Hydro Ottawa Climate Change Adaptation Plan

FINAL REPORT

November 11, 2019

Prepared for:

Hydro Ottawa
3025 Albion Road North
Ottawa ON K1V 9V9

Prepared by:

Stantec Consulting Ltd.
400-1331 Clyde Avenue
Ottawa ON K2C 3G4

Project No.: 122170294

This document entitled Hydro Ottawa Climate Change Adaptation Plan was prepared by Stantec Consulting Ltd. ("Stantec") for the account of Hydro Ottawa (the "Client"). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Nicole Flanagan

Digitally signed by Nicole Flanagan
Date: 2019.11.12 10:31:43 -05'00'

Prepared by ____
(signature)

Nicole Flanagan, M.A.Sc., P.Eng.

Daniel Hegg

Digitally signed by Daniel Hegg
Date: 2019.11.11 15:18:49 -08'00'

Reviewed and Approved by ____________________________
(signature)

Daniel Hegg, M.Sc., CEM

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Executive Summary

Hydro Ottawa Limited (Hydro Ottawa) provides electricity to over 330,000 residences and businesses in the City of Ottawa and the Village of Casselman, who depend on a continuous and reliable supply of energy. In recent years, particularly in 2018, Hydro Ottawa distribution infrastructure was subjected to notably extreme weather events that caused severe damages to their system. These events resulted in widespread outages and costly recoveries. In an effort to maintain reliable service in the coming years, Hydro Ottawa has retained Stantec Consulting Ltd. (Stantec) to conduct a Climate Change Adaptation Plan (the Plan) for their distribution system and supporting infrastructure to follow up on the risk and vulnerabilities identified in an earlier phase of work. This work is compiled in a standalone report prepared by Stantec, titled Distribution System Climate Risk and Vulnerability Assessment (CRVA).

This Climate Change Adaptation Plan considers the entire geographic extent of Hydro Ottawa's service territory which includes a vast portion of the City of Ottawa and the Village of Casselman and includes both overhead and underground electrical distribution assets. The purpose of this Plan is to identify and make recommendations for actions to reduce the risks identified in the CRVA as well as recommendations for integrating actions into the Hydro Ottawa planning systems and operation practices and procedures.

Both this assessment and the CRVA were completed in general conformance with the Canadian Electricity Association's (CEA) Guide On Adaptation To Climate Change, and the Engineers Canada Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol. Furthermore, this methodology aligns with the principles, requirements and guidelines of the ISO 31000:2018 Risk Management Framework and ISO 14090:2019 Adaptation to Climate Change.

Climate changes in the Ottawa region include historical warming trends (approximately 1.7°C per century) which are projected to continue into the future. Seasonally, the most dramatic changes observed are associated with winter minimum temperatures, which constituted a 2.5°C increase between 1939 and 2010. Similarly, Ottawa has seen an increase in precipitation, where total precipitation has increased by 25.9mm over the past 30 years. Future projections indicate increases in total precipitation as well as an increase in the frequency of short duration, high intensity events. Furthermore, the climate modelling projections indicate that wind and other complex events (ex: freezing rain, lightning, etc.) are expected to increase as well.

The Climate Risks and Vulnerability Assessment identified impacts to Hydro Ottawa's infrastructure and operations which are expected to become more prominent in the future due to climate change. For this assessment, infrastructure systems identified in the CRVA have been grouped into four main asset categories: Pole Line Systems (PLS), Underground Line Systems (ULS), Substations (SUB), and Operations (OPS). Adaptation plans were created based on potential mitigation actions developed in a workshop with Hydro Ottawa. The timelines and prioritization of action plans were based on the current risk, future risk and the change in risk over time.

The Adaptation Plan includes recommendations based on possible measures developed in Hydro Ottawa workshops to mitigate the impact of climate related events. These prioritized recommendations are summarized in Table E-1.

Table E-1: Adaptation Plans

ID	Action	Accountability	Timeline to Complete and Integrate into Business Operations (if applicable)
OPS-1	Refine and establish a policy on wind conditions when a lift bucket should not be used and when work should not be completed to mitigate the risk of injury related to wind.	Distribution Operations Health and Safety	1 year
PLS-1	Develop anti-cascading strategies and standards for hardening of pole line systems to protect against wind and ice accumulation events, including: • Introducing break or stress points into the distribution lines. • Anchoring. • Type of pole. Complete a cost-benefit review of the strategies at critical areas and/or strategic timelines (end of life).	Asset Planning	2 years
PLS-2	Consider further updates to the vegetation management plan to account for the climate impacts and risks of increased invasive species and their potential to damage infrastructure or injure personnel during wind and ice events. Noting past program augmentations made in response to past storm events, evaluate feasibility of further augmentation with: • Trimming trees more often/aggressively or include heritage trees. • Include trees in the fall zone outside of Hydro Ottawa right away if condition assessment indicates vulnerability. Working with the City of Ottawa and the Village of Casselman to choose tree species that will be more resistant to future climate.	Forestry Asset Planning	2 years
PLS-3	Complete a technology review and feasibility study of technology that may use reduce ice build-up through pulsing or vibration of distribution lines to prevent ice build-up and galloping of lines.	Standards	2 years
PLS-4	Complete a study/analysis of potential methods to increase detection capabilities for downed lines to increase response time to repair damaged pole line system after damage from wind and/or ice accumulation.	Asset Planning	2 years
SUB-1	Review additional requirements for sanding and gritting prior to site access.	Facilities	2 years

ID	Action	Accountability	Timeline to Complete and Integrate into Business Operations (if applicable)
OPS-2	Consider a review of policies surrounding heat stress on outdoor workers and revise to include projected climate changes to mitigate the impacts of heat stress. Policies to consider should including: • A policy on work redistribution (scheduling) to avoid outdoor work during peak heat hours. • Where feasible and risk assessment permits, consider a policy around the adoption and use of modified PPE to improve cooling / ventilation.	Distribution Operations Health and Safety	2 years
OPS-3	Work with Hydro One, and provincial regulators to ensure supply design and standards are aligned with climate risks.	Asset Planning System Operations	2 years
OPS-4	Consider the cost-benefit of the following measures to reduce the risk of employee injuries related to ice accumulation events: • Review, and consider revising policy for requiring installation of winter tires on Hydro-owned vehicles to prevent injuries to personnel rather than through a request/approval process. • Installation and use of additional automated devices to limit need to travel during inclement conditions. • Introducing policies to include heated steps or walkways on Hydro Ottawa properties versus continued salting/sanding.	Fleet & Facilities Asset Planning	2 years
PLS-5	While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life. Underground distribution lines and infrastructure would mitigate risk from wind, ice accumulation and fog.	Asset Planning	5 years
ULS-1	Complete an engineering review to identify if there are locations vulnerable to overheating (via a detailed assessment of locations that could be vulnerable to temperatures higher than 40°C) and complete a cost-benefit analysis for mitigation options, which may include: • Institute either operational constraints on how much power can be conveyed through cables to limit overheating of cables. • Cool ducts either actively or passively, for example, with thermal fill (a clay slurry).	Asset Planning Standards	5 years

ID	Action	Accountability	Timeline to Complete and Integrate into Business Operations (if applicable)
ULS-2	Identify new technologies and processes through research and feasibility or pilot studies to reduce freeze thaw impacts. These may include: • Exploring the use of different materials for manholes instead of concrete that are less susceptible to freeze-thaw (e.g. fiber glass). • Redesign civil structure collars to move with the heading (e.g. telescopic collars).	Asset Planning Standards	5 years
SUB-2	Develop a policy to monitor and inspect substation building and structural components after an ice event to mitigate the risk of structural damage and loss of assets as a result of ice damage to substations.	Facilities Stations	5 years
SUB-3	Complete a cost-benefit analysis of installing protective covers on small exterior equipment, where feasible, to prevent damage/failure as a result of ice accumulation.	Facilities	5 years
SUB-4	In light of current design standards (40 mm of ice accumulations), assess the need for changes to technical specifications and policies for increased load break switch protection which may include: • Installation of alternative devices (i.e. breakers) to switch loads when load break switches are difficult to switch or inoperable. • Installation of switches without exposed contacts (replacement or protection). Update equipment specifications to require that switch operators break ice to allow for operability.	System Operations Asset Planning Standards	5 years
OPS-5	Develop a policy to monitor and inspect building and roofs after an ice event.	Facilities	5 years
OPS-6	Consider updating the work from home policy to eliminate or reduce commuting during extreme weather events and hazardous road conditions, particularly ice accumulation.	Human Resources	5 years
OPS-7	Consider future climate projections at end of life of current system when deciding to replace or rehabilitate building HVAC systems. Integrate requirement into Procurement Policy to size and design based on climate projections (heating and cooling requirements) in conjunction with critical needs (IT server requirements). By integrating future needs into procurement, the risk that cooling is not adequate during 40ºC is minimized.	Facilities	5 years
PLS-6	Consider the feasibility of further increasing the frequency of pole washing and cost/benefit based on risk level (current/future) to prevent increase risk of fires related to an increase in anticipated fog days.	Asset Planning	5-10 years

ID	Action	Accountability	Timeline to Complete and Integrate into Business Operations (if applicable)
PLS-7	Complete a cost/benefit analysis of expedited replacement of insulators and fused cut-outs with porcelain to prevent increase risk of fires related to an increase in anticipated fog days.	Asset Planning	5-10 years

These and other risk mitigation strategies are discussed in more detail in the main report along with a series of suggested best practices to help improve the resilience of Hydro Ottawa operations moving forward. Suggested best practices are summarized below.

- **Action 1:** Continue to invest in Smart Grid technology to increase resilience of the distribution system.
- **Action 2:** Continue to conduct post-disaster event analyses to identify lessons learned.
- **Action 3:** Continual improvement of emergency response planning, including communication protocols before, during and after extreme weather event.
- **Action 4:** Require that operating budgets account for climate risks and resiliency needs.
- **Action 5:** Continue to collaborate and plan with third-party service (e.g. City of Ottawa) providers to mitigate emerging risks and increase resilience of emergency planning procedures.
- **Action 6:** Consider wildfires as a potential risk that may emerge in the future and review the need for Wildfire Management Plans on an annual basis.
- **Action 7:** Collaborate with other utilities, regulators, and governments to develop guidance and protocols for climate resilience electrical infrastructure.
- **Action 8:** Build broad awareness and education among staff, such as incorporating extreme climate events and risks into health and safety communication and training materials.

Abbreviations

CRVA	Climate Risk and Vulnerability Assessment
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
OPS	Operations
PIEVC	Public Infrastructure Engineering Vulnerability Committee
PLS	Pole Line System
RCP	Representative Concentration Pathways
SUB	Substations
ULS	Underground Line Systems

1.0 INTRODUCTION

1.1 ABOUT HYDRO OTTAWA LIMITED

Hydro Ottawa Limited (Hydro Ottawa) provides electricity to over 330,000 residences and businesses in the City of Ottawa and the Village of Casselman, who depend on a continuous and reliable supply of energy. Its core business is electricity distribution and utility services with a service area of 1,116 km^2 which includes both the City of Ottawa and the Village of Casselman.

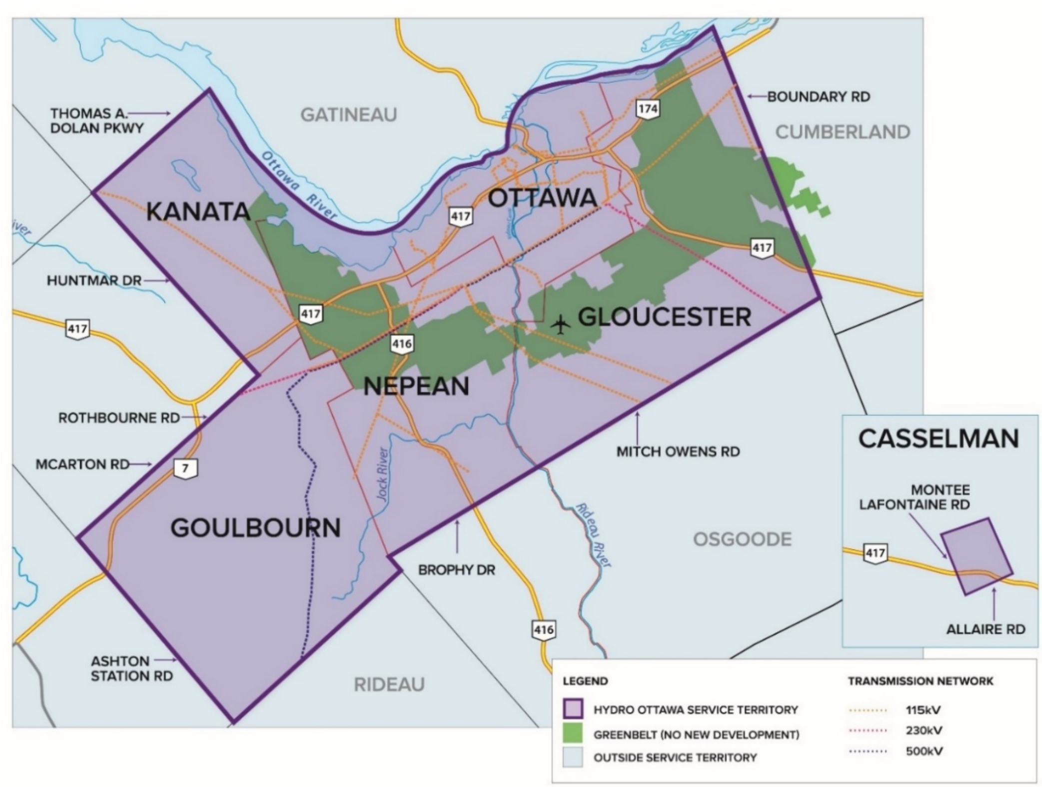

Figure 1: Map of Hydro Ottawa Service Territory[1]

[1] Hydro Ottawa. 2018. <https://hydroottawa.com/about/governance/overview>

1.2 FUTURE CLIMATE CHALLENGE

Hydro Ottawa is committed to creating long-term value for its shareholder, benefitting their customers and the communities it serves. However, climate change poses a serious threat to Hydro Ottawa's ability to deliver on that commitment. This was recently evidenced by the 2018 ice and windstorms of the spring, and the tornadoes that struck the service territory on September 21st, 2018. While these weather events had unavoidable impacts on the outage durations, Hydro Ottawa was able to moderate that impact due to past improvements to the physical infrastructure as well as to monitoring and remote response capabilities.

Hydro Ottawa has recognized the that changes in climate, as reflected in long-term trends and in increases in both frequency and intensity of extreme weather events, are expected to cause a greater range of potentially costly and disruptive impacts to the electrical distribution system, services, and operations. The inevitability of these climatic changes has prompted Hydro Ottawa to plan, monitor and adapt their systems and infrastructure to increase their resilience and limit the impact and damage that these extreme weather events can have on their services.

Hydro Ottawa has retained Stantec Consulting Ltd. (Stantec) to conduct a Climate Change Adaptation Plan (the Plan) for their distribution system and supporting infrastructure to follow up on the risk and vulnerabilities identified in an earlier phase of work. This work culminated in a standalone report prepared by Stantec, titled Distribution System Climate Risk and Vulnerability Assessment (CRVA). The risks identified in the CRVA are further detailed in Section 5 and available under separate cover. As a follow up to the CRVA, this Climate Change Adaptation Plan was developed.

1.3 PURPOSE OF THIS PLAN

This Climate Change Adaptation Plan (the Plan) considers the entire geographic extent of Hydro Ottawa's service territory which covers a vast portion of the City of Ottawa and the Village of Casselman, and includes both overhead and underground electrical distribution assets. The purpose of this Plan is to identify and make recommendations for actions to reduce the risks identified in the CRVA as well as recommendations for integrating actions into the Hydro Ottawa planning systems and operations.

The Plan, similar to the CRVA, was developed through a series of interviews and workshops with Hydro Ottawa staff.

2.0 CLIMATE CHANGE ADAPTATION

2.1 THE RISKS

In 2007, the Intergovernmental Panel on Climate Change (IPCC) concluded that "[the] warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level."[2] The impacts of climate change are already being experienced, and the inertia in the atmosphere dictates that the planet is 'locked into' some level of temperature rise due to historic greenhouse gas (GHG) emissions. In fact, some changes are "effectively irreversible", e.g. major melting of the ice sheets[3], and can have abrupt and severe impacts to our global climate.

2.2 THE COSTS

While the costs of extreme weather events depend on multiple factors, climate change is already increasing the intensity of storms, floods, droughts and other severe weather events in Canada. Since the 1980's, catastrophic losses from weather-related events have been growing (Figure 2: Catastrophic Losses in Canada (1983-2018)

and are expected to grow from about $5 billion in 2020 to between $21 billion and $43 billion under a 2°C scenario.[4] The Canadian insurance industry defines a catastrophic event as one that exceeds a threshold of $25 million in insured losses.

[2] IPCC (2007) Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Paschauri, R.K. and Reisinger, A. (eds)], (Geneva, Switzerland: IPCC), p. 2.
[3] http://www.ipcc.ch/ipccreports/tar/vol4/011.htm
[4] Canada, National Round Table on the Environment and the Economy (2011) Paying the Price: The Economic Impacts of Climate Change for Canada (Ottawa: National Round Table on the Environment and the Economy), 162 p.

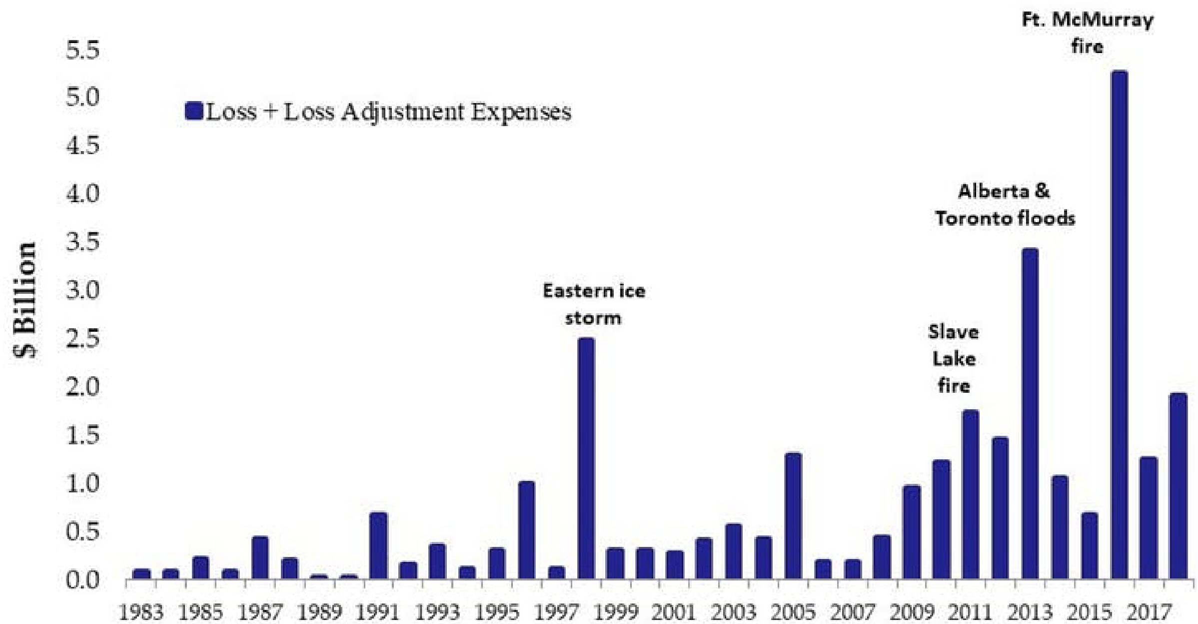

Figure 2: Catastrophic Losses in Canada (1983-2018)[5]

These costs have come close to, or exceeded, $1 billion in most years since 2009. They surpassed $1.5 billion in 2011 and 2017, $2.0 billion in 2018, $3 billion in 2013 and $5.0 billion in 2016. In the past decade, the sum of all severe weather-related catastrophic events has exceeded $20 billion. In 2018 alone, Hydro Ottawa's electrical distribution infrastructure was impacted by costly climate events including a freezing rain event in April, a heavy wind event in May, and a series of tornados that touched down in September in the Ottawa region. The impact of these events range in magnitude, but included service disruption to customers, damage to private property and distribution infrastructure and systems such as structural damage, reduced service life for asset components and for assets themselves, and increased stress to systems and operations. Increases in the frequency and intensity of these extreme events are likely to result in higher repair and maintenance costs, loss of asset value, and interruption of services or production if no risk mitigation and adaptation actions are taken.

With the IPCC concluding that the electricity sector is one of the sectors most at risk of disruption from climate change, and the occurrence of climate events already causing costly impacts, there is growing pressure from stakeholder for organizations to take responsibility to minimize the vulnerability of assets to a changing climate. Liabilities can often be attributed to the inadequate design or mismanagement of infrastructure that arise as a result of climate change and the impact can create public and environmental hazards that should have been mitigated or avoided entirely.

[5] https://globalnews.ca/news/5060791/commentary-climate-change-construction/

2.3 RESPONDING TO THE IMPACTS OF CLIMATE CHANGE

Addressing climate change requires efforts to prepare for changes that are irreversible and already underway, known as climate adaptation. Climate change adaptation involves making adjustments not only to infrastructure and operations but by integrating considerations for climate change into the decision-making process. Adaptation means enabling a sector or process to have a greater range of tolerance to extreme weather events (Figure 3). Most importantly, climate adaptation is now an essential aspect of managing infrastructure.

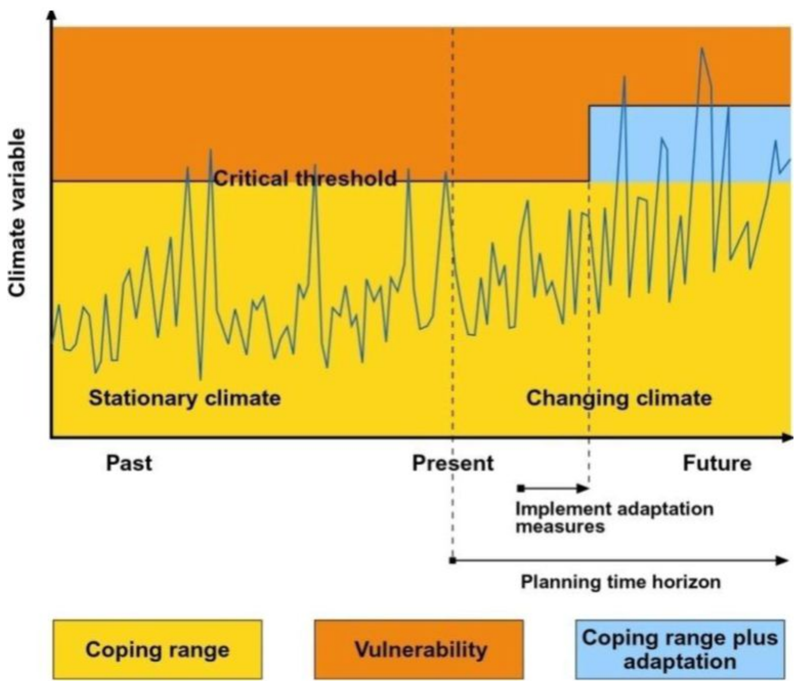

Figure 3: Adaptation Aims to Reduce Vulnerability by Increasing Coping Ranges[6]

Adaptation actions that are taken prior to experiencing specific climate change trends are called "anticipatory or proactive" and those taken after a trend or event has occurred are considered "reactive". Planned proactive adaptation actions typically incur lower long-term costs as the actions preserve assets, address issues of premature aging and increase overall resilience[7]. Successful adaptation does not necessarily mean that climate related impacts will no longer occur; rather, the impacts will still likely occur, but will be less severe in both harm and economic costs than if no adaptation measures been implemented.

[6] http://www.erm.com/en/insights/feature-articles/a-changing-climate-for-the-extractives-sector/

[7] Natural Resources Canada. (2009). What is adaptation? Retrieved from https://www.nrcan.gc.ca/environment/impacts-adaptation/adaptation-101/10025.

Although it is no longer possible to avoid the impacts of climate change, it is possible to reduce the cost and impacts of climate change to various extents. There is a business case for adaptation; this was clearly outlined in an economic report commissioned by the UK government called *The Stern Review*, which concluded, "the benefits of strong and early action far outweigh the economic costs of not acting." Using results from economic models, *The Stern Review* estimated that if society does not act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global Gross Domestic Product (GDP) annually – potentially as much as 20% of GDP. In contrast, the estimated costs of implementing actions to reduce GHG emissions and avoid some of the worst impacts of climate change could be limited to around 1% of global GDP. Most recently, the National Round Table on the Environment and the Economy concluded that the for every dollar spent on climate change adaptation now, $9 to $38 of damages can be avoided in the future.[8]

[8] http://nrt-trn.ca/wp-content/uploads/2011/09/paying-the-price.pdf

3.0 PREDICTING FUTURE CLIMATE CHANGE AND RISK

To understand anticipated future climate conditions in Hydro Ottawa's service territory, current and historical data from regional Environment Canada weather stations was analyzed in relation to projected global climate trends. Future climate conditions were projected based on Intergovernmental Panel on Climate Change (IPCC) global Representative Concentration Pathways (RCPs), while current and historical weather data was retrieved from Environment Canada records from local weather stations located at the Macdonald-Cartier International Airport and Russell, ON. From this data, localized climate projections were developed for the representative 30-year climate period centered on the 2050s (2041 – 2070) under the "business-as-usual" carbon emissions scenario, RCP8.5. These projections were then used estimate potential extreme weather events and general long-term patterns and trends by that could be expected to be experienced in the service territory during this future climate period.

The future climate conditions identified in the CRVA are based on a 'business as usual' greenhouse gas emissions scenario, which is referred by the IPCC as RCP 8.5 (Figure 4). Based on this scenario, it is assumed that global carbon emissions will continue to rise until 2100. Although some progress has been made in reducing global GHG emissions, current estimates of GHG emissions are still close to following the RCP 8.5 path and thus the CRVA and this Plan are based on risks identified from future climate projections estimated by the RCP 8.5 scenario.

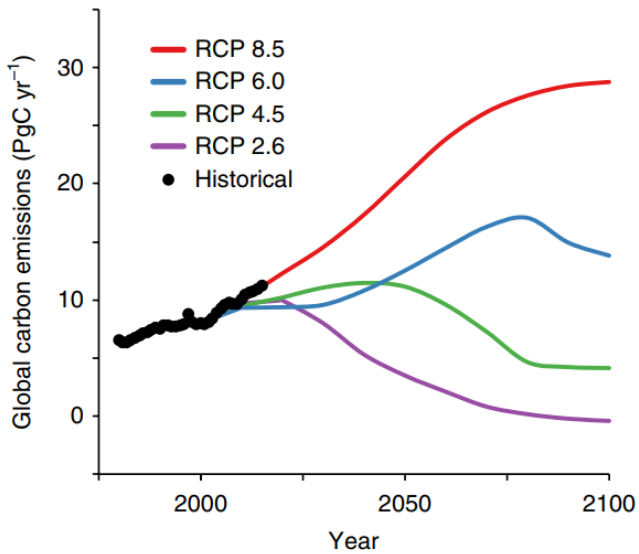

Figure 4: RCP Emissions Scenarios[9]

Climate modeling uses various GHG emissions scenarios, known as Representative Concentration Pathways (RCPs), to project future climate variables under different concentrations and rates of release of GHGs to the atmosphere, as well as different global energy balances. Various future trajectories of GHG emissions are possible depending on the global mitigation efforts in the coming years. RCPs are established by IPCC the international body for assessing the science related to climate change. The IPCC has set four GHG emissions scenarios through RCPs. RCP 8.5 is the internationally recognized the most pessimistic - "business as usual" GHG emissions scenario. Other GHG emissions scenarios represent more substantial and sustained reductions in GHG emissions: RCP 6, 4.5 and 2.6 (For example, the RCP 2.6 emissions scenario may be achievable with extensive adoption of biofuels/renewable energy and large-scale changes in global consumption habits, along with carbon capture and storage. RCP2.6 is representative of a scenario that aims to keep global warming likely below 2°C above pre-industrial temperatures. RCP 4.5 is considered the 'medium stabilization' scenario where global mitigation efforts result in intermediate levels of GHG emissions (IPCC, 2014).

A summary of potential climate changes centered around the 2050s identified in the CRVA for the Hydro Ottawa service area, is presented in Table 1.

[9] Source: https://www.nature.com/articles/s41558-018-0253-3

Table 1: Summary of Potential Climatic Changes by 2050

Climate Parameter	Projected Climatic Changes by Mid-Century
Temperature – Extreme Heat	• Increased frequency and intensity • Increased frequency and length of heat waves
Temperature – Extreme Cold	• Decreased frequency and intensity • Occurrence of extreme cold outbreaks ("Polar Vortex" winters) likely to continue
Rain (Short Duration – High Intensity)	• Increased intensity of events • Reduced return periods (e.g. 20-yr return period event becoming a 10-yr return period event in the future)
Freezing Rain & Ice Storms	• Increased frequency • Increased winter season (e.g. January) events
Snow	• Likely decrease in annual total accumulation • Continued occurrence and steady frequency of larger individual events
High Winds	• Slight increase in frequency of high wind events (e.g. 90 km/h; 120 km/h)
Lightning	• Increased frequency (by about 12% per degree Celsius of warming) • Increased length of the higher frequency lightning season
Tornadoes	• Increased frequency (25% increase by mid-century) • Increase (near 2x) in number of severe thunderstorm days by mid-century (capable of possibly producing tornadoes, hail, extreme winds, and extreme rainfall events)
Fog	• Likely increase
Frost (Freeze-Thaw Cycles)	• Decrease in annual total number of freeze-thaw days • Increase in monthly totals in the shoulder seasons (e.g. November and March)

4.0 APPROACH TO RISK AND ADAPTATION PLANNING

4.1 IDENTIFYING RISK AND ADAPTATION MEASURES

The CRVA was used to evaluate potential impacts and risks to the Hydro Ottawa electrical distribution system and supporting infrastructure as a result of changing climate and extreme weather events. This assessment process followed the Canadian Electricity Association's guide on adaptation to climate change, and Engineers Canada's Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol. The process involved the systematic review of historical climate information and the projection of the nature, severity and probability of future climate changes and events. The assessment of climatic changes was used to establish the exposure of infrastructure systems to these climate events. The impact of a particular damaging or disruptive climate event was then quantified and used to calculate the risk for a particular climate-infrastructure interaction. This process was repeated for all applicable infrastructure elements to produce an electrical distribution infrastructure climate risk profile.

The CRVA followed the following methodology (details of the process are provided in the CRVA report):

1. Identification of climate events (e.g. temperature, precipitation, winds) and their threshold values above which infrastructure performance would be affected and projecting the probability of occurrence of the climate hazards in the future (i.e. 2050s).

2. Assignment of a probability score for each climate event based on the climate data. This involved converting the projected probability of occurrence of future climate parameters into the five-point rating scale used in Hydro Ottawa's Asset Management System Risk Procedures.

3. Assignment of a severity rating for the impact of climate events on each element of the distribution system considered in the assessment. Impacts on the infrastructure were assessed for various performance criteria. This part of the assessment was completed through a staff workshop.

4. Calculation of the risk for each infrastructure element was performed using the formula: Risk = Severity x Probability (Table 2).

5. Using Hydro Ottawa's Asset Management System Risk Table (Table 3), medium, high and very high risks to infrastructure and operations were identified.

The adaptive capacity – the ability of a system to respond which takes into consideration factors like, age, design setting, etc.– of the infrastructure elements were taken into account during the risk assessment stage.

Table 2: Sample Risk Scoring Visualization

		Severity				
		Insignificant	Minor	Moderate	Extreme	Significant
Likelihood	Rare	1	4	8	16	25
	Unlikely	2	8	16	32	50
	Possibly	3	12	24	48	75
	Likely	4	16	32	64	100
	Almost Certain	5	20	40	80	125

Table 3: Hydro Ottawa Risk Rating System

Risk Score	Risk Rating
Low	≤10
Medium	11-30
High	31-60
Very High	≥60

The development of the Adaptation Plan consisted of the following steps:

1. Validation of medium to very high risks to infrastructure and operations as well as the impacts in a workshop with Hydro Ottawa staff (See Appendix B for the list of the attendees).

2. Selection of risk mitigation or adaptation measures to reduce the impacts of medium to very high future climate risks; developed through the workshop with Hydro Ottawa.

3. Prioritization of actions based on the risk levels, change in risk (current to future) and Hydro Ottawa's Asset Management System Risk Procedures.

4. Assignment of responsibilities and the development of indicators to track and monitor progress in the Enterprise Risk Management System (ERMS).

5.0 IDENTIFIED RISK AND ADAPTATION MEASURES

5.1 INFRASTRUCTURE ELEMENTS AT RISK

The medium, high and very high future climate related risks developed in the CRVA are provided in Table 4 for a given climate parameter. For each climate parameter, the asset performance affected, impacts and consequences are identified as well as the current and future risk rating. The difference between the current risk and the future risk is generally attributed to the impact of a changing climate as well as the age of the infrastructure. Red risk ratings identify high and very high risks.

Table 4: Medium and Very High Climate Related Risks

Climate Parameter	System/Component Affected	Risk Rating		Asset Performance Affected	Impacts	Result / Consequence
		Current Climate	Future Climate			
Daily maximum temp. of 40°C and higher	Operators Powerline Maintenance Staff	26 26	65 65	Resource Efficiency Asset Value – Financial	• Potential heat stress impacts on personnel working outdoors. • Exacerbated by humidex.	• Health and safety concerns requiring precautionary measures such as more frequent resting periods, hydration, etc. • Delay in restoration. • Loss in productivity.
	Administrative and Operational Buildings	8	20	Asset Value – Financial	• Increased cooling demands for the building critical systems (e.g., communication and IT systems).	• Capacity of cooling system may not be adequate to maintain ambient temperature within the design range of equipment affected which can lead to loss of efficiency, functionality or failure.
	Underground Cables	10	25	Level of Service: Service Quality Asset Value – Financial	• Potentially reduced capacity due to increased daily electricity demand from end user (e.g., A/C units).	• Additional strain on, and limits to the underground electrical infrastructure capacity.
Annual wind speeds of 120 km/h or higher (30-year occurrence)	Operators Powerline Maintenance Staff	36 36	36 36	Level of Service: Service Quality Resource Efficiency Asset Value – Financial	• Instability of equipment (lift buckets), flying debris, or broken tree limbs hazards.	• Health and safety concern for personnel working outdoors.
	Power Distribution: East-West lines and poles	81	81	Level of Service: Service Quality Resource Efficiency Asset Value – Financial	• Damage to poles and lines from high wind events.	• Loss of assets. • Disruption of service. • Difficulty in restoring service due to health and safety concerns for staff. • Public safety concerns due to downed power lines. • Impact on scheduling/productivity/ resources.
					• Risk of damages from falling trees, broken tree limbs or flying debris.	• Loss of assets. • Disruption of service. • Difficulty in restoring service due to health and safety concerns for staff. • Public safety concerns due to downed power lines.
	Power Distribution: North-South lines and poles	108	108	Level of Service: System Accessibility Level of Service: Service Quality Resource Efficiency Asset Value – Financial	• Damage to poles and lines from high wind events.	• Loss of assets. • Disruption of service. • Difficulty in restoring service due to health and safety concerns for staff. • Public safety concerns due to downed power lines. • Impact on scheduling/productivity/ resources.
					• Risk of damages from falling trees, broken tree limbs or flying debris.	• Loss of assets. • Disruption of service. • Difficulty in restoring service due to health and safety concerns for staff. • Public safety concerns due to downed power lines.

Climate Parameter	System/Component Affected	Risk Rating: Current Climate	Risk Rating: Future Climate	Asset Performance Affected	Impacts	Result / Consequence
Easterly winds of 80 km/h or higher (cool season [Oct.-March])	North-South lines and poles	32	32	Level of Service: System Accessibility Level of Service: Service Quality Resource Efficiency Asset Value – Financial	• Risk of damages from falling trees or broken tree limbs.	• Loss of assets. • Disruption of service. • Difficulty in restoring service due to health and safety concerns for staff. • Public safety concerns due to downed power lines.
	Operators Powerline Maintenance Staff	24	24	Level of Service: Service Quality Resource Efficiency Asset Value – Financial	• Instability of equipment (lift buckets), flying debris, or broken tree limbs hazards.	• Health and safety concern for personnel working outdoors.
	Power Distribution: East-West Lines and Poles	24	24	Level of Service: Service Quality Resource Efficiency Asset Value - Financial	• Damage to poles and lines from high wind events.	• Loss of assets. • Disruption of service. • Difficulty in restoring service due to health and safety concerns for staff. • Public safety concerns due to downed power lines. • Impact on scheduling/productivity/ resources.
					• Risk of damages from falling trees, broken tree limbs or flying debris.	• Loss of assets. • Disruption of service. • Difficulty in restoring service due to health and safety concerns for staff. • Public safety concerns due to downed power lines.
Ice accumulation of 40mm (30-year occurrence)	Third Party Services and Interactions: Hydro One	54	72	Level of Service: Service Quality Asset Value – Financial	• Loss of supply to Hydro Ottawa Damages to shared resources between Hydro One and Hydro Ottawa. • Loss of transmission. • Loss of redundancy. • Damage to equipment.	• Disruption of service. • Inability to restore service. • Loss of redundancy. • Loss of efficiency. • Potential damage to Hydro Ottawa and Hydro One shared resources • Damage to shared facilities.
	Administrative and Operational Buildings	24	32	Resource Efficiency Asset Value – Financial	• Access to the building is hindered due to heavy ice accumulation.	• Health and safety concerns for staff, contractors and/or public.
					• Increase in load on building due to ice accumulation, particularly if event occurs at a time where abundant snow on the roof.	• Potential structural and/or functional damage to roof elements (e.g., membrane on flat roofs). • May result in blocked roof drains. • Possible ice damming. • Potential loss of assets.
					• Ice accumulation on building mounted equipment (roof, exterior walls).	• Reduced efficiency and/or functionality, and failure of equipment affected.
	Substations - Buildings and Structural Components	24	32	Resource Efficiency Asset Value – Financial	• Access to the building is hindered due to heavy ice accumulation.	• Health and safety concerns for staff, contractors and/or public. • Delay in restoration.
					• Increase in load on building due to ice accumulation, particularly if event occurs at a time where abundant snow on the roof.	• Potential structural and/or functional damage to roof elements (e.g., membrane on flat roofs). • May result in block drains. • Possible ice damming. • Potential loss of assets. • Disruption of service.
					• Ice accumulation on building mounted equipment (roof, exterior walls).	• Reduced efficiency and/or functionality, and failure of equipment affected.

Climate Parameter	System/Component Affected	Risk Rating: Current Climate	Risk Rating: Future Climate	Asset Performance Affected	Impacts	Result / Consequence
Ice accumulation of 40mm (30-year occurrence) (continued)	Operators Powerline Maintenance Staff	39 39	52 52	Resource Efficiency Asset Value – Financial	• Difficulty accessing areas needing repair due to icy conditions; e.g., ice on roadways and walkways, equipment.	• Potential delays in arriving to work site. • Potential delays in performing work due to ice accumulation on equipment. • Health and safety concerns.
	Power Distribution: East-West lines and poles	51	68	Level of Service: Service Quality Resource Efficiency Asset Value - Financial	• Damage from increased weight on overhead lines. • Ice falling off of lines.	• Loss of assets. • Disruption of service. • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work. • Public safety concerns due to downed power lines.
					• Ice accretion on lines in excess of 12.5 mm (0.5 inches) accompanied by a 90km/h wind could result in structural failure. • Uneven ice accretion could cause swinging or 'galloping' in the lines. • Damage to poles and attached equipment.	• Potential for flashovers. • Ice break-up from lines may cause public safety concerns. • Loss of assets. • Disruption of service. • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work. • Public safety concerns due to downed power lines.
					• Damages to lines from fallen trees or broken tree limbs.	• Loss of assets. • Disruption of service. • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work. • Public safety concerns due to downed power lines.
					• Damage to poles and other surface equipment from vehicles losing control on icy roads.	• Loss of assets. • Disruption of service. • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work. • Public safety concerns due to downed power lines.
	Power Distribution: North-South lines and poles	36	48	Level of Service: Service Quality Resource Efficiency Asset Value - Financial	• Damage from increased weight on overhead lines. • Ice falling off of lines.	• Loss of assets. • Disruption of service. • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work. • Public safety concerns due to downed power lines.
					• Ice accretion on lines in excess of 12.5 mm (0.5 inches) accompanied by a 90km/h wind could result in structural failure. • Uneven ice accretion could cause swinging or 'galloping' in the lines. • Damage to poles and attached equipment.	• Potential for flashovers. • Ice break-up from lines may cause public safety concerns. • Loss of assets. • Disruption of service. • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work. • Public safety concerns due to downed power lines.

Climate Parameter	System/Component Affected	Risk Rating		Asset Performance Affected	Impacts	Result / Consequence
		Current Climate	Future Climate			
Ice accumulation of 40mm (30-year occurrence) (continued)					• Damages to lines from fallen trees or broken tree limbs.	• Loss of assets. • Disruption of service. • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work. • Public safety concerns due to downed power lines.
					• Damage to poles and other surface equipment from vehicles losing control on icy roads.	• Loss of assets. • Disruption of service. • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work. • Public safety concerns due to downed power lines.
	Substations: Station Load Break Switch	18	24	Level of Service: Service Quality Resource Efficiency Asset Value – Financial	• Ice accretion on load break switches could result in difficulty transferring loads.	• Removal of ice required for the switch to be operable. • Delay in restoration.
Daily maximum temp. of 35°C and higher	Administrative and Operational Buildings	12	20	Asset Value – Financial	• Increased cooling demands for the building critical systems (e.g., communication and IT systems).	• Capacity of cooling system may not be adequate to maintain ambient temperature within the design range of equipment affected which can lead to loss of efficiency, functionality or failure.
Season with ≥ 50 fog days (Nov.-March)	Power Distribution: East-West Poles	18	24	Level of Service: Service Quality Resource Efficiency Asset Value – Financial	• Pole fires which are a result of contaminant build-up on the insulators and the fog reducing the dielectric strength of the air which increases the probability of a flashover.	• Risk of electrical arcs, flashovers and pole fires. • Loss of assets. • Disruption of service. • Public safety concerns.
	Power Distribution: North-South Poles	18	24	Level of Service: Service Quality Resource Efficiency Asset Value – Financial	• Pole fires which are a result of contaminant build-up on the insulators and the fog reducing the dielectric strength of the air which increases the probability of a flashover.	• Risk of electrical arcs, flashovers and pole fires. • Loss of assets. • Disruption of service. • Public safety concerns.
	Power Distribution: North-South - Fused Cut Out	12	16	Level of Service: System Accessibility Level of Service: Service Quality Resource Efficiency Asset Value – Financial	• Insulator breakdown on fused cut outs. • Pole fires which are a result of contaminant build-up on the insulators and the fog reducing the dielectric strength of the air which increases the probability of a flashover probability of a flashover.	• Risk of electrical arcs, flashovers and pole fires. • Loss of assets. • Disruption of service. • Public safety concerns.
Freeze-thaw cycles – Daily Tmax/Tmin temp. fluctuation of ±4°C around 0°C	Power Distribution: Underground - Civil Structures	16	24	Resource Efficiency Asset Value – Financial	• Water penetration into or around civil structures which freezes causing stress on material.	• Deterioration and damage (short- and long-term) to materials. • Uplift of near-surface infrastructure causing higher risks of damage during winter maintenance (e.g., snow removal) operations.

5.2 ADAPTATION MEASURES

5.2.1 Adaptation Workshop

A climate adaptation planning workshop was conducted on June 27, 2019 with Hydro Ottawa staff and Stantec's risk and adaptation planning team. The purpose of the workshop was to validate the risks identified in the CRVA and to identify adaptation measures.

The workshop split participants into two groups to review the medium, high and very high climate risks and develop a range of adaptation measures for each.

A list of participants who attended the risk assessment workshop is presented in **Appendix B**.

5.2.2 Prioritizing Actions

The adaptation measures from the workshop were assessed and prioritized based on the level of risk as well as the change in risk in the current climate and future climate. Actions were prioritized taking into consideration both current and future risk ratings prioritizing those in the very high and high category and an assessment of the change in risk as identified by the risk factor. The risk factor represents the change in risk in the future climate scenario and is calculated by dividing the future risk by the current risk rating. Timelines to implement were developed based on the same review with longer implementation times for lower risk rating that increase in the future scenario. The timelines for adaptation measures represent the schedule for completing any analysis (e.g. cost-benefit analysis, policy review and revisions, etc.) and incorporation into a business operation such as policy, or plan.

The sections below present the significant risks and potential adaptation measures for each of the major infrastructure categories evaluated. The four categories used are pole line systems, underground line systems, substations and operations.

5.3 POLE LINE SYSTEM

5.3.1 Risk and Potential Adaptation Actions

High winds (>120 km/h - 30-year occurrence) causing direct damage to the poles, pole mounted equipment, and distribution lines as well as damage from falling tree or tree limbs pose the highest climate risk to Hydro Ottawa's infrastructure in current and future climates.

Ice accumulation (>40 mm - 30-year occurrence) currently poses a medium and high risk to infrastructure elements with the risk escalating to very high for the East-West distribution lines. The risk rating increased in the future for all assets impacted by ice accumulation.

Risks to infrastructure elements from fog are projected to increase in the future but remained in the medium range.

Easterly winds (>80 km/h) currently pose a medium risk to North-South distribution lines; this is not expected to measurably change in the future.

The actions identified during the Hydro Ottawa workshop are identified in Table 5.

Table 5: Impacts to Pole Line System - Current and Future

Climate Parameter	System / Component Affected	Description of Impact	Current Risk Score	Future Risk Score	Risk Factor (Change)	Possible Actions to Mitigate Risk
Annual wind speeds of 120 km/h or higher (30-year occurrence)	Power Distribution: East-West lines and poles	Damage to poles and lines from high wind events.	81	81	1.0	Use of higher strength structures (e.g. concrete, composite, metal poles) as anchoring in anti-cascading strategy. While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life.
Annual wind speeds of 120 km/h or higher (30-year occurrence)	Power Distribution: East-West lines and poles	Risk of damages from falling trees, broken tree limbs or flying debris.	81	81	1.0	Consider further updates to the vegetation management plan to account for the climate impacts and risks of increased invasive species and their impacts on infrastructure and personnel. Recent revisions have been made to include more aggressive and frequent trimming, including wire to sky trimming. Consider the feasibility of further augmentation with: • Trimming trees more often/aggressively or include heritage trees. • Include trees in the fall zone outside of Hydro Ottawa right away if condition assessment indicates vulnerability. • Working with the City of Ottawa and the Village of Casselman to choose tree species that will be more resistant to future climate. While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life.
Annual wind speeds of 120 km/h or higher (30-year occurrence)	Power Distribution: North-South lines and poles	Damage to poles and lines from high wind events.	108	108	1.0	Use of higher strength structures (e.g. concrete, composite, metal poles) as anchoring in anti-cascading strategy. While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life.
Annual wind speeds of 120 km/h or higher (30-year occurrence)	Power Distribution: North-South lines and poles	Risk of damages from falling trees, broken tree limbs or flying debris.	108	108	1.0	Consider further updates to the vegetation management plan to account for the climate impacts and risks of increased invasive species and their impacts on infrastructure and personnel. Recent revisions have been made to include more aggressive and frequent trimming, including wire to sky trimming. Consider the feasibility of further augmentation with: • Trimming trees more often/aggressively or include heritage trees. • Include trees in the fall zone outside of Hydro Ottawa right away if condition assessment indicates vulnerability. • Working with the City of Ottawa and the Village of Casselman to choose tree species that will be more resistant to future climate. While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life.
Easterly winds of 80 km/h or higher (cool season [Oct.-March])	Power Distribution: North-South Lines and Poles	Damage from falling trees, broken tree limbs or flying debris.	32	32	1.0	Develop anti-cascading strategies (e.g. introduce break or stress points in lines). Increase detection capabilities for downed lines. Consider further updates to the vegetation management plan to account for the climate impacts and risks of increased invasive species and their impacts on infrastructure and personnel. Recent revisions have been made to include more aggressive and frequent trimming, including wire to sky trimming. Consider the feasibility of further augmentation with: • Trimming trees more often/aggressively or include heritage trees. • Include trees in the fall zone outside of Hydro Ottawa right away if condition assessment indicates vulnerability. • Working with the City of Ottawa and the Village of Casselman to choose tree species that will be more resistant to future climate. While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life.

Climate Parameter	System / Component Affected	Description of Impact	Current Risk Score	Future Risk Score	Risk Factor (Change)	Possible Actions to Mitigate Risk
Easterly winds of 80 km/h or higher (cool season [Oct.-March]) (continued)	Power Distribution: East-West Lines and Poles	Damage from falling trees, broken tree limbs or flying debris.	24	24	1.0	Develop anti-cascading strategies (e.g. introduce break or stress points in lines). Increase detection capabilities for downed lines. Consider further updates to the vegetation management plan to account for the climate impacts and risks of increased invasive species and their impacts on infrastructure and personnel. Recent revisions have been made to include more aggressive and frequent trimming, including wire to sky trimming. Consider the feasibility of further augmentation with: • Trimming trees more often/aggressively or include heritage trees. • Include trees in the fall zone outside of Hydro Ottawa right away if condition assessment indicates vulnerability. • Working with the City of Ottawa and the Village of Casselman to choose tree species that will be more resistant to future climate. While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life.
Ice accumulation of 40mm (30-year occurrence)	Power Distribution: East-West lines and poles	Damage from increased weight on overhead lines. Ice accretion on lines in excess of 12.5 mm (0.5 inches) accompanied by a 90km/h wind could result in structural failure and uneven ice accretion could cause swinging or 'galloping' in the lines. Damages to lines from fallen trees or broken tree limbs. Damage to poles and other surface equipment from vehicles losing control on icy roads.	51	68	1.3	Develop anti-cascading strategies (e.g. introduce break or stress points in lines). Increase detection capabilities for downed lines. Consider further updates to the vegetation management plan to account for the climate impacts and risks of increased invasive species and their impacts on infrastructure and personnel. Recent revisions have been made to include more aggressive and frequent trimming, including wire to sky trimming. Consider the feasibility of further augmentation with: • Trimming trees more often/aggressively or include heritage trees. • Include trees in the fall zone outside of Hydro Ottawa right away if condition assessment indicates vulnerability. • Working with the City of Ottawa and the Village of Casselman to choose tree species that will be more resistant to future climate. While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life. Research technology and feasibility of pulsing or vibrating lines to reduce ice build-up.
Ice accumulation of 40mm (30-year occurrence)	Power Distribution: North-South lines and poles	Damage from increased weight on overhead lines. Ice accretion on lines in excess of 12.5 mm (0.5 inches) accompanied by a 90km/h wind could result in structural failure and uneven ice accretion could cause swinging or 'galloping' in the lines Damages to lines from fallen trees or broken tree limbs. Damage to poles and other surface equipment from vehicles losing control on icy roads.	36	48	1.3	Develop anti-cascading strategies (e.g. introduce break or stress points in lines). Increase detection capabilities for downed lines. Consider further updates to the vegetation management plan to account for the climate impacts and risks of increased invasive species and their impacts on infrastructure and personnel. Recent revisions have been made to include more aggressive and frequent trimming, including wire to sky trimming. Consider the feasibility of further augmentation with: • Trimming trees more often/aggressively or include heritage trees. • Include trees in the fall zone outside of Hydro Ottawa right away if condition assessment indicates vulnerability. • Working with the City of Ottawa and the Village of Casselman to choose tree species that will be more resistant to future climate. While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life. Research technology and feasibility of pulsing or vibrating lines to reduce ice build-up.

Climate Parameter	System / Component Affected	Description of Impact	Current Risk Score	Future Risk Score	Risk Factor (Change)	Possible Actions to Mitigate Risk
Ice accumulation of 40mm (30-year occurrence) (continued)	Power Distribution: North-South lines and poles	Damages to lines from fallen trees or broken tree limbs.	36	48	1.3	Consider updating the vegetation management plan to account for the impacts and risks of increased invasive species and their impacts on infrastructure and personnel. For example, modify the vegetation management plan to include the following actions: • Trimming trees more often/aggressively or include heritage tree. • Include trees in the fall zone if vulnerable through a condition assessment. • Work with the City of Ottawa and the Village of Casselman to choose tree species that will be more resistant to future climate. While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life.
Season with ≥ 50 fog days (Nov.-March)	Power Distribution: All directions	Pole fires as a result of contaminants accumulating onto insulators and presence of fog.	18	24	1.3	Expedite the replacement of porcelain insulators with polymer insulators beyond replacement during maintenance. Consider the feasibility of further increasing the frequency of pole washing and cost/benefit based on risk level (current/future). While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life.
Season with ≥ 50 fog days (Nov.-March)	Power Distribution: North-South - Fused Cut Out	Insulator breakdown on fused cut outs.	12	16	1.3	Replace porcelain fused cutouts with polymer fused cutouts on an expedited basis. While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life.

5.3.2 Pole Line System Recommended Actions

To address the future climate risks in the pole line system, the following recommendations are built on the actions identified by Hydro Ottawa in the Workshop.

Table 6: Recommendations for Pole Line System (PLS)

Priority Level	Initiative	Responsibility	Business Operation to Integrate Outcome	Climate Event Mitigated	Timeline to Complete and Integrate into Business Operations (if applicable)	Monitoring Strategy
PLS-1	Develop anti-cascading strategies and standards for hardening of pole line systems to protect against wind and ice accumulation events, including: • Introducing break or stress points into the distribution lines. • Anchoring. • type of pole. Complete a cost-benefit review of the strategies at critical areas and/or strategic timelines (end of life).	Asset Planning	Asset Management Plan Pole, Fixtures and Primary Overhead Conductor	Wind, ice accumulation	2 years	Monitor power outages from cascading events year over year and track by climate event.
PLS-2	Consider further updates to the vegetation management plan to account for the climate impacts and risks of increased invasive species and their potential to damage infrastructure or injure personnel during wind and ice events. Noting past program augmentations made in response to past storm events, evaluate feasibility of further augmentation with: • Trimming trees more often/aggressively or include heritage trees. • Include trees in the fall zone outside of Hydro Ottawa right away if condition assessment indicates vulnerability. • Working with the City of Ottawa and the Village of Casselman to choose tree species that will be more resistant to future climate.	Forestry Asset Planning	Vegetation Management Plan	Wind, ice accumulation	2 years	Review outage report as a result of tree damage on an annual basis and adjust Vegetation Management Plan as required.
PLS-3	Complete a technology review and feasibility study of technology that may use reduce ice build-up through pulsing or vibration of distribution lines to prevent ice build-up and galloping of lines.	Standards	Asset Management Plan Pole, Fixtures and Primary Overhead Conductor	Ice accumulation	2 years	Line and pole damage and ice accumulation.
PLS-4	Complete a study/analysis of potential methods to increase detection capabilities for downed lines to increase response time to repair damaged pole line system after damage from wind and/or ice accumulation.	Asset Planning	Asset Management Plan Pole, Fixtures and Primary Overhead Conductor	Wind, ice accumulation	2 years	Monitor power restoration response time to event.
PLS-5	While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life. Underground distribution lines and infrastructure would mitigate risk from wind, ice accumulation and fog.	Asset Planning	Asset Management Plan Pole, Fixtures and Primary Overhead Conductor	Wind, ice accumulation, fog	5 years	Outage reports for weather events and cost of damage estimates.
PLS-6	Consider the feasibility of further increasing the frequency of pole washing and cost/benefit based on risk level (current/future) to prevent increase risk of fires related to an increase in anticipated fog days.	Asset Planning	Asset Management Plan Pole, Fixtures and Primary Overhead Conductor	Fog	5-10 years	Monitor pole fires and fog days on a year over year basis.
PLS-7	Complete a cost/benefit analysis of expedited replacement of insulators and fused cut-outs with porcelain to prevent increase risk of fires related to an increase in anticipated fog days.	Asset Planning	Asset Management Plan Pole, Fixtures and Primary Overhead Conductor	Fog	5-10 years	Monitor pole fires and fog days on a year over year basis.

5.4 UNDERGROUND LINES SYSTEM

5.4.1 Risk and Potential Adaptation Actions

The CRVA identified only one interaction that presented a medium or higher risk: impacts of freeze-thaw events on civil structures. This risk is currently medium and projected to remain medium in the future.

The actions identified during the Hydro Ottawa workshop are identified in Table 7.

Table 7: Impacts to Underground Lines System - Current and Future

Climate Parameter	System / Component Affected	Description of Impact	Current Risk Score	Future Risk Score	Risk Factor (Change)	Possible Actions to Mitigate Risk
Daily maximum temp. of 40°C	Power Distribution: Underground – Underground Cables	Loss of asset life due High ambient temperatures in combination with the heating of cables resulting from increasing electrical loading.	10	25	2.5	Review to identify, if there are locations vulnerable to overheating (via a detailed assessment of locations that could be vulnerable to temperatures higher than 40°C) and: • Institute either operational constraints on how much power can be conveyed through cables to limit overheating of cables. • Cool ducts either actively or passively, for example, with thermal fill (a clay slurry).
Freeze-thaw cycles – Daily Tmax/Tmin temp. fluctuation of ±4°C around 0°C	Power Distribution: Underground - Civil Structures	Water penetration into or around civil structures which freezes causing stress on material.	16	24	1.5	Explore the use of different materials for manholes (fiber glass instead of concrete) that are less susceptible to freeze-thaw. Redesign civil structure collars to move with the heading (e.g. telescopic collars).

5.4.2 Underground Line Systems Recommended Actions

To address the future climate risks with underground line systems, the following recommendations are built on the actions identified by Hydro Ottawa in the Workshop.

Table 8: Recommendations for Underground Line Systems (ULS)

Priority Level	Initiative	Responsibility	Business Operation to Integrate Outcome	Climate Event Mitigated	Timeline to Complete and Integrate into Business Operations (if applicable)	Monitoring Strategy
ULS-1	Complete an engineering review to identify if there are locations vulnerable to overheating (via a detailed assessment of locations that could be vulnerable to temperatures higher than 40°C) and complete a cost-benefit analysis for mitigation options, which may include: • Institute either operational constraints on how much power can be conveyed through cables to limit overheating of cables. • Cool ducts either actively or passively, for example, with thermal fill (a clay slurry).	Asset Planning Standards	Asset Management Plan UG Cable R0	Maximum Temperatures	5 years	Temperature runs within prescribed levels. Premature cable failure events and occurrences of 40°C days.
ULS-2	Identify new technologies and processes through research and feasibility or pilot studies to reduce freeze thaw impacts. These may include: • Exploring the use of different materials for manholes instead of concrete that are less susceptible to freeze-thaw (e.g. fiber glass). • Redesign civil structure collars to move with the heading (e.g. telescopic collars).	Asset Planning Standards	Asset Management Plan - Civil Structures	Freeze-thaw events	5 years	Track freeze-thaw damage and annual freeze-thaw days.

5.5 SUBSTATIONS

5.5.1 Risk and Potential Adaptation Actions

All climate risks identified for substations and substation components are related to ice accumulation of 40mm (30-year occurrence), which has been found to impact building access, roof loading, exterior mounted equipment, and load break switches. All these risks were found to increase in the future. The risks related to substation buildings increased from medium to a high in the future. The actions identified during the Hydro Ottawa workshop are identified in Table 9.

Table 9: Substations - Current and Future

Climate Parameter	System / Component Affected	Description of Impact	Current Risk Score	Future Risk Score	Risk Factor (Change)	Possible Actions to Mitigate Risk
Ice accumulation of 40mm (30-year occurrence)	Substations - Buildings and Structural Components	Access to the building is hindered due to heavy ice accumulation.	24	32	1.3	Increase spreading of gravel and grit before site access.
Ice accumulation of 40mm (30-year occurrence)	Substations - Buildings and Structural Components	Increase in load on building due to ice accumulation, particularly if event occurs at a time where abundant snow on the roof.	24	32	1.3	Develop a policy to monitor and inspect substation building and structural components after an ice event.
Ice accumulation of 40mm (30-year occurrence)	Substations - Buildings and Structural Components	Ice accumulation on building mounted equipment (exterior walls).	24	32	1.3	Install covers on vulnerable equipment attached to buildings (where feasible).
Ice accumulation of 40mm (30-year occurrence)	Substations: Station Load Break Switch	Ice accretion on load break switches could result in difficulty transferring loads.	18	24	1.3	Install switches without exposed contacts. Update equipment specifications to require that switch operators break ice to allow for operability. Consider alternative devices (i.e. breakers) to switch loads when load break switches are difficult to switch or inoperable.

5.5.2 Substations: Recommended Actions

To address the future climate risks to substations, the following recommendations are built on the actions identified by Hydro Ottawa in the Workshop.

Table 10: Recommendations for Substations (SUB)

Priority Level	Initiative	Responsibility	Business Operation to Integrate Outcome	Climate Event Mitigated	Timeline to Complete and Integrate into Business Operations (if applicable)	Monitoring Strategy
SUB-1	Review additional requirements for sanding and gritting prior to site access.	Facilities	Maintenance Procedures	Ice accumulation	2 years	Delays due to inaccessibility.
SUB-2	Develop a policy to monitor and inspect substation building and structural components after an ice event to mitigate the risk of structural damage and loss of assets as a result of ice damage to substations.	Facilities Stations	Maintenance Procedures	Ice accumulation	5 years	Number of leaks or damages. Track maintenance costs.
SUB-3	Complete a cost-benefit analysis of installing protective covers on small exterior equipment, where feasible, to prevent damage/failure as a result of ice accumulation.	Facilities	Asset Management Plans	Ice accumulation	5 years	Number of failures of attached equipment due to ice.
SUB-4	In light of current design standards (40 mm of ice accumulations), assess the need for changes to technical specifications and policies for increased load break switch protection which may include: • Installation of alternative devices (i.e. breakers) to switch loads when load break switches are difficult to switch or inoperable. • Installation of switches without exposed contacts (replacement or protection). • Update equipment specifications to require that switch operators break ice to allow for operability.	System Operations Asset Planning Standards	Asset Management Plan - Station Switchgear and Breakers	Ice accumulation	5 years	Number of operational failures due to ice.

5.6 OPERATIONS

5.6.1 Risk and Potential Adaptation Actions

Climate risks related to operations are associated with personnel, administrative buildings, and third-party interactions with Hydro One. These assets are impacted by daily maximum temperatures of 35°C and 40°C and higher, winds of 80 km/h and 120 km/h and higher, and ice accumulation of 40mm. The highest rated climate risks to Hydro Ottawa operations are heat stress on outdoor operators and maintenance personnel, and a loss of supply from Hydro One due to ice accumulation; these risks will increase in the future.

Risks associated with ice accumulation include impacts on administrative building roof loads and access; these risks have a medium risk rating in the current climate but will increase to high in the future. Ice accumulation was also identified as a high risk (current and future climates) to outdoor operators and maintenance staff.

Lastly, high maximum temperatures requiring higher cooling demands on administrative buildings produces a medium risk level in the current climate; this risk will remain medium in the future.

The actions identified during the Hydro Ottawa workshop are identified in Table 11.

Table 11: Impacts to Operations - Current and Future

Climate Parameter	System / Component Affected	Description of Impact	Current Risk Score	Future Risk Score	Risk Factor (Change)	Possible Actions to Mitigate Risk
Daily maximum temp. of 40°C and higher	Operators	Potential heat stress impacts on personnel working outdoors. Exacerbated by humidex.	26	65	2.5	Work redistribution (scheduling) to avoid outdoor work during peak heat hours. Risk assessment to be completed to determine if potential for use of modified PPE that has improved cooling / ventilation and consideration for modifying worksite requirements where fire retardant may not be necessary.
Daily maximum temp. of 40°C and higher	Administrative and Operational Buildings	Increased cooling demands for the buildings, including critical systems (e.g., communication and IT systems).	8	20	2.5	Consider future climate projections at end of life of current system when deciding to replace or retrofit building HVAC systems.
Daily maximum temp. of 35°C and higher	Administrative and Operational Buildings	Increased cooling demands for the buildings, including critical systems (e.g., communication and IT systems).	12	20	1.7	Consider future climate projections at end of life of current system when deciding to replace or retrofit building HVAC systems.
Annual wind speeds of 120 km/h or higher (30-year occurrence)	Operators	Instability of equipment (lift buckets), flying debris, or broken tree limbs hazards.	36	36	1.0	This would result in a stop work authority; however, there is a need to refine and establish a wind condition policy establishing when a lift bucket should not be used and when work should not be completed.
Easterly winds of 80 km/h or higher (cool season [Oct.-March])	Operators/ Powerline Maintenance Staff	Instability of equipment (lift buckets), flying debris, or broken tree limbs hazards.	24	24	1.0	This would result in a stop work authority; however, there is a need to refine and establish a wind condition policy establishing when a lift bucket should not be used and when work should not be completed.
Ice accumulation of 40mm (30-year occurrence)	Third Party Services and Interactions: Hydro One	Loss of supply to Hydro Ottawa. Damages to Hydro One and Hydro Ottawa shared resources. Loss of transmission. Loss of redundancy. Damage to equipment.	54	72	1.3	Work with Hydro One, and provincial regulators to ensure supply design and standards are aligned with climate risks.
Ice accumulation of 40mm (30-year occurrence)	Administrative and Operational Buildings	Access to the building is hindered due to heavy ice accumulation.	24	32	1.3	Update the work from home plan to eliminate commuting during extreme weather events and hazardous road conditions.

Climate Parameter	System / Component Affected	Description of Impact	Current Risk Score	Future Risk Score	Risk Factor (Change)	Possible Actions to Mitigate Risk
Ice accumulation of 40mm (30-year occurrence)	Administrative and Operational Buildings	Increase in load on building due to ice accumulation, particularly if event occurs at a time where abundant snow on the roof may impact structural and assets.	24	32	1.3	Monitor, inspect and repair roof after climate event to prevent protect assets, equipment within the building.
Ice accumulation of 40mm (30-year occurrence)	Operators/Powerline Maintenance Staff	Injuries to operators and personnel.	39	52	1.3	Review, and consider revising policy for requiring installation of winter tires on Hydro-owned vehicles to prevent injuries to personnel rather than through a request/approval process. Installation and use of remotely operable switching devices to reduce travel requirements during inclement conditions. Introduce policies to include heated steps or walkways on Hydro Ottawa properties versus continued salting/sanding.

5.7 OPERATIONS: RECOMMENDED ACTIONS

To address the future climate risks to operations, the following recommendations are built on the actions identified by Hydro Ottawa in the Workshop.

Table 12: Recommendations for Operations (OPS)

Priority Level	Initiative	Responsibility	Business Operation to Integrate Outcome	Climate Event Mitigated	Timeline to Complete and Integrate into Business Operations (if applicable)	Monitoring Strategy
OPS-1	Refine and establish a policy on wind conditions when a lift bucket should not be used and when work should not be completed to mitigate the risk of injury related to wind.	Distribution Operations Health and Safety	Health and Safety Policy/Practice	Wind	1 year	Monitoring of the number of wind-related events and health and safety incidents associated with wind and lift buckets.
OPS-2	Consider a review of policies surrounding heat stress on outdoor workers and revise to include projected climate changes to mitigate the impacts of heat stress. Policies to consider should including: • A policy on work redistribution (scheduling) to avoid outdoor work during peak heat hours. • Where feasible and risk assessment permits, consider a policy around the adoption and use of modified PPE to improve cooling / ventilation.	Distribution Operations Health and Safety	Health and Safety Policy/Practice	Heat events	2 years	Monitor the number of heat-related incidents and daily max temperatures in excess of 35 ºC and 40ºC.
OPS-3	Work with Hydro One, and provincial regulators to ensure supply design and standards are aligned with climate risks.	Asset Planning System Operations	Various	Ice accumulation, wind	2 years	Track the frequency and scale of outages resulting from Hydro One service disruption.
OPS-4	Consider the cost-benefit of the following measures to reduce the risk of employee injuries related to ice accumulation events: • Review, and consider revising policy for requiring installation of winter tires on Hydro-owned vehicles to prevent injuries to personnel rather than through a request/approval process. • Installation and use of additional automated devices to limit need to travel during inclement conditions. • Introducing policies to include heated steps or walkways on Hydro Ottawa properties versus continued salting/sanding.	Fleet & Facilities Asset Planning	Health and Safety Policy/Practice	Ice accumulation	2 years	Monitor the number of ice-related incidents (near miss, incidents).
OPS-5	Develop a policy to monitor and inspect building and roofs after an ice event.	Facilities	Maintenance Procedures	Ice accumulation	5 years	Tracking of damage by weather event (if known). Track maintenance costs.
OPS-6	Consider updating the work from home policy to eliminate or reduce commuting during extreme weather events and hazardous road conditions, particularly ice accumulation.	Human Resources	Human Resources Policy	Ice accumulation	5 years	Safety bulletin for tracking number of slips, falls, and other ice-related incidents.
OPS-7	Consider future climate projections at end of life of current system when deciding to replace or rehabilitate building HVAC systems. Integrate requirement into Procurement Policy to size and design based on climate projections (heating and cooling requirements) in conjunction with critical needs (IT server requirements). By integrating future needs into procurement, the risk that cooling is not adequate during 40ºC is minimized.	Facilities	Procurement Policy	Heat event	5 years	Monitor the efficiency and service requirements of the building's HVAC system and environmental controls.

5.8 BEST PRACTICES FOR A CHANGING CLIMATE

In addition to the recommendations for adaptation measures identified and prioritized in Section 5.3 to 5.6 that were developed in the Hydro Ottawa workshop, the Table 13 presents a number of best practices recommended to guide the organization in their on-going efforts to build resilience.

Table 13: Best Practices for Operations

Action	Action Description
Action 1: Continue to invest in Smart Grid technology to increase resilience of the distribution system.	Hydro Ottawa has invested and continues to invest in capital funding projects to build Smart Grid technology. As Smart Grid technology continues to evolve and mature, Hydro Ottawa should continue to seek opportunities to increase resilience of the system through enhanced Smart Grid technology and system transfer capacity.
Action 2: Continue to conduct post-disaster event analyses to identify lessons learned.	Continue to comprehensively review the outcomes of disaster and emergency events and their effect on Hydro Ottawa owned properties, staff, and service delivery. Continue to track and report data on damages experienced and identify recommended mitigation strategies and response protocols for future similar events. Consider whether events will warrant strategic decisions for Hydro Ottawa properties (e.g. hardening, replacement, relocation, etc.). Distribute findings to all relevant staff and leadership via standardized reports.
Action 3: Continual improvement of emergency response planning, including communication protocols before, during and after extreme weather events.	Continual improvement of Crisis Management Plan with lessons learned and post-disaster analyses and consider opportunities to: • Clarify protocols and staff education within Hydro Ottawa for staff to better understand their roles during an emergency. • Implementing an equipment sharing program or equipment rental agreements with local companies / contractors to avoid equipment limitations during an emergency • Contingency planning for fuel supply.
Action 4: Require that operating budgets account for climate risks mitigation and resiliency needs.	To successfully integrate climate change into an organization, it must be accounted for by management and operational decision-makers through budget planning, service planning, project management, enterprise risk management, asset management, energy management and procurement decisions.
Action 5: Continue to collaborate and plan with third-party service (e.g. City of Ottawa) providers to mitigate emerging risks and increase resilience of emergency planning procedures.	Other third-party risks to Hydro Ottawa's operations are related to their partnerships with the City of Ottawa (fuel supply, stormwater drainage and winter maintenance), partners for emergency response, and telecommunications. Engage and collaborate with third-parties to mitigate emerging risks, share lessons learned and build resilient emergency planning procedures.
Action 6: Consider wildfires as a potential risk that may emerge in the future and review the need for Wildfire Management Plans on an annual basis.	Wildfires are considered as a special case as they are generally related to a combination of weather events (i.e. temperature, rainfall). Wildfires currently pose a low risk to Hydro Ottawa; however, wildfire threat may escalate in the future. It is recommended that Hydro Ottawa monitor changes in fire threat days year over year and complete an assessment of the need to development a Wildfire Management Plan as part of the annual planning system.
Action 7: Collaborate with other utilities, regulators, and governments to develop guidance and protocols for climate resilience electrical infrastructure.	Work with partners to develop guidance and protocols for climate resilient electrical infrastructure. Review pilot projects conducted by peers to assess lessons learned. Adopt findings as necessary.
Action 8: Build broad awareness and education among staff, such as incorporating extreme climate events and risks into health and safety communication and training materials.	Share existing information and best practices with employees, contractors and the public to promote electrical system safety in extreme temperatures and weather.

5.9 IMPLEMENTATION

The Chief Electricity Distribution Officer will be primarily responsible for the implementation of Plan with individual actions falling to the responsibility of the relevant departments as deemed appropriate. Hydro Ottawa will need to dedicate staff time and annual funding for the Plan to be successful in its implementation. It will also be important for Hydro Ottawa to continually monitor, report and review progress on these activities so that they can be adjusted as necessary to improve the outcomes.

5.10 IMPLEMENTATION SCHEDULE

The Plan is intended to be a living document. Updates may be made to accommodate changes in policies, staff or financial resources, and unexpected extreme weather events. This flexibility will ensure that Hydro Ottawa is not constrained to certain parameters should new opportunities for implementation arise. The preliminary implementation schedule was developed to identify and allocate resources required to implement priority actions.

A summary of prioritize recommendations for Adaptation Planning is provided in Table 14.

Table 14: Prioritized Actions

ID	Action	Accountability	Timeline to Complete and Integrate into Business Operations (if applicable)
OPS-1	Refine and establish a policy on wind conditions when a lift bucket should not be used and when work should not be completed to mitigate the risk of injury related to wind.	Distribution Operations Health and Safety	1 year
PLS-1	Develop anti-cascading strategies and standards for hardening of pole line systems to protect against wind and ice accumulation events, including: • Introducing break or stress points into the distribution lines. • Anchoring. • Type of pole. Complete a cost-benefit review of the strategies at critical areas and/or strategic timelines (end of life).	Asset Planning	2 years

ID	Action	Accountability	Timeline to Complete and Integrate into Business Operations (if applicable)
PLS-2	Consider further updates to the vegetation management plan to account for the climate impacts and risks of increased invasive species and their potential to damage infrastructure or injure personnel during wind and ice events. Noting past program augmentations made in response to past storm events, evaluate feasibility of further augmentation with: • Trimming trees more often/aggressively or include heritage trees. • Include trees in the fall zone outside of Hydro Ottawa right away if condition assessment indicates vulnerability. Working with the City of Ottawa and the Village of Casselman to choose tree species that will be more resistant to future climate.	Forestry Asset Planning	2 years
PLS-3	Complete a technology review and feasibility study of technology that may use reduce ice build-up through pulsing or vibration of distribution lines to prevent ice build-up and galloping of lines.	Standards	2 years
PLS-4	Complete a study/analysis of potential methods to increase detection capabilities for downed lines to increase response time to repair damaged pole line system after damage from wind and/or ice accumulation.	Asset Planning	2 years
SUB-1	Review additional requirements for sanding and gritting prior to site access.	Facilities	2 years
OPS-2	Consider a review of policies surrounding heat stress on outdoor workers and revise to include projected climate changes to mitigate the impacts of heat stress. Policies to consider should including: • A policy on work redistribution (scheduling) to avoid outdoor work during peak heat hours. • Where feasible and risk assessment permits, consider a policy around the adoption and use of modified PPE to improve cooling / ventilation.	Distribution Operations Health and Safety	2 years
OPS-3	Work with Hydro One, and provincial regulators to ensure supply design and standards are aligned with climate risks.	Asset Planning System Operations	2 years

ID	Action	Accountability	Timeline to Complete and Integrate into Business Operations (if applicable)
OPS-4	Consider the cost-benefit of the following measures to reduce the risk of employee injuries related to ice accumulation events: • Review, and consider revising policy for requiring installation of winter tires on Hydro-owned vehicles to prevent injuries to personnel rather than through a request/approval process. • Installation and use of additional automated devices to limit need to travel during inclement conditions • Introducing policies to include heated steps or walkways on Hydro Ottawa properties versus continued salting/sanding	Fleet & Facilities Asset Planning	2 years
PLS-5	While likely cost prohibitive, where it may be warranted, complete a cost/benefit analysis to converting overhead lines to underground infrastructure when major damage has occurred, or when the infrastructure is nearing its end of life. Underground distribution lines and infrastructure would mitigate risk from wind, ice accumulation and fog.	Asset Planning	5 years
ULS-1	Complete an engineering review to identify if there are locations vulnerable to overheating (via a detailed assessment of locations that could be vulnerable to temperatures higher than 40°C) and complete a cost-benefit analysis for mitigation options, which may include: • Institute either operational constraints on how much power can be conveyed through cables to limit overheating of cables. • Cool ducts either actively or passively, for example, with thermal fill (a clay slurry).	Asset Planning Standards	5 years
ULS-2	Identify new technologies and processes through research and feasibility or pilot studies to reduce freeze thaw impacts. These may include: • Exploring the use of different materials for manholes instead of concrete that are less susceptible to freeze-thaw (e.g. fiber glass). • Redesign civil structure collars to move with the heading (e.g. telescopic collars).	Asset Planning Standards	5 years
SUB-2	Develop a policy to monitor and inspect substation building and structural components after an ice event to mitigate the risk of structural damage and loss of assets as a result of ice damage to substations.	Facilities Stations	5 years
SUB-3	Complete a cost-benefit analysis of installing protective covers on small exterior equipment, where feasible, to prevent damage/failure as a result of ice accumulation.	Facilities	5 years

ID	Action	Accountability	Timeline to Complete and Integrate into Business Operations (if applicable)
SUB-4	In light of current design standards (40 mm of ice accumulations), assess the need for changes to technical specifications and policies for increased load break switch protection which may include: • Installation of alternative devices (i.e. breakers) to switch loads when load break switches are difficult to switch or inoperable. • Installation of switches without exposed contacts (replacement or protection). • Update equipment specifications to require that switch operators break ice to allow for operability.	System Operations Asset Planning Standards	5 years
OPS-5	Develop a policy to monitor and inspect building and roofs after an ice event.	Facilities	5 years
OPS-6	Consider updating the work from home policy to eliminate or reduce commuting during extreme weather events and hazardous road conditions, particularly ice accumulation.	Human Resources	5 years
OPS-7	Consider future climate projections at end of life of current system when deciding to replace or rehabilitate building HVAC systems. Integrate requirement into Procurement Policy to size and design based on climate projections (heating and cooling requirements) in conjunction with critical needs (IT server requirements). By integrating future needs into procurement, the risk that cooling is not adequate during 40oC is minimized.	Facilities	5 years
PLS-6	Consider the feasibility of further increasing the frequency of pole washing and cost/benefit based on risk level (current/future) to prevent increase risk of fires related to an increase in anticipated fog days.	Asset Planning	5-10 years
PLS-7	Complete a cost/benefit analysis of expedited replacement of insulators and fused cut-outs with porcelain to prevent increase risk of fires related to an increase in anticipated fog days.	Asset Planning	5-10 years

5.11 RESOURCE & BUDGET PLANNING

Many priority actions will be constrained by financial resources, available human resources and conflicting demands. By continuing to use a risk-based approach to action planning and considering climate resilience infrastructure and staffing needs in the budget planning process, Hydro Ottawa will be well-positioned to implement resilience strategies.

5.12 REPORTING & COMMUNICATION

Monitoring is an important part of the adaptation planning process. It provides an opportunity for Hydro Ottawa to examine performance of the adaptation actions and assess whether the estimated risks and vulnerabilities have changed. These learning outcomes can then be integrated into future strategies and actions. It is recommended that monitoring and reporting be undertaken on an annual basis. Designated lead managers should be responsible for providing updates on the status of action implementation, timelines, costs, indicators, and other details as required. The purpose of this reporting is to:

- Raise awareness and increase understanding of anticipated climate trends and their consequences for Hydro Ottawa and to provide context on specific risks, barriers and opportunities.
- Inform and consult with stakeholders on climate science, risk assessment methodologies used, findings, and recommendations to empower decision-making and collaboration around the actions recommended in this Plan.
- Take stock of both Hydro Ottawa and their partners efforts to share success stories and foster learning in the energy distribution sector.

At a minimum, the reporting should include:

- A description of the work that has been completed.
- Identification of any issues or challenges faced in advancing each action.
- List of new actions to address issues, barriers and challenges.
- An indication of progress toward achieving each initiative, using the following scale:
  - Not Started – The initiative has not been implemented.
  - On Track – The initiative has been implemented. For various initiatives, progress will be measured through metrics like maintenance costs, number of failures due to ice, damages due to trees, mitigation return on investment, etc. Other actions will either be noted as completed or not.
  - Outstanding – An issue, barrier and/or challenge is prohibiting the action from being implemented.
  - Delayed – The action has been delayed or placed on hold.
  - Completed – The action has been completed.

For initiatives that are at risk or delayed, the report should identify the barriers and challenges so that new initiatives can be implemented to address these aspects.

Formal updates to this Plan are recommended to occur on a five-year cycle and should focus on reviewing current climate science and its anticipated impacts to operations, staff, and infrastructure. This will also provide opportunity to take stock of progress made, share lessons learned, and to revisit the planning process to take advantage of any new technologies, or knowledge that could benefit operations.

APPENDICES

Appendix A WORKSHOP SUMMARY TABLES

ASSET ELEMENT: BUILDING & STRUCTURAL ELEMENTS

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
High	24	32	Administrative and Operational Buildings	Ice accumulation of 40mm (30-year occurrence)	• Access to the building is hindered due to heavy ice accumulation	• Health and safety concerns for staff, contractors and/or public	1. C/P – Salting entranceway, parking area, and walkways 2. P – Work at home policy	1. Low 2. Low	1. Low (issue remains off-property, i.e. challenge of getting to work still exists) 2. Medium: • Field staff: low • Office staff: high	1. Low 2. Medium	1. Availability of salt 1. Environmental concern 2. Doesn't work for everyone 2. Ability to respond to emergencies 2. Ability to track productivity	1. Facilitator 2. Human Resources	1. Maintenance contractor 2. IBEW (staff union)	1. Low 2. Medium	• Number of slips and falls • Develop a way to monitoring productivity remotely
High	24	32	Administrative and Operational Buildings	Ice accumulation of 40mm (30-year occurrence)	• Increase in load on building due to ice accumulation, particularly if event occurs at a time where abundant snow on the roof	• Potential structural and/or functional damage to roof elements (e.g., membrane on flat roofs) • May result in blocked roof drains • Possible ice damming • Potential loss of assets	• Monitor / inspections • Repair roof if damaged *Since Hydro Ottawa does not know how increased ice storms might affect their buildings, they suggest monitoring and acting reactively until the consequences are known. *In the past, Hydro Ottawa has sent someone up to rook to clear snow/ ice, however, this is an H&S issue	• Low	• Medium	• Low	• Access • Resources	• Facilities • Operations	• Facilities/Ops	• Low	• Number of leaks/damages • Maintenance cost

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: BUILDING & STRUCTURAL ELEMENTS

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
High	24	32	Administrative and Operational Buildings	Ice accumulation of 40mm (30-year occurrence)	• Ice accumulation on building mounted equipment (roof, exterior walls)	• Reduced efficiency and/or functionality, and failure of equipment affected	• Monitor and inspect • Install cover on smaller equipment. • *Since Hydro Ottawa does not know how increased ice storms might affect their buildings, they suggest monitoring and acting reactively until the consequences are known.	1. Low 2. Low	1. Medium 2. Medium	1. Low 2. Low	• Identifying problem area/devices • Access • Resources	• Stations • Grid technology	• Stations • Grid technology • System operation • Facilities	1. Low 2. Low	• Number of failures due to ice. • Monitor mitigation expenditures
Moderate	12	20	Administrative and Operational Buildings	Daily maximum temp. of 40°C and higher	• Increased cooling demands for the building critical systems (e.g., communication and IT systems)	• Capacity of cooling system may not be adequate to maintain ambient temperature within the design range of equipment affected which can lead to loss of efficiency, functionality or failure	• Building automation system could likely handle the change, however if overloaded, might sound an alert. *it was noted that the IT group has critical infrastructure within the building that is specially climate controlled.								

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: OPERATORS / POWERLINE MAINTENANCE STAFF

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Short, Medium, Long)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*
Very High	**26**	**65**	**Operators / Powerline Maintenance Staff**	Daily maximum temp. of 40°C and higher	• Potential heat stress impacts on personnel working outdoors. • Exacerbated by humidex.	• Health and safety concerns requiring precautionary measures such as more frequent resting periods, hydration, etc. • Delay in restoration • Loss in productivity	1. C – follow recommendations from H&S for work conditions related to heat stress 2. C – safety meetings / summer letdown with staff 3. P – possible work redistribution (scheduling) to avoid outdoor work during peak heat hours 4. P – modified PPE to improve cooling / ventilation 5. C – modify work site to not require full fire-retardant clothing – expand to other PPE requirements	3. Low – Cap 4. Medium – O&M 5. Low – Cap	3. Medium 4. Low 5. Low	3. Low 4. Low 5. Low	3. Other work to redistribute to 4. H&S approval technology exists safety requirement 5. Ability to modify	3. Operations/ scheduling 4. Health & Safety 5. Operations	3. Union 4. Vendors	3. Medium 4. Low 5. Low
High	**39**	**52**	**Operators / Powerline Maintenance Staff**	Ice accumulation of 40mm (30-year occurrence)	• Difficulty accessing areas needing repair due to icy conditions; e.g., ice on roadways and walkways, equipment.	• Potential delays in arriving to work site • Potential delays in performing work due to ice accumulation on equipment • Health and safety concerns	1. C – Boot ice spikes as needed 2. C – Safety driving training 3. P – Winter tires 4. C – Salt usage increased 5. P – automated devices 6. P – heated steps/ walkways policy (new)	3. Medium 5. High 6. Low	3. Medium 5. Low 6. Low	3. Low 5. High 6. Low	3. Cost, storage 5. Scada bond width, visual open 6. None	3. Fleet 5. Asset planning 6. Facilities	3. Tire shops 5. Vendors 6. Vendors	3. Low 5. Medium 6. Low
High	**36**	**36**	**Operators / Powerline Maintenance Staff**	Annual wind speeds of 120 km/hr or higher (30-year occurrence)	• Instability of equipment (lift buckets), flying debris, or broken tree limbs hazards	• Health and safety concern for personnel working outdoors, especially at heights	• C – Winds of this magnitude would result in a stop work authority • P – Need a more concrete policy on wind conditions where you would not use the lift bucket							

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

Stantec

ASSET ELEMENT: OPERATORS / POWERLINE MAINTENANCE STAFF

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Short, Medium, Long)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*
High	24	24	Operators / Powerline Maintenance Staff	Easterly winds of 80 km/hr or higher (cool season [Oct.-March])	• Instability of equipment (lift buckets), flying debris, or broken tree limbs hazards	• Health and safety concern for personnel working outdoors, especially at heights	• C – Winds of this magnitude may result in a stop work authority • P – Need a more concrete policy on wind conditions where you would not use the lift bucket							

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: SUBSTATIONS

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
High	24	32	Buildings and Structural Components	Ice accumulation of 40mm (30-year occurrence)	• Access to the building is hindered due to heavy ice accumulation	• Health and safety concerns for staff, contractors and/or public • Delay in restoration	• Plow and spread gravel / grit before site access. *This takes place regularly under contract, but additional 'as needed' calls to the snow removal contractor are needed from time to time. *Hydro Ottawa avoids using salt where possible for environmental reasons.	• Low	• Medium	• Low	• Availability of contractors to spread grit	• Field operators/ managers (facilities)	• Contractor • Hydro One	• Low	• Safety bulletin for tracking • H&S, number of slips & falls / incidents
High	24	32	Buildings and Structural Components	Ice accumulation of 40mm (30-year occurrence)	• Increase in load on building due to ice accumulation, particularly if event occurs at a time where abundant snow on the roof	• Potential structural and/or functional damage to roof elements (e.g., membrane on flat roofs) • May result in block drains • Possible ice damming • Potential loss of assets • Disruption of service	• Monitor / inspections • Repair roof if damaged *Since Hydro Ottawa does not know how increased ice storms might affect their buildings, they suggest monitoring and acting reactively until the consequences are known. *In the past, Hydro Ottawa has sent someone up to roof to clear snow/ ice, however, this is an H&S issue.	• Low	• Medium	• Low	• Access • Resources	• Facilities • Operations	• Facilities/Ops	• Low	• Number of leaks/damages • Maintenance cost

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: SUBSTATIONS

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
High	**24**	**32**	**Buildings and Structural Components**	Ice accumulation of 40mm (30-year occurrence)	• Ice accumulation on building mounted equipment (roof, exterior walls)	• Reduced efficiency and/or functionality , and failure of equipment affected	1. Monitor and inspect 2. Install cover on smaller equipment. *Since Hydro Ottawa does not know how increased ice storms might affect their buildings, they suggest monitoring and acting reactively until the consequences are known.	1. Low 2. Low	1. Medium 2. Medium	1. Low 2. Low	• Identifying problem area/devices • Access • Resources	• Stations • Grid technology	• Stations • Grid technology • System operation • Facilities	1. Low 2. Low	• Number of failures due to ice • Monitor mitigation expenditures
Moderate	**18**	**24**	**Station Load Break Switch**	Ice accumulation of 40mm (30-year occurrence)	• Ice accretion on load break switches could result in difficulty transferring loads.	• Removal of ice required for the switch to be operable • Delay in restoration	1. Operators to break ice to allow for operability 2. Use alternative devices to switch loads 3. Install switches without exposed contacts	1. Low 2. Low 3. High	1. Medium 2. Medium 3. High	1. Low 2. Low 3. High	1. Limitations of safe practices 1. Availability of qualified operators 3. Cost of devices 3. Space limitation 3. Risk assessment	1. Operations 3. Engineering and operations	1. Health & Safety 3. Health & Safety 3. Standards 3. Operations 3. Vendors	1. Low 2. Medium 3. Medium -high	• Number of operation failures to ice

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
Very High	108	108	Lines & Poles	Annual wind speeds of 120 km/hr or higher (30-year occurrence)	• Damage to poles and lines from high wind events.	• Loss of assets • Disruption of service • Difficulty in restoring service due to health and safety concerns for staff • Public safety concerns due to downed power lines • Impact on scheduling/ productivity/ resources	1. P – Convert to underground lines 2. C/P – Increased storm guying, possibly to every pole 3. P – Break/stress point to limit cascading failure 4. C – increase pole class (new installs) 5. C – Design for 90km/hr winds 6. C – Partnering agreements with contractors/ utilities for resourcing when needed 7. P – increased detection capabilities for downed lines 8. C – Public safety lines on grounds 9. C – review of N-S arterial lines and guying	1. High – Cap 2. Medium – O&M 3. Medium – Cap 7. Medium – Cap	1. High 2. Medium 3. Low 7. Low	1. High 2. Medium 3. Medium 7. High	I. Cost casements, equipment, location, resources, customer acceptance 2. Easements, study 3. Study 7. Study	1. Asset planning 2. Standards 3. Standards 7. Asset planning	1. Utility coordination 2. City of Ottawa consultant 3. Consultant 7. CEA/CEATZ	1. Hight 2. Medium 3. Medium 7. High	• Monitor weather activity in comparison to damaged equipment. • Did the investment mitigate the expected outcome?

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

Stantec

ASSET ELEMENT: POWER DISTRIBUTION: NORTH-SOUTH

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
Very High	**108**	**108**	**Lines & Poles**	Annual wind speeds of 120 km/hr or higher (30-year occurrence)	• Risk of damages from falling trees, broken tree limbs or flying debris.	• Loss of assets • Disruption of service • Difficulty in restoring service due to health and safety concerns for staff • Public safety concerns due to downed power lines	1. P – Convert to underground lines 2. P – Break/stress point to limit cascading failure 3. P – increased detection capabilities for downed lines 4. C – Public safety lines on grounds 5. C – 2/3-year cycle per policy, line to sky smart review of cust. Trees 6. P – Trim trees more often/aggressively or heritage trees 7. C – tree planting advice brochure/ standards *Hydro Ottawa to explain to the city and other groups where and how to plant trees such that they do not affect Hydro infrastructure/ equipment 8. P – include trees in fall zone/condition assessment	1. High 2. Medium 3. Medium 6. High 8. Medium	1. High 2. Low 3. Low 6. Medium 8. Medium	1. High 2. Medium 3. High 6. Medium 8. Medium	1. Cost casements, equipment, location, resources, customer acceptance 2. Study 3. Study 6. Budget, customer, city acceptance 8. Customer and city acceptance	1. Asset planning 2. Standards 3. Asset planning 6. Forestry 8. Standards	1. Utility coordination 2. Consultant 3. CEA/CEATZ	1. High 2. Medium 3. High 6. High 8. High	• SAIDI/SAIFI Due to tree damage. • Potentially annual contacts

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

Stantec

ASSET ELEMENT: POWER DISTRIBUTION: NORTH-SOUTH

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
High	36	48	Lines & Poles	Ice accumulation of 40mm (30-year occurrence)	• Damage from increased weight on overhead lines • Ice falling off of lines	• Loss of assets • Disruption of service • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work • Public safety concerns due to downed power lines	1. P – Convert to underground lines 2. C/P – Increased storm guying, possibly to every pole 3. C – increase pole class (new installs) 4. Install hardened equipment (strength of insulators) expedite vs. normal replacement *current action is just to implement based on design practices 5. Pulse/vibrate lines	1. High 2. Medium 3. Medium 4. High - Cap 5. High - O&M	1. High 2. Low 3. Low 4. Medium 5. High	1. High 2. Medium 3. Medium 4. Medium 5. High	1. Cost casements, equipment, location, resources, customer acceptance 2. Easements, study 4. Study to ensure no unwanted consequences ex. Now poles fail vs insulators 5. Study needed, resources, cost, public safety	1. Asset planning 2. Standards 4. Asset planning 5. System office	1. Utility coordination 2. City of Ottawa consultant 4. Vendors 5. Other utilities CEATZ	1. High 2. Medium 4. Medium 5. High	• Monitor weather activity in comparison to damaged equipment. • Did the investment mitigate the expected outcome?
High	36	48	Lines & Poles	Ice accumulation of 40mm (30-year occurrence)	• Ice accretion on lines of 12.5 mm (0.5 inches) and more accompanied by a 90km/h wind could result in swinging or 'galloping' in the lines • Damage to poles and attached equipment	• Potential for flashovers • Ice break-up from lines may cause public safety concerns • Loss of assets • Disruption of service • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work • Public safety concerns due to downed power lines	***Covered in previous***								

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: NORTH-SOUTH

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
High	36	48	Lines & Poles	Ice accumulation of 40mm (30-year occurrence)	• Damages to lines from fallen trees or broken tree limbs.	• Loss of assets • Disruption of service • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work • Public safety concerns due to downed power lines	1. P – Convert to underground lines 2. P – Break/stress point to limit cascading failure 3. P – increased detection capabilities for downed lines 4. C – Public safety lines on grounds 5. C – 2/3-year cycle per policy, line to sky smart review of cust. Trees 6. P – Trim trees more often/aggressively or heritage trees 7. C – tree planting advice brochure/ standards *Hydro Ottawa to explain to the city and other groups where and how to plant trees such that they do not affect Hydro infrastructure/ equipment	1. High 2. Medium 3. Medium 7. High	1. High 2. Low 3. Low 7. Medium	1. High 2. Medium 3. High 7. Medium	1. Cost casements, equipment, location, resources, customer acceptance 2. Study 3. Study 7. Budget, customer, city acceptance	1. Asset planning 2. Standards 3. Asset planning 7. Forestry	1. Utility coordination 2. Consultant CEA/CEATZ	1. High 2. Medium 3. High 7. High	• SAIDI/SAIFI Due to tree damage. • Potentially annual contacts
High	36	48	Lines & Poles	Ice accumulation of 40mm (30-year occurrence)	• Damage to poles and other surface equipment from vehicles losing control on icy roads	• Loss of assets • Disruption of service • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work • Public safety concerns due to downed power lines	1. C – Install pole laterals for risers 2. C – Install bollards for pad-mounted equipment in vehicle areas 3. P – Install pole laterals on all poles 4. P – Change pole standard to a higher strength material 5. P – Underground pad-mounted equipment (submersible)	3. Medium 4. High (+) 3. High (+)							

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: NORTH-SOUTH

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
High	32	32	Lines & Poles	Easterly winds of 80 km/hr or higher (cool season [Oct.-March])	• Guy wires in north-south lines are installed to support against prevailing westerly winds; poles and lines are therefore damaged from to high easterly winds	• Loss of assets • Disruption of service • Difficulty in restoring service due to health and safety concerns for staff • Public safety concerns due to downed power lines • Public safety concern is falling branches	1. P – Convert to underground lines 2. C/P – Increased storm guying, possibly to every pole 3. P – Break/stress point to limit cascading failure 4. C – increase pole class (new installs) 5. C – Design for 90km/hr winds 6. C – Partnering agreements with contractors/ utilities for resourcing 7. P – increased detection for downed lines 8. C – Public safety lines on grounds C – reviewed N-S arterial lines and guying	1. High - Cap 2. Medium - O&M 3. Medium - Cap 7. Medium - Cap	1. High 2. Medium 3. Low 7. Low	1. High 2. Medium 3. Medium 7. High	1. Cost casements, equipment, location, resources, customer acceptance 2. Easements, study 3. Study 7. Study	1. Asset planning 2. Standards 3. Standards 7. Asset planning	1. Utility coordination 2. City of Ottawa consultant 3. Consultant 7. CEA/CEATZ	1. High 2. Medium 3. Medium 7. High	• Monitor weather activity in comparison to damaged equipment. • Did the investment mitigate the expected outcome?

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: NORTH-SOUTH

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
High	32	32	Lines & Poles	Easterly winds of 80 km/hr or higher (cool season [Oct.-March])	• Risk of damages from falling trees or broken tree limbs.	• Loss of assets • Disruption of service • Difficulty in restoring service due to health and safety concerns for staff • Public safety concerns due to downed power lines	1. P – Convert to underground lines 2. P – Break/stress point to limit cascading failure 3. P – increased detection capabilities for downed lines 4. C – Public safety lines on grounds 5. C – 2/3-year cycle per policy, line to sky smart review of cust. Trees 6. P – more often/aggressively or heritage trees 7. C – tree planting advice brochure/standards *Hydro Ottawa to explain to the city and other groups where and how to plant trees such that they do not affect Hydro 8. P – include trees in fall zone/condition assessment	1. High 2. Medium 3. Medium 6. High 8. Medium	1. High 2. Low 3. Low 6. Medium 8. Medium	1. High 2. Medium 3. High 6. Medium 8. Medium	1. Cost casements, equipment, location, resources, customer acceptance 2. Study 3. Study 6. Budget, customer, city acceptance 8. Customer and city acceptance	1. Asset planning 2. Standards 3. Asset planning 6. Forestry 8. Standards	1. Utility coordination 2. Consultant 3. CEA/CEATZ	1. High 2. Medium 3. High 6. High 8. High	• SAIDI/SAIFI Due to tree damage. • Potentially annual contacts
Moderate	18	24	Poles	Season with ≥ 50 fog days (Nov.-March)	• Pole fires as a result of salt and other conductive contaminants accumulating onto insulators.	• Risk of electrical arcs, flashovers and pole fires. • Loss of assets • Disruption of service • Public safety concerns	1. C – replace porcelain insulators with polymer when doing work on pole 2. C- insulator water washing (twice/year in high travelled roads) 3. P – proactive/ expedited replacement of porcelain insulators with polymer 4. P – increase pole washing program	3. High - Cap 4. Medium - O&M	3. High 4. Medium	3. Medium 4. Low	3. Budget 4. Ongoing O&M expenses	3. Asset planning 4. Asset planning	4. Contractor	3. Low 4. Low	• Number of pole fires • SAIDI/SAIFI

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: NORTH-SOUTH

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
Moderate	**12**	**16**	**Fused Cut Out**	Season with ≥ 50 fog days (Nov.-March)	• Insulator breakdown on fused cut outs. • Pole fires as a result of salt and other conductive contaminants accumulating onto insulators.	• Risk of electrical arcs, flashovers and pole fires. • Loss of assets • Disruption of service • Public safety concerns	1. C – replace porcelain with polymer fused cutouts when doing work on pole 2. P – proactive/ expedited replacement of porcelain with polymer	1. High 2. Medium	1. High 2. High	1. Medium 2. Medium	1. Budget 2. Budget	1. Asset Planning 2. Asset Planning		1. Low 2. Low	• Number of pole fires • SAIDI/SAIFI

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: EAST-WEST

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
Very High	**108**	**108**	**Lines & Poles**	Annual wind speeds of 120 km/hr or higher (30-year occurrence)	• Damage to poles and lines from high wind events.	• Loss of assets • Disruption of service • Difficulty in restoring service due to health and safety concerns for staff • Public safety concerns due to downed power lines • Impact on scheduling/productivity/ resources	1. P – Convert to underground lines 2. C/P – Increased storm guying, possibly to every pole 3. P – Break/stress point to limit cascading failure 4. C – increase pole class (new installs) 5. C – Design for 90km/hr winds 6. C – Partnering agreements with contractors/ utilities for resourcing when needed 7. P – increased detection capabilities for downed lines 8. C – Public safety lines on grounds 9. C – review of N-S arterial lines and guying	1. High – Cap 2. Medium – O&M 3. Medium – Cap 7. Medium – Cap	1. High 2. Medium 3. Low 7. Low	1. High 2. Medium 3. Medium 7. High	1. Cost casements, equipment, location, resources, customer acceptance 2. Easements, study 3. Study 7. Study	1. Asset planning 2. Standards 3. Standards 7. Asset planning	1. Utility coordination 2. City of Ottawa consultant 3. Consultant 7. CEA/CEATZ	1. Hight 2. Medium 3. Medium 7. High	• Monitor weather activity in comparison to damaged equipment. • Did the investment mitigate the expected outcome?

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: EAST-WEST

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
Very High	**108**	**108**	**Lines & Poles**	Annual wind speeds of 120 km/hr or higher (30-year occurrence)	• Risk of damages from falling trees, broken tree limbs or flying debris.	• Loss of assets • Disruption of service • Difficulty in restoring service due to health and safety concerns for staff • Public safety concerns due to downed power lines	1. P – Convert to underground lines 2. P – Break/stress point to limit cascading failure 3. P – increased detection capabilities for downed lines 4. C – Public safety lines on grounds 5. C – 2/3-year cycle per policy, line to sky smart review of cust. Trees 6. P – Trim trees more often/aggressively or heritage trees 7. C – tree planting advice brochure/ standards *Hydro Ottawa to explain to the city and other groups where and how to plant trees such that they do not affect Hydro infrastructure/ equipment 8. P – include trees in fall zone/condition assessment	1. High 2. Medium 3. Medium 6. High 8. Medium	1. High 2. Low 3. Low 6. Medium 8. Medium	1. High 2. Medium 3. High 6. Medium 8. Medium	1. Cost casements, equipment, location, resources, customer acceptance 2. Study 3. Study 6. Budget, customer, city acceptance 8. Customer and city acceptance	1. Asset planning 2. Standards 3. Asset planning 6. Forestry 8. Standards	1. Utility coordination 2. Consultant 3. CEA/CEATZ	1. High 2. Medium 3. High 6. High 8. High	• SAIDI/SAIFI Due to tree damage. • Potentially annual contacts.

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: EAST-WEST

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
Very High	36	68	Lines & Poles	Ice accumulation of 40mm (30-year occurrence)	• Damage from increased weight on overhead lines • Ice falling off of lines	• Loss of assets • Disruption of service • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work • Public safety concerns due to downed power lines	1. P – Convert to underground lines 2. C/P – Increased storm guying, possibly to every pole 3. C – increase pole class (new installs) 4. Install hardened equipment (strength of insulators) expedite vs. normal replacement *current action is just to implement based on design practices 5. Pulse/vibrate lines	1. High 2. Medium 3. Medium 4. High – Cap 5. High - O&M	1. High 2. Low 3. Low 4. Medium 5. High	1. High 2. Medium 3. Medium 4. Medium 5. High	1. Cost casements, equipment, location, resources, customer acceptance 2. Easements, study 4. Study to ensure no unwanted consequences ex. Now poles fail vs insulators 5. Study needed, resources, cost, public safety	1. Asset planning 2. Standards 4. Asset planning 5. System office	1. Utility coordination 2. City of Ottawa consultant 4. Vendors 5. Other utilities CEATZ	1. High 2. Medium 4. Medium 5. High	• Monitor weather activity in comparison to damaged equipment. • Did the investment mitigate the expected outcome?
Very High	36	68	Lines & Poles	Ice accumulation of 40mm (30-year occurrence)	• Ice accretion on lines of 12.5 mm (0.5 inches) and more accompanied by a 90km/h wind could result in swinging or 'galloping' in the lines. • Damage to poles and attached equipment	• Potential for flashovers • Ice break-up from lines may cause public safety concerns • Loss of assets • Disruption of service • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work • Public safety concerns due to downed power lines	***Covered in previous***								

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: EAST-WEST

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
Very High	**36**	**68**	**Lines & Poles**	Ice accumulation of 40mm (30-year occurrence)	• Damages to lines from fallen trees or broken tree limbs.	• Loss of assets • Disruption of service • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work • Public safety concerns due to downed power lines	1. P – Convert to underground lines 2. P – Break/stress point to limit cascading failure 3. P – increased detection capabilities for downed lines 4. C – Public safety lines on grounds 5. C – 2/3-year cycle per policy, line to sky smart review of cust. Trees 6. P – Trim trees more often/aggressively or heritage trees 7. C – tree planting advice brochure/ standards *Hydro Ottawa to explain to the city and other groups where and how to plant trees such that they do not affect Hydro infrastructure/ equipment	1. High 2. Medium 3. Medium 7. High	1. High 2. Low 3. Low 7. Medium	1. High 2. Medium 3. High 7. Medium	1. Cost casements, equipment, location, resources, customer acceptance 2. Study 3. Study 7. Budget, customer, city acceptance	1. Asset planning 2. Standards 3. Asset planning 7. Forestry	1. Utility coordination 2. Consultant 3. CEA/CEATZ	1. High 2. Medium 3. High 7. High	• SAIDI/SAIFI Due to tree damage. • Potentially annual contacts

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: EAST-WEST

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementa tion *(High, Medium, Low)*	Monitoring and Evaluation
Very High	**36**	**68**	**Lines & Poles**	Ice accumulation of 40mm (30-year occurrence)	• Damage to poles and other surface equipment from vehicles losing control on icy roads	• Loss of assets • Disruption of service • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work • Public safety concerns due to downed power lines	1. C – Install pole laterals for risers 2. C – Install bollards for pad-mounted equipment in vehicle areas 3. P – Install pole laterals on all poles 4. P – Change pole standard to higher strength material 5. P – Underground pad-mounted equipment (submersible)	3. Medium 4. High (+) 5. High (+)							
Moderate	**18**	**24**	**Poles**	Season with ≥ 50 fog days (Nov.-March)	• Pole fires as a result of salt and other conductive contaminants accumulating onto insulators.	• Risk of electrical arcs, flashovers and pole fires. • Loss of assets • Disruption of service • Public safety concerns	1. C – replace porcelain insulators with polymer when doing work on pole 2. C- insulator water washing (twice/year in high travelled roads) 3. P – proactive/ expedited replacement of porcelain insulators with polymer 4. P – increase pole washing program	3. High – Cap 4. Medium - O&M	3. High 4. Medium	3. Medium 4. Low	3. Budget 4. Ongoing O&M expenses	3. Asset planning 4. Asset planning	4. Contractor	3. Low 4. Low	• Number of pole fires • SAIDI/SAIFI

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: EAST-WEST

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
Moderate	**32**	**32**	**Lines & Poles**	Easterly winds of 80 km/hr or higher (cool season [Oct.-March])	• Risk of pole damage from strong winds	• Loss of assets • Disruption of service • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work • Public safety concerns due to downed power lines	1. P – Convert to underground lines 2. C/P – Increased storm guying, possibly to every pole 3. P – Break/stress point to limit cascading failure 4. C – increase pole class (new installs) 5. C – Design for 90km/hr winds 6. C – Partnering agreements with contractors/ utilities for resourcing 7. P – increased detection for downed lines 8. C – Public safety lines on grounds 9. C – reviewed N-S arterial lines and guying	1. High - Cap 2. Medium - O&M 3. Medium - Cap 7. Medium - Cap	1. High 2. Medium 3. Low 7. Low	1. High 2. Medium 3. Medium 7. High	1. Cost casements, equipment, location, resources, customer acceptance 2. Easements, study 3. Study 7. Study	1. Asset planning 2. Standards 3. Standards 7. Asset planning	1. Utility coordination 2. City of Ottawa consultant 3. Consultant 7. CEA/CEATZ	1. High 2. Medium 3. Medium 7. High	• Monitor weather activity in comparison to damaged equipment. • Did the investment mitigate the expected outcome?

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: EAST-WEST

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
Moderate	**32**	**32**	**Lines & Poles**	Easterly winds of 80 km/hr or higher (cool season [Oct.-March])	• Risk of damages from falling trees or broken tree limbs.	• Loss of assets • Disruption of service • Difficulty or delays in restoring service due to health and safety concerns for staff, delays in accessing sites, or performing restoration work • Public safety concerns due to downed power lines	1. P – Convert to underground lines 2. P – Break/stress point to limit cascading failure 3. P – increased detection capabilities for downed lines 4. C – Public safety lines on grounds 5. C – 2/3-year cycle per policy, line to sky smart review of cust. Trees 6. P – more often/aggressively or heritage trees 7. C – tree planting advice brochure/standards *Hydro Ottawa to explain to the city and other groups where and how to plant trees such that they do not affect Hydro 8. P – include trees in fall zone/condition assessment	1. High 2. Medium 3. Medium 6. High 8. Medium	1. High 2. Low 3. Low 6. Medium 8. Medium	1. High 2. Medium 3. High 6. Medium 8. Medium	1. Cost casements, equipment, location, resources, customer acceptance 2. Study 3. Study 6. Budget, customer, city acceptance 8. Customer and city acceptance	1. Asset planning 2. Standards 3. Asset planning 6. Forestry 8. Standards	1. Utility coordination 2. Consultant 3. CEA/CEATZ	1. High 2. Medium 3. High 6. High 8. High	• SAIDI/SAIFI Due to tree damage. • Potentially annual contacts

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: EAST-WEST

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	Monitoring and Evaluation
Moderate	**18**	**24**	**Poles**	Season with ≥ 50 fog days (Nov.-March)	• Pole fires as a result of salt and other conductive contaminants accumulating onto insulators.	• Risk of electrical arcs, flashovers and pole fires. • Loss of assets • Disruption of service • Public safety concerns	1. C – replace porcelain insulators with polymer when doing work on pole 2. C- insulator water washing (twice/year in high travelled roads) 3. P – proactive/ expedited replacement of porcelain insulators with polymer 9. P – increase pole washing program	3. High - Cap 4. Medium - O&M	3. High 4. Medium	3. Medium 4. Low	3. Budget 4. Ongoing O&M expenses	3. Asset planning 4. Asset planning	4. Contractor	3. Low 4. Low	• Number of pole fires • SAIDI/SAIFI
Moderate	**12**	**16**	**Fused Cut Out**	Season with ≥ 50 fog days (Nov.-March)	• Insulator breakdown on fused cut outs. • Pole fires as a result of salt and other conductive contaminants accumulating onto insulators.	• Risk of electrical arcs, flashovers and pole fires. • Loss of assets • Disruption of service • Public safety concerns	1. C – replace porcelain with polymer fused cutouts when doing work on pole 2. P – proactive/ expedited replacement of porcelain with polymer	1. High 2. Medium	1. High 2. High	1. Medium 2. Medium	1. Budget 2. Budget	1. Asset Planning 2. Asset Planning		1. Low 2. Low	• Number of pole fires • SAIDI/SAIFI

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: UNDERGROUND

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	
Moderate	**10**	**25**	**Underground Cables**	Daily maximum temp. of 40°C and higher	• Potentially reduced capacity due to increased daily electricity demand from end user (e.g., A/C units)	• Additional strain on, and limits to the underground electrical infrastructure capacity.	Identifying vulnerable locations (via a detailed assessment of locations that could be vulnerable to temperatures higher than -40°C) and; 1. institute either operational constraints on how much power can be conveyed through cables to limit overheating of cables 2. replacing cable material to one that will not overheat as readily 3. Cool ducts either actively or passively with thermal fill (a clay slurry) 4. Deploy community level energy storage to reduce peaks	1. Low 2. High 3. High 4. High	1. High 2. High 3. Medium 4. Medium	1. Low 2. Medium 3. High 4. High	1. Insufficient alternative (low system cap) 3. Cost 3. Room for cooling equipment 3. Increased O&M 4. Coordinating with community 4. Customer implications	1. Assets 2. Assets 3. Assets 4. Assets	1. Operation finances 2. Operation finances 3. Operation finances 4. Operation finances & community	1. Low 2. Low 3. Medium 4. High	Monitor cables for premature failure Trending within SCATA, data monitoring Temps run within the prescribed levels

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

ASSET ELEMENT: POWER DISTRIBUTION: UNDERGROUND

	Current Climate Risk Score	Future Climate Risk Score	Asset / Element	Climate Parameter	Impacts	Result / Consequence	Actions Available *Current + Potential*	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action	Difficulty of Implementation *(High, Medium, Low)*	
Moderate	**16**	**24**	**Civil Structures**	Freeze-thaw cycles – Daily Tmax Tmin temp. fluctuation of ±4°C around 0°C	• Water penetration into or around civil structures which freezes causing stress on material	• Deterioration and damage (short- and long-term) to materials. • Uplift of near-surface infrastructure causing higher risks of damage during winter maintenance (e.g., snow removal) operations	1. Explore different materials for manholes instead of concrete that are less susceptible to freeze-thaw (e.g. fibre glass) 2. Explore continuous pipe rather than sectional pieces to eliminate joints were shifting can occur 3. Exploration of redesign collars to move with the heading (e.g. telescopic heading) 4. Explore moving utility to under sidewalk from under roadway where the temperature is more consistent	1. Low 2. Low 3. Low 4. Low	1. Low 2. Low 3. Low 4. Low	1. Low 2. Low 3. Low 4. Low	Resourcing	Assets Standards	Asset/standards	1. Low 2. Low 3. Low 4. Low	Viable solutions came out of exploratory work

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

EXTERNAL THIRD PARTIES

Element	External Third Party(ies) Affected	Impacts	Result / Consequence	Actions Available *Current + Potential*	Resource Requirements (Cost, Staff Time, Etc.)	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action
Power supply, shared infrastructure, attached equipment	**Hydro-One**	• Loss of supply to Hydro Ottawa (this happens to some extent approximately once per month) • Damages to poles shared between Hydro One and Hydro Ottawa • Loss of transmission • Loss of redundancy • Damage to equipment due to Hydro One-related issues	• Disruption of service • Inability to restore service • Loss of redundancy • Loss of efficiency • Potential damage to Hydro Ottawa equipment (attached to Hydro One poles) • Damage to shared facilities	1. C – System distribution / contingency planning (need to install distribution ties to remedy, doing so continues building the resilience of the system as well) 2. P – Coordination of construction standards between Hydro Ottawa and Hydro One	1. Resources/financial 2. Resources/financial	1. Medium	1. Medium	1. Medium	1. Cost 1. Availability of physically redundant system (since all power is channeled to Ottawa through one corridor)	1. Asset planning / system operations 2. Asset planning / system operations	1. Hydro One 1. IESO 2. Hydro One
Telecommunications	**Phone Service & Fibre lines**	• Potential for Hydro Ottawa equipment damage if support by damaged communication poles • Loss of communication services	• Health and Safety • Communication to field personnel and field equipment • Loss of communication to customers • SCATA system	• C – Any vendor that runs a critical service to Hydro Ottawa, an agreement is in place. • C – Highly redundant communications services plan. For example, the operations center has landline phones, cell phones, and satellite phones			• High • High				

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

EXTERNAL THIRD PARTIES

Element	External Third Party(ies) Affected	Impacts	Result / Consequence	Actions Available *Current + Potential*	Resource Requirements (Cost, Staff Time, Etc.)	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action

Emergency Response (Capability & Capacity)	Partners & Internal	• Inability to get resources for response both external and holiday staff
		• Logistically complex
		• Staff potentially not fit for duty
			• Stress on staff
			• Delayed services restoration
				• C – For large-scale events, difficult to acquire additional resources as most geographically close resources are also affected. For small-scale events, Hydro Ottawa calls external aid when internal resources are exhausted. Logistics for external aid includes:
				  ◦ 12-hour on/off scheduling
				  ◦ Food services provided to aid workers
				  ◦ Hydro Ottawa headquarters building open to aid workers and provides critical services
				  ◦ Lodging provided
				HO noted the difficulties of how to determine when to call for aid. Sometimes there is political pressure to call for aid prematurely.
				• C – Have increased stand-by capacity
				• P – Formalize emergency response plan and clarify protocols and staff education within Hydro Ottawa for staff to better understand their roles during an emergency.
				• P – Equipment sharing program or equipment rental agreements with local companies / contractors if limited by equipment during an emergency							

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

EXTERNAL THIRD PARTIES

Element	External Third Party(ies) Affected	Impacts	Result / Consequence	Actions Available *Current + Potential*	Resource Requirements (Cost, Staff Time, Etc.)	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action
Stormwater drainage, winter maintenance	City Ottawa	• Surface flooding • Snow removal • Debris removal • Plows hitting U/G equipment and poles • Flooded areas and overland flow flooding vaults and transformers due to plugged storm drains *For example, blocked rear-yard storm drains are a regular culprit for overland flooding and impacting pad-mounted transformers. • Manholes full of water • Snowplows hitting/damaging response vehicle • City of Ottawa plan hitting roadside transformers • Snow piling and storage on or around pad-mounting transformers • Salting damages to Hydro Ottawa equipment	• Potential impacts on equipment if City does not maintain stormwater system • Damages and delays due to winter maintenance activities • Delays in service or in response capacity	1. Identify location where there are particular issues related to stormwater / flooding and winter road maintenance issues to Hydro Ottawa equipment and work with the City of Ottawa to mitigate 2. Install snow marker flags to highlight the location of equipment during winter months Note: Hydro Ottawa calls the City of Ottawa to provided extra snow removal if needed when HO requires access to snowed-in areas		• Low • Low	• High • Medium	• Medium • Low	• City of Ottawa budgets • Public push back	• Asset planning • Standards • Operations • Communications	• Public works department • Community communication

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

EXTERNAL THIRD PARTIES

Element	External Third Party(ies) Affected	Impacts	Result / Consequence	Actions Available *Current + Potential*	Resource Requirements (Cost, Staff Time, Etc.)	Costs (Low, Medium, High)	Effectiveness of Adaptation Low, Medium, High)	Time to Implement (Low, Medium, High)	Barriers to Action *(e.g. cost, timing, lack of information available, existing controls, existing policies, etc.)*	Staff / Department Responsible for Action	Partners / Stakeholders That May Support Action
Fuel Supply	City Ottawa	• Hydro Ottawa vehicles not able to travel • Lack of fuel supply for backup generators • Partner and contractors' inability to support while stranded at work/home	• Delays in service • People stranded at work/site/home • Lack of emergency backup power	1. P – Store fuel 2. P – Modify work to manage fuel 3. P – EV fleet 4. C – Contract with fuel suppliers for generators 5. P – City of Ottawa / Hydro Ottawa emergency fuel strategy. Understand City's risk	1. Cost, staff, space, training 2. N/A 3. Cost, tech, Power 5. Staff time	1. Medium 2. N/A 3. High 5. Low	1. Medium 2. N/A 3. High 5. High	1. Medium 2. N/A 3. Low 5. Medium	1. Historical practice 2. Policies, union 3. Chargers, purchasing, existing fleet 5. Relationships	1. Facilities/fleet 2. OPS 3. Fleet 5. Fleet	1. City, field partners 2. City, union 3. Vendors 5. City
	Hydro Ottawa Subsidiaries	*No real impacts from subsidiaries*									

	Capital Costs	O&M Costs	Time to Implement	Effectiveness of Implementation
Low	< $100,000	< $10,000	< 1 year	< 25%
Medium	$100,000 - $2,000,000	$10,000 - $200,000	1 – 3 years	25 – 75%
High	> $2,000,000	> $200,000	> 3 years	> 75%

Appendix B ADAPTION PLANNING WORKSHOP ATTENDEES

Appendix B Adaption Planning Workshop Attendees

Participant	Role
Nicole Flanagan	Stantec, Project Manager
Guy Félio	Stantec, Climate Change Resilience Advisor
Riley Morris	Stantec, Environmental Engineer
Eric Lafleur	Stantec, Electrical Engineer, Subject Matter Expert
Matthew McGrath	Hydro Ottawa, Project Manager, Supervisor, Distribution Layouts
Greg Bell	Hydro Ottawa, Manager, Distribution Operations (Underground)
Margret Flores	Hydro Ottawa, Supervisor, Asset Planning
Ben Hazlett	Hydro Ottawa, Manager, Distribution Policies and Standards
Ed Donkersteeg	Hydro Ottawa, Supervisor, Standards
Doug Boldock	Hydro Ottawa, System Operations
Chris Murphy	Hydro Ottawa, Supervisor, Distribution Design
Kyle Smith	Hydro Ottawa, Supervisor, Standards