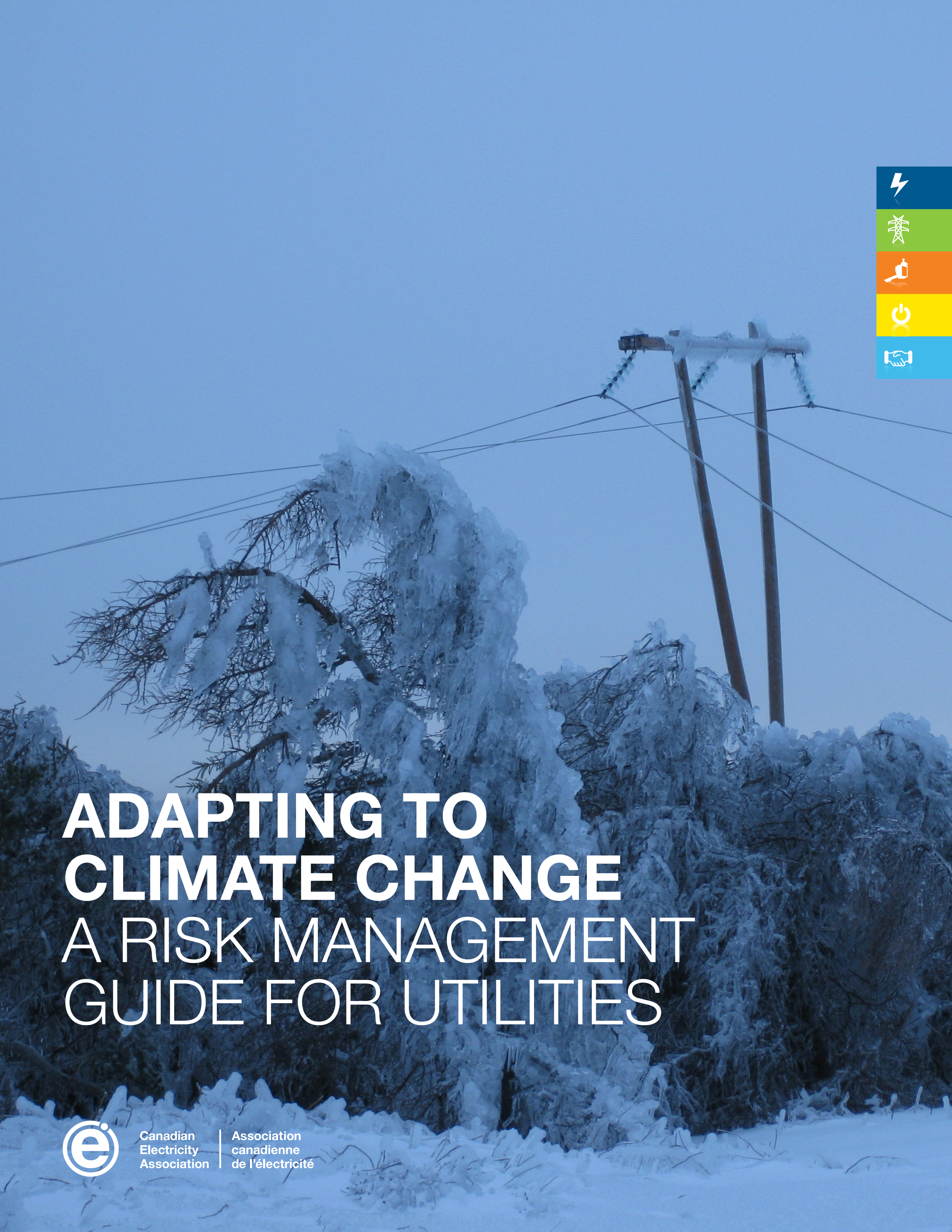


ADAPTING TO CLIMATE CHANGE

A RISK MANAGEMENT GUIDE FOR UTILITIES

Canadian Electricity Association | Association canadienne de l'électricité

CONTENTS

EXECUTIVE SUMMARY

The unavoidable impacts associated with climate change and weather extremes have the potential to adversely affect infrastructure, including electricity infrastructure. It is thus imperative that organizations in the business of generating electricity have the tools and resources they need to effectively anticipate, plan for, and respond to climate-related risks.

The Canadian Electricity Association's (CEA) Sustainable Electricity Program™ Advisory Panel identified the need for active climate change adaptation management planning across the sector. CEA has taken the lead on the development of a template to provide consistency and guidance for member companies as they develop these plans.

Some in the legal community warn that "those who are responsible for the safe and effective management of our electrical systems will be expected to exercise reasonable care in preparing for and responding to these [climate change and extreme weather] hazards." The need for proactive climate change risk management is a business imperative.

The purpose of this guidance document is to support the creation of practical, useful climate change adaptation management plans and to ensure a consistent approach across the sector. This risk-based framework will define the characteristics and key considerations of adaptation planning. It will take an approach similar to the International Organization for Standardization's (ISO) management system standards by providing a framework that allows users to flesh out the details in a utility-specific manner.

This document outlines a strategic, risk-based framework that can be readily incorporated into existing enterprise risk management (ERM) processes. In the absence of ERM processes, it supports the creation of an adaptation-management process.

Characteristics, criteria, and key considerations of adaptation are defined. The approach includes tools for better understanding the impacts of climate change and identifying adaptation elements.

The framework is not intended to be an exhaustive treatment of the subject, but to instead provide an outline of management characteristics illustrated by some implementation suggestions. It is not intended to be prescriptive but rather is meant to stimulate critical thinking on the part of utility practitioners. It recognizes the fact that each utility's suite of and appetite for risk(s) is unique and that management strategies will vary accordingly. Management plans need to be tailored to utility-specific circumstances, like the approach currently used in ISO frameworks.

1.0 INTRODUCTION

1.1 Purpose

The purpose of this guidance document is to support the creation of effective climate change adaptation management plans, and to ensure a consistent approach across the sector. It is not intended to be prescriptive. This risk-based guidance framework defines the characteristics of and key considerations in adaptation planning. Consistent with ISO management system standards, it discusses management system approaches and best practices and allows flexibility for each user to flesh out details in a utility-specific manner. Where examples are provided, they are intended to be illustrative and guide further development. The examples are not intended to be comprehensive. As with all risk management, the level of rigor should be commensurate with the degree of risk. It is also important to recognize that, once risks are assessed, responsible individuals should define appropriate mitigation efforts.

1.2 Background

The climate is changing. Regardless of the success of global initiatives to reduce greenhouse gas (GHG) emissions, further climate change and associated impacts are inevitable. Even if GHG levels stabilize, warming and sea level rise will continue for centuries due to the nature of the climate system and its feedback mechanisms.

Climate change mitigation and adaptation are distinct but related concepts that should be viewed as complementary. Indeed, continued efforts to mitigate the rate and extent of climate change affects the need for and the potential success of adaptation measures. Greater magnitudes of change require more extensive adaptation, while greater rates of change may make adaptation more challenging.

Studies continue to identify increasing air and water temperatures, shifting precipitation patterns, rising sea level, reduced snow and sea ice cover, retreating glaciers, and changes to weather extremes. It is now widely accepted that a warming world will be accompanied by increases in the intensity, frequency, duration, and geographic reach of extreme weather and climatic conditions.

The impacts associated with changing climate and weather extremes are being felt in Canada and globally. Canada is a large, geographically diverse country that will experience varied climate impacts. Climate change may exacerbate existing risks and present new risks as well as opportunities. The implications for infrastructure may be significant.

The Intergovernmental Panel on Climate Change (IPCC) suggests that the electricity sector is one of the sectors most at risk of disruption from climate change. Donald Lemmen et al. also indicate that "future changes in the frequency and magnitude of extreme weather events, particularly ice storms, heavy snow storms and wind storms, are likely to increase the risk of interrupted electricity supply and distribution."

Factors such as intense precipitation (which can lead to flooding), storm surges, freezing rain (which can cause ice accretion), snow load, hail, high winds, extreme heat, and heat waves can affect the integrity and reliability of infrastructure. Infrastructure must be resilient under both current and future climate conditions; therefore, it is important to consider climate change when making design decisions.

There is often an inclination to focus on weather extremes. However, it should be remembered that gradual changes in average temperature, precipitation, and sea level can also impact infrastructure and operations, for example the ability to cool thermal plants or recharge reservoirs.

The impacts associated with new average climate conditions may be within the current design specifications of equipment. However, factors such as increased load, accelerated aging, and cumulative effects should also be considered. An example of cumulative effects is the greater frequency of heat waves leading to increased peak demand for air conditioning at a time when infrastructure components are stressed by heat.

The effects of climate change and extreme weather can have direct and indirect impacts on infrastructure. Examples of direct impacts include ice accretion and lightning strikes on overhead conductors, wind damage, premature aging, and conductor sag and annealing. Indirect impacts include changes to vegetation management, ice road integrity, vector-borne disease, and supply chain issues, as well as precipitation overwhelming riverine and urban drainage systems, resulting in flooding. Changes to climate means may affect natural systems that control snow cover, frost depth, permafrost, ice cover

on waterways, and lake-effect snow, which may, in turn, affect the integrity of infrastructure.

Adaptation to climate change involves taking actions specifically to achieve acceptable levels of risk. Adaptive actions can also take advantage of potential long-term opportunities that accompany climate change. Adaptation enhances resilience, preserves assets, and addresses issues of premature aging. “A robust risk assessment process, applied consistently throughout the organization, empowers management to better identify, evaluate, and exploit the right risks for their business, all while maintaining the appropriate controls to ensure effective and efficient operations and regulatory compliance.”

Climate change and extreme weather can be effectively managed as risks. Existing risk-management strategies may well be capable of incorporating these risks. Where such strategies exist they should be used. Where they are not already in place, or are deemed insufficient, they should be developed or reworked.

Risk-mitigation strategies should consider a range of options from asset hardening to administrative controls such as improving response capability. Managing climate change impacts by using a planned approach can improve resilience and minimize risk.

1.3 Benefits of Risk Management

Planned adaptation can result in lower costs and is often more effective than reactive adaptation. Proactive adaptation measures guide strategic resource allocation and help avoid costly future repairs or replacements. Cost-effective strategies can be exploited by considering future design needs and component life expectancy when installing or retrofitting equipment. The National Round Table on the Environment and the Economy suggests that, under a rapid growth - high climate change scenario, the benefit-to-cost ratio of proactive adaptation is 38:1; while under a slow growth - low climate change scenario, the benefit-to-cost ratio of proactive adaptation is 9:1. For example, a proactive adaptation strategy of prohibiting building in coastal, flood-prone areas and gradually moving operations out of buildings that have been flooded is projected to result in 96% less cost than if the strategy had not been employed.

1.4 Format

This document guides users through a series of steps. In recognition that there are a wide variety of users with different processes in place, a series of appendices provide detailed supplemental information. Not everyone will require this level of detail.

An understanding of future extreme weather projections is critical for the design and maintenance of infrastructure and for effective emergency response. This document considers key aspects of adaptation planning, including:

- The adaptation process
- Model selection (including consideration of resolution, timeframes, and uncertainty)
- Management of adaptation challenges
- Examples of observed and projected impacts
- Process considerations
- Risk assessment
- Adaptation planning cycles

1.5 Approach

Critical infrastructure exhibits many interdependencies and interrelationships. It may be prudent to consider climate change adaptation drivers in aggregate to make the best management and spending decisions. Drivers such as stakeholder expectations and statutory requirements are also important, though beyond the scope of this technical document.

To understand and manage the potential impacts of climate change and extreme weather on electricity system infrastructure, the vulnerability of equipment and systems must be assessed. As infrastructure ages, it may become increasingly vulnerable to extremes. Therefore, age should be taken into account when determining risk. "Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity." As such, vulnerability combines the external climate stress with internal characteristics such as design. Weather extremes may put unexpected pressure on existing designs, leading to failure. Understanding the potential impacts of climate change and extreme weather on infrastructure is a business imperative.

To the extent possible, organizations should apply existing risk-management processes and philosophies. Those organizations that have robust risk-management processes in place simply need to ensure that climate change risk is captured. This guide is intended to supplement or inform existing processes and serve as a roadmap for those lacking formal ones. It is not intended to supplant existing processes. While some of the impacts of climate change and extreme weather may pose new or more significant risks, the principles of risk management are still applicable. Risks need to be periodically revisited and reassessed as new information comes to light.

The goals of adaptation may include ensuring that risks associated with asset reliability, performance, operating costs, replacement, and renewal are effectively managed. This can be achieved by managing current impacts and increasing resilience.

Following a risk identification process, like the one outlined above, will lead to improved understandings of inherent risks. Specific risks and ratings will likely be utility specific. Once risks have been assessed, individuals with appropriate levels of authority and accountability can make informed risk management decisions.

2.0 ADAPTATION PLANNING

Adaptation planning includes the steps outlined in Figure 1, each of which is discussed in detail below.

Figure 1: The Adaptation Planning Process

Note: The process is cyclical and iterative and requires stakeholder engagement throughout.

Phases	Steps
Preparation	Problem definition
	Stakeholder engagement
Risk review (or Risk mapping)	Risk assessment
	Risk prioritization
Risk Control	Risk mitigation
Monitoring and Evaluation	Monitor, measure and evaluate
Monitoring Review	Program adjustment

2.1 Recognizing and Defining Problems

That climate change can impact electrical infrastructure is recognized at the international, national, and industry level. Detailed definitions and characterizations of risks are undoubtedly utility specific. Figure 1 (above) enables each user to tailor an adaptation strategy that is aligned with their risks.

2.2 Determining Future Projections

To adapt to climate change impacts, the expected changes must first be understood. Much of the existing climate-sensitive infrastructure was designed using historical climate data that may not be representative of future risks. Climate conditions are projected to change on an ongoing basis for the foreseeable future.

Observation, qualitative descriptions of future conditions, and climate models can all help to inform future climate projections. Select the methods that best suit your utility-specific risks and requirements. Qualitative descriptions can readily be found in online publications and journals. Climate models based on well-established physical laws have been used for decades. The IPCC has developed a series of scenarios that provide alternative ideas on how the future may unfold in terms of GHG increases in the atmosphere. These scenarios provide essential inputs for climate models. Models can be used to both forecast and backcast. Backcasting enables comparison with the actual observed conditions, thereby demonstrating model veracity.

For modeling results to be meaningful, both climate means and weather extremes should be included. It is crucial to determine the relevant climate parameters to be modeled (e.g. precipitation and temperature), the specific criteria (e.g. heat waves, humidex, cumulative precipitation, freezing rain accumulation, and specified wind gusts), the appropriate timeframes (near, mid, and/or long-term), and the geographic range and appropriate spatial resolution (local, regional, or global). The required resolution may change across the geographic range of interest depending on the degree of homogeneity or, conversely, the significance of local influences such as lake effects and topography. These considerations should be based on an understanding of vulnerable and critical equipment and systems: vulnerable from the standpoint of asset preservation and critical from the standpoint of grid reliability.

Climate risk-adaptation planning can be approached from the top down or the bottom up. Top-down methods involve downscaling Global Climate Models (GCMs) under a range of IPCC GHG emission scenarios. The resulting scenarios are then considered in the development of mitigation strategies. The bottom-up method focuses on reducing vulnerability to past or present climate variability, often in the wake of an extreme weather event.

Temperature and precipitation are commonly modeled parameters. Careful selection of criteria that is tailored to specific areas of vulnerability is necessary. Once the model has been run, data specific to the end user's needs must be extracted. The end user must make informed requests in order to get useful data. Criteria may be found in design standards and used as the basis for data extraction requirements. Appendix A documents examples of transmission line design limits for ice and wind loadings. Such data can be used as the basis for data extraction.

Modeling temperature and precipitation may not directly yield the necessary results to assess risks. Precipitation projections alone may not provide sufficient information to understand the risk of flooding, for example. However, the data may be used to estimate future intensity, duration, and frequency (IDF) curves. The IDF curves can then be used to inform hydrology models to better predict riverine flooding. A conservation authority in Southern Ontario is working with a university partner to explore the potential of this model for projecting climate-related risks.

If the risk is the potential for lightning strikes, one may need to extrapolate from related data, such as vertical cloud height records. "The high potential for lightning strikes was characterized by looking at the vertical development of clouds […] [and] it was found that if the modeled cloud depth was greater than approximately 11 kilometres this corresponded well with observed lightning activity."

Changes in climate are typically expressed as changes between a baseline and future period. The World Meteorological Organization recommends that that baseline and future periods be separated by a 30-year interval. Caution should be exercised when selecting the duration of the baseline and future periods. Shorter periods are more sensitive to rapidly changing conditions, whereas longer periods tend to discount or downplay rapid and recent changes in weather. The timeframes should take into account the lifespan of the infrastructure. Infrastructure being designed today that has a 30-year lifespan could be subject to more rapid changes in weather than is indicated over a 30-year projection. Knowledge of projections outside the lifespan of equipment may be of limited value.

Selecting the appropriate scale or degree of spatial resolution of the model is essential.

Considerable work has been done on downscaling models to address the scale mismatch between coarse-resolution GCMs and the need for location-specific information. Robust estimates of future climate at the Regional Climate Model (RCM) scale can be achieved by employing ensembles of climate change projections. The ability to downscale to a finer resolution does not guarantee better model performance or imply greater confidence in the resulting scenarios. Downscaling from global or regional climate models may be necessary to achieve the finer resolution required for a given location or parameter. Specifically, higher-resolution models can often better represent extremes. Consideration should be given to whether RCM results may be adequate for areas that display relative climate homogeneity. The RCMs may be readily available at substantially less cost than local climate models for the same area.

Both the climate parameters and characteristics of the area of interest should be taken into account when deciding on the necessity of downscaling. Align the scale to the variability of the parameters and the need for precise information. The surface air temperature may be uniform over large areas but change dramatically near the coast. Precipitation, on the other hand, tends to be more variable in space. Thunderstorm cells and other extreme weather events often operate at a local scale in the order of a square kilometre. The influences of local topography, geology, coastlines, floodplains and drainage, and vicinity to the moderating influences of water bodies should be considered. Typically, modeling temperature and heat waves tends to be easier than modeling precipitation and storms, but these easier modeling efforts can result in more variable results.

GCM and RCM models depict very large areas. At this scale, the weather and climate of Buffalo, Toronto, and North Bay could be shown as being the same. In Southern Ontario, GCM and RCM models may not capture the effects of the Great Lakes, Niagara Escarpment, or Oak Ridges Moraine. The Finch Avenue washout (August 19, 2005) was not captured by Environment Canada modeling. RCM modeling actually put the storm well into New York State, with less intensity.

Many models (including ensembles) identify means of climate and weather. While knowledge of means is valuable, the knowledge of weather extremes is essential to understanding risk. Many models are tuned such that the projections match observations. This practice means that if a model projects an outcome that is greater than expected, tuning may result in the projection being reduced. The risk of tuning is the potential loss of extreme projections.

The case for committing resources to adaptation is sound. The challenge is how to ensure that adaptation measures produce the desired outcomes in light of uncertainty about climate change. Selecting the right model is thus essential.

2.3 Managing Uncertainty

Adaptation to climate change is often regarded as a complex challenge due to the uncertain outcomes of managing associated risks. Uncertainty can arise from a variety of factors, including vague or unclear objectives, inherent uncertainty associated with models, selection of inappropriate model scale, complex linkages, the assessed impacts of change, as well as changing external factors such as influences to climate change, demographics, socioeconomic conditions, and adaptive capacity. Risk-management techniques provide well-understood, credible, and practical means for dealing with such uncertainties.

Climate models project a range of future scenarios. Projection uncertainty varies with the timescale and parameters. Typically, the nearer-term projections have greater certainty. Adaptation planning needs to consider a wide range of possible futures (IPCC scenarios) and incorporate flexibility to enable modifying actions over time. Those actions that will be beneficial regardless of the future condition may not require the same degree of consideration of multiple futures.

Adaptation plans should be designed to achieve strategic objectives. They need to be iterative and flexible. As the future unfolds, plans need to be able to capture and adapt to what is actually experienced and learned. Plans need to be informed by both present knowledge and an understanding of what is anticipated. Built-in monitoring points and contingency planning can help adapt the basic plan to new information over time.

Robust adaptation frameworks are characterized by resilience, reversibility, flexibility, cost effectiveness, incorporation of safety margins, consideration of soft solutions, and employment of the principle of no or low (no/low) regret.Ideally, no/low regret strategies result in benefit regardless of how the future climate unfolds. For example, flood-management strategies for underground vaults can guard against current vulnerabilities that are projected to become more frequent or severe in future.

2.4 Managing Challenges and Overcoming Barriers

Climate change adaptation presents a range of challenges. The challenges are not necessarily new. Barriers and challenges to adaptation management include managing the uncertainty of future outcomes, lack of knowledge, lack of leadership on both the corporate and political front, a focus on mitigation, and financial implications. Appendix B provides insight into managing these and other challenges.

2.5 Considering Observed Climate Impacts

Changes to the frequency, intensity, duration, or range of extreme weather events can significantly impact the built environment. These events can involve the hydrosphere (as in the case of floods), cryosphere (as with ice jams), or lithosphere (such as when landslides occur). Climate change and extreme weather events that could impact the achievement of objectives (i.e. pose risk) are listed below and discussed in more detail in Appendix C. Consideration should be given to related or secondary impacts as well as the degree of control. This following list is not intended to be exhaustive and needs to be tailored to support specific adaptation plans.

1. Precipitation: Rain, extreme rain, snow, rain on snow, ice storms, hail, and freezing rain
2. Storms: Electrical (lightning strikes), wind (including hurricanes and tornadoes) and storm surges, destructive waves, and tides
3. Temperature (mean and extreme): Heat and humidity, highs and lows, duration, permafrost thaw, freeze thaw cycles, and changes to vegetation and growing seasons
4. Rising sea level: Melting ice sheets, expansion as oceans warm, and groundwater withdrawal
5. Changes to lake and river levels and timing of peak flows
6. Constraints on water availability
7. Reduced extent and duration of ice cover (sea, lake, and river)
8. Widespread reduction in mass and area of glacier cover
9. Emergence or re-emergence of vector- and rodent-borne disease

2.6 Adaptation Process Considerations

The International Organization for Standardization (ISO) states that "organizations manage risk by identifying it, analyzing it, and then evaluating whether the risk should be modified by risk treatment. Throughout this process they communicate and consult with stakeholders and monitor and review the risk and the controls that are modifying the risk in order to ensure that no further risk treatment is required."

Adaptation to climate change and extreme weather is a means of managing risk and a driver of innovation and change. Risks posed by future climate impacts are somewhat unique in that they are tied to actions and decisions taken today.

Mainstreaming of climate change adaptation planning through integration into ERM, business planning, and overall decision-making can lead to improved efficiency and effectiveness.

Successful adaptation does not mean that negative impacts will not occur. However, the impacts will be less severe than if no adaptation action had been taken. Adaptation can be either anticipatory (proactive) or reactive (after the impact has occurred). Both proactive and reactive adaptation can be planned. Generally, proactive adaptation results in lower long-term costs and is more effective than reactive measures. There are, however, risks inherent with implementing actions to deal with an uncertain future, including the potential for maladaptation and opportunity costs.

Adaptation can occur at different stages in the lifecycle of infrastructure. For example, an analysis of risk may be undertaken when deciding whether to build or restore infrastructure, relocating it inland from the coast, when considering building designs or the type of construction materials, or when establishing maintenance programs.

Maladaptation can result from either making decisions based on uncertain futures or from not adequately considering the future. For example, committing to underground vaults may not be prudent as the potential risk for flooding increases.

Climate information should be supplemented with other considerations, such as cost-benefit and hazard mapping to help ensure that actions generate results that mitigate risk, are economically feasible and socially acceptable, and do not generate other undesirable effects.

An example of hazard mapping is using climate model projections to produce flood plain maps. The location of critical infrastructure, particularly infrastructure that is at or below grade, can be overlaid on the maps of flood-prone areas, yielding critical planning information and providing valuable input into the assessment of risk.

For any given risk, there may be a range of potential responses. Decisions regarding the most appropriate control measure require an understanding of the process of adaptation, as well as vulnerability and resilience. Adaptation to climate change should not take place in isolation but rather consider interdependencies and interrelationships, and seek to identify potential synergies and conflicts.

While the approach must be tailored to each organization, decision-makers should keep the following in mind:

1. Adaptation governance structures must be well defined, including commitments, oversight, accountability, objectives, and resource allocation.

2. Adaptation planning occurs through a rigorous and ongoing process conducted at the appropriate level in the organization, and considers the full range of relevant risks.

3. Organizations must assess risk in relation to their objectives and define their risk tolerance (i.e. levels of risk that management is willing to accept).

4. Risk-rating scales, defined to enable a meaningful evaluation and prioritization of the event, should consider the objectives and scope. Where possible, scales should use the same units of measure that are used for objectives, and should be tailored to the organization.

5. Risk scales may be qualitative or quantitative. Quantitative scales are characterized by greater precision and measurability. However, qualitative scales may be used when the risk does not lend itself to quantification, the data is not available, or data analysis is not cost effective.

6. Risks are rated individually against relevant objectives; however, they should also be considered from a portfolio standpoint. Interrelationships should be considered. When viewed in aggregate, the risk profile may be different than when viewed in isolation.

7. Indicators should be developed to anticipate potential risks.

2.7 Assessing Risk

Effective risk assessments give organizations a clear view of impacts to which they may be exposed, and inform management of issues that could impact the achievement of objectives. Risk assessments identify potential adverse events, enabling organizations to proactively establish appropriate controls, thereby reducing loss. Risk assessment should be integrated into management practices to provide relevant and timely information to decision makers. They must be owned by the accountable business unit and embedded in the business cycle, and should include both a top-down and bottom-up approach. Risk assessment can have a strategic or operational focus.

It is important to ensure that cumulative and non-traditional impacts are considered. For example, global supply chains mean that extreme weather impacts elsewhere can have negative consequences locally.

3.0 RISK ASSESMENT AND MANAGEMENT

3.1 Risk Management Process

Risk management should be integral to policy development, business and strategic planning, and change management.

"The organization should identify sources of [climate change] risk, areas of impacts, events and their likely causes and potential consequences. The risks are based on those events that might create, enhance, prevent, degrade, accelerate or delay the achievement of objectives."

Sound risk management principles should:

Be based on the best available information, including historical and scientific data, experiences, observations, forecasts, stakeholder feedback, and expert judgment;

- Contribute to continual improvement;
- Support informed decision-making;
- Take uncertainty into account;
- Integrate with organizational processes such as strategic planning and change management;
- Be systematic, structured, and timely; and
- Be dynamic, iterative, and responsive to change.

Adapting to climate change by anticipating and preparing for risks is an iterative process of information collection and analysis, awareness raising, planning and design, implementation, and monitoring and evaluation. The model shown in Figure 2 is a plan/do/check/act composite model.

Adapting to climate change by anticipating and preparing for risks is an iterative process of information collection and analysis, awareness raising, planning and design, implementation, and monitoring and evaluation. The model illustrated below is a plan/do/check/act composite model.

Figure 2: The Risk-Management Cycle

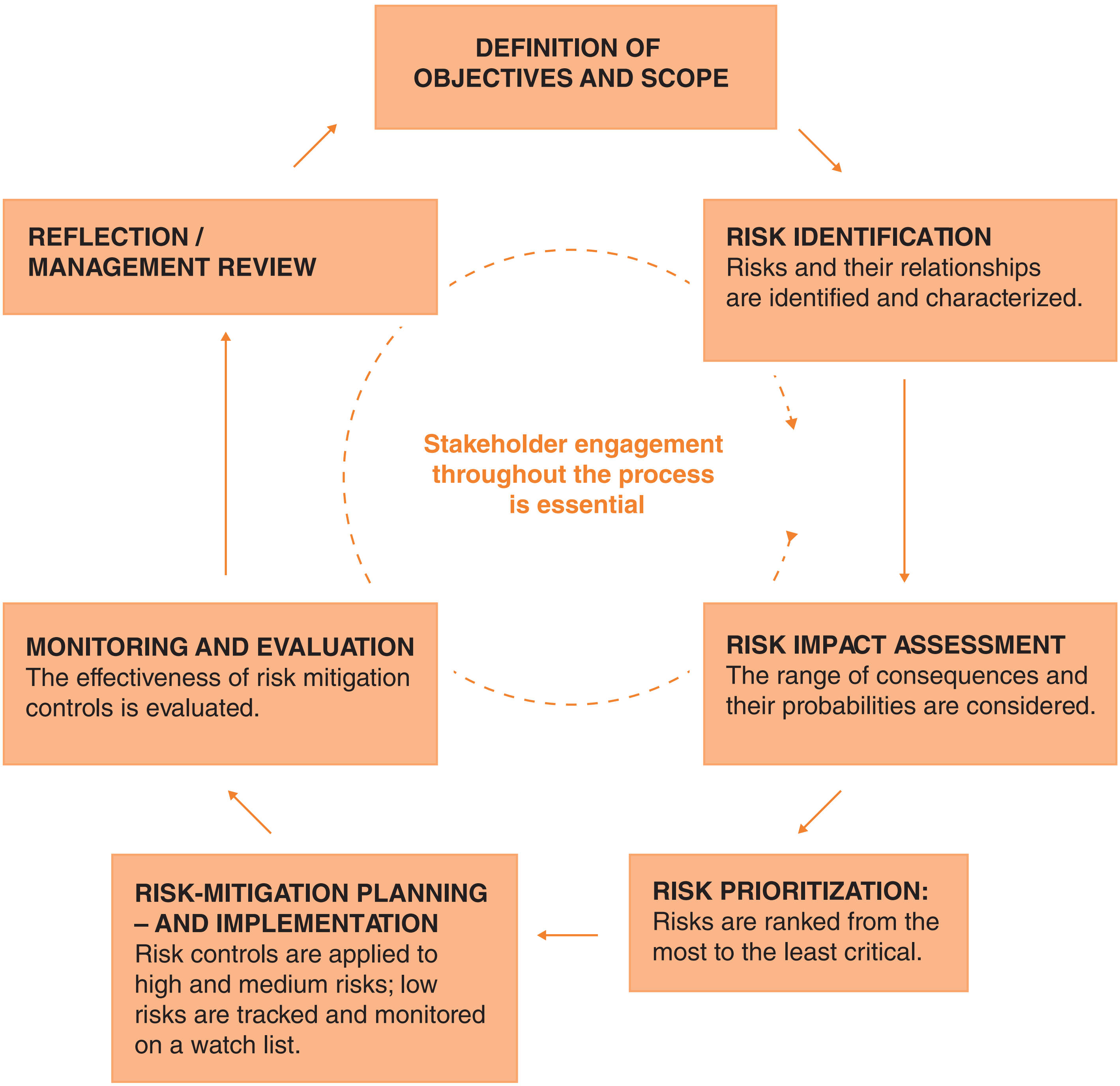


Figure 3:
Risk Assessment Flow

Notes on figure 3

1. The tolerance of those with accountability (and authority) must be established. Tolerance thresholds may vary by risk category.

2. Inherent risk refers to the risk without control actions applied.

3. Residual risk refers to the risk that remains after risk treatment measures are applied.

The reasoning behind assessing both the inherent and residual risk is to determine the adequacy of existing controls. If the existing controls mitigate the risk (present and future) to within the tolerance levels, then no further action may be required. For example, consider critical infrastructure that is located in a flood-prone area. Evaluate the inherent risk of a flood. Consider the historical and projected frequency of floods as well as the consequence (i.e. what is the estimated damage that would result from a flood?). Have there been any changes that could affect the potential consequences (for example altered expectations or liability)? Response strategies could include sharing the financial impact through insurance, moving the facility (or critical components) to higher ground, waterproofing critical equipment, or developing emergency-response plans. Residual risk consideration helps determine whether the risk is adequately, over, or under controlled.

Climate change risk management provides a systematic approach for developing adaptation strategies in response to projected changes that either create new or change existing risks. For additional detail refer to Appendix D.

3.1.1 Definition of Objectives and Scope

Objectives and scope must be clearly defined and approved by the leadership team. Well-defined objectives can be focused on different aspects, such as strategy, operations, process or function. Consider organizational objectives and types of potential risks under consideration as well as the administrative and geographic scope.

Climate modeling parameters, such as timeframes, need to be consistent with objectives.

Ensure that the objectives related to climate change adaptation are consistent and coordinated with other planning priorities such as business plan objectives, maintenance, renewal, and new build activities.

3.1.2 Risk Identification: Risks and their relationships are identified and characterized

Key facilities and infrastructure in a utility's jurisdiction must be identified and the location must be correlated with the climate hazards. Equipment vulnerable to climate change (extreme weather) should be identified to ensure infrastructure is safeguarded.

If the objective goes beyond infrastructure risk to include reliability, then equipment critical to achieving this objective must also be identified. Once the equipment is identified, it is necessary to understand both the design criteria and existing response strategies.

3.1.3 Risk Impact Assessment: Probability and consequence is assessed (consider range of consequences)

Assess the probability and consequences associated with each risk (or opportunity). The potential impacts to all phases of operation, including construction and design, should be considered. The assessment can be quantitative, semi quantitative or qualitative (see Appendix E). The scales should be appropriate so that each utility can undertake a meaningful process of evaluation and prioritization.

Any given climate event may have multiple consequences and affect multiple objectives. When multiple consequences are evaluated, the value of the most significant consequence should be used to calculate the overall risk. Decisions may be made to apply controls to only those high-consequence areas.

3.1.4 Risk Prioritization: Risks are ranked in order from most to least critical

A process to rank risks from most to least critical will help prioritize the implementation of risk-reduction or -control strategies. The prioritization scheme may consider whether the risk is immediate or longer term. Typically, immediate risks are considered higher priority.

Management's risk appetite (risk tolerance) needs to be understood to control risks to within tolerance levels. Risks need not be eliminated unless, of course, the tolerance level is zero.

Consideration should be given to controlling high negative consequence - low probability risks.

Risks and response strategies can be mapped on a heat map. Heat mapping provides a quick visual reference to relative priority. (See Appendix D.)

3.1.5 Risk Mitigation Planning - Implementation

Risk controls are applied to high and medium risks; low risks may be tracked / monitored on a watch list.

Risk treatment involves implementing one or more options to mitigate the risk. It is a cyclical process of assessing risk controls, determining the acceptability of residual risks, generating new risk treatment if residual risks are not tolerable, and assessing the effectiveness of the treatment.

3.1.6 Monitor and Evaluate

Evaluate effectiveness of controls in mitigating risk to acceptable levels. At predetermined points (milestones), evaluate the effectiveness of controls in mitigating risk to acceptable levels. Monitor performance of the controls and monitor factors that influence the risk profile.

3.1.7 Management Review

- At this stage, consider the following questions:
- Is the strategy is generating the desired results?
- Are new risks are present?
- Is new information or data is available?
- Has the context has changed? (e.g. stakeholder expectations, regulatory environment)

… And then:

- Identify lessons for transfer; and
- Determine whether changes need to be made to the control environment or objectives.

Objectives, risks, and controls must be periodically reevaluated to determine whether the current controls are producing the desired results and whether there is a reasonable expectation that they will continue to do.

3.2 Adaptation Management Checklist:

A simple checklist of adaptation management steps can be found in Appendix F. As with most processes, some steps must be performed in sequence, while others can be done in parallel. The first column of the table assigns a number to each step. The second column cross-references the step with sections of this report. The third column identifies the step itself. The fourth and fifth columns are intended to track implementation.

The companion chart at the end read left to right shows the series of steps (i.e. column one must be completed before column two). Steps within a column can be performed in parallel, but should be completed before progressing to the next column.

4.0 CONCLUSION

Adaptation planning is required to address the risk(s) posed by climate change and weather extremes to infrastructure. Society's response to climate change needs to address both mitigation and adaptation. Mitigation is required to limit the extent of change and adaptation because, regardless of the success of mitigation efforts, the climate is changing and will continue to change for centuries.

Effective climate change adaptation management can be achieved by following risk-management principles that should be incorporated into business-planning practices.

Ensuring that model projections are credible and implementing no/low regret, flexible strategies can help address the challenge of making decisions for an uncertain future. A great deal of information and experience, including models and response strategies, exists today. This information should be assessed for applicability. Some existing information may be readily adopted, or may inform what specific, localized data should to be modeled or extracted.

As with any risk-management process, clear direction from senior management is required in the form of policy and objectives. Further, those with management accountability need to define and communicate their risk tolerance. Multidisciplinary teams need to understand the information required to assess the risk and to develop appropriate risk-mitigation strategies.

The field is continually and rapidly evolving as new information, experience, and expectations develop. Adopting a flexible, iterative approach in the near term enables proactive decisions that may prove to be cost effective and address the risk of premature failure. Consideration should be given to aligning the introduction of more robust design with the existing cycle of equipment replacement. Certain types of infrastructure such as pole-top transformers, poles, and culverts have individual components that are at different stages in their lifecycle at any given point in time. The need for ongoing renewal enables a phased-in approach to new design. A simple example is resizing culverts at the end of life. Since the culvert requires replacing anyway, the incremental cost is largely the cost associated with a larger diameter of pipe.

Risk-control programs should be implemented strategically. More frequent severe storms may result in precipitation that overwhelms the design of drainage systems. The consequential damage may be assessed as high risk. One aspect of the control strategy could be to install larger culverts. Consideration should be given to the fact that the overall risk is not uniform for all culverts and the controls should be applied accordingly. The risk associated with low consequence culverts may simply be accepted.

Where the accountability to manage the fundamental risk lies outside the utility's jurisdiction, consider actions that those with accountability could take to mitigate the risk. For example, urban flooding impacts the electricity sector but the accountability for sewage and drainage lies outside the electricity sector jurisdiction. The sector could take action to safeguard underground and surface equipment, and/or it could work with the accountable authority to address the fundamental issue. In this example, the electric utility is a stakeholder to the municipality.

In those instances that the life expectancy of the vulnerable equipment is near term, it may suffice to compare the design against the current climate. However, where the life expectancy and required adaptation measures span decades, the adequacy of controls should take into account potential future climate scenarios. Where appropriate models do not exist (e.g. the parameters or resolution do not meet the need), then models may need to be commissioned. If it is not feasible to commission new models, it may be necessary to rely on qualitative descriptions of climate change (e.g. increased rainfall, increased temperature, and more frequent severe extremes). Even these qualitative descriptions can help identify more resilient options.

As with any management system, the identification of appropriate metrics and monitoring requirements is crucial. Monitoring at key milestones and intervals supports effective management by identifying the adequacy of existing controls and identifying the need for improvement to the control environment.

At first glance the risks associated with climate change may appear outside risk managers' existing scope of activities. However, processes that have proven effective managing other risks in the past will likely serve the organization well in managing climate risks. As with all new types of risk, there is a need to become informed.

5.0 DEFINITIONS

Adaptation:

Refers to any modification of a system or process made in response to the changing climate. It involves adjusting decisions, activities, and thinking to reduce the negative impact of climate change and/or take advantage of the opportunities presented.

The goals of adaptation include mitigating current and projected impacts, reducing sensitivity and exposure to climate-related hazards, increasing resilience to climatic and non-climatic stressors.

Successful adaption does not mean that negative impacts will not occur but rather that they should be less severe than if no adaptation measures had been taken.

Adaptive capacity:
Adger et al. have described adaptive capacity as the the ability or potential of a system to respond successfully to climate variability and change including adjustments in both behaviour and in resources and technologies. They note that the presence of adaptive capacity has been shown to be a necessary condition for the design and implementation of effective adaptation strategies the likelihood and the magnitude of harmful outcomes resulting from climate change. The authors also state that"adaptive capacity also enables sectors and institutions to take advantage of opportunities or benefits from climate change."

Consequence:
Refers to the outcome or impact of an event that affects the achievement of objectives. Any given event can lead to a range of consequences. Consequence can be expressed either quantitatively or qualitatively.

Climate change:
Refers to any change in climate over time regardless of the source (natural factors, human activities, or both).

Critical infrastructure:
Refers to systems and services that are essential to societal well-being.

Extreme weather event:
Weather that is severe (i.e. at the extremes of the historical distribution).

Inherent risk:
The risk without control actions applied.

Probability:
The chance or likelihood of something happening, whether defined, measured, or determined objectively, subjectively, qualitatively, or quantitatively.

Mitigation:
The term often applies to reducing climate change through anthropogenic intervention to reduce GHG emissions or increase the sinks for them. The goal is to reduce or prevent changes in the climate system. It is regarded as complementary to adaptation.

This guide also uses the term mitigation to refer to mitigating risk. Every effort will be made to clearly distinguish between the two uses. The context should provide clarity.

Maladaptation:
Refers to control activities that result in increased vulnerability to climate change and/or significantly undermine present and future adaptation opportunities.

No or low (no/low) regrets:
Refers to adaptation options that bring benefits regardless of changes in climate.

Even though the understanding of climate change will improve, uncertainty will remain inherent to adaptation decision-making. In cases such as infrastructure renewal one cannot wait in hope of certainty. No/low regrets can be an efficient first step in adaptation strategies.

Planned adaptation:
Refers to risk-mitigation strategies that are driven by informed policy decisions.

Residual risk:
The risk that remains after risk treatment (controls) are applied.

Resilience:
The IPCC describes resilience as “the amount of change that a system can undergo without changing state.”

Risk:
Refers to the possibility that an event will occur (likelihood) and adversely affect (consequence) the achievement of objectives.

Risk assessment:
A systematic process for identifying and evaluation events that could affect the achievement of objectives.

Risk management:
A systematic approach to selecting the most appropriate course of action to mitigate risk. It involves the application of policies, procedures, and practices to analyze, evaluate, control, and communicate risk.

Soft adaptation options
Refers to building capacity within the organization to improve the ability to cope with a range of climate impacts. It may involve the introduction of administrative controls.

Uncertainty:
Refers to how well something is known. Often, in science, full quantification or absolute certainty is not possible; information is instead qualified with descriptions of the level of certainty (such as “very likely outcome” meaning greater than 90% likelihood).

Vulnerability:
Refers to “the degree to which systems are susceptible to, and unable to cope with, adverse impacts” of climate change including climate variability and extremes. It is influenced by three factors: 1) the nature of the climate change; 2) the sensitivity of the system; and 3) the capacity of the system to adapt to the change.

6.0 APPENDICES

Appendix A: Typical Overhead Conductor Design Limits for Ice and Wind Loading

Refer to the design, construction, and operating specifications set forth in applicable federal and provincial standards, guidelines, codes, mandatory requirements, and regulations. One such example is the Canadian Standards Association (CSA) Overhead System Standard C22.3. In addition to radial ice loading and wind, consider wind gust velocity and wet snow loading along with the return period.

kV	Design Limits		
	Radial Ice Only	Radial Ice and Wind	Wind Only
500	50.5 mm	19 mm + 100 km/h (10 psf)	160 km/h (24 psf)
230	19–50.8 mm (mostly 25.4 mm)	12.7–19 mm mostly 12.7 mm +	160 km/h (24 psf)
115	25.4 mm	12.7 mm + 90 km/h (8 psf)	124 km/h (16 psf)

(Example provided by Hydro One)

Appendix B: Managing Challenges and Overcoming Barriers

Climate change adaptation presents a range of challenges and barriers, not all of which are necessarily new. These are outlined in the table below.

Challenge or Barrier	Considerations
Uncertainty	Plans need to be flexible and iterative to identify and capture emerging information. Consider using a no/low regrets strategy. Monitoring and feedback loops as well as consideration of whether desired outcomes are being achieved should be incorporated. Plans should identify which decisions need to be made now and which can be deferred. Trigger points for initiating future plans should be identified and monitored (e.g. linking design upgrades to renewal schedules). Is the impact likely to be felt prior to the projected end of life of a component? Uncertainty in climate projections requires application of ensembles of simulations. A caveat to using the ensemble model approach (aside from cost) is that it loses sight of extremes.
Adaptive capacity of stakeholders	Engage stakeholders throughout the process, particularly when the adaptive strategy has an impact on their expectations.

Lack of access to knowledge and information	A great deal of information exists today. The challenge is to ensure that relevant, easily understood information is accessible. Determine site- and organization-specific needs. Identify the adequacy of existing knowledge and assess gaps. Recognition of the potential impacts posed by climate change and extreme weather will drive the need to gather information, which will be recognized as a business imperative. Share information and lessons learned within industry associations to the extent that proprietary / confidentiality limitations permit.
Societal expectations	Identify, engage, and inform relevant stakeholders throughout the process. Understanding societal expectations is necessary in determining the consequence of potential impacts. Managing expectations may be a component of the adaptation plan.
Reliance on historical or anecdotal information to forecast future risk	There is a need to move from a reliance on historical climate information to forward-looking projections that can identify potential risks that historical data would fail to identify. Improving resilience or emergency-response measures based on historical (observed) data may prove to be of limited value and not adequately account for future extremes.
Lack of access to predictive modeling technology to forecast and thereby inform responses to future risks	Models able to provide good projections based do exist, but ones that are relevant in terms of spatial or temporal resolution or parameters of concern may need to be commissioned.
Lack of climate leadership	Adaptation planning requires the engagement of senior management. Leadership must understand that climate risk is a business risk and needs to be treated with the same degree of attention as other enterprise risks. Those with authority (ownership or operation of infrastructure) are generally regarded as having the accountability to act in a duly diligent fashion. This has been the legal position for several years, as evidenced by recent court cases.

[1] National Round Table on the Environment and the Economy, *Paying the Price*, 17.
[2] National Round Table on the Environment and the Economy, *Paying the Price*, 17.

Focus on mitigation vs. adaptation	Mitigation and adaptation planning are complementary strategies. Regardless of mitigation efforts, the climate will continue to change. The changes are having impacts today and projections indicate that the extent of impact will likely increase in the future. The success of mitigation efforts will influence the extent of future impacts, which will affect adaptation efforts.

Regulatory environment • Lack of awareness or support from regulators • Specific regulations or legislation	Where there is insufficient support (with regard to regulations and legislation or financial incentives) at the national level, investigate whether there is support at the sub-national level. In recent years, sub-national climate leaders including provinces, cities, and regions have organized into networks. In some cases, a sub-national consensus may in fact be the better way to achieve progress across a wide geographic area.
Concerns related to financial impact on customers and pressure to keep rates low	Under a rapid growth - high climate change scenario the benefit-to-cost ratio is estimated at 38:1 while under a slow growth - low climate change scenario it is 9:1.[1] Prohibiting new construction in coastal areas at risk of flooding combined with a “strategic retreat” by gradually abandoning dwellings once flooded reduces the costs of climate change to only 3–4% of what the costs would have been without adaptation.[2]

Appendix C: Observed Climate and Weather Impacts

This table provides examples of climate change and extreme weather events that could impact the achievement of objectives (i.e. pose risk). Consideration should be given to related or secondary impacts as well as the degree of control. This table is not intended to be an exhaustive list and needs to be tailored to support specific adaptation plans.

Event: Precipitation – rain, extreme rain, snow, rain on snow, ice storms, hail, freezing rain **Changes to precipitation and extreme precipitation events.**	**Impact Type**		**Control**	
	Primary: simple cause and effect relationship (e.g. freezing rain causing ice accretion or lightning strikes on overhead conductors; wind damage to structures)	Secondary: the relationship between cause and effect is separated by intermediate events (e.g. warmer temperatures leading to longer growing seasons, causing a greater need for vegetation management, or extreme rain overwhelming drainage systems, leading to flooding)	Direct	Indirect
Extreme precipitation, rain on snow, rain with frozen ground	Reservoir management	Potential to overburden storm drainage, leading to flash flooding (flooding of underground vaults and surface infrastructure) and related damage and outages Flooding resulting in oil / chemical spills	Direct	Indirect
Changes to spatial and temporal availability of water	Hydroelectric operations may need to be modified to prevent upstream or downstream flooding.	Changes to operations could have impacts on spawning grounds. Disruptions to supply chain transportation routes (including fuel supply)		
Saturation or destabilization of soil		Slope stability, landslides		
Freezing rain / ice storms	Ice accretion, leading to overhead conductor failure			

[3] Lemmen et al., *From Impacts to Adaptation*, 251.
[4] Lemmen et al., *From Impacts to Adaptation*, 251.

Event: Precipitation – rain, extreme rain, snow, rain on snow, ice storms, hail, freezing rain Changes to precipitation and extreme precipitation events.	Impact Type		Control	
	Primary	Secondary	Direct	Indirect
Specify based on design criteria for overhead conductors (typically 12.5, 25, and 50 mm over a storm cycle) Note that the parameter measured is freezing rain while the parameter of concern is ice accretion. There is not necessarily a direct correlation between the two. Ice accretion is affected by factors such as the shape and temperature of the surface. Typically storm fronts are of a 72-hour duration so the concern is not the freezing rain (accretion) per day (wave) but rather the accretion over the storm event. For example, the 1998 ice storm failures were the result of build up over three days. Further, one must consider whether the freezing rain is accompanied by wind. If so, the design limits should be revised downwards (see Appendix A).	Ice accretion, leading to overhead conductor support structure failure (poles and towers) The 1998 ice storm damaged over 30% of the 2,900 circuit kms of transmission lines in the Ottawa and Belleville Districts.[3] The 1998 ice storm damaged more than 100 high-voltage transmission towers and required at least 10,500 new poles.[4]		Direct	Indirect
Tree and branch failure due to ice accretion (15 mm ice accretion is the value often used for tree branches)		Failure of trees and branches, resulting in damage to overhead conductors and outages		
Drier summers		Drought-related fires, resulting in risks to infrastructure		

Snow pack

Reduced annual extent and duration of snow cover

Snow pack	**Impact Type**		**Control**	
Reduced annual extent and duration of snow cover Changes in precipitation, reduced snowpack, and fluctuations in the timing of spring melt	Primary	Secondary	Direct	Indirect
	Reservoir recharge	Likely influence pattern of energy and water use May impact permafrost		

Snow Cover

Snow cover insulates the ground, affecting the thermal regime and permafrost distribution. Snow cover also affects surface radiation balances and water budgets.

Event: Lightning	**Impact Type**		**Control**	
	Primary	Secondary	Direct	Indirect
Increased frequency of lightning strikes	Direct strikes on equipment (e.g. overhead conductors, pole top transformers), causing damage, outages	Forest fires – ignition source		

Event: Wind (including hurricanes, tornadoes)	**Impact Type**		**Control**	
	Primary	Secondary	Direct	Indirect
Increased frequency of storm events	Galloping lines, leading to failure Tornadoes' EF2 potential to damage concrete poles and other permanent structures	High winds (70 km/h+), resulting in tree branch failure with subsequent damage to overhead conductors		

[5] Hong Chen, *Morbidity Mortality Study*, Public Health Ontario, 2014.

Heat and Humidity

Extreme heat and humidity pose threats to the health and productivity of outdoor workers and challenges to energy systems. Projections for certain areas suggest that humidity may surpass the threshold at which the human body can maintain its core temperature (i.e. heat stroke). "Overwhelming evidence has linked extreme weather events (e.g. heat waves) to increased mortality and morbidity."

Event: Temperature – heat and humidity, highs and lows, duration	**Impact Type**		**Control**	
	Primary	Secondary	Direct	Indirect
Increased frequency of extreme temperatures and/or humidity Note that maximum temperatures and heat waves may need to be specified based on design criteria. Projections indicate that some regions will exceed the threshold for heat stroke.	Increased demand Reduced performance / increased line losses Premature aging (increased heat may cause conductor sag and annealing) Sagging may lead to issues of phase-to-phase shortages, or affect safe limits of approach. Increased maintenance requirements Reduced cooling efficiency.	Maintenance and operating personnel Comfort levels for Humidex readings are: • 20-29: comfortable • 30-39 : varying degrees of discomfort • 40-45: almost every-one is uncomfortable • 45+: many types of work and exercise should be avoided		
Increased average winter and summer temperatures (wetter, warmer winters, hotter, more humid summers) Growing seasons begin earlier and go longer		Ice roads - access - quality and duration of roads Accessibility can affect the serviceability of infrastructure. Road surfaces may buckle under higher summer temperatures. It may be necessary to increase vegetation management to prevent damage to overhead conductors and supports.		

[3] Lemmen et al., *From Impacts to Adaptation*, 251.
[4] Lemmen et al., *From Impacts to Adaptation*, 251.

Winter Roads

Factors contributing to poor winter road conditions are warmer weather and high, rapidly fluctuating water levels with strong currents. A warmer climate leads to weaker and thinner ice, altered ice composition (i.e. more milky white ice, which is less strong than blue-black ice), excess slush, earth patches, potholes, hanging ice, and ice pockets on roads, effectively shortening and/or delaying the winter road season. (For example, the average length of the winter road season in Manitoba is projected to decrease by eight days in the 2020s, 15 days in the 2050s, and 21 days in the 2080s as a result of climate change). The delayed and shortened road season may also restrict access to remote areas.

Event: Temperature – permafrost	Impact Type		Control	
	Primary	Secondary	Direct	Indirect
Loss of permafrost due to warming and deepening of annual thaw	Thaw sensitivity and settlement of permafrost have important implications to the stability of the ground and infrastructure. Damage to structure integrity Failure of dykes and containment, leading to releases and spills	High winds (70 km/h+), resulting in tree branch failure with subsequent damage to overhead conductors		

Permafrost

Permafrost refers to earth that remains below 0°C for two consecutive summers. Approximately 50% of Canada's land mass is covered by permafrost, which may be either continuous or discontinuous. Projections indicate that continuous permafrost will degrade to become discontinuous, and that discontinuous permafrost will start to disappear, especially on southern boundaries of the respective zones.

Design, construction, and operation of infrastructure in permafrost regions must account for the challenges posed by frozen ground. While permafrost can provide a strong foundation for infrastructure, thawing can lead to instability.

Event: Temperature – permafrost	Impact Type		Control	
	Primary	Secondary	Direct	Indirect
Loss of permafrost due to warming and deepening of annual thaw	An increase in freeze-thaw cycles accelerates degradation. Physical damage to asphalt and concrete Potential foundation issues Increased maintenance Failure of dykes	Rain on snow or high snowfall followed by rapid thawing can lead to flooding. This is an example of combined events that can have more impact than discrete events.		

Event: Storm surges, destructive waves, and tides associated with storms	Impact Type		Control	
	Primary	Secondary	Direct	Indirect
	Increased coastal erosion and flooding Impacts to infrastructure, and damage to drainage and sewage systems			

Event: Rising sea level	Impact Type		Control	
	Primary	Secondary	Direct	Indirect
		Potential large-scale loss of coastal property and infrastructure Losses from hurricanes and other coastal storms will likely grow due to sea-level rise alone. Increased risk of flooding and erosion of coastal areas may exacerbate other hazards, such as ice ride up and pile up.		

[6] As cited in Lemmen et al., *From Impacts to Adaptation*, 251.
[7] Lemmen et al., *From Impacts to Adaptation*, 9.

Event: Changes to lake and river levels and timing of peak flows	Impact Type		Control	
	Primary	Secondary	Direct	Indirect
	Projected decreases in the level of the Great Lakes may compromise hydroelectricity output. Lower levels, coupled with the rise in water temperatures, may affect the efficiency of cooling systems for thermal and nuclear plants.[6]			

Declining lake levels may be due to earlier and lessened spring freshet, lower summer and fall low flows, extended duration low flow periods, increased frequency of high flows, increased water temperature, increased evapotranspiration, ice cover season decreased (or eliminated), and reduced snow cover (depth, area, duration).

Event: Water availability constraints	Impact Type		Control	
	Primary	Secondary	Direct	Indirect
	Hydroelectric capacity, cooling capacity			

Event: Loss of sea, lake, and river ice cover (reduced extent and duration of freezing)	Impact Type		Control	
	Primary	Secondary	Direct	Indirect
		Increased coastal erosion due to reduced ice cover, sea level rise, and increased storms		

Event: Reduced glacier cover	Impact Type		Control	
	Primary	Secondary	Direct	Indirect
Widespread reductions in the mass and area of glaciers The estimated loss of ice mass in the Canadian Artic was 25 km³/a in the 1995-2000 period.[7]				

Vector- and Rodent-borne disease

More favourable conditions brought about by climate change would modify the distribution of parasites and disease transmitted by insects, ticks, and animals, thereby increasing infectious disease.

Temperature, spring migratory bird densities, and woodland habitats are thought to be constraining factors for Lyme disease. Increases in temperature could lead to the northern expansion of the range for Lyme disease. By 2080, it is estimated that the suitable habitat will increase by 213%, moving northward by up to 1,000 km. This will significantly increase expansion in Canada and greatly improve the survival rates of ticks.

Mosquito-borne diseases such as West Nile Virus and malaria may become more prevalent due to climate change.

Zoonotic diseases such as hantavirus pulmonary syndrome, a potentially fatal lung disease spread by the excreta of rats, could increase with the propagation of rats into new areas. Outbreaks in the US have been linked to climate change.

Event: Vector- and rodent-borne disease	**Impact Type**		**Control**	
	Primary	Secondary	Direct	Indirect
Emergence or re-emergence of vector- and rodent-borne disease		Increased exposure of outdoor workers to West Nile Virus, Lyme disease, etc.		

Appendix D: Sample Principles of Climate Change Adaptation Plans

The following principles may be included in climate change adaptation plans.

Category	**Action**
Capacity Management	Incorporate anticipated climate change into capacity and redundancy planning to manage peak demands. This is particularly important in urban centers to ensure quality and continuity of supply.
Climate Change Impact Assessments	Conduct vulnerability assessments of existing electrical infrastructure to relevant future climate change projections and identify existing weaknesses. Incorporate assessments into reports on infrastructure reliability and investments to evaluate the impact of climate change against other drivers of infrastructure investment. Assessments may be used to establish future benefits and avoided costs for the purposes of rate increase approvals.

[8] Scientific American March 23, 2012

Category	Action
Collaboration	Effective climate change adaptation requires cooperation, collaboration, and information sharing between utilities, regulators, and governments on anticipated climate change and related regulatory, policy, and other adaptation responses.
Consumption Management	Develop strategies and programs to manage demand shocks (e.g. increases in peak demand and periods of sustained high electricity usage) due to climate and weather events, such as more frequent and intense heat waves.
Emergency Planning	Develop strategies and tools to anticipate and react to extreme weather events and associated impacts.
Engineering Design	Incorporate climate change considerations into the design of new or refurbished electrical facilities to increase resilience (i.e. harden assets). Utilize modeling of risk scenarios to determine the best response. Determine level of worst case to use (e.g. 1 in 250-year storm vs. 1 in 100).
Environmental Assessments	Incorporate climate change factors into environmental impact assessments, where applicable.
Indicators	Incorporate climate change factors into performance indicators to monitor the climate vulnerability and resilience of electricity infrastructure.
Information Sharing	Cooperation with government agencies is required to obtain data on climate change and impacts.
Reliability Standards	Incorporate climate change resilience considerations into reliability standards for electric apparatus and power system design.
Research	Support, participate in, and monitor research into utility-sector climate change adaptation issues and options.
Route and Site Considerations	Incorporate climate change considerations into the route- and site-selection process for new electrical facilities to avoid locations that may pose unacceptable risks (i.e. spatial planning around areas prone to flooding, high winds, etc.). Consider relocating existing infrastructure in high-risk situations (entire facilities or specific equipment).
Technical Standards	Formalize hardening requirements in technical standards. Technical standards have an important impact on the resilience of electric products, processes and construction, as they are used in every phase during the lifetime cycle of infrastructure.
Vegetation Management	Incorporate climate change considerations into vegetation-management practices and schedules. These may include changes in practices / standards to reduce vulnerability to outages caused by trees falling as a result of more frequent storms.

Appendix E: The Management Cycle

Climate change risk management provides a systematic approach for developing adaptation strategies in response to projected changes that either create new or change existing risks.

DEFINITION OF
OBJECTIVES AND SCOPE

The first step for utilities is to define the Objectives of their adaptation strategy, as well as its scope. The following list describes things that utilities should address in this step.

- Objectives must be clearly defined and approved by the leadership team.
- Objectives should be strategic, operational, and process or function oriented.
- Stakeholders, including the project team, should be identified and engaged.
- Stakeholder awareness of the risk should be raised.
- Appropriate project team competencies must be ensured.
- Climate modeling parameters (e.g. temperature and precipitation, freezing rain, lightning) need to be defined.
- Specific weather criteria such as temperature ranges, duration, and extremes need to be established.
- Model timeframes (e.g. near, mid or long-term) need to be identified and should be consistent with objectives.
- The scope of the assessment must be defined. Key to determining the scope of the risk assessment is understanding the organizational objectives and types of potential risks under consideration. The scope may be enterprise wide or limited to a business unit or geographic region.
- Appropriate model resolution (spatial and temporal) must be determined so that meaningful decisions can be made.
- Climate simulations and projections must be well understood.

Project teams should be multidisciplinary in order to:

- Ensure understanding of risk and risk assessment process;
- Bring direct knowledge of infrastructure operation and engineering;
- Bring climatic and meteorological expertise relevant to the region (e.g. regional or local climate expertise);
- Have sufficient practical operating experience and management-level knowledge of infrastructure; and
- Maximize local knowledge and history.

Strategic planning priorities need to be consistent with the challenges of climate change adaptation. If alignment is not achieved then successful implementation will be less assured. The adaptation process must be sufficiently flexible and iterative to capture new information as it becomes available. To the extent possible, ensure that the objectives related to climate change adaptation are consistent and coordinated with other planning priorities such as business plan objectives, maintenance, renewal, and new build activities. The plan needs to foster innovation through creativity and paradigm shifts.

Key facilities and infrastructure in a utility's jurisdiction must be identified and their locations correlated with the climate hazards. Equipment vulnerable to climate change and extreme weather should be identified in order to ensure infrastructure is safeguarded.

RISK IDENTIFICATION:

Risks and their relationships are identified and characterized.

If the objective goes beyond infrastructure risk to consider reliability, then equipment critical to achieving this objective must also be identified. Once the equipment is identified, it is necessary to understand both the design criteria and existing response strategies.

Risk analysis requires a comprehensive understanding the nature of the risk(s). Analysis informs risk evaluation and decisions on whether risks need to be treated and what the most appropriate risk-treatment strategy or method may be.

To fully assess the impacts on infrastructure, consider primary and secondary, direct and indirect impacts (see Appendix C). The integrity of electrical infrastructure can be affected by infrastructure serving other areas, such as telecommunications, supply chain, access roads, and drainage systems. Failure of support processes can have direct consequences (flooding) or indirect consequences (inhibiting response plans because of the inaccessibility of access roads).

Climate change will affect infrastructure. The extent of impact must be assessed. Risk analysis involves careful consideration of the causes of risk(s) and the likelihood that the consequences will occur.

RISK IMPACT **ASSESSMENT:**

Probability and consequence is assessed (consider range of consequences).

Assess the probability and range of consequence associated with each risk (or opportunity). The potential impacts on all phases of operation, including construction and design, should be considered. The assessment can be quantitative, qualitative, or a mix of both. The scales should be appropriate to each utility to undertake meaningful evaluation and prioritization.

Any given climate event may have multiple consequences and affect multiple objectives. The categories of consequences that are relevant should be considered and rated. The value of the most significant consequence should factor prominently in the calculation of overall risk. Using an average of consequence values may dilute the risk and hide issues of potential significance. Decisions may be made to apply controls to only high-consequence areas.

The efficiency and effectiveness of existing controls should be considered. Risks should be evaluated both without existing (or inherent) controls and considering (or residual) controls. This will enable the determination of whether existing management processes are adequate to control for current and future risk.

RISK **PRIORITISATION:**

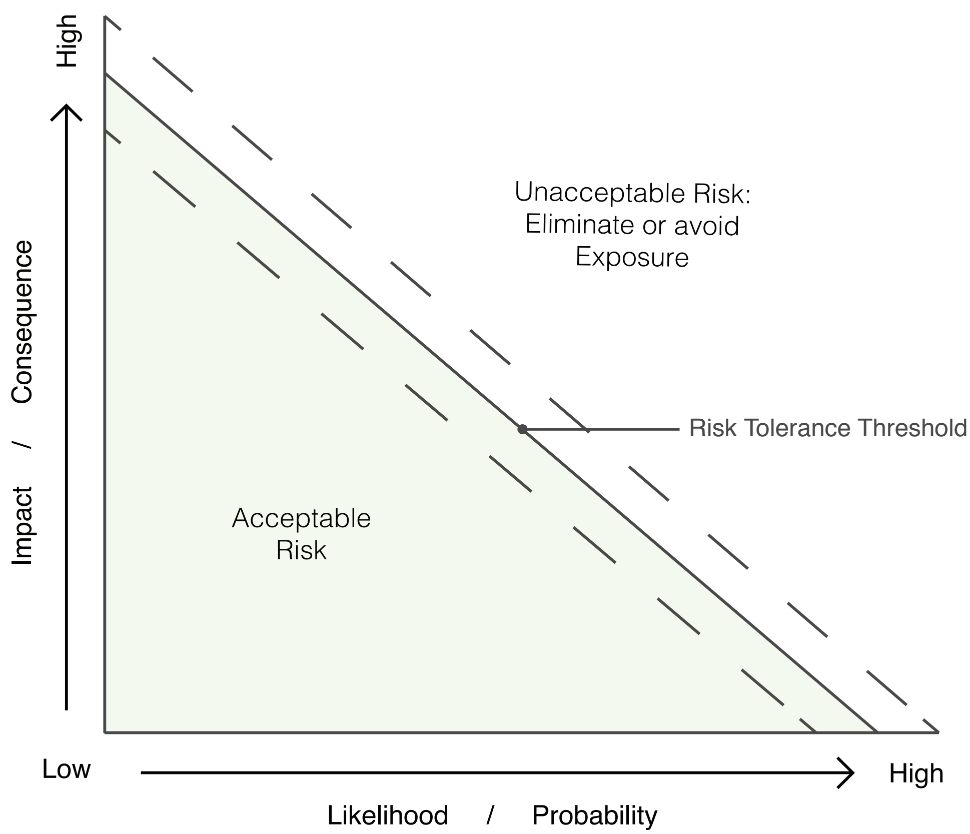
Risks are ranked in order from most to least critical.

A process to rank risks from the most to least critical should be developed. This will help prioritize the implementation of risk-reduction or control strategies. The prioritization scheme may consider whether the risk is immediate or longer term. Typically, immediate risks are considered higher priority. Management's risk appetite (or risk tolerance) should be understood. The level of tolerance will vary from one management team to another. The goal is to control risks to within tolerance levels. Risks need not be eliminated unless, of course, the tolerance level is zero.

RISK RESPONSE STRATEGIES / RISK MAPPING

Risks can be mapped on a heat map such as the one shown below. Heat mapping provides a quick visual reference to relative priority. Risks that exhibit a high likelihood and high consequence and/or have weak controls are high priority. Inherent risks that rank high should have controls applied to reduce the risk to within mangement's risk tolerance, which is depicted below as the diagonal line. Residual risks that continue to rank above management's risk tolerance have inadequate controls in place. High negative consequence – low-probability risks may require treatment even if they cannot be economically justified.

Adaptation Planning Guide



RISK MITIGATION PLANNING
IMPLEMENTATION:

Risk controls are applied to high and medium risks; low risks may be tracked/ monitored on a watch list.

Risk treatment involves implementing one or more options to mitigate a risk. It is a cyclical process of assessing risk controls, determining the acceptability of residual risks, generating a new risk treatment if residual risks are not tolerable, and assessing the effectiveness of the treatment. Response strategies need to be tailored, taking into account local and/or regional conditions such as specific climate and extreme weather projections, stakeholder expectations, regulatory regimes, and the risk tolerance of individual organizations.

Risk treatment options include:

- Avoidance (removing the risk source and/or eliminating involvement in activities that lead to the possibility of the risk being realized);
- Sharing or transferring (shifting the burden of the risk to another party through vehicles such as insurance or through joint ventures);
- Mitigation (applying appropriate techniques to reduce the likelihood of an occurrence, its consequences, or both); and
- Acceptance (accepting the consequences and likelihood of a particular risk where mitigation is either impossible, not cost effective, or resources are better directed to other higher profile risks).

Controls typically focus on high and medium risks, with low risks being tracked or monitored on a watch list. The purpose of tracking low risks is to ensure that their profile does not change with as circumstances do. Risk-control strategies must be planned and implemented. Process considerations include:

- Identifying actions to mitigate risks to acceptable levels;
- Benchmarking to determine whether other jurisdictions have developed and/or implemented designs or strategies that address the risk (If control strategies are identified through benchmarking, they need to be assessed for adoption suitability.);
- Considering the extent of control that the organization has over the process and treatment options;
- Considering implementing actions that can be modified as necessary in future;
- Considering the uncertainty related to the costs, benefits, and effectiveness of the process controls;
- Considering implementing a variety of mitigation strategies to experiment and determine which is most effective;
- Identifying adaptation options, ranging from hard engineering solutions to soft solutions such as administrative controls (e.g. emergency response planning or modified infrastructure maintenance/ inspections);
- Identifying preferred adaptation measures that reduce risk, are socially acceptable, and technologically and economically feasible, while taking into account the prevailing regulatory environment;
- Ensuring that interdependencies and interconnections are considered;
- Capturing actions in the business-planning process; and

- Capturing severe (high negative consequence), low-probability risks that require treatment even if they cannot be economically justified.

Implement the control strategy. Ensure that new infrastructure designs and requests for proposals (RFPs) include climate change risk assessments for consideration by the engineer.

MONITOR and EVALUATE:

Evaluate effectiveness of controls in mitigating risk to acceptable levels.

At predetermined points (or milestones), evaluate the effectiveness of controls in mitigating risk to acceptable levels. In addition to monitoring the performance of the controls, monitor factors that influence the risk profile. Consideration should be given to such changes as those to climate and weather projections, best available science, interdependencies, and stakeholder expectations or the regulatory regime. The failure or ineffectiveness of a risk-treatment measure can introduce risk.

Monitoring and review processes must:

- Ensure that controls are effective and efficient both in design and operation (For all relevant climate parameters, the team must know the thresholds for infrastructure damage, operational failure, and maintenance decisions.);
- Analyze and learn from events, changes, trends, successes, and failures;
- Detect changes that may require revision of the plan and priorities; and
- Identify emerging risks.

REFLECTION/MANAGEMENT **REVIEW:**

Objectives, risks, and controls must be periodically re-evaluated. Consideration should be given to whether the current controls are producing the desired results and whether there is a reasonable expectation that they will continue to do. Evolving scientific evidence, experience, and stakeholder attitudes towards risk continually shape adaptation measures. Plans need to be iterative and adaptive to capture feedback on outcomes achieved and lessons learned. Questions to consider include:

- Is the strategy generating the desired results?
- Are new risks present?
- Have there been changes to available information, such as projections? What are the implications?
- Has the context changed? (e.g. stakeholder expectations, regulatory environment, or adaptive capacity)?
- Are there lessons to be transferred?
- Is there time to implement actions previously deferred?
- Do changes need to be made to the control environment or objectives?
- Does the plan require adjustment?
- Do modified strategies need to be adopted?

[9] Other examples can be found in various IPCC documents and PricewaterhouseCoopers, *A practical guide to risk*, 17.

Appendix F: Examples of Probability and Consequence Scales[9]

A variety of probability and consequence scales are available in the literature, varying in granularity. Common ranges are from one to three and one to 10. Select a scale that has the granularity to support sufficient discrimination of risk, but does not create unnecessary categories that will simply add effort without value. Experience has shown that a scale of one to five often works well.

Probability Scale

Rate the probability (or likelihood) of the impact occurring using the following table, which employs a five-point scale.

Score	Description
1	**Very unlikely** to occur in the timeframe related to the objective. Extremely remote, highly improbable, very infrequent, rare, occurring less than once every 25 years.
2	**Unlikely** but to occur in the timeframe related to the objective, not negligible. Remote possibility, low probability but noticeably greater than 0 (i.e. may arise once in 10 to 25 years).
3	**As likely as not** to occur in the timeframe related to the objective. Moderate probability, reasonably likely, 50/50 chance, occasional, periodic (i.e. may arise once in 10 years).
4	**Likely** to occur in the timeframe related to the objective. greater than 50% probability (i.e. may arise about once per year).
5	**Very likely** to occur in the timeframe related to the objective. Virtually certain, frequent, routine or ongoing, could occur several times per year, greater than 90% probability.

Consequence Scale

Select the consequence (or impact) categories in accordance with the organization's strategic objectives and areas of interest. Additional categories could include community and lifestyle, environment, and health and safety.

Ensure that the scales are adjusted to match business-planning categories for the organization or unit. For example, the financial scale should be adjusted to reflect the significance at the organizational level being considered. What may be ranked a three from a corporate perspective may in fact be a five at a business unit or divisional level. Taking this approach enables relevant issues to be mapped at all business-planning levels. Another example is stakeholder interest; something of significant local concern may have a lower rating from a corporate standpoint.

Score	Financial	Stakeholder Interest, Reputational	Regulatory
1	Does not affect asset value Impact less than $10, 000, negligible or minor shortfalls Little to no impact on economic growth, employment.	Relatively unimportant, stakeholders either unaware or aware but not concerned No threat to image Minor reputational consequence Media not involved	Unimportant / little to no potential for regulatory action Pending legislation
2	Impact greater than $10,000, less than or equal to $100,000 Isolated areas of reduced economic growth relative to forecasts	Stakeholder concerns / complaints limited to individuals or local group(s)	Notification to regulator required Warning from regulator
3	Impact greater than $100,000, less than or equal to $500,000 Reduction in economic growth relative to forecasts	Somewhat important to stakeholders	Regulatory sanction, fine, regulatory involvement, potential for increased reporting
4	Impact greater than $500,000, less than $1M Business health and employment affected	Significant local concern for stakeholders, media attention	Conviction, potential loss of license, potential for regulatory orders, potential for additional license requirements
5	Potential to significantly affect value of assets Impact greater than = $ 1M Significant economic impact, loss of employment, business failure	Permanent, significant reputational loss, very damaging with stakeholders	High potential for regulatory action Subject to past regulatory action / compliance problems Intrusive involvement by regulator Loss of regulatory approval to operate

Appendix G: Steps to Adaptation Planning

(cross-reference section 3.2)

#	Xref	Steps	Notes	Status
	2.1 / 3.1.1, p38	Direction from the Top Problem Recognition / Definition		
1		Clearly define and approve objective		
2		Define scope of climate change adaptation management		
		Preparation		
3		Engage stakeholders		
4		Raise stakeholder awareness		
5	2.4, App D	Ensure project team competency		
6	2.2	Define climate-modeling parameters		
7	2.2	Establish specific climate and weather criteria		
8	2.2	Identify model timeframe(s) (e.g. near, mid, or long-term) consistent with objectives		
9	2.2	Determine appropriate model resolution (spatial and temporal)		
		Obtain Future Climate and Extreme Weather projections		
10		Execute model and/or obtain qualitative descriptions of future climate and weather, as suits utility need		
		Risk Universe		
	3.1.2, p39	**Risk Identification**		
11		Identify key facilities and infrastructure		
12		Correlate key infrastructure locations with climate hazards		
13		Identify equipment vulnerable to climate change and extreme weather		
14		Identify equipment critical to achieve the objective		
15		Understand both the design criteria and existing response strategies		
16		Consider primary and secondary, direct and indirect impacts		
	3.1.3 p 45	**Risk Assessment**		

#	Xref	Steps	Notes	Status
17		Ensure scales are appropriate to support meaningful evaluation and prioritization		
18		Assess the probability and consequence(s) associated with each risk (or opportunity)		
19		Consider potential impacts on all phases of operation, including construction and design		
20		Evaluate inherent and residual risk(s)		
21		The value of the most significant consequence should most influence overall risk		
		Risk-Control Strategy		
	3.1.4, p 40	**Risk Prioritization**		
22		Rank risks from most to least critical		
23		Understand management's risk appetite (or tolerance)		
24		Consider plotting risks on a heat map for quick visual reference		
25		Consider controlling high negative consequence – low-probability risks even if they cannot be economically justified		
	3.1.5 , p 42	**Risk Mitigation / Implementation**		
26		Consider the range of risk-treatment options including avoidance, sharing / transferring, mitigating, and accepting		
27		Consider the extent of control that the organization has over the process and treatment options		
28		Consider interdependencies and interconnections		
29		Benchmark with other jurisdictions for existing design or strategies that address the risk		
30		Assess control strategies identified through benchmarking for adoption suitability.		
31		Consider implementing actions that can be modified as necessary in future		
32		Consider implementing a variety of mitigation strategies to experiment and determine which is most effective		
33		Identify hard and soft adaptation options, as appropriate		

#	Xref	Steps	Notes	Status
34		Ensure response strategies take into account local / regional conditions such as specific climate and extreme weather projections, stakeholder expectations, regulatory regimes, and the risk tolerance of individual organizations		
35		Identify preferred adaptation measures that reduce the risk to acceptable levels, are socially acceptable, and technologically and economically feasible. The prevailing regulatory environment should be taken into account.		
36		Ensure that new infrastructure designs and RFPs include climate change risk assessments for consideration by the engineer		
37		Consider the uncertainty related to costs, benefits and the effectiveness of the process controls		
38		Align climate change adaptation plans with strategic-planning priorities		
39		Capture actions in the business-planning process		
40		Implement the control strategy, and one or more options to mitigate risk(s) requiring additional controls		
41		Control risks to within tolerance levels		
	3.1.6, p 43	**Monitor and Evaluate**		
42		Ensure that the suite of metrics is appropriate to risk (Have leading metrics been considered?)		
43		At predetermined points (milestones): • Evaluate the effectiveness of controls in mitigating risk to acceptable levels • Monitor factors that influence the risk profile		
44		Track or monitor low risks to ensure that the profile does not change as circumstances do		
45		Analyze and learn from events, changes, trends, successes, and failures		
46		Detect changes that may require revision of the plan and priorities		

#	Xref	Steps	Notes	Status
47		Adopt a cyclical process of assessing risk controls, determining the acceptability of residual risks, generating new risk treatment if residual risks are not tolerable, and assessing the effectiveness of the treatment		
	3.1.7, p 44	**Management Review / Program Adjustment** Periodically re-evaluate objectives, risks, and controls (Plans need to be iterative and adaptive to capture feedback on outcomes achieved and lessons learned)		
48		Determine whether current controls are producing the desired results and whether there is a reasonable expectation that they will continue to do so		
49		Consider changes to the risk universe: • Are new risks present? • Has the context changed? (e.g. stakeholder expectations, regulatory environment, or adaptive capacity)		
50		Have there been changes to available information or projections? What are the implications?		
51		Have lessons for transfer been identified and communicated?		
52		Is it time to implement actions previously deferred?		
53		Does the plan require adjustment? • Do changes need to be made to the control environment or objectives? • Do modified strategies need to be adopted?		

Direction		Risk Identification				Risk Assessment					Risk Prioritization		Risk Mitigation / Implementation									Monitor and evaluate		Management Review	
1	2	3	4	10	11	12	17	18	20	21	22	24	26	29	30	35	37	38	39	40	41	42	43	48	51
		5				13		19			23	25	27		31	36							44	49	52
		6	7			14							28		32								45	50	53
		8				15									34								46		
		9				16																	47		

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