DS-25

CLIMATE CHANGE INFORMED DATA STANDARD

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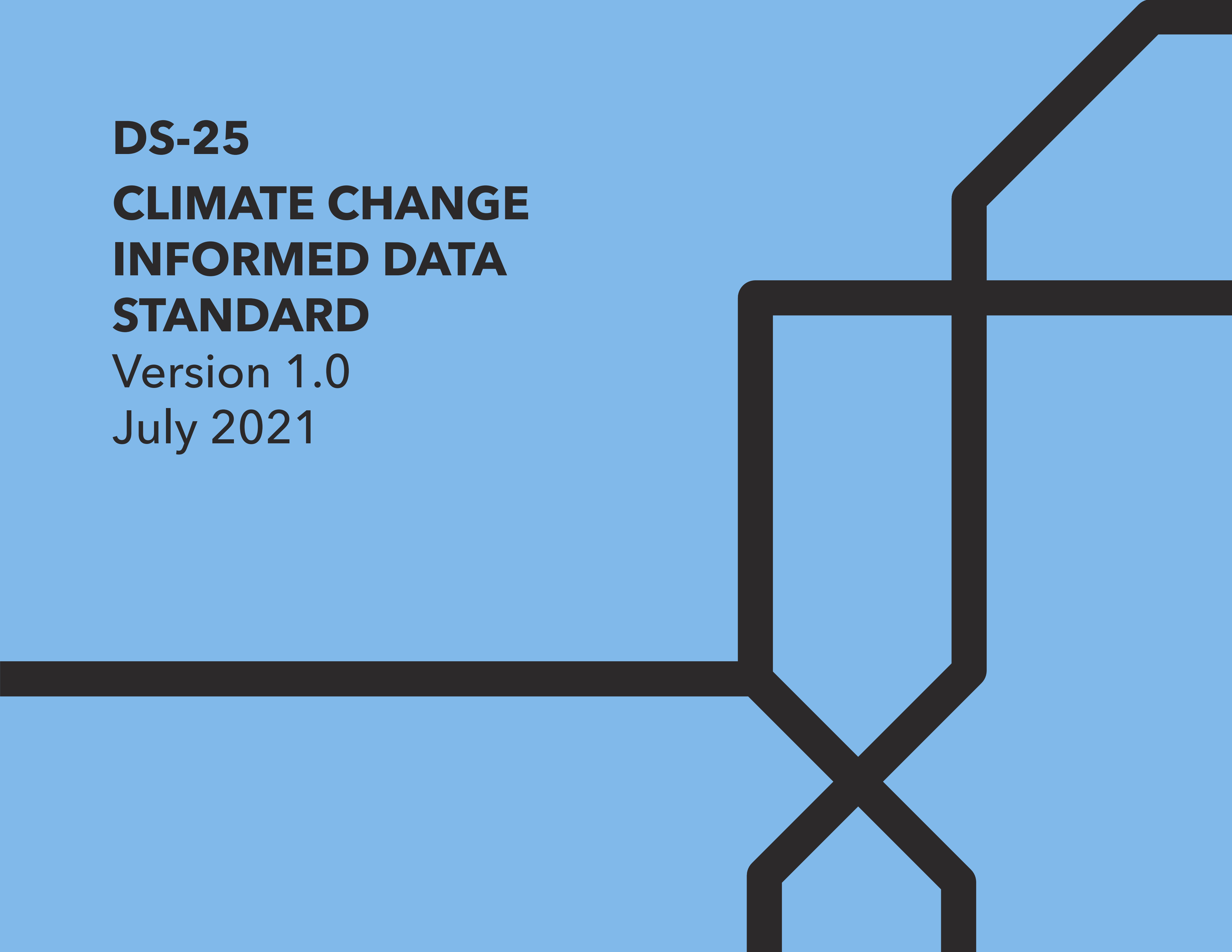

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Figure 1: Time horizons and their respective data needs regarding climate and weather. Historical normal, present weather forecasts and future climate projections all play key roles in different phases of project development. Note: Figure is for illustrative purposes only .

1 PURPOSE

This is the first edition of the Metrolinx Climate Change Informed Data standard. Questions and suggestions for improvement will be directed to the responsible team by contacting designstandards.announcement@metrolinx.com. Climate change informed data (climate change data) includes historical climate data to establish a baseline for climate models, output of climate change models (i.e. climate change projections), and the modification of IDF statistics to account for future climate.

The purpose of the Metrolinx Climate Change Informed Data standard is to identify and describe requirements and best practices for obtaining climate parameters and data that reflect appropriate climate projections. Climate change data has potential uses in the planning, design, construction, operations and maintenance of Metrolinx infrastructure; however, the purpose of the standard excludes identifying when or where such data shall be used.

Through higher data quality, this standard supports the Provincial Government's Made-in-Ontario Environmental Plan, Metrolinx's Sustainability Strategy, Metrolinx's Climate Adaptation plan and the Infrastructure for Jobs and Prosperity Act, 2015, through demonstrating how Metrolinx is designing infrastructure to be resilient to the effects of climate.

The Standard outlines the steps that should be taken to obtain the appropriate climate change data, recognizing that specific weather and climate change data needs rely upon data sets that may have spatial and temporal constraints (see Figure 1). This could vary from immediate daily weather forecasts, to climate change projections that corresponds with the design life of new infrastructure (10-80 years). In the case of climate change, the challenge is to manage infrastructure effectively within a changing climate that will become even more extreme, especially by the middle to end of this century (see Figure 2).

In the context of using climate change data to assess climate risk, an example of the application includes vulnerability and risk assessments (See Figure 3). Climate-informed planning and design parameters

Business Cycle	**Timeframe**
Operations & Maintenance	Daily, Seasonal, Annual
Capital Planning	1 year - End of Asset
Design & Construction	End of Asset

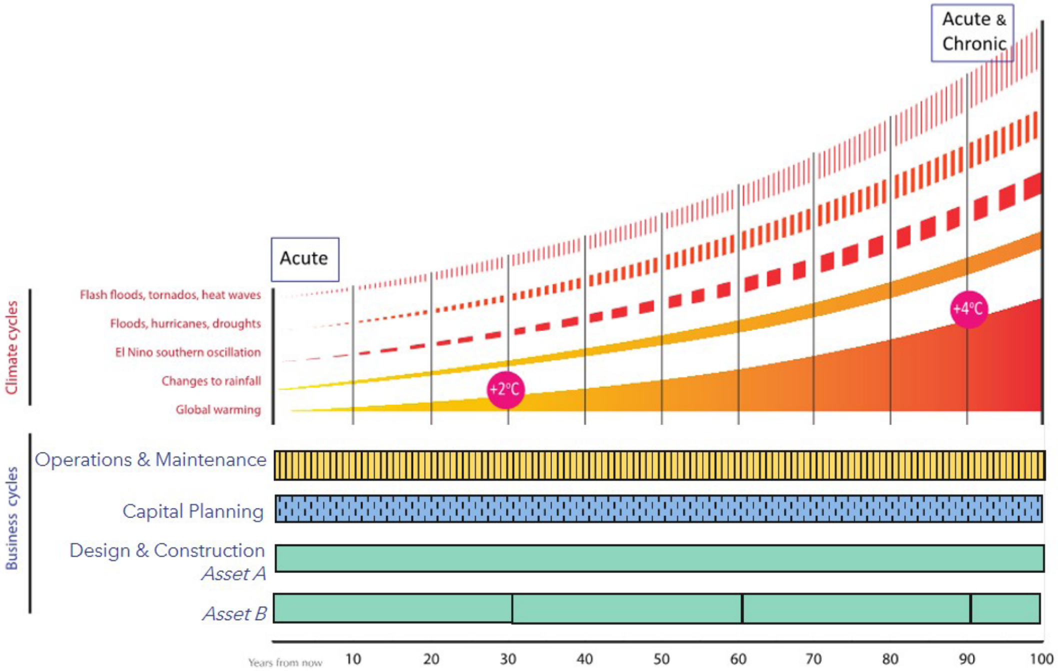


Figure 2: Climate change cycles corresponding with Metrolinx operations and maintenance, capital planning and design and construction of new projects. Length of cycle for capital planning is dependent on asset type and business needs. For example, improvements such as refurbishment or retrofits would extend the expected lifecycle by years, while reconstruction or major upgrades could extend expected lifecycle by decades. Design and the construction of new assets focuses on the climate conditions at end of asset life. For example, for an asset with an expected lifecycle of 100 years (e.g. Asset A), the design would consider climate projections to at least 2100. For an asset with a shorter expected lifecycle of 30 years (e.g Asset B), the design would consider climate projections to at least 2050. Note: Figure is for illustrative purposes only.

Source: Viner, D., Rawlins, M., Allison, I., Howarth, C. and A. Jones (2015) Climate Change and business survival: The need for innovation in delivering climate resilience. Mott MacDonald, pp. 10-11.

may include considerations around the geographical proximity of weather and climate observations and climate modelling to project sites, appropriate historical periods for a climate baseline, use of an ensemble of Global Climate Models, which future scenarios to apply, the selection of time horizons that align with asset life-cycles, and dealing with uncertainties through the use of percentile projections from multiple climate runs. Further, more spatially granular data may be needed that is generate from regional climate models that based on statistical or dynamic downscaling, considers lake effect snow or snowbelt conditions, or even requires the application of micro-scale modeling of fluid dynamics that takes winds and/or hydrology into account.

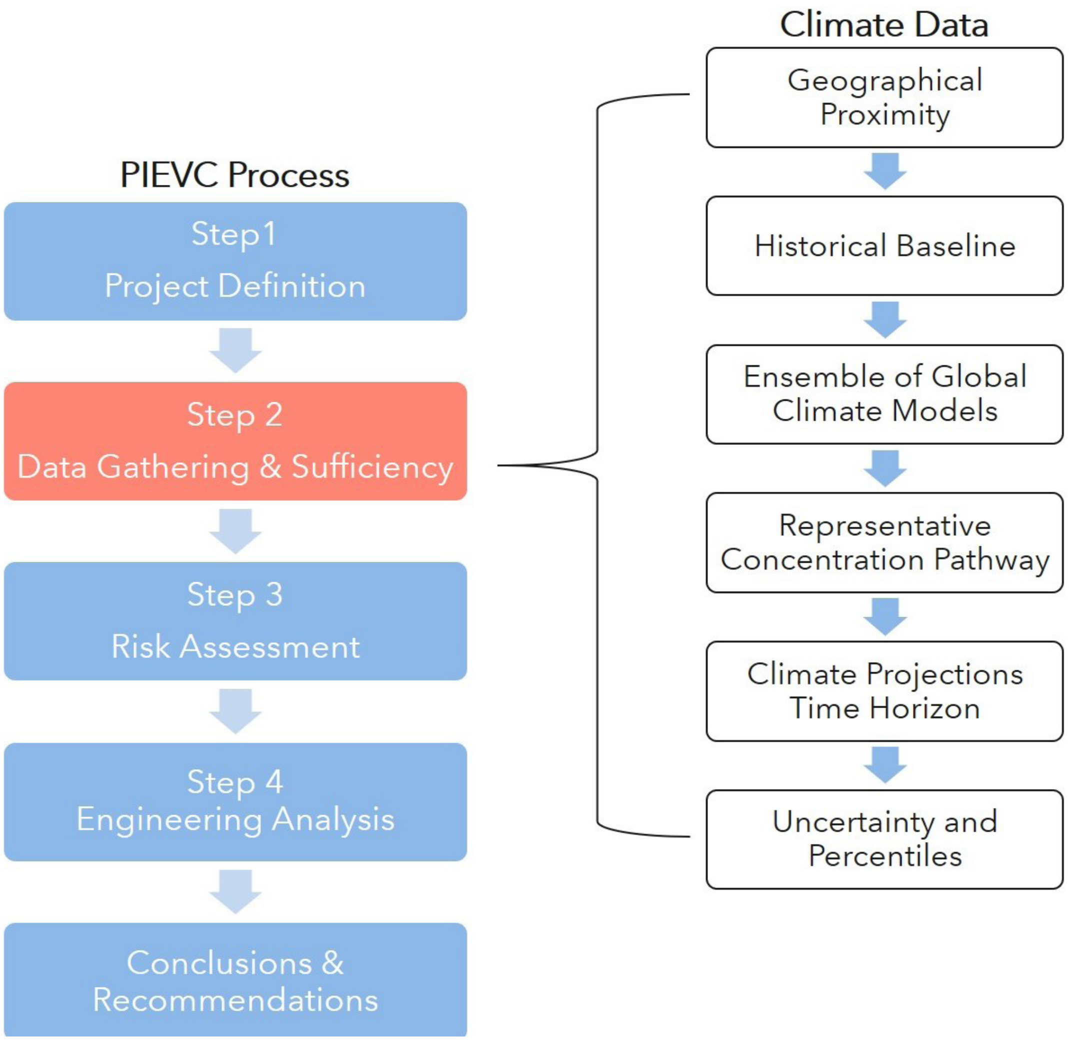


Figure 3: Examples of climate data considerations in climate risk an vulnerability assessment. Depicted above is the process used in the PIEVC protocol, and where climate data ultimately interacts.

2 SCOPE

All projects requiring climate change data and projections shall consult this standard to ensure a consistent approach and high degree of data quality, including:

- New projects through planning, design, and construction;
- Operations and maintenance;
- State of good repair projects; and
- Engineering design standards.

Detailing when and how projects shall incorporate climate change data is out of scope of this standard. The requirements outlined in Section 3 of this standard are expected to inform these processes and reflect Metrolinx's commitment to delivering climate resilient infrastructure.

3 CLIMATE CHANGE DATA STANDARD REQUIREMENTS

To help navigate through the growing body of climate information, projects undertaking climate change projections shall:

a) Acquire climate change data that is of closest geographic location to the asset. When working with linear projects spanning large distances and/or significantly different regional climate and weather zones, multiple data sets may be required to ensure that each segment of the project is best represented by the closest data set;

b) Ensure that the historical climate change data is a minimum thirty-year record of the climate variable of interest;

c) Utilize an ensemble of Global Climate Models (GCM), as it is not appropriate to utilize the projection of just one GCM. Users shall state where model data was obtained, and what models were including in the ensemble;

d) Apply an RCP8.5 (high carbon) scenario to the ensemble. Other scenarios may be included for reference; however, the RCP8.5 scenario shall be the scenario used when informing critical decisions about Metrolinx assets;

e) Ensure the final projections are downscaled to represent local climatic variations. Global climate projections, on their own, shall not be used due to the resolution of their output – however shall be used to inform the downscaling process;

f) Reflect a minimum 30-year projection period of future climatic conditions. Projections shall not be reflective of a single year or season;

g) Use percentiles reflecting sound engineering judgement. Percentiles shall be evaluated on a case by case basis to ensure the most relevant projection is being represented and utilized; and

h) Include sources and references to data in final projections. This allows for traceability.

4 PRECIPITATION EVENTS

Rainfall events are captured through Intensity-Duration-Frequency (IDF) statistics (also known as IDF curves). IDF statistics require a different data source than broad based climate projection data portals. The overall objective is to enhance hydrological and hydraulic analyses to incorporate unbiased assessments of future climate change and account for uncertainties in the projections; the enhanced storm water criteria may be stricter than those from Authorities Having Jurisdiction (AHJ).

When accounting for climate change in the application of design storms, users shall apply one of the following approaches to the relevant IDF curves to account for the range of possible climate change outcomes (this approach can be applied against the full range of return period events from the 2 through 100 year):

a) A percentage increase to the peak flow for the design storm; or

b) Modification of IDF IDF curve modifications as per CSA Plus 4013:19 (Technical Guide: Development, Interpretation and Use of Rainfall Intensity-Duration-Frequency (IDF) Information).

Existing IDF information can be obtained from Environment Canada, Ministry of Transportation IDF web application http://www. eng.uwaterloo.ca/~dprincz/mto_site/terms.shtml. Option A is simpler to apply as it uses the existing hydraulic model outputs; while option B requires additional modelling, the output is more defensible and the level of resiliency more readily understood.

All projects that must determine a floodplain, shall apply the greater of the following storm events to account for the range of possible climate change outcomes to the high-water riverine flood elevation:

c) Regional storm (designated by the local conservation authority); or

d) A percentage increase in the peak flow indicated within the approved hydraulic model for the 100-year storm event.

All projects accounting for climate change per requirements 4a, 4b, 4c or 4d should consider:

e) An increase of 25% to the peak flow against the major and minor storm events as has been used in various Metrolinx projects and standards; and

f) The methodology in section 5 of CSA Plus 4013:19 whereby a 7% increase in IDF statistics is applied for every 1°C increase in local mean temperature, determined per RCP 8.5 projections.

APPENDIX A: CLIMATE CHANGE DATA RESOURCES

The following data portals are recommended by Metrolinx as credible sources of data, including ncessary and climate change projections. Additional resources may be required to obtain required data and projections.

- Historical Climate Data
    - Canadian Climate Normals and Averages: http://climate.weather.gc.ca/climate_normals/
    - Canadian Histroical Climate Data: https://climate.weather.gc.ca/historical_data/search_historic_data_e.html
- Climate Models and Projections
    - Climate Atlas of Canada: https://climateatlas.ca/
    - Climate Data for a Resilient Canada: https://climatedata.ca/
    - Ontario Climate Data Portal: http://lamps.math.yorku.ca/OntarioClimate/index_v18.htm
    - Ontario Climate Change Data Portal: http://www.ontarioccdp.ca/
- Additional Climate Service/Information
    - Canadian Centre for Climate Services: https://www.canada.ca/en/environment-climate-change/services/climate-change/canadian-centre-climate-services/about.html
    - Climate Change Hazards Information Portal (CCHIP): https://www.cchip.ca/
    - Climate-Resilient Buildings and Core Public Infrastructure: https://climate-scenarios.canada.ca/?page=buildings-report

APPENDIX B: CLIMATE CHANGE IMPACTS

Since 1985, the cost of insured losses by extreme weather events that have impacted Ontario in whole or in part has been estimated at over $8 Billion by 2020 (in 2019 dollars).[1] Weather events such as storms, tornadoes, flooding, wind, snowstorms, rainstorms, hail, lightning, and other water-related hazards have been the cause of these impacts. Notably, these costs do not include temperature related events such as extreme cold, extreme heat and freeze/thaw cycles that are known to impact thermal expansion of infrastructure, influence energy demand, and affect human health, among others. On a national scale both the number of extreme weather events and the cost of insured losses have been increasing over the past few decades, at the same time in Ontario when there have been detectible changes in average and extreme climate conditions, reflecting that climate change is already occurring and the consequences are being felt now.

In addition to changes in climate that are already occurring, future climate change impacts caused by changes in both average conditions and extreme weather event severity and frequency present growing risks to the reliability, effectiveness, and sustainability of the Province's transit infrastructure and operations. Across the Greater Golden Horseshoe Region (GGH) annual average temperatures are projected to increase about 2°C by 2021-2050, 4°C by 2051-2080 and 5°C by the last 30 years of this century compared to the historical 1981-2010 baseline. Similarly, average annual precipitation is projected to increase about 7% by 2021-2050, 11% by 2051-2080 and up to 15% by the last 30 years of this century compared to the historical 1951-1980 baseline. Extreme temperature and precipitation events, including heat waves, periods of droughts, and flooding, are also projected to increase in intensity, last longer, and occur more frequently than in the past. Changes in climate projections will also vary spatially across the GGH, where the baselines and projections for annual average temperature and average annual precipitation may vary by up to 2°C and 100 mm respectively.[2]

Given the expectation for climate change to impact transit infrastructure in the GGH and surrounding regions serviced by Metrolinx, it's crucial to incorporate changing climate adaptation into engineering designs. Released in 2019 Canada's Changing Climate Report outlines the range of climate change futures projected for Canada, but for the purposes of infrastructure design more localized climate projections are generally recommended. High-level projections of climate change may be sufficient for future planning, but when it comes to the design of new infrastructure more detailed climate information may be needed. New infrastructure assets will be informed by their own design standards, with each having their own critical thresholds where upon exceedance their performance may become compromised. Assessing vulnerability and risk for new infrastructure assets under future climate change projections may require data such as unique and different climate parameters, timelines that match design lifecycles, and consideration of a wider range of future conditions as the degree of uncertainty increases.

The design life of transit infrastructure is inherently long, and service requirements for railways, bridges, tunnels, tracks, stations, maintenance and storage facilities, and other assets may be required for decades, while rights-of-way and specific facilities may continue to be used for transit purposes for even longer periods of time. In addition to normal deterioration, transit infrastructure is subject to a range of environmental risks over long time spans, including floods, wildfires, tornadoes, snow, ice accretion, extreme temperatures and precipitation, and storms of various intensities. Global climate change creates additional challenges for effectively operating and maintaining the transit system in the short-term (2030s), medium-term (2050s) and long-term (2080s). Infrastructure assets are designed to perform within a wide range of climatic conditions throughout the course of their expected lifecycle and may fail when critical thresholds are exceeded during extreme weather events. Unless improvements are made in operations, capital planning, and/or design standards, infrastructure will be at greater risk of failure with climate change (Figure 4). In the past, when climate was relatively stationary, the "coping range" of infrastructure assets was likely to be large enough to handle a vast majority of weather conditions, with critical thresholds being exceeded only on rare occasions. Such events might cause assets to fail, with consequences going beyond damage to assets, and extending to safety concerns, on-time performance, service disruptions, reputation, and financial costs. In the latter case these failures could trigger Force Majeure in service delivery contracts, placing operators in the position of receiving relief in compensation for damaged assets, lost revenue, or costs incurred before full service is restored.

However, in recent years as the impacts of a changing climate are already being felt, critical thresholds are being exceeded more often, and there is growing recognition that existing assets and design standards are becoming less capable to manage these new extreme conditions. Climate change is expected to bring an increase in more extreme weather events where critical thresholds will be exceeded more often, where "Acts of God" may occur more frequently, placing safety, service delivery, and financials at unacceptable levels of risk. Taking climate change into account, embedding higher design standards into new infrastructure assets where critical thresholds are also higher than in the past can help increase the coping range, in addition to implementing improvements in operations and capital planning. By increasing the coping range that is informed by climate change projections, future extreme events that would have previously exceeded critical thresholds would now be manageable, ensuring that business continues as usual, with expectations of minimal impacts on assets, safety, service delivery and financials. As always, extreme weather events that exceed higher critical thresholds and result in asset failure may still occur, but with appropriate future planning, these will be back to being considered as rare occurrences, wherefor which emergency preparedness and business continuity planning can also help manage residual risks. Further, as extreme weather events become more frequent and intense, as temperatures warm, so will there be potential benefits (e.g. becoming less cold), that also need to be considered.

Having accurate and credible climate change data and projections thus becomes particularly important not just for managing changes in averages and extreme weather events, but also changes in variability and expected normal distribution of conditions. Cascading and cumulative effects may also need to be considered, whereby flooding is caused not just by more intense rainfall, but due to rain on snow events, sudden spring freshette caused by unusually warm temperatures after a heavy snow fall winter season etc. Having guidance and clarity regarding what climate change data to use and where to find this information is essential to managing future climate risks.

How well infrastructure is designed and constructed to take climate change into account could have significant implications for the cost of new infrastructure, yet any shortfall in design standards could result in climate-related risks being transferred to those managing the assets, and responsible for the annual maintenance of that asset, and the day to day operations and delivery of service (Figure 5). Finding the optimal mix of design, capital planning, maintenance and operation of new infrastructure assets then becomes the goal, which would greatly benefit from evaluating and assessing climate risks and using the most appropriate climate change data.

Endnotes

1 See IBC 2020 Facts, “Catastrophic Losses”, pp.18-26

2 Canadian Centre for Climate Services, climatedata.ca

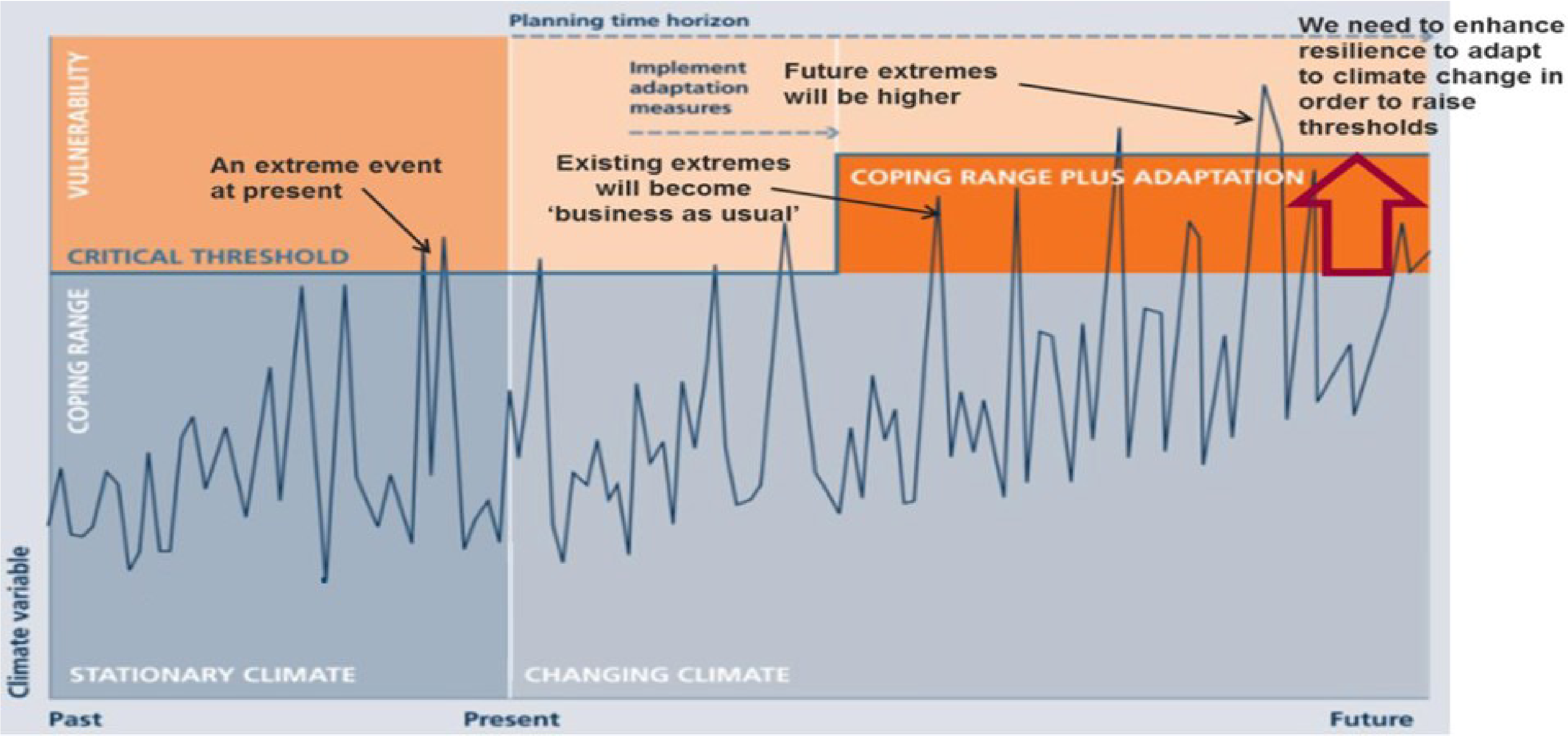


Figure 4: Coping thresholds and the need to manage unacceptable risks. Source: Figure 8: Coping thresholds and the need to manage unacceptable risk, in Network Rail (2017) Safety, Technical and Engineering: Weather Resilience and Climate Change Adaptation Strategy 2017-2019, p. 13; adapted from Figure 3.1 in Willows, R. and R. Connell (eds) (2003) Climate adaptation: Risk, uncertainty and decision-making, UK CIP Technical Report, p. 73; , see also Figure 3: Adaptation will increase the coping range, making systems more resilient, and therefore less vulnerable, to climate change, in Warren and Egginton (2008) “Chapter 2: Background Information: Concepts, Overviews and Approaches”, in Lemmen, D.S., Warren, F.J., Lacroix, J. and Bush, E. (eds) From Impacts to Adaptation: Canada in a Changing Climate 2007 (Ottawa: Government of Canada).

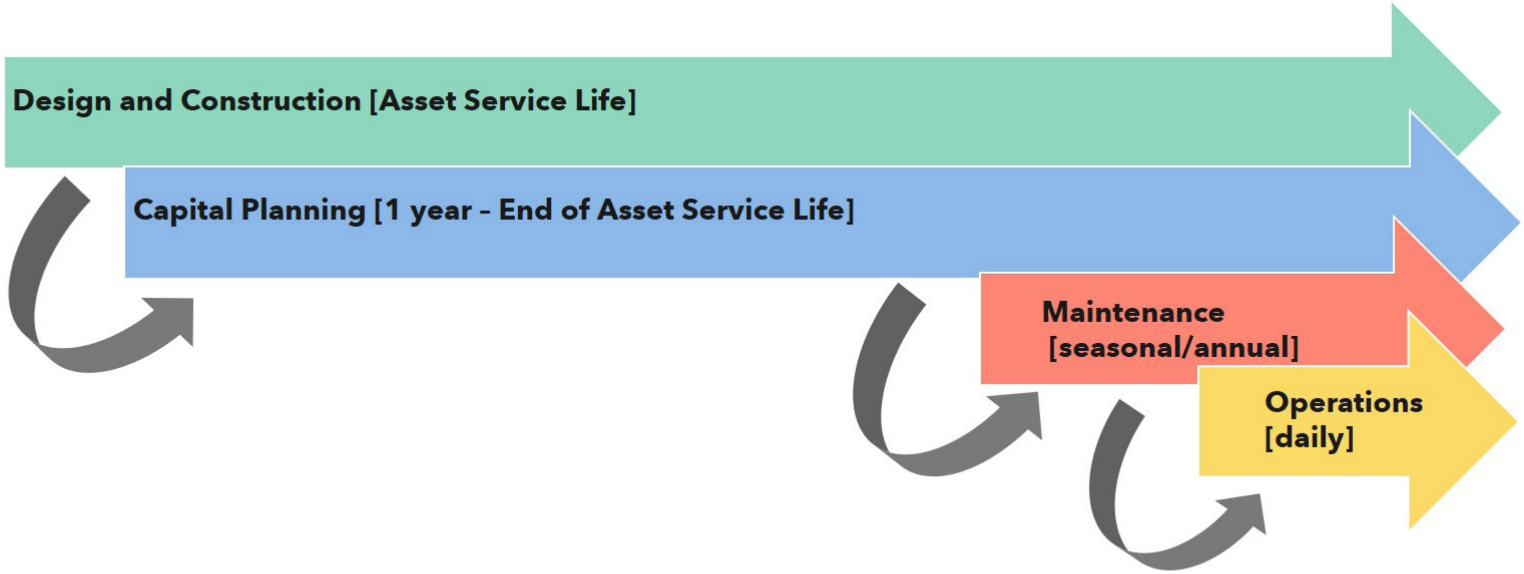


Figure 5: Any insufficient action to address climate risk and resiliency within a business function has the potential to shift/transfer a disproportionate burden of risk to another business function. This typically has the biggest impact upon Operations. Note: figure is for illustrative purposes only.

APPENDIX C: IPCC PROJECTIONS

Climate change adaptation is the practice of implementing actions to address projected climate changes and impacts. Adapting transit infrastructure to these impacts is critical to alleviating potential damage, disruptions in service, and other concerns. Consideration of impacts, along with other economic, social and environmental factors, will result in transit infrastructure that is resilient and reliably maintains operational capacity, using resources that are invested wisely to protect current and future investments.

In the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, scenarios were developed that reflected the radiative forcing that would result by 2100 from achieving certain atmospheric concentration levels of Greenhouse Gases. These are known as Representative Concentration Pathways (RCPs). These evolved from scenarios that were based on economic, demographic and technological considerations, otherwise known as SRES (Special Report on Emissions Scenarios) published in 2000 to make projections of future climate change. The upcoming Sixth Assessment Report of the IPCC will be based on an updated and expanded suite of climate models (CMIP6 – Coupled Model Intercomparison Project 6 group of models), as well as reveal new scenarios. The Shared Socioeconomic Pathways will represent a hybrid of these two approaches, noting that the actual projections from each of three approaches are quite similar. An update to this standard will be issued after the IPCC Sixth Assessment Report is released. It is anticipated that there will be a lag before climate data portals will be updating their climate change projections with the latest IPCC reports.

There are four Representative Concentration Pathways that have been produced ranging from a stringent emission reduction scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0) and one scenario that with very high GHG emissions (RCP8.5):

i. RCP2.6: This is a low emissions pathway that leads to a very low CO2e concentration levels in the atmosphere of approximately 490 ppm. It is a “peak-and-decline” scenario, where its radiative forcing level first reaches a value of around 3.1 W/m2 by mid-century and returns to 2.6 W/m2 by 2100. In order to reach such radiative forcing levels, GHG emissions are reduced substantially, over time.

ii. RCP4.5: This is a low-intermediate emissions pathway in which global emissions peak and begin to decline by ~ 2035, with CO2e concentration levels reaching 650 ppm, resulting in a stabilization of radiative forcing of 4.5 W/m2 shortly after 2100;

iii. RCP6.0: This is a high-intermediate emissions pathway in which global emissions peak and begin to decline by ~ 2060, with CO2e concentration levels reaching 850 ppm, resulting in a stabilization of radiative forcing of 6 W/m2 shortly after 2100; and

iv. RCP8.5: This is a high emissions pathway in which global emissions of GHGs increase over time, with CO2e concentration levels reaching 1370 ppm, resulting in radiative forcing reaching 8.5 W/m2 by 2100 and continuing to rise.

While each of these scenarios could lead to changes in global mean temperatures of 1.5˚C, 2.4˚C, 3.0˚C and 4.9˚C respectively by the end of this century, in the Greater Golden Horseshoe area average temperatures could increase 5.3˚C (averaged over the last 30 years of this century) under a high emissions scenario.

The deviation of temperature and other climate variables is very small among the different RCP scenarios from the historical baseline period up to 2040 and even 2050, reflecting delays in how the climate will react to changes in GHG emissions and CO2e concentration levels in the atmosphere. However, climate change projections begin to noticeably separate by 2050 if not before and deviate substantially by 2100 (Figure 6).

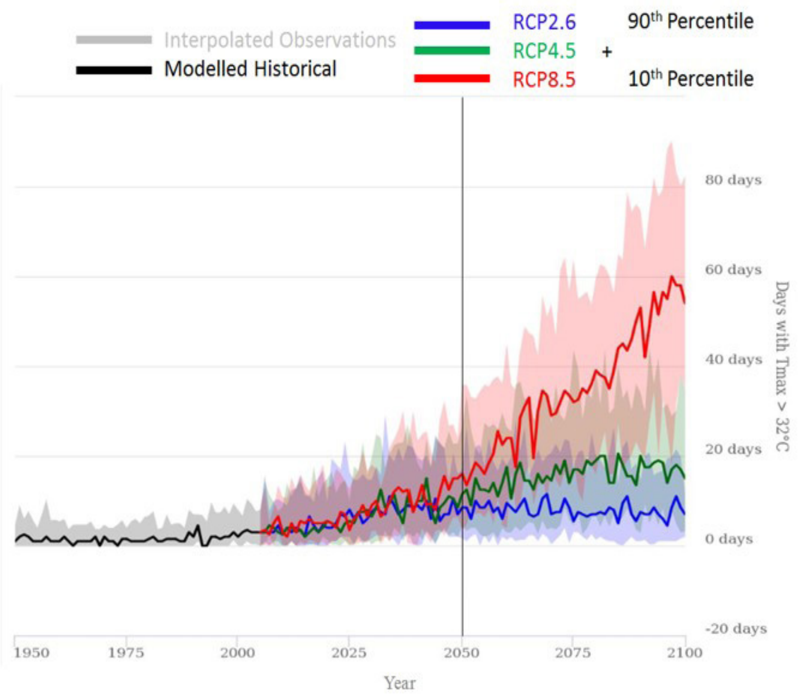


Figure 6: The number of days with a maximum temperature greater than 32˚C for Toronto Island. Three RCP scenarios are represented, RCP2.6, RCP4.5 and RCP 8.5. Source: climatedata.ca

APPENDIX D: STANDARD APPLICATION

A previous study was conducted applying the PIEVC Protocol to a selection of representative assets owned and operated by Metrolinx (2 stations, 2 facilities (bus and rail), and segments of two rail corridors). In this study there were 12 climate parameters and 21 critical thresholds considered, using the 50th percentile for RCP8.5 projections to 2050 (Table 1). Figure 1 details the process necessary to produce the results of a climate vulnerability and risk assessment using the PIEVC Protocol, whereas Figure 4 illustrates the climate data that was actually used in the Metrolinx PIEVC study. The red text in Figure 7 highlights the climate data used to inform the PIEVC study, and the dark bands represent where additional climate data may be needed, drawn from the climate sources identified in Appendix A.

Users of climate data and projections will have specific needs that apply to the asset or system that they are assessing and given its design lifecycle they may require their own unique set of climate parameters and critical thresholds. From assets with shorter design lifecycles historical trends and projections to 2030 may be appropriate, whereas for other assets with longer design lifecycles projections to 2080 and beyond might be required. In either case assessors of climate risk can draw upon the 2050 projections developed for the original PIEVC analysis, and supplement this information by adding additional climate data (e.g. upper and lower percentiles) that is provided through the publicly accessible portals, or secured through private sector firms that offer a suite of climate

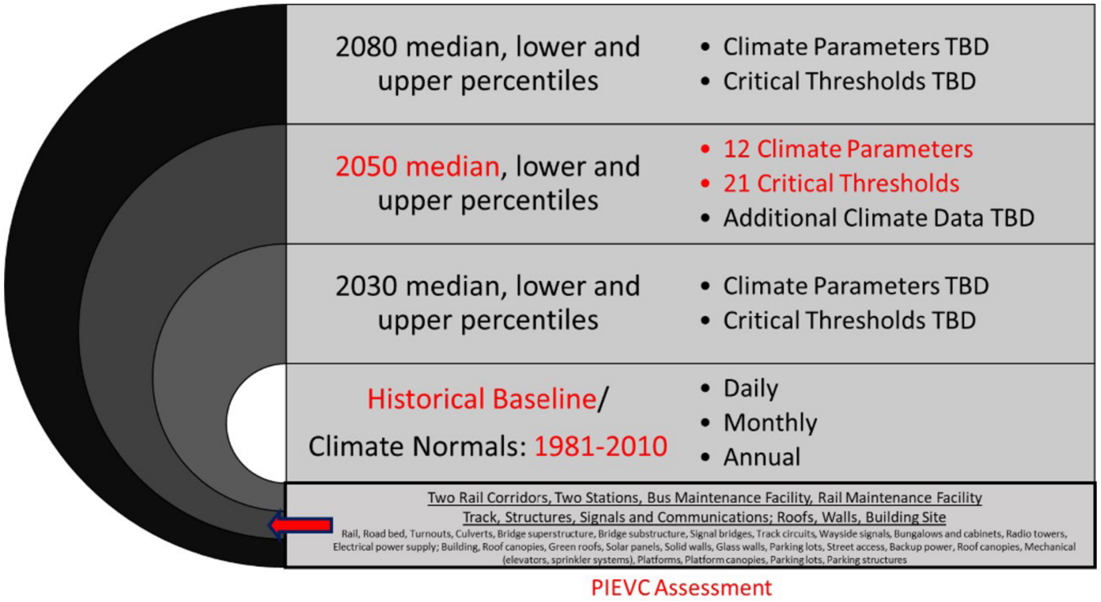
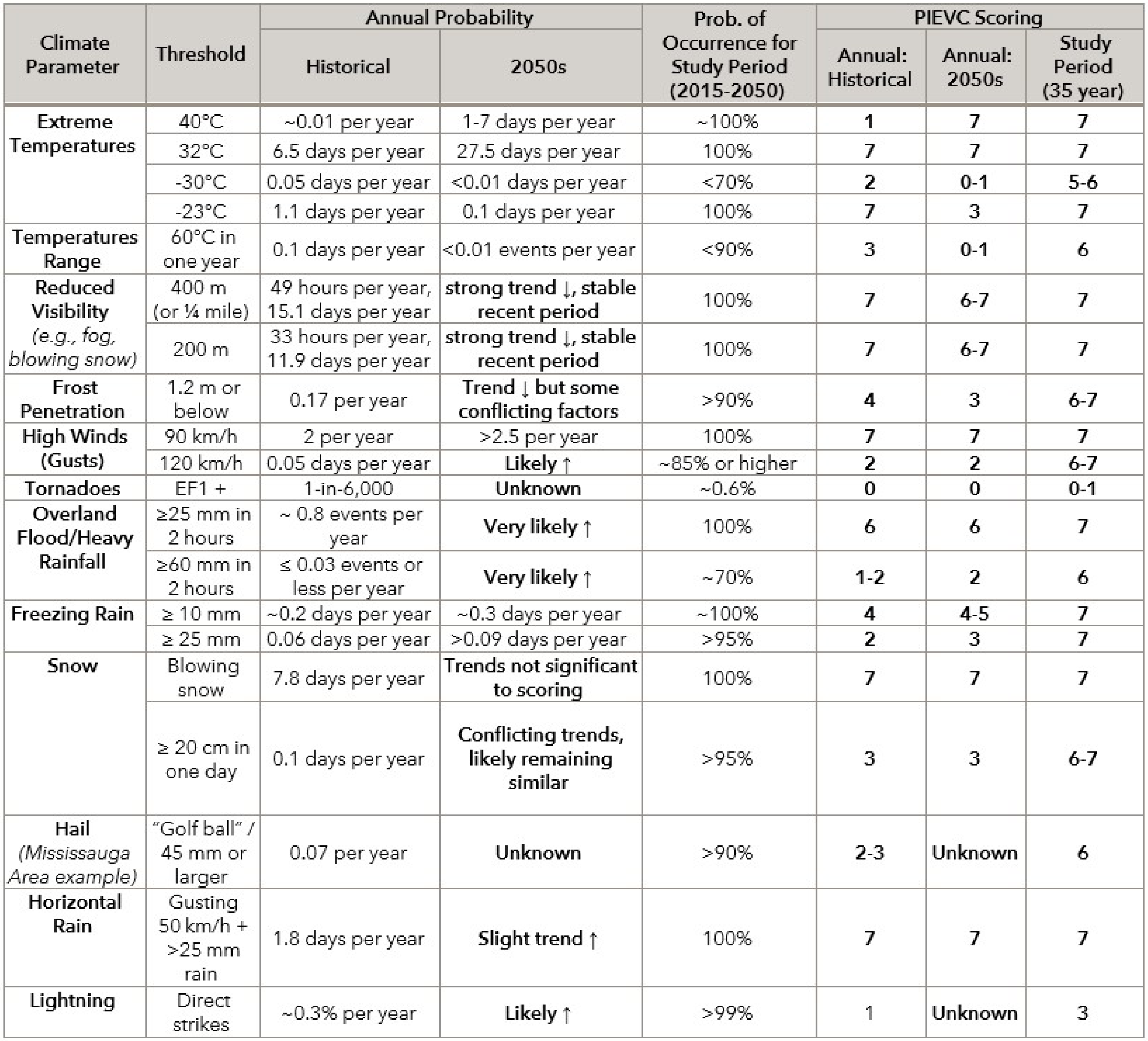


Figure 7: Using climate data to inform a PEIVC protocol. The dark rings represent climate data and associated climate portals.



Climate Parameter	Threshold	Annual Probability		Prob. of Occurrence for Study Period (2015-2050)	PIEVC Scoring		
		Historical	2050s		Annual: Historical	Annual: 2050s	Study Period (35 year)
Extreme Temperatures	40°C	~0.01 per year	1-7 days per year	~100%	**1**	**7**	**7**
	32°C	6.5 days per year	27.5 days per year	100%	**7**	**7**	**7**
	-30°C	0.05 days per year	<0.01 days per year	<70%	**2**	**0-1**	**5-6**
	-23°C	1.1 days per year	0.1 days per year	100%	**7**	**3**	**7**
Temperatures Range	60°C in one year	0.1 days per year	<0.01 events per year	<90%	**3**	**0-1**	**6**
Reduced Visibility *(e.g., fog, blowing snow)*	400 m (or ¼ mile)	49 hours per year, 15.1 days per year	**strong trend ↓, stable recent period**	100%	**7**	**6-7**	**7**
	200 m	33 hours per year, 11.9 days per year	**strong trend ↓, stable recent period**	100%	**7**	**6-7**	**7**
Frost Penetration	1.2 m or below	0.17 per year	**Trend ↓ but some conflicting factors**	>90%	**4**	**3**	**6-7**
High Winds (Gusts)	90 km/h	2 per year	>2.5 per year	100%	**7**	**7**	**7**
	120 km/h	0.05 days per year	**Likely ↑**	~85% or higher	**2**	**2**	**6-7**
Tornadoes	EF1 +	1-in-6,000	**Unknown**	~0.6%	**0**	**0**	**0-1**
Overland Flood/Heavy Rainfall	≥25 mm in 2 hours	~ 0.8 events per year	**Very likely ↑**	100%	**6**	**6**	**7**
	≥60 mm in 2 hours	≤ 0.03 events or less per year	**Very likely ↑**	~70%	**1-2**	**2**	**6**
Freezing Rain	≥ 10 mm	~0.2 days per year	~0.3 days per year	~100%	**4**	**4-5**	**7**
	≥ 25 mm	0.06 days per year	>0.09 days per year	>95%	**2**	**3**	**7**
Snow	Blowing snow	7.8 days per year	**Trends not significant to scoring**	100%	**7**	**7**	**7**
	≥ 20 cm in one day	0.1 days per year	**Conflicting trends, likely remaining similar**	>95%	**3**	**3**	**6-7**
Hail *(Mississauga Area example)*	"Golf ball" / 45 mm or larger	0.07 per year	**Unknown**	>90%	**2-3**	**Unknown**	**6**
Horizontal Rain	Gusting 50 km/h + >25 mm rain	1.8 days per year	**Slight trend ↑**	100%	**7**	**7**	**7**
Lightning	Direct strikes	~0.3% per year	**Likely ↑**	>99%	1	**Unknown**	3

Table 1:Results of Metrolinx PIEVC Protocol for 2 stations, 2 facilities and segments of 2 rail corridors. 12 climate parameters were considered with 21 critical thresholds for RCP8.5 projections to 2050.