to 110 km/h.

2010 Heat Event

- Between July 3rd and 9th, a heat wave gripped Ontario and Quebec.

- In Toronto, paramedics received 51% more complaints about breathing problems and 39% more calls related to fainting.

- In Ottawa, the RCMP musical ride was cancelled.

- In Montreal, heat-related deaths doubled. Across 8 health regions of Quebec, there was a 33% increase in mortality rate (280 excess deaths).

2010 Earthquake

- The 5.0-magnitude earthquake, its epicenter near Val-des-Bois, Que., about 60 kilometers north of Ottawa, struck at 1:41:41 p.m. on June 23, 2010, and was felt as far away as Windsor, Ont., and some U.S. states.

- It was the most powerful earthquake to strike the capital in 65 years. According to data from Earthquakes Canada, two aftershocks followed that night and the next day, a 3.3-magnitude, and a 3.2-magnitude.

- In Ottawa, the quake shattered windows and knocked down a brick chimney near city hall. A church in Grace field, Que., suffered considerable damage, and a section of Highway 307 near Bowman, Que., collapsed.

2012 Severe Thunderstorms

- In the late afternoon of July 22nd, a series of thunderstorms tracked over parts of southwestern Ontario. In Hamilton, 66mm of rain fell in a matter of a few hours; an unofficial gauge recorded 140 mm. The storms continued into eastern Ontario the next day. Strong winds were recorded in the Lake Nipissing area, up the Ottawa River Valley and into Quebec. Straight line winds, golf-ball-sized hail, where heavy localized rain was reported in both Ontario and Quebec. The system caused $92.6 million (CAD 2012) in insurable losses.

2016 Winter Storm

- Ontario, Quebec, New Brunswick, Nove Scotia, Prince Edward Island and Newfoundland, February 24-26, 2016. A storm system tracked its way northeast into the Great Lakes from the United States in late February. The system moved towards eastern Canada, causing widespread damages to Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland.

May 2017 Flood

- Montreal and the National Capital Region experienced their wettest springs in recorded history with over +400 mm of rainfall. Several communities declared States of Emergency including Gatineau, Montreal, and many smaller towns. The Canadian military deployed 4,000 personnel to help with the flood efforts.

October 2017 Flood

- From 3:00pm on October 28th to 1:00pm on October 30th, 112.5 mm of rain fell over Ottawa. As a result, there was significant pluvial/urban flooding within Ottawa and road washouts in western Quebec. Insurable losses were estimated to be $99.8 million (2017 CAD).

2018 Winter Storm

- A large winter storm with high winds, heavy snow and ice accumulation affected parts of southern Ontario and southern Quebec.

- Several large buildings were damaged when sheets of ice fell from neighboring buildings – Parliament building windows were broken in Ottawa; 1,800 car accidents were reported including a 50-car pileup on Highway 400 near Barrie. There were over 15,000 insurance claims and $190 million in insured losses.

2018 Spring Storm

- On May 4th, the Highway 401 corridor through southern Ontario and southern Quebec experienced a fast-moving squall line with wind gusts of over 100 km/hr.

- Wind speeds of 126 km/hr. were recorded in Hamilton and 117 km/hr. in Montreal.

- The windstorm caused widespread power outages, roof damage and downed trees.

- Over 925,000 customers across Ontario and Quebec were without power; some were without power until May 9.

- The windstorm caused $680 million in insured losses, with at least $380 million in Ontario alone.

2018 Wildfires

- 2018 was an exceptionally busy fire season in Ontario with twice as many fires and more than double the burned area than the 10-year average. At the end of the season, there were reported 1,325 fires that burned over 275,000 ha of land.

- Some of the most notable fires were Nipigon 30, which was the largest fire and burned almost 33,000 ha; and both Parry Sound 33 and the Temagami fire cluster led to multiple evacuation orders of communities, the closure of provincial parks, and air quality advisories.

2018 Tornadoes

- On September 21st, 6 tornadoes touched down in and near the National Capital Region. The strongest was an EF-3 that touched down near the City of Ottawa's rural neighborhoods of Kinburn and Dunrobin and tracked almost 40 km across the Ottawa River into the lower Pontiac (Luskville) and the Mont Bleu neighborhood of Gatineau between 4:40 pm and 5:20 pm. The estimated wind speeds were up to 265 km/hr.

- Hydro Ottawa crews and contractors worked a combined 3,800+ hours to restore power.

- An EF-2 tornado, the second largest tornado of the outbreak, struck the Ottawa neighbourhoods of Arlington Woods and Craig Henry at around 6:00pm. The estimated wind speeds of this tornado were up to 220 km/hr.

- In Quebec, the tornadoes caused $8.4 million in damages/losses to Hydro-Quebec. Extensive building damage was reported – almost 1,700 housing units were damaged in Gatineau, and 160 buildings with serious structural damage in the City of Ottawa, in addition to apartment complexes and commercial businesses in both affected areas. The tornado outbreak caused $334 million in insured damage, with at least $192 million in eastern Ontario and $102 million in the Gatineau Region.

2019 Flood

- Extensive flooding in April and May was experienced across Ontario, Quebec, and New Brunswick due to a combination of heavy rainfalls and snow melt.

- States of emergency extended across the 3 provinces, including Ottawa and Montreal. By the end of April, over a dozen states of emergency had been declared along the Ottawa River and its tributaries alone. Around 2,000 Canadian Forces personnel were deployed, which was more than the number deployed overseas.

- Canadian Disaster Database last updated November 2020, the following timeline is found using the weather events by year resource.

Unseasonably warm fall 2020

- Among the records set in such places as Windsor, Toronto, Ottawa and Montréal and several other locations were multiple mean daily maximum and minimum temperature records; the warmest November day ever; latest date in the year when the temperature topped 20°C or more; and the longest consecutive stretch of days above 15°C so late in the year.

Unseasonably cold spring 2020

- It is often said that spring is reluctant to arrive in Canada. In 2020, spring was not late; it went missing. Following a mild winter, the weather turned cold across most of southern Canada in March and persisted for another two months.

- Ottawa set a record daily low minimum and maximum temperatures on several days in the beginning of May. On May 12, it was -4.6°C shattering the record minimum for the day by 3 degrees and the coldest ever post-May 12 at the airport. May snowfalls plagued many areas of Ontario and Quebec, especially near open lakes, causing them to be snowier than March and April.

2020 Heat Event

- Before the second week of July, Ottawa already had as many days above 30°C, with four exceeding 35°C, as it would normally see an entire summer.

- In Montréal and Ottawa, the average temperature for the hot spell was the highest in 145 years.

- As temperatures sizzled, it also meant deteriorating air quality on many days, adding to the high air quality health risk.

2020 Drought

- In the east, going into the planting season, Ontario and Quebec had a significant moisture deficit with spring precipitation between 25-75% of normal totals. Deficits ranged from 110 to 130 mm in places such as Chatham-Kent in southwestern Ontario and in the Montreal area.

- May was among the driest on record from London to Ottawa covering 75 years. Welcome rains finally came in June a little late for the strawberries, but great for the crops that followed.

2022 Derecho

- Just before the May long weekend, two days of intense heat and humidity propelled a hugely powerful line of storms across central Ontario and Quebec, bringing torrential rains, large hail, and frequent lightning.

- Passengers on trains, airlines and transit services faced hours-long delays due to downed power lines and live wires across roads and tracks.

- In rural areas, winds flattened 100-year-old barns, took down silos, tossed around farm equipment and flattened early crops.

- More than a million hydro customers across Ontario and Quebec were left without power. A week later power was still out for nearly 30,000 homes.

- Ottawa Hydro claimed the damage and disruption to the hydro system was worse than the ice storm of January 1998 and the swarm of tornadoes in September 2018.

- Tragically, 11 people died in the aftermath, mostly by fallen trees. At least 13 communities declared states of emergency, including the towns of Uxbridge and Clarence-Rockland, east of Ottawa.

- The storm resulted in more than a million insurance claims, topping one billion dollars in damages, making it the sixth largest in terms of insured losses in Canadian history.

- Hydro Ottawa is trying to update their infrastructure: https://hydroottawa.com/en/blog/future-proofing-electricity-grid

2022 Heat Event

- Summer 2022 was the third warmest Canadian summer on record, eclipsed only by 2012 and 1998. Across the country it was consistently warm – almost 1.6°C above normal.

2023 Wildfires

- The wildfire season across Canada was one for the record books on so many fronts. It began early, ended late, burned faster and was extremely active from British Columbia and the Territories to the Atlantic coast.
- On June 6, there were out-of-control fires burning in every single province and territory except in Prince Edward Island and Nunavut.
- Northerly winds pushed smoke from Québec and northeastern Ontario fires into Montréal, Ottawa, Toronto, and major cities in the eastern United States. Rains at the beginning of July helped extinguish some fires, although large blazes still burned out of control near James Bay.
- On June 7, air quality in Ottawa was rated high risk at 10+. The amount of fine particulate matter in Ottawa's air hit 511 when PM2.5 normally ranges from 4 to 11.

2023 Hottest Summer on Earth and Canada

- It was the warmest summer in 76 years, dating back to the start of national record-keeping in 1948. The average temperature anomaly was +2.0°C, beating the previous warmest in 2012.
- By mid-summer, Easterners had written summer off. But summer came back when Ottawa registered four days above 30°C in September and two in October. Never in 141 years of weather records has Ottawa ever seen a temperature above 30°C after September 22.

2023 Flooding

- Summer in Southeastern Canada was as moisture laden as the West and Northwest were dry. Stagnant low-pressure systems were repeatedly positioned between James Bay through the Great Lakes to the Maritimes favouring lengthy bouts of rain, overcast and coolness.
- Storms led to widespread street flooding and left 55,000 without power. On August 3, more storms moved through southern Ontario and Québec, packing billiard ball-size hailstones, violent wind gusts of more than 110 km/h and torrential downpours.
- On August 10, between 80 to 120 mm of rain in about an hour and a half fell across Montréal. Roads and underpasses were submerged along with warehouses, schools, and lower levels of shopping malls. In Ottawa, with 100 mm of rain in six hours, roads became canals. To avoid flooding, motorists drove on sidewalks or abandoned their cars.
- Two weeks later a steady stream of showers and thunderstorms pushed through southwestern Ontario on August 23 and 24 bringing storm rainfalls as much as 185 mm to several locations. Flooding led to road washouts and the tragic death of a trucker who perished in a 3-m deep sinkhole. Greatest rainfall totals exceeded 200 mm in Pelee Island and Harrow, Ontario. Some of the moisture came from the remnants of Tropical Storm Hilary from Mexico via British Columbia and the prairies. Insurance costs to property losses from some of the more impactful storms this summer in Ontario and Québec totalled more than three quarters of a billion dollars.

2023 Winter/Ice Storm

- On April 5, 2023, before the Easter weekend, a powerful late-season storm moved into the Great Lakes-St. Lawrence region bringing widespread freezing rain, ice pellets, hail, and heavy rains.
- The ugly weather then featured up to twelve continuous hours of freezing rain in Montréal and nine in Ottawa. Ice accretion amounts totalled 30 to 37 mm in Montréal, 25 to 30 mm in Ottawa-Gatineau, and 15 to 25 mm in central Québec.
- Power outages topped one million customers in Québec including half a million in Montréal and 200,000 in Ontario. Thousands were still without power two days later.
- Ottawa's light-rail transit went down leaving dozens of commuters waiting hours to be evacuated.

2023 Tornadoes

- It was a busy summer for tornadoes in Ottawa with five tornadoes including an EF1 storm on July 13 that struck Barrhaven, 20 km south of Ottawa city center.
- A research project from Northern Tornado Project out of Western University (NTP) found about 20 tornadoes occurred across the Ottawa Valley over the past six years. It included seven tornadoes on September 21, 2018, one of which was an EF3 in the Dunrobin region with winds up to 265 km/h.

2023 Thunderstorms

- The summer brought not just one, but two large outages fuelled by thunder and lightning.
- On June 26, a storm took out power for approximately 15,413 customers, followed by a subsequent outage on July 28 when a series of severe thunderstorms and lightning hit the National Capital Region, impacting about 37,821 hydro Ottawa customers across the city.
- This was another multi-day restoration effort due to the extent of the damage from downed power lines and trees.

APPENDIX B: NCC CLIMATE PROJECTIONS

In 2020, the National Capital Commision (NCC) released the climate projections for the National Capital Region (NCR). This was a step in their wider plan to create a Climate Adaptation Plan for their Operations. Due to the responsibility as a federal Crown corporation dedicated to ensuring that Canada's Capital is a dynamic and inspiring source of pride for all Canadians, their projections needed to be applicable to the whole region. Their thorough methodology improved confidence in their results as a reference point for this plan. The methodology included climate models that divide the earth into 3D cells and use equations to simulate atmospheric, oceanic, and other processes.

The following are the results of the projections mentioned in the plan:

Temperature Projections:

- **Increase in Average Temperatures (all Seasons)** – The average annual temperature is projected to increase from approximately 6.1°C in the baseline to approximately 7.5-7.9°C in the 2030s, 8.2-9.3°C in the 2050s, and 8.8-11.4°C in the 2080s. No single season is projected to warm significantly faster than the others.
  - **Less Cold Extremes** – Cold extremes are expected to decrease in intensity and frequency. The number of days per year where the daily minimum temperature is less than -10°C ("Deep Freeze Events") is projected to decrease from approximately 71 days in the baseline to approximately 59-57 days in the 2030s, 53-46 days in the 2050s and 48-28 days in the 2080s. Although these projections are for an extreme index, they represent an "average year" since they are averaged over 30-year time slices.
  - **More Warm Extremes** – There will be an increase in the frequency and intensity of high temperature extremes. In the baseline, the NCR experienced approximately 11 days that reached 30°C ("Hot Days") per year. Models project an increase to approximately 25-28 days in the 2030s, 32-43 days in the 2050s and 36-72 days in the 2080s. That is twice as many hot days in the 2030s, 3-4 times as many in the 2050s, and 3-6 times as many in the 2080s.
  - **Change in Seasonal Characteristics** – The first day of fall frost is projected to occur approximately 1-2 weeks later by the 2030s, 2-3 weeks later by the 2050s, and 3-4 weeks later by the 2080s compared to the baseline. The last day of spring frost is projected to occur approximately 1-2 weeks earlier in the 2030s and 2050s, and 2-4 weeks earlier in the 2080s.

- **Shift in Freeze-Thaw Cycles** – Models project that winter temperatures will hover around 0°C more frequently in the future. Therefore, winter freeze-thaw cycles (December–February) are projected to increase, whereas freeze-thaw cycles that occur during spring (March–May) and fall (September–November) are projected to decrease as temperatures warm.

Precipitation Projections:

- **Increase in Total Precipitation (Except Summer) –** The annual total precipitation in the NCR is expected to increase from approximately 921 mm/year in the baseline to approximately 949-968 mm in the 2030s, 979-993 mm in the 2050s and 983-1028 mm in the 2080s. Increases will be concentrated in the winter and shoulder seasons with no increases projected for June–September.

- **No change in Frequency of Wet Days –** Although the annual total precipitation is increasing, precipitation is projected to be concentrated within the same number of wet days (where precipitation > 1 mm) that occurred in the baseline.

- **More Intense Precipitation –** The annual maximum precipitation that falls in one day is expected to increase from approximately 37 mm in the baseline to 39-39 mm in the 2030s, 41-42 mm in the 2050s and 41-44 mm in the 2080s. The increase in precipitation is consistent with a greater amount of total precipitation falling in the same number of wet days (see above). Extreme precipitation is projected to increase for multiple durations (sub daily, daily, and multi-day precipitation events). These projections represent an "average year" (since they are averaged over 30-year time slices), for a 10 km x 10 km area.

- **Decrease in Total Snowfall –** The annual total snowfall is projected to decrease from about 223 cm in the baseline to 193–201 cm in the 2030s, 184–179 cm in the 2050s and 154–124 cm in the 2080s. This represents a decrease of 31-44% by the 2080s. Due to year-to-year variability, values similar to the baseline are still possible past mid-century.

- **Shorter Snow Season –** The timing of the first snowfall is projected to be later in the year, and the timing of last snowfall earlier. As a result (and due to increasing temperatures), the number of days with snow cover is projected to decrease from approximately 115 in the baseline to approximately 95-94 days in the 2030s, 90-72 days in the 2050s and 78-43 days in the 2080s.

- **High Variability in Extreme Snow –** Projections suggest a decrease in the maximum snow depth and mixed findings for the maximum 1-day snowfall. Average projections suggest that annual maximum 1-day snowfall (averaged across the study area) will change from approximately 20 cm in the baseline to 21-20 cm in the 2030s, 22-20 cm in the 2050s and 20-16 cm in the 2080s. There is a decrease by the 2080s for the high emission scenario (RCP Climate Projections for the National Capital Region 20 8.5) but not for the moderate emission scenario (RCP 4.5). These projections represent total snow falling over the study area during an "average year" (since they are averaged over 30-year time slices). Due to year-to-year variability, values similar or higher than the baseline are still possible past mid-century.

Wind Projections:

- **No Detectable Trends in Averages –** Projections for monthly average wind speed show little to no change. However, only two RCMs with wind projections were available for this study, which reduces the confidence in the findings.

- **Reduced Wind Chill –** Due to warming temperatures, models project that the number of days with wind chill between -35°C and -25°C will decrease from approximately 17 days in the baseline to 11-8 days in the 2030s, 6-5 days in the 2050s and 5-1 days in the 2080s. These values represent an "average year" (since they are averaged over 30-year time slices).

Extreme Events and Other Phenomena

- **Freezing Rain and Ice Storms –** A possible increase in freezing rain during the coldest months is anticipated due to the higher frequency of conditions around 0°C. A decrease or no change is projected during the transition seasons.

- **Extreme Snow and Blizzards –** Models generally project a decrease in average snowfall, but high year-to-year variability makes it difficult to project changes in extremes.

- **Extreme Wind and Gusts –** Increases are possible; however, the supporting literature and models remain inconclusive at this time.

- **Tornadoes –** It is uncertain whether tornado occurrences will change with climate; however, climate change is projected to favour the atmospheric conditions that support their formation.

- **Hurricanes –** The amount of precipitation produced by hurricanes, and the intensities of hurricanes will likely increase on average. Furthermore, the latitude of maximum intensity appears to be moving north, which would increase the NCR's exposure.

- **Lightning –** There is no scientific consensus on how the frequency and intensity of lightning will be impacted by climate change, although increases in convection activity would suggest a possible increase.

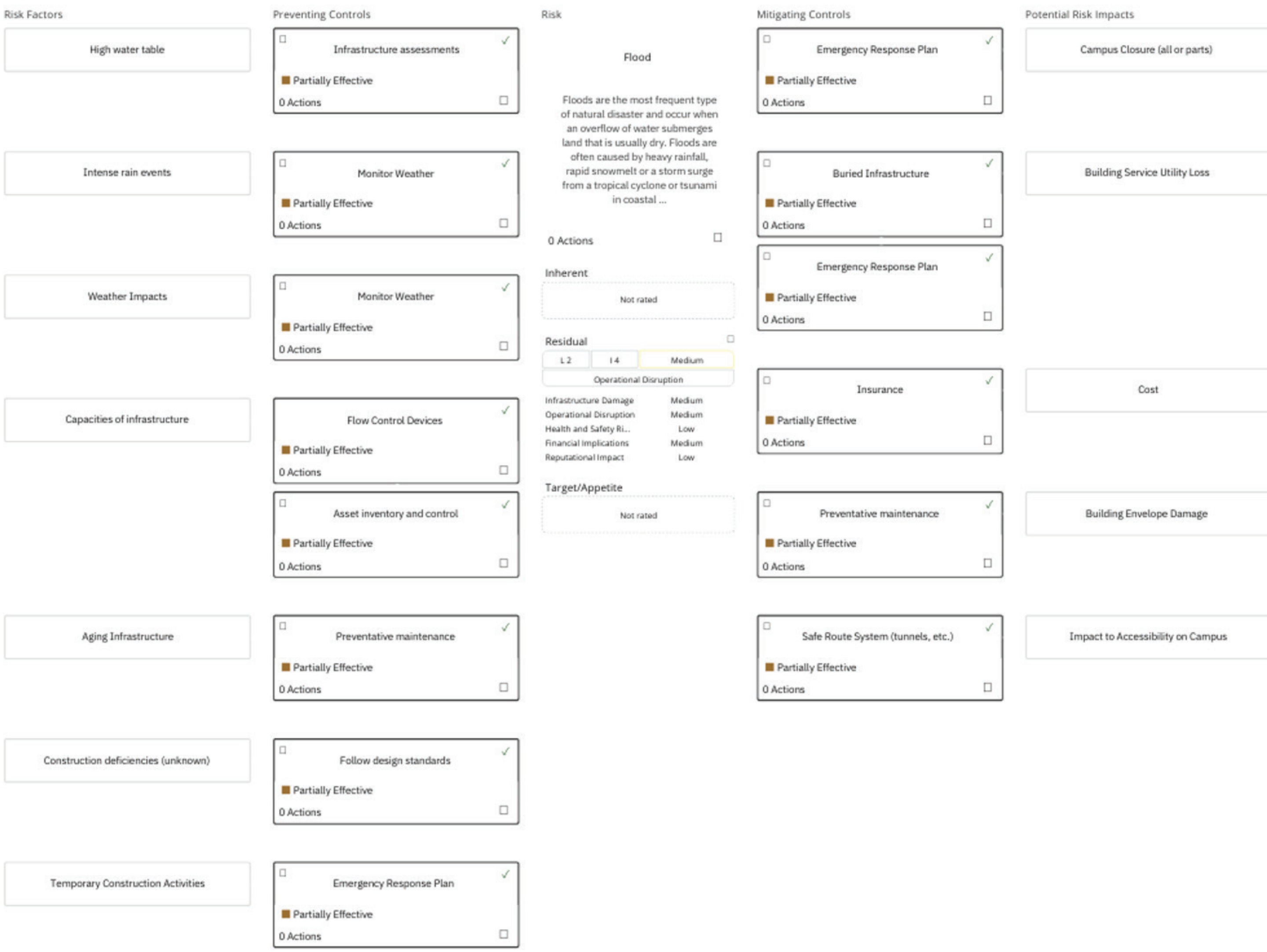
- **Wildfires –** It is predicted that the fire season will lengthen and that the number and extent of wildfires will increase, especially in boreal forest types.

- **Air Quality –** It is possible that climate warming could worsen some aspects of air quality; however, there is not enough information to data to draw conclusions.

APPENDIX C: RISK BOWTIES

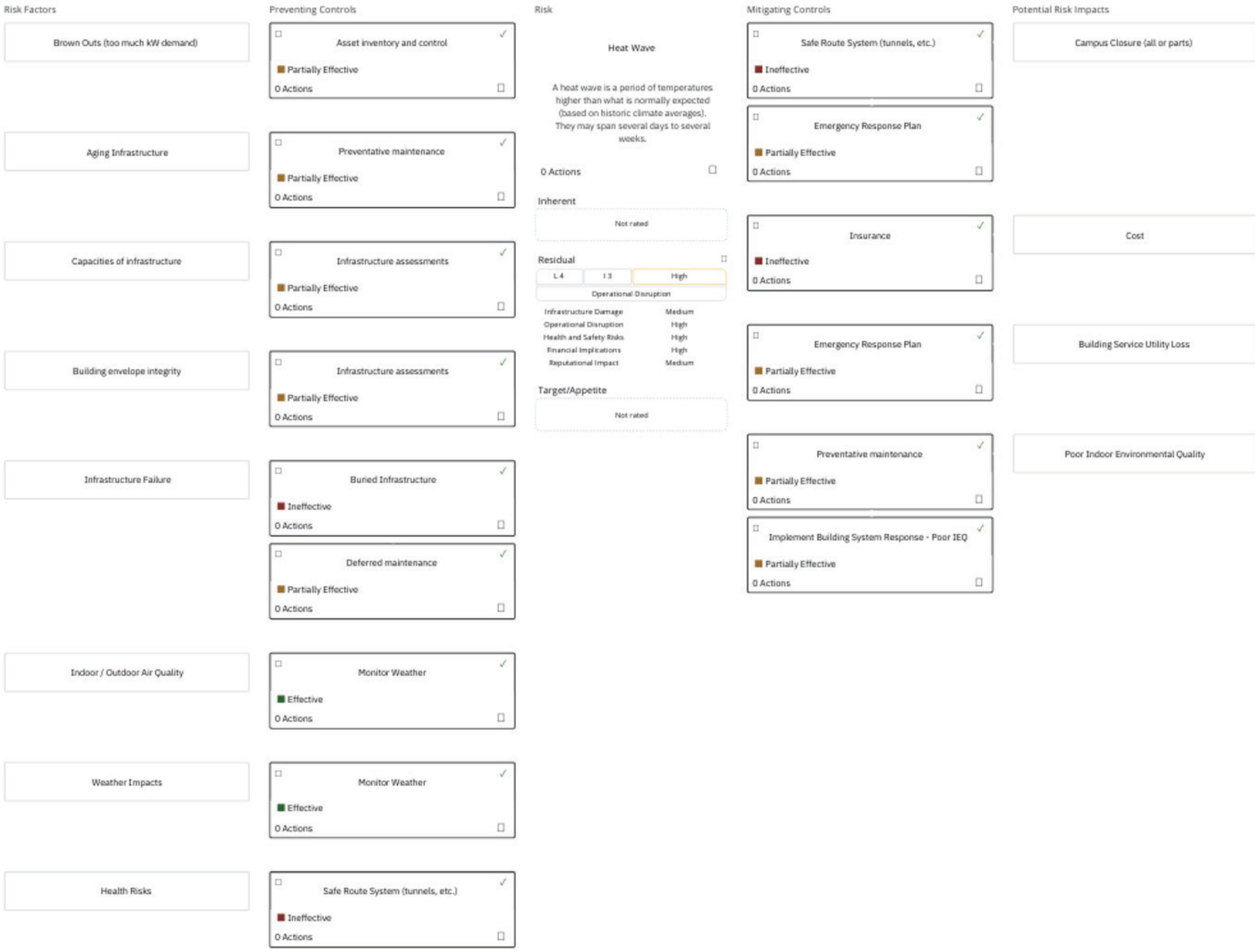
To visually support this risk analysis, the team utilized the CGR risk software to create risk bowties for each climate event examined during the workshops. These risk bowties provide a clear and structured visual representation of the causal relationships between risks, preventive and mitigative controls, and their potential impacts. The screenshots included in this appendix highlight how the CGR software was instrumental in facilitating a structured and detailed risk assessment process, allowing the team to effectively communicate and document the complexities of climate-related risks at Carleton University.

Flood Risk Bowtie

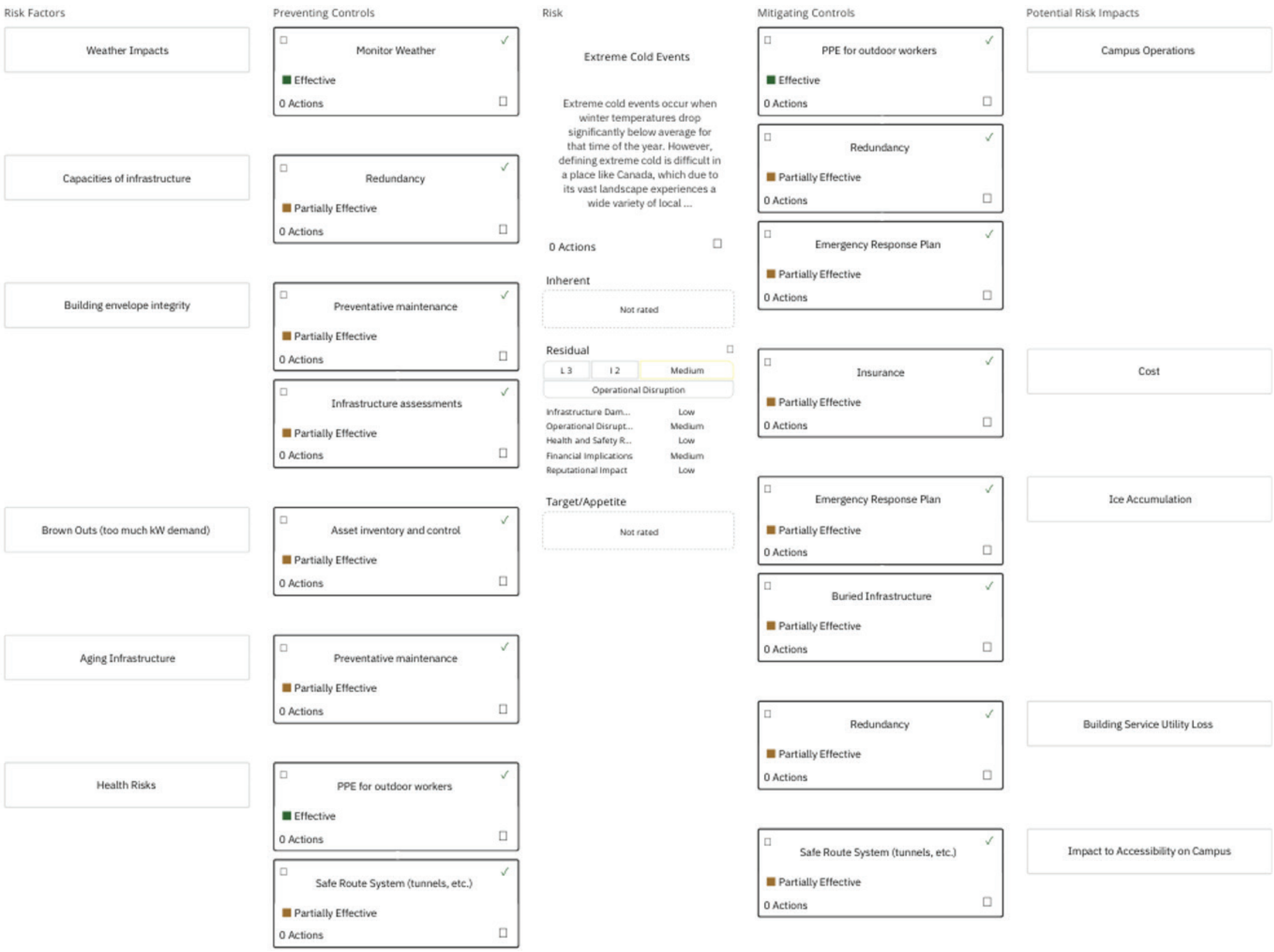


Wildfire Smoke Bowtie

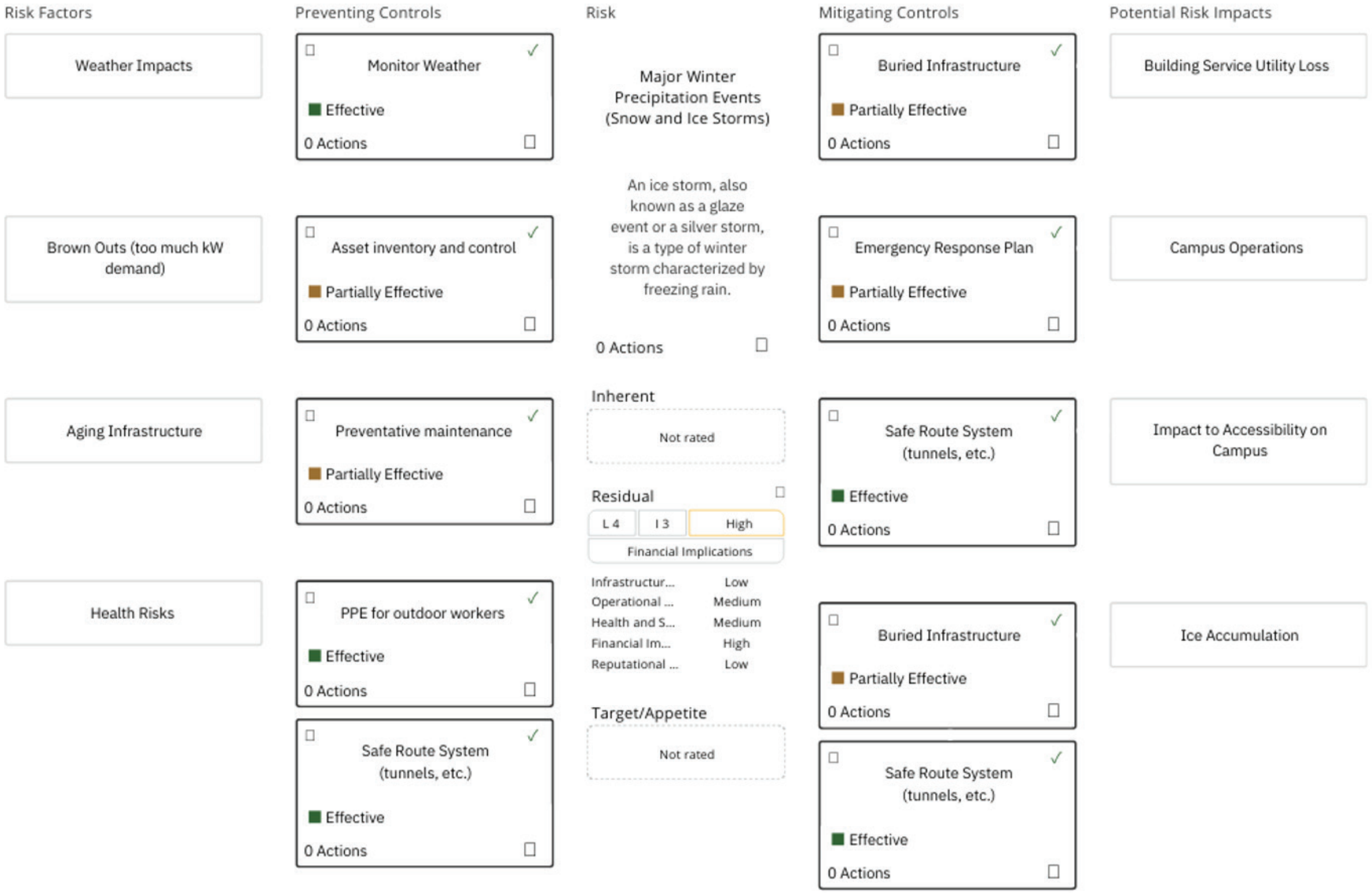
Heat Wave Bowtie



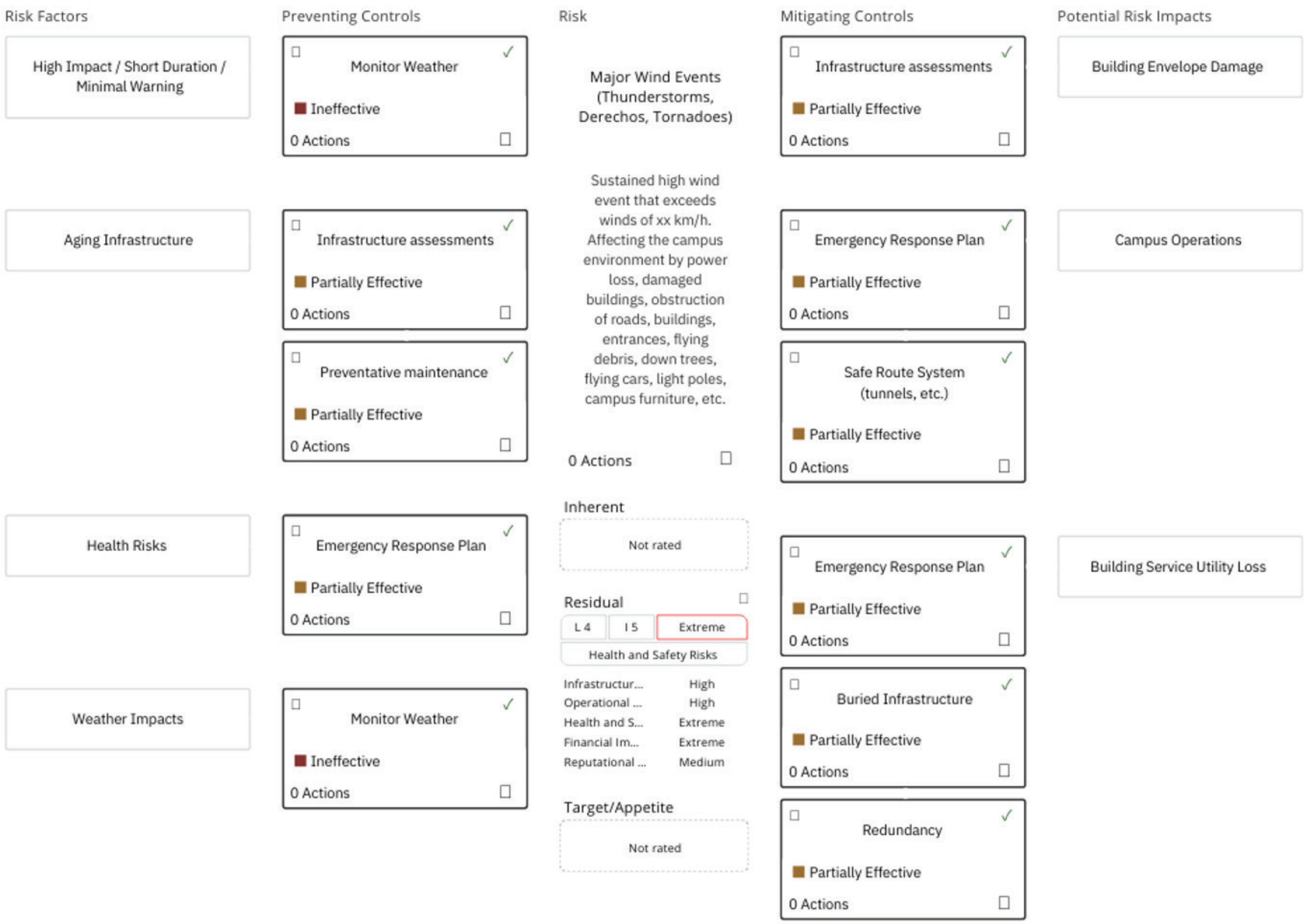
Extreme Cold Events



Major Winter Precipitation Events (Ice and Snowstorms) Bowtie



Major Wind Events (Thunderstorms, Derechos, Tornadoes)



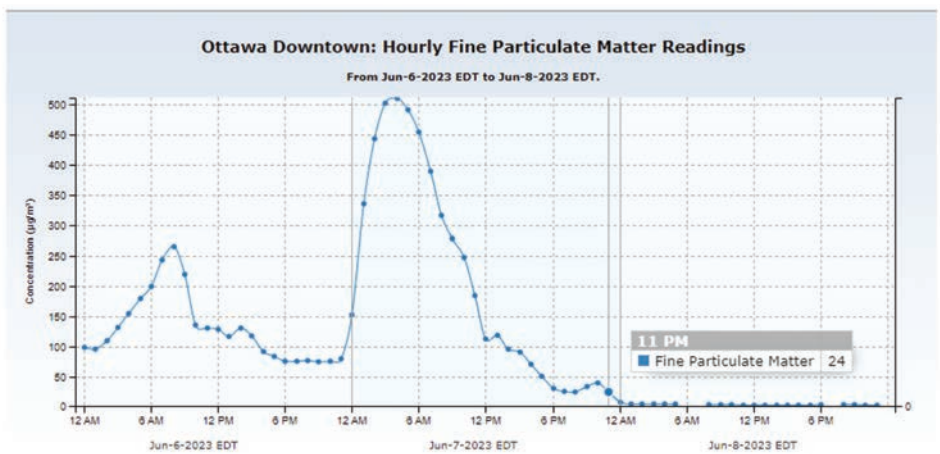
APPENDIX D: AUGUST 2023 FLOODING

On August 10, 2023, Carleton University faced significant flooding across various parts of the campus, resulting in over 40 cases of flooding and substantial restoration costs exceeding $300,000. The most common sources of flooding were the natural overflow from the Rideau River and Canal, particularly affecting the loading dock and print shop in Pigiarvik (formerly Robertson) and the shipping and receiving dock at the National Wildlife Research Center (NWRC). Additionally, infrastructure failures contributed to the severity of the event, with water leaking through windows in Dunton Tower and an interesting case in the Richcraft building where water seeped from the walls into a computer lab. This latter incident was traced back to a missing cap on a roof drainpipe that had been leaking since its installation in 2013, but the overwhelming amount of water during this event revealed the construction oversight.

The university's stormwater system was overwhelmed, leading to internal damage and excess overland flooding that sought paths of least resistance. Notable areas of impact included the entire basement of the Minto Case building, which flooded due to the drainage system overflowing and backing up. Similar occurrences were reported across campus including ceiling leaks in multiple rooms in Nideyinàn (former University Centre), Nesbitt, Loeb, Patterson, Library, and many more. The underground parking lot in Richcraft featured a drain spewing upwards and a cracked wall letting water in. Critical infrastructure like mechanical and high voltage electrical rooms in the Herzberg building, St Patrick building, and others were either flooded or experienced leaks that could have damaged equipment or posed a risk to life safety. This also impeded accessibility with sections of the tunnels with 6 feet of water and stairwells flooding.

The August 2023 flooding highlighted the need for localized weather monitoring. FMP's Building Operations team established a weather station capable of tracking wind, rain, humidity, and temperature, which proved essential given the discrepancies in rainfall measurements between the university and the nearest weather station, Ottawa Airport. While the airport recorded only 30mm of rain on August 10th, 2023, Carleton received 100 mm in under 2 hours. The current setup of the weather station can only send a rain alert to one central location once the forecast or current measurements go above an identified threshold, facilitating a quicker response to emerging weather threats. This event underscored the influence of architectural choices and value engineering on the functionality and accessibility of critical infrastructure, particularly in severe weather conditions, prompting ongoing discussions within FMP to enhance resilience and implement robust flood mitigation strategies.

APPENDIX E: JUNE 2023 WILDFIRE EVENT



On June 6, 2023, Carleton University and the wider Ottawa region experienced an unprecedented influx of wildfire smoke, part of a record-breaking wildfire season across Canada. The fires, fueled by unusually dry and windy conditions, ignited early in the season and persisted with intensity across many parts of the country, from British Columbia to the Atlantic coast. By June 6, active fires were reported in every province and territory, except for Prince Edward Island and Nunavut.

Northerly winds compounded the situation by pushing smoke from fires in Québec and northeastern Ontario towards densely populated areas in Montréal, Ottawa, Toronto, and even reaching into the eastern United States. The air quality in Ottawa deteriorated dramatically, reaching a high-risk rating of 10+ on the Air Quality Health Index on June 7. The fine particulate matter (PM2.5) levels in the city's air spiked to 511, far exceeding the normal range of 4 to 11.

During this period, Carleton University's Facilities Management and Planning (FMP) Building Operations team received an influx of work orders from campus occupants reporting health-related issues such as shortness of breath and itchy eyes. Given the air flow requirements of the affected buildings, immediate solutions to significantly alleviate the situation were limited. This event highlighted the need for improved preparedness and response strategies to protect health during such environmental emergencies. In response to the challenges posed by the wildfire smoke event, the FMP team developed a comprehensive Wildfire Smoke Readiness Plan. This plan leverages the capabilities of the Building Automation System (BAS) to enhance the university's responsiveness to similar incidents in the future.

Operating Principles to Limit Exposure for Building Occupants to Wildfire Smoke:

For air handling systems serving normally occupied areas which recirculate a portion of the air from the building, the building automation system will reduce the outdoor and exhaust air damper position to 5%.

The operation of air handling systems serving unoccupied service areas such as elevator machine rooms will remain unchanged.

Make-Up Air units serving corridors in Residence buildings will shut down.

Some air handling equipment operates with stand-alone controls with no external control of damper operations. The operation of these units will remain unchanged.

There will be no change to paring garage operations.

Make-Up Air units serving lab spaces which cannot be shutdown will have the filters temporarily upgraded to MERV 13.

The mitigation strategy is designed to address the unique air handling characteristics of different types of buildings on campus, ensuring that indoor smoke levels are minimized, and health risks are mitigated without causing significant operational disruptions:

- **Lab Buildings (Steacie, Nesbitt, NWRC, etc.):** These buildings operate with 100% outdoor air, which is a requirement due to the chemicals used in these facilities. During wildfire smoke events, pre-installed MERV 13 filters are used to remove particulate matter, though they do not eliminate odours. This approach addresses health risks but could lead to potential operational disruptions due to odour persistence.
- **Academic Buildings:** These buildings generally recirculate a portion of the outside air for energy efficiency. In the event of wildfire smoke, the system minimizes the intake of outdoor air and aids filtration efforts to reduce indoor smoke levels effectively.
- **Residence Buildings:** Each room or unit in residence buildings has its own heating and cooling system that recirculates air within the space. Hallway systems, which intake outdoor air to create a positively pressurized environment, are shut off during smoke events to prevent smoke infiltration, thereby reducing exposure to harmful particulates.

REFERENCES

- Ministry of Environment and Climate Change Strategy (2019). *Preliminary Strategic Climate Risk Assessment for British Columbia. Report prepared for the Government of British Columbia, Victoria, BC.* Accessible at: https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/prelim-strat-climate-risk-assessment.pdf

- *Adapting to Climate Change.* (2020, June). NCC-CCN. https://ncc-ccn.gc.ca/our-plans/climate-change-adaptation

- Public Safety Canada. (2020). *Canadian Disaster Database.*

- Canada, E. a. C. C. (2024, June 26). *Canada's top ten weather stories*. Canada.ca. https://www.canada.ca/en/environment-climate-change/services/top-ten-weather-stories/2023.html

- Campus Master Plan 2023 - Finance and Administration. (2024, June 6). Finance and Administration. https://carleton.ca/finance-admin/campus-master-plan-2023/

Flood

- Rideau Valley Conservation Authority. (2020). *Map created: Brewer Park / Carleton University (100 YR Flood Extent).* https://www.rvca.ca/images/hydrometric/06_BrewerPark_FloodExtent_Combined_Optimized.pdf

- Rideau Valley Conservation Authority (RVCA). (2020). *Brewer Park Neighborhood Flood Maps.* https://www.rvca.ca/watershed-conditions/neighbourhood-flood-maps

Wildfire

- ASHRAE Guideline 44P, *Protecting Building Occupants from Smoke During Wildfire and Prescribed Burn Events*. (2023). https://www.ashrae.org/file%20library/technical%20resources/covid-19/guidance-for-commercial-building-occupants-from-smoke-during-wildfire-events.pdf

- Wildfire season: What can Ottawa expect? (2024, April 11). Ottawa. https://ottawa.ctvnews.ca/wildfire-season-what-can-ottawa-expect-1.6842270

- Pilkington, C. (2023, November 6). Whitehorse in the midst of building "Canada's first" permanent firebreak — out of trees. CBC. https://www.cbc.ca/news/canada/north/whitehorse-building-first-permanent-firebreak-1.7018183#:~:text=Crews%20in%20Whitehorse%20are%20in,calling%20it%20%22natural%20infrastructure.%22

- Wildfire smoke is an increasing threat to Canadians' health. (2023, August 28). https://www.preventionweb.net/news/wildfire-smoke-increasing-threat-canadians-health#:~:text=Canada's%202023%20wildfire%20season%20is,very%20small%20particles%20called%20PM2.

- Why Ottawa's air quality is among the worst in Canada. (2023, June 7). CBC. https://www.cbc.ca/news/canada/ottawa/air-quality-index-ottawa-worst-city-1.6868661#:~:text=Wind%20patterns%20are%20funnelling%20the,there%20is%20the%20valley%20effect.

- Home - FireSmoke.ca. (n.d.). https://firesmoke.ca/

- Government of Ontario, Ministry of the Environment. (n.d.). Ottawa downtown: Hourly fine particulate matter concentrations 51001. https://www.airqualityontario.com/history/pollutant.php?stationid=51001&pol_code=124&start_day=7&start_month=6&start_year=2023&showType=chart&station_id=51001&submitter=Refresh+Page

- Hillarylutes. (2023, June 8). Air quality statement in Ottawa ended - Current students. Current Students. https://students.carleton.ca/2023/06/air-quality-statement-in-ottawa/

Heat Wave

- Morgan, R. (2021, August 11). Heatwave and severe storms to roil Ontario. Capital Current. https://capitalcurrent.ca/heatwave-and-severe-storms-to-roil-ontario/

- Bustinza, R., Lebel, G., Gosselin, P., Bélanger, D., & Chebana, F. (2013). Health impacts of the July 2010 heat wave in Québec, Canada. BMC Public Health, 13(1). https://doi.org/10.1186/1471-2458-13-56

Extreme Cold Events

- The Canadian Press. (2017, December 29). Cold snaps shuts down NYE in parts of Canada. Northern Sentinel. https://www.northernsentinel.com/news/cold-weather-threatens-nye-in-ottawa-6146905

- Winter's 1st deep cold snap hits Ottawa this week. (2023, February 1). CBC. https://www.cbc.ca/news/canada/ottawa/ottawa-cold-frostbite-weather-warming-locations-1.6732430

- 4-day cold snap beginning Thursday in Ottawa: Environment Canada. (2018, January 3). CBC. https://www.cbc.ca/news/canada/ottawa/cold-snap-ottawa-environment-canada-1.4471690

- Extreme cold warning covers Ottawa's coldest night of the pandemic. (2022, January 11). CBC. https://www.cbc.ca/news/canada/ottawa/extreme-cold-warning-january-10-11-2022-1.6309710

- Extreme cold warnings return for most of Ottawa-Gatineau area. (2022, January 20). CBC. https://www.cbc.ca/news/canada/ottawa/extreme-cold-warning-renfrew-outaouais-january-21-1.6321297

- Ottawa ON Lowest temperature each year - Current results. (n.d.). https://www.currentresults.com/Yearly-Weather/Canada/ON/Ottawa/extreme-annual-ottawa-low-temperature.php

- Cold snap begins in Ottawa, expected to last several days. (2021, January 28). Ottawa. https://ottawa.ctvnews.ca/cold-snap-begins-in-ottawa-expected-to-last-several-days-1.5285612

Major Winter Precipitation Events (Ice and Snowstorms)

- Brière, F. (2024, January 12). With a strong El Niño winter ahead, could the ice storm of 1998 repeat itself? The Weather Network. https://www.theweathernetwork.com/en/news/weather/seasonal/with-a-strong-el-nino-winter-ahead-could-the-north-american-quebec-eastern-ontario-ice-storm-of-1998-repeat-itself

- User, S. (2021, May 2). Winter's Icy Grip - The Historical Society of Ottawa. https://www.historicalsocietyottawa.ca/publications/ottawa-stories/momentous-events-in-the-city-s-life/winter-s-icy-grip

Major Wind Events (Thunderstorms, Derechos, Tornados)

- Writers, D. (2023, July 6). Severe risk continues in Ontario, Quebec as storms hit muggy heat. The Weather Network. https://www.theweathernetwork.com/en/news/weather/forecasts/stifling-heat-and-humidity-continues-fuelling-storm-risk-for-ontario-quebec

Transition Risks

- Climate Risks and opportunities defined | US EPA. (2024, March 8). US EPA. https://www.epa.gov/climateleadership/climate-risks-and-opportunities-defined

- Government of Canada, Statistics Canada. (2022, December 7). The Daily — The impact of the COVID-19 pandemic on college finances for the 2020/2021 fiscal year. https://www150.statcan.gc.ca/n1/daily-quotidien/221207/dq221207a-eng.htm

- Henne, D. Dickson, B. (2024, March 27). *New Sustainability Financial Reporting Requirements-Implementation Toolkit* [PowerPoint Slides]. Canadian Association of University Business Officers (CAUBO). https://www.caubo.ca/knowledge-centre/learningevents/webinars/

MITIGATION STRATEGIES
Flood

- Stormwater Details can be found in Mitigation Strategies sections and Appendix

- Ontario Building Code Act, 1992, O. Reg. 350/06, s. 1.1 https://www.ontario.ca/laws/regulation/060350/v13

- About green roofs — Green roofs for healthy cities. (n.d.). Green Roofs for Healthy Cities. https://greenroofs.org/about-green-roofs

- TrapBag. (2023, August 30). How to build a water retaining wall for flood control. TrapBag. https://trapbag.com/water-retaining-wall-flood-control/#:~:text=A%20water%20retaining%20wall%20can,at%20the%20beach%20or%20embankment.

- Hershfield, M. (2020, July 16). Improving Community Safety with the Rideau River Multi-Use Pathway. Morrison Hershfield. https://blog.morrisonhershfield.com/improving-community-safety-with-the-rideau-river-multi-use-pathway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