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Adaptation Return On Investment (RoI) Project

Task 9 : Final Toolkit Packaging Reference Guide for Methods and Supplemental Tool

Defence Research and Development Canada (DRDC)
Public Safety Canada (PSC)

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1. Introduction

1.1 Purpose

The Adaptation Return on Investment (RoI) Project is part of the Canadian Safety and Security (CSS) Program, managed by Defence Research and Development Canada (DRDC) CSS in collaboration with Public Safety Canada. AECOM and the Institute of Catastrophic Loss Reduction (ICLR), in partnership with Public Safety Canada, City of Ottawa, City of Clarence-Rockland and the City of Calgary, are developing an Adaptation RoI Toolkit for assets and infrastructure to become more resilient to disaster risks and climate change impacts, by building on the best available tools and methods. The cities of Toronto, Vancouver and Montreal have been identified as supporting partners to the project.

The purpose of the Adaptation RoI Reference Guide is to provide municipalities and users with an overview of the application, the toolkit usage, the return-on-investment analysis, and the location of toolkit guidance documents and helpful information. This guide also outlines sources of additional information needed to use the Adaptation RoI Toolkit to estimate the RoI for a single project or multiple projects.

1.2 Glossary of Key Terms

For reference, a glossary of key terms is provided using definitions identified in the FEMA BCA Reference Guide [1].

Benefits (returns): Future losses prevented or reduced by an adaptation project. The returns counted in the RoI are in the present value of the sum of the expected annual avoided damages over the adaptation project useful life.

Benefit-Cost Analysis (BCA): An analysis that estimates the potential positive effects of an adaptation measure and comparing them to the cost of the measure. With the FEMA BCA modules, the positive effect is a reduction in future damages from natural hazards; this is the benefit of adaptation.

Benefit-Cost Ratio (BCR): The ratio is the project benefits divided by the project cost and is the result of a BCA. A BCR greater than 1.0 indicates the benefits are greater than the cost and the project is cost-effective.

Building Replacement Value (BRV): The cost to replace a building with a functionally equivalent building of the same size and quality, based on the current cost of labor and materials. The BRV is not the same as the current market value of the building.

Depth Damage Function (DDF): A way of expressing expected flood damages for various types of buildings, their contents, or their functions at different water depths. For floods, this relationship is expressed as depth versus percentage damage to the element being considered.

Displacement Costs: The costs when occupants (of residential, commercial, or public buildings) are displaced to temporary quarters while damage is repaired. These costs include rent and other monthly costs, such as furniture rental and utilities, and one-time costs, such as moving and utility hook-up fees.

Hazard: In the context of an adaptation project, a naturally occurring phenomenon that poses a risk of asset damages, economic losses, or casualties.

1 Federal Emergency Management Agency, Final BCA Reference Guide, June 2009. Retrieved https://www.fema.gov/sites/default/files/2020-04/fema_bca_reference-guide.pdf

Hazard Adaptation: Reduction of the risk of natural hazards through the implementation of projects or procedures that reduce or prevent future damages.

Indirect Benefits: In the context of an adaptation project, the reduction in damages from natural hazard events that are not directly caused by the hazard itself.

Loss of Function Damages: Costs and direct economic impacts that occur when physical damages are severe enough to interrupt the function of a building or other facility.

Loss of Public Services: The cost of providing services, plus a continuity premium, for services that are critical to immediate disaster response and recovery.

Monetize: To express in terms of money to compare actions or results of actions that are not comparable in other terms.

Project Useful Life (PUL): The estimated amount of time that the adaptation project investment will be effective.

Recurrence Interval: The average or mean time in years between the expected occurrence of an event of specified intensity. The mean recurrence interval is known as the return period, which is the average or mean time in years between the expected occurrences of an event of specified intensity.

2. Impact Categories

The benefits derived from an adaptation project correspond to any avoided future costs or losses and other benefits. These avoided future costs/losses and other benefits can include avoided economic losses, social benefits, environmental benefits, and cultural benefits. The impact categories considered in this RoI Toolkit are illustrated in the following subsections. More details on benefit estimations for each of the hazard are provided in Sections 3.2 to 3.5.

For all four impact categories that will be analyzed — Economic, Social, Environmental, and Cultural — a distinction will be made from the direct or indirect relationship to the natural hazard affecting the selected asset. Also, each impact category described will be evaluated under the hazard exposed and the asset type selected. Not every category listed will be available or applicable to all hazards considered or asset types defined. The RoI Toolkit will match the potential and most likely category needed based on the information provided by the user. A detailed section discussing impact categories calculations is presented below. The standard data types and corresponding values and sources are summarized in Appendix A.

2.1 Economic Impact Calculation

As previously indicated, economic categories will be composed of the direct and indirect dollar losses resulting from the natural hazard selected by the user. The distinction between direct and indirect (damages/losses) depends on the time interval between the occurrence of the natural hazard and the moment when (damages/losses) caused by this natural hazard are (observed/noted/reported). Asset, content, or property (damages/losses) that are (observed/notes/reported) as the hazard event is occurring are typically considered as direct impacts. On the other hand, the loss of services, business interruptions, or temporary service costs are categorized as indirect impacts resulting from the natural hazard selected by the user. For some hazards, such as the wind or ice storms, damages to the property or to the asset are considered as direct impacts, whereas damages to contents are considered as indirect damages. This is based on the assumption that damages caused to façades or enclosed protections are primarily the result of the natural hazard selected by the user, whereas the damages to the contents of these assets were primarily caused by exposure to subsequent rainfall or other elements.

Table 2-1 below summarizes the economic impact categories captured in the RoI Toolkit and includes a summary of the calculation methods, affected asset categories, and applicable natural hazards.

Table 2-1: Economic Impact Categories

Economic Impact	Format	Application	Calculation Method	Affected Asset Category	Hazard Covered
Asset Value	Present-day dollar asset value.	Applicable to modeled damage modules. Asset and content values are determined based on the building replacement vale.	Dollar value related to the damaged caused to the asset	All water, transportation, and building and facilities asset categories.	All
Content Value	Present-day dollar asset value.	Applicable to modeled damage modules. Asset and content values are determined based on the building replacement value.	Dollar value related to the damaged caused to the content equipment and furniture	Some water assets and all building and facilities asset categories.	All

Economic Impact	Format	Application	Calculation Method	Affected Asset Category	Hazard Covered
Loss of Service/ Function	• Days to repair or loss of service. • Number of people affected. • AADT. • Vehicle miles traveled. • Road speed limits. • Value of unit of service.	Benefits associated with loss of function are available for utilities (electrical, potable water, wastewater) and for transportation assets. For transportation infrastructure, the toolkit calculates values based on additional distance (VMT) and time (VKT) per trip from road closure.	Estimated dollar value of the loss of service due to the damage caused. Population and service affected will vary depending on the asset type and hazard.	• All water and transportation asset category. • Some building and facility asset categories.	All
Business Loss	• Days to repair or loss of service. • Present-day dollar values	Benefits associated with business loss are available for non-residential assets, classified as displacement costs.	Estimated dollar value of the loss of business operation due to the damage caused.	All building and facilities asset categories.	• Flooding • Wind • Ice storm • Extreme temperatures
Climate Change Impacts	Estimated magnitude of climate change.	Applicable to hazards for which acceleration due to climate change can be estimated.	Escalates average damages pursuant to the magnitude (rate of change) of climate change.	All building and facilities, transportation, and water asset categories.	• Flooding • Wind • Ice Storm • Extreme temperatures

2.2 Social Impact Calculation

Only injuries and fatalities will be accounted for as direct social impacts. Mental health and anxiety, lost productivity, and displacement costs will be considered as indirect impacts. The monetization of injuries and fatalities damage will be supported by the user safety record for the hazard and the asset selected. The adaptation projects information will be encouraged to provide safety improvement, so safety hazards can be effectively reduced. Displacement cost will require an additional level of calculation, as it will account not only for the people affected, either by the lack of an essential service or by the inability to reside in a facility, but also the potential cost incurred by them for the time required to complete repairs or restore the service. The cost incurred will be based on the per diem rate set by the Canada Revenue Agency for meals, lodging, and incidentals allowances [2].

Health issues resulting from a natural hazard, such as mental health and anxiety and lost of productivity, have become a major field of study in the last decade. FEMA has incorporated and initiated a research program to cover mental stress and anxiety levels developed because of flooding and other natural hazard events. The RoI Toolkit will include the FEMA's generated default values for mental stress and anxiety treatment [3] coverage as default. Understanding that there are major differences between the Canadian and the American health systems, the research team considers that although most of provinces and federal government health plans cover basic needs, major and basic mental health treatments are not covered by these public plans and are only partially covered by private insurance plans; therefore, the value provided by FEMA will be a good approximation of the benefits associated with the avoided displacement of residents. A Canadian study to update and expand on the subject is encouraged.

[2] https://www.canada.ca/en/revenue-agency/corporate/about-canada-revenue-agency-cra/travel-directive/appendix-b-meals-allowances-oct-2020.html

[3] 2014, FEMA, Benefit Cost Analysis Toolkit Sustainment and Enhancement, Updated Social Benefits Methodology Report – Final.

Tableau 2-2 below summarizes the main social impact categories, format, type of asset impacted, and impact calculation methods.

Table 2-2: Social Impact Categories

Social Impact	Format	FEMA BCA Toolkit	RoI Toolkit	Calculation Method	Affected Asset Category	Hazards Covered
Additional Living expenses	Number of people affected.	Based on number of households and number of residents (residential) and first floor area and building size (non-residential).	Based on number of households and number of residents (residential) and first floor area and building size (non-residential).	Calculated by applying standard per diem rates for lodging and meals and incidentals to households and residents displaced, respectively. Duration of displacement is a function of depth of inundation.	Water (people affected by the lack of service) and some building and facilities.	All
Injuries and Fatalities	Historic safety records.	Based on population at risk. Applicable to projects that address hazards that have little or no warning time.	Based on population at risk. Applicable to projects that address hazards that have little or no warning time for modeled damages module. Applicable to all hazards for DFA module.	Estimated historic number of people affected by injuries and fatalities caused by the hazard event, multiplied by the monetized values assigned for injuries or fatalities.	Some transportation assets and building and facilities.	All modules
Post Traumatic Stress Disorder	Number of people affected.	Based on number of residents and number of residents that work. Applicable to residential structures only.	Number of residents and number of employed residents affected.	Assigns an average cost to treat mental health and anxiety per individual affected and average lost productivity per employed individual affected.	Water (people affected by the lack of service) and some building and facilities.	All
Hospitalization cost	Number of people affected.	Not covered	Population affected	Using the attributable fraction per disease (Hypertension, Stroke, Coronary)	Nature-Based Solution	Extreme Heat

2.3 Environmental Impact Calculation

Environmental impacts assessed include benefits resulting from a change in land use, for certain adaptation measures. The ecosystem services and land cover categories selected for the tool are those used and described by FEMA[4]. FEMA unit values have been adapted to represent the Canadian context from various sources (see Appendix A). Table 3-4 presents the main environmental impact categories that can be triggered by certain nature-based adaptation measures. As an example, when acquiring land, reforestation or restoration actions, improvement, or creation of wooded or vegetated areas will allow the toolkit user to benefit from ecosystem benefits in the benefits-costs calculation.

Below is a summary of the environmental impact categories discussed, including their description, the calculation method, and the affected asset category. For all environmental impact categories listed, the estimated area affected by the project is subjected to the pre-calculated ecosystem service values to account for natural assets gained with adaptation project.

Table 2-3: Environmental Impact Categories

Environmental Impact	Description	FEMA BCA	RoI	Calculation Method	Affected Asset Category
Air quality	Removing air pollutants, such as particulate matter or ozone, from the atmosphere	Project area (in acres or square feet).	Project area (in square meters, hectares or number of urban trees)	Can be captured by certain large-scale nature-based adaptation measures that involve a change of land-cover (ha). Can be captured by urban green infrastructures.	- Forests - Green open spaces - Riparian areas - Green roofs - Bioretention - Urban trees
Climate regulation	Process of removing and storing carbon dioxide (CO_2) from the atmosphere or by avoiding carbon emissions	Project area (in acres or square feet).	Project area (in square meters, hectares, or number of urban trees)	Can be captured by certain large-scale nature-based adaptation measures that involve a change of land-cover (ha). Can be captured by urban green infrastructures.	- Forests - Green open spaces - Riparian areas - Inland wetlands - Green roofs - Permeable pavements - Bioretention - Urban trees
Erosion control	Benefits and avoided costs related to erosion control	Project area (in acres or square feet).	Project area (in square meters or hectares)	Can be captured by certain large-scale nature-based adaptation measures that involve a change of land-cover (ha).	- Forests - Green open spaces - Riparian areas

[4] FEMA. (2022). Economic Benefit Values for Green Infrastructure. And FEMA. (2022). Ecosystem Service Value Updates.

Environmental Impact	Description	FEMA BCA	RoI	Calculation Method	Affected Asset Category
Habitat	Providing shelter and refugia to maintain biological diversity	Project area (in acres or square feet).	Project area (in square meters, hectares, or number of urban trees)	Can be captured by certain large-scale nature-based adaptation measures that involve a change of land-cover (ha). Can be captured by urban green infrastructures.	- Green open spaces - Riparian areas - Inland wetlands - Green roofs - Bioretention - Urban trees
Building energy savings	Reduction in energy use for heating and cooling by insulating buildings from large changes in temperature	Project area (in acres or square feet).	Project area (in square meters or number of urban trees)	Can be captured by urban green infrastructures.	- Green roofs - Urban trees
Drought risk reduction	Mitigating drought risk by increasing water supply through groundwater infiltration	Project area (in acres or square feet).	Project area (in square meters or number of urban trees)	Can be captured by urban green infrastructures.	- Permeable pavements - Bioretention - Urban trees
Heat risk reduction	Reducing the risk of human heat-related illness by reducing local temperatures through shade and evapotranspiration	Project area (in acres or square feet).	Number of urban trees	Can be captured by urban green infrastructures.	- Urban trees
Property value improvement	Increase in home sales price because of proximity to green infrastructure	Project area (in acres or square feet).	Project area (in square meters or number of urban trees)	Can be captured by urban green infrastructures.	- Green roofs - Bioretention - Urban trees
Reduction of stormwater volume and quality	Reducing the quantity of stormwater runoff and pollutant loading through increased infiltration	Project area (in acres or square feet).	Project area (in square meters, hectares, or number of urban trees)	Can be captured by certain large-scale nature-based adaptation measures that involve a change of land-cover (ha). Can be captured by urban green infrastructures.	- Forests - Green open spaces - Riparian areas - Inland wetlands - Green roofs - Permeable pavements - Bioretention - Urban trees

3. RoI — Toolkit Structures

The RoI prototype includes four modeled damage impact models and three damage frequency tabs. Figure 3-1 shows the data requirements and options for each natural hazard. The modeled damage has three options (wildfire, ice storm and wind) that can be directly used for building and facilities (depicted as residential and non-residential building in the toolkit). To use the riverine flood modules, the user must have relevant hydrology and hydraulic data (see Section 3.2.1 for more information on flood data requirement). In the wildfire option, input data will be ingested directly in the future version of the prototype. Default data are already ingested for the wind and ice storm options, so the user can use the modeled damage for any location in Canada. In the current prototype version, default climate change mode is incorporated for the four natural hazards in modeled damage but is not accounted in the damage frequency analysis (DFA) modules. Extreme temperatures can only be used if historical data are available.

The DFA modules require the user to integrate data on historical damage for at least three events. Three different sheets are available for specific road and bridges projects, utilities and building and facilities. The user can rely on the Canadian Disaster Database for data on past hazards or on other archives documenting the cost of disaster.

The project configuration tabs will allow the user to navigate and be redirected to the appropriate sheet. The benefit-cost analysis would output the project benefits, the net present value the benefit-cost ratio as well as the return on investment.

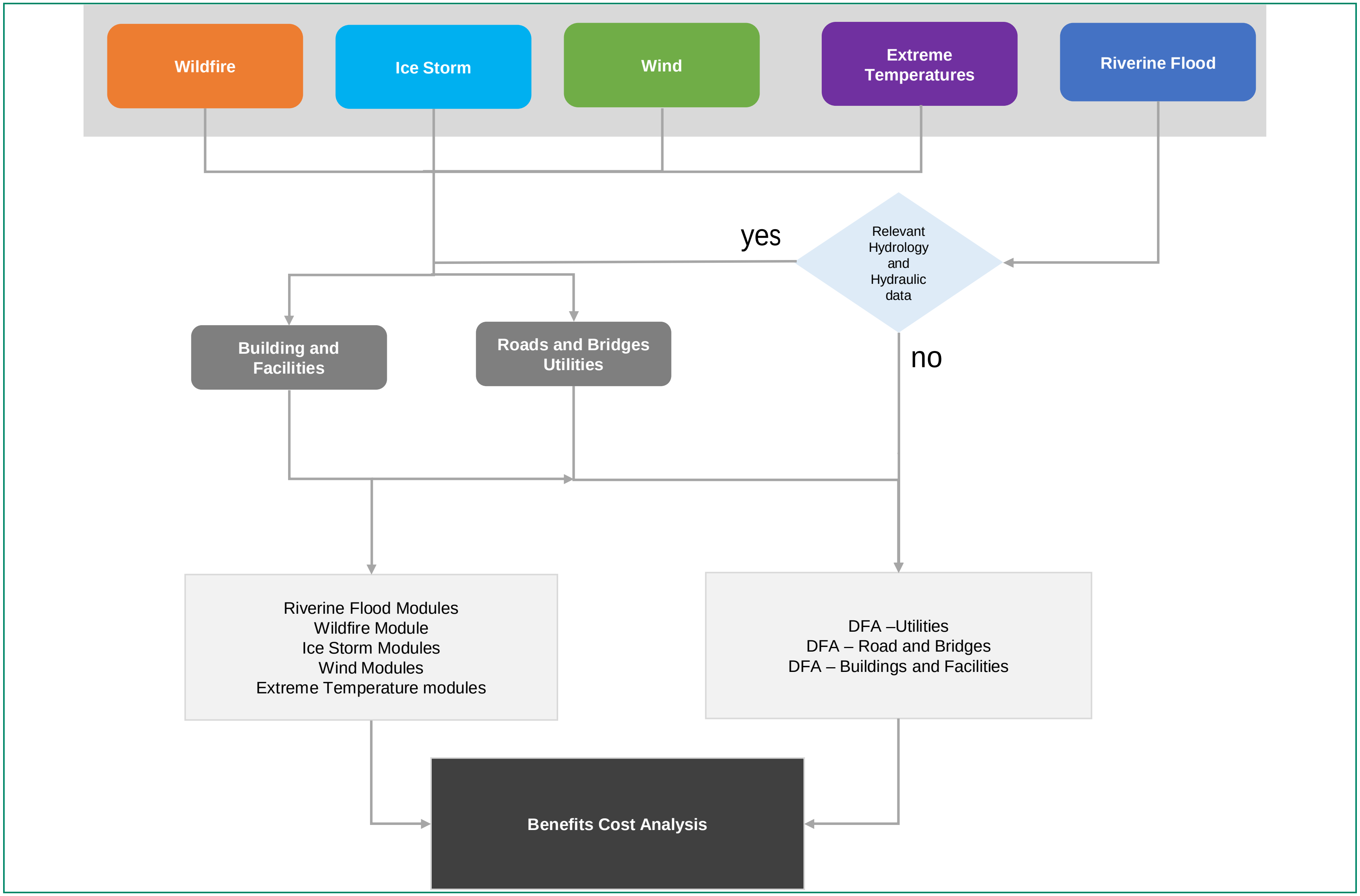

Figure 3-1: Overview of the RoI Toolkit

3.1 Project Configuration

The Project Configuration sheet is the main panel where the user can enter vital information about the location of the project, the adaptation projects and related costs. Based on the information entered, the user will be redirected to the appropriate modules within the toolkit. A color chart as been developed to guide the user to indicate which information need to be filled. The Table 3-1 illustrates the color chart associated to each color within the toolkit.

Table 3-1: Color Chart Used in the RoI Toolkit

Color Chart	Meanings
	Enter Value
	Default Value: can be override
	Default Value: impossible to override
	Missing Information: need to be fulfilled

3.1.1 Adaptation Project Description

Users need to enter basic information regarding hazard, adaptation projects and project location:

Hazard Type: The following Hazard Type are available within the toolkit:

- Flood
- Wildfire
- Wind
- Ice Storm
- Extreme Temperatures
- Historical event - Multihazard

Damage and frequency relationship based on:

Modeled Damages: The BCA results for the selected hazard will be modeled based on probabilistic damage function. The Modeled damage only apply to building and facilities for riverine flood, wildfire, wind, and ice storm.

Damage Frequency Assessment: User should select this option in the following cases:

- Insufficient data to use modeled damages (e.g.: no hydrology and hydraulics data).
- If the property structure type is not a building.
- The primary data are historic damages and losses and the dates (years) of those events.
- If extreme temperatures hazard is selected.

To use the Historical data, there must be at least three events, which means that the user only has the dates and damage amount documentation for each historic event.

Property Structure Type

Selections for the Property Structure Type include:

Building and Facilities That include the following option:

- **Residential Building** – select this option if the Property is a single- or multi-family residence.
- **Non-Residential Building** – select this option if the Property is an apartment building or non-residential. For non-flood projects, select this option if the proposed adaptation project seeks to mitigate the damage to and the loss of function/loss of service for a critical facility.

Utilities – select this option if the Property is a utility, such as electric, wastewater, or water utility. This option is only available for the DFA Modules

Roads and Bridges – select this option if the Property is a roadway, culvert, bridge, or related use. This option is only available for the DFA Modules.

Other – select this option if the Property does not fit any of the above Structure Types. This option is only available for the DFA Modules

Adaptation Action Type

The Toolkit hosts a default adaptation projects for each type of hazard; therefore, options will depend on the Hazard Type selection (flooding, wildfires, wind, extreme temperatures and ice storms). The table in appendix C presents the adaptation project library. The adaptation projects library classifies the adaptation according to the type of hazard, the components that are targeted by the adaptations and the different stakeholders that could be involved. The section 0 illustrate all the possible category of adaptation project.

Adaptation Projects

The adaptation project to be selected will be short-listed based on the Adaptation Action Type selected. The adaptation projects within the Toolkit are adapted to the Canadian reality and Canadian standards, such as CSA standards, Fire Smart, etc. The calculation of adaptation project costs will be undertaken for structural measures within the Toolkit by considering their costs and the project or structure's useful life. For non-structural adaptation projects, it is hard to establish default costs, therefore the user will have to input their own data for non-structural measure costs.

Incorporate Climate Change

The default climate change mode allows the user to account for climate change. The default value came from the project useful life (by the extraction of the corresponding anomaly based on the corresponding years), for the specific location entered. If the user has more precise data for climate change, the user needs to put "no" to the default mode and input his data in the Hazard Probability Parameters corresponding to the specified Hazard.

Enter Project Component Name

Within each hazard module a project component name is required. Users can have different project components inside the same project. Within the benefits panel, the project component will remain separate. For each module, users can enter multiple project components or simply enter one component and directly go to the benefit tabs.

3.1.2 Costs Estimation

Cost of an adaptation project should include construction costs, projected related cost such as permits, etc., maintenance costs during the project useful life. All project cost should be counted regardless of who is paying for them. In the RoI Toolkit, the cost estimation section inputs include:

Discount Rate: the discount rate is used to determine the present value of benefits. Discounting facilitates comparisons of benefits that may occur in the future to the costs of a project that most often occur immediately or in the near term.

Project Useful Life (in years): The PUL is the estimated amount of time (in years) that the adaptation action will be effective. It is one of the important parameters in the calculation because it establishes the timeframe to calculate benefits. Project maintenance cost may also be calculated using the project useful life if assuming the number of maintenance years is the same value as the project useful life. Please refer to **Appendix B** for standard values and expected service life for new Canadian municipal assets.

Project Evaluation Period (in years): Because there are limits in the utility of modeling project benefits over very large time scales, the project evaluation period should be set based on the expected project useful life.

Initial Project Cost ($): The Total Project Costs value includes all costs required for completing the project, which is more than just construction. For example, additional project costs could include land acquisition, design, permitting, construction labor and materials, construction oversight, quarterly report writing, subaward closeout, and others.

Annual Maintenance Cost ($): Annual maintenance costs are those costs necessary for the upkeep or repair of Adaptation project components so that the project maintains its originally designed and approved level of effectiveness ("effectiveness" meaning how much or how well the project will reduce risk when completed). Maintenance costs can include activities like road maintenance, drainage network inspections and debris removal, landscaping maintenance, and other types of site maintenance. Estimates can be provided by standard cost estimating software, contractors, engineering documents, or documentation from a reliable source such as a professional with relevant expertise.

Total Adaptation Project Cost ($): The Total Adaptation Project Cost is the Initial Project Costs value, plus the Annual Maintenance Costs. The future maintenance costs are discounted so that the present value is used in the calculation.

3.2 Flood Module

The Flood Module will account for the most frequent types of flooding occurring in Canada such as:

- Overbank flooding
- Flash flooding
- Snowmelt flooding
- Intense localized rainfall or prolonged rainfall occurring over a saturated surface
- Urban (including pluvial) drainage flooding
- Rain-on-snow flooding (combination of snowmelt and storm rainfall runoff)
- Ice jam flooding
- Natural dam (glacier or moraine) failures
- Man-made dam and levee failures

The assessment of riverine flood hazards requires:

- Data on return period for a specific flood event
- Data on depth of inundation for a specific flood event
- Asset information such as the first-floor elevation and the building replacement value.

Data on depth of inundation for various return periods are often necessary to estimate damages from flood events since these damages can be estimated by applying the depth of flood inundation to depth damage function (DDF) curves. These curves provide a ratio of (depth) inundation to damage for each general asset type. The flowchart (Figure 3-2) displays (flood hazard data requirements) and the hierarchy of information sources based on the amount of data available to the user.

3.2.1 Input Data

Data from Hydrology and Hydraulic Studies (H&H): Detailed H&H data gathered (by/under the supervision of) flood mapping experts and hydraulic engineers should be preferred over data coming from other (types of) sources. Before using H&H data, the user shall ensure that appropriate types of flooding and damage-causing event were selected. Output data from these studies may differ in terms of structure, return period, climate change (scenarios?), etc. For instance, software like HEC-RAS can provide direct outputs such as water depth grids for (specific/various) return periods, that can in turn be used to (estimate/derive) the depth of flood inundation for each asset under study.

National Flood Hazard Data Layer (NFHDL) - (ongoing work at NRCAN): The federal government is currently collecting all flood data across Canada, with the goal of harmonizing all data within one unified layer depicting floodway (20-year return period) and flood fringe (100-year return period). To extract water depth for each of the NFHDL scenarios, topographic data will be required. The elevation difference from the maximum flood extent in the area of interest and the elevation of the building footprint will give an approximation of the flood depth. It is recommended to use topographic data coming from a LiDAR to convert NFHDL flood extent to depth of flooding.

Environment Canada Hydrometric Stations: When there are no relevant flood data for the area of interest, data from variables, such as discharge and water levels, can be obtained from the nearest hydrometric station or the most adapted one for the area of interest. Hydrometric stations shall only be used for open-water flooding unless the data of the event have been correctly captured by the station. The exceedance probability of a specific event will need to be calculated from historical data at the station (generally more than 10 years of data are required). The user will need to know the level of flooding (for instance whether the water level reached the first floor during a certain flood event) or know the streambed elevation close to the asset location in conjunction with topographic data, to convert station water levels to flood depth.

Extraction of Damage Data from Local Knowledge: It might be possible to extract damage data for a specific asset from historical events in the area of interest. This method will skip the usual damage assessment using DDF and will provide only basic assumptions on the return period. It is also possible to extract damage based on visual inspection to use the DDF methodology. For example, the waterline with regards to the first-floor elevation can be extracted by visual inspection and ingest in the RoI Toolkit. FEMA has released a Preliminary Damage Assessment (PDA) pocket guide for that purpose[5]. This method should be used with caution and only if other types of data sources are unavailable.

Limitations Related to Flood Data Availability and Format

Flood mapping data and hydrometric data are scarce in Canada and are not organized into a standard structured. In some cases, the user will be required to enter information manually on past flooding events for the concerned assets as well as some basic hydraulic information on the flooding watercourse, such as the streambed elevation.

Ice jams considerations in flooding assessment: If flooding is caused by ice jams, the user will need to ensure that ice jams were accounted for within the H&H study. Under these circumstances, the user should not use data from Environment Canada hydrometric stations as rating curves (the water stage-discharge relationship) for a large number of these stations were not established under ice-cover conditions. It is worth mentioning that water level increases caused by ice jams might be negligible further downstream. The user can also consult the Canadian River Ice Database[6] to obtain data on specific events recorded at 196 stations across Canada.

Climate Change Considerations

In addition, data considering the impact of climate change on flooding does not exist in a uniform standard. Some H&H studies account for climate change, but those studies do not cover all of Canada. Once the information is available from H&H, the toolkit let the user account for climate change. In the meantime, the toolkit assess changes in extreme precipitation patterns and provide the user the ability to modify the water level by a certain percentage based on the magnitude of change. Therefore, flood impact assessment considering climate change in the toolkit will need to be treated with caution. The choice of whether to account for climate change or not is at the user discretion.

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[5] US Department of Homeland Security- FEMA: https://www.msema.org/wp-content/uploads/2021/03/fema_preliminary-disaster-assessment_pocket-guide.pdf

[6] Environment and Climate Change Canada: https://open.canada.ca/data/en/dataset/c5b58ccd-0011-4a80-8f24-034c86cbc14d

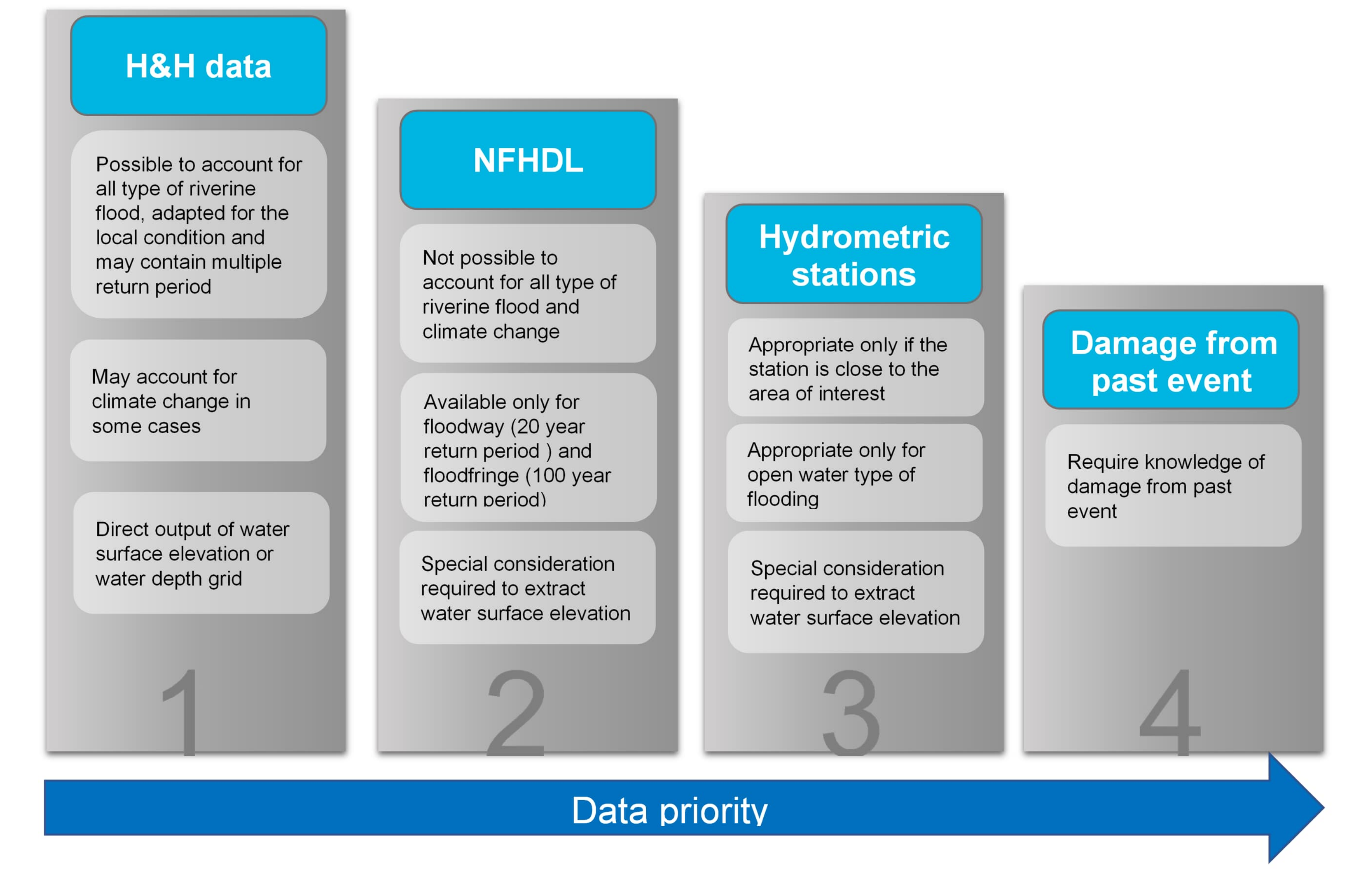

Figure 3-2: Flood Data Requirement and Data Hierarchy

3.2.2 Hazard Probability Parameters

The following section establishes the before-adaptation flood risk for the structure being mitigated. For project types like elevations and flood barriers, there is an additional input required about the elevation of these activities that are used to calculate the after-adaptation damages and losses.

Select Depth-Damage Function

A Depth-Damage Function (DDF) is used to estimate direct damage to a building based on the depth of flooding. The damage depending on the DDF selection, can be measured in percent of the BRV or in dollars per square metres. The DDF is also used to estimate displacement and loss of function at various flood depths. There is a separate DDF for each combination of Building Type, Basement, number of storeys etc. The Table 3-2 present all the DDF option within the prototype.

Table 3-2: Depth Damage Function (DDF) Option in RoI Prototype

	Depth Damage Function		
Type	**USACE-Generic** [7]	**IBI 2015** [8]	**Doyon et al. 2021** [9]
Residential Asset	Residential Split-Level Slab Mobile-Home	Residential Mobile-Home Apartments	Residential
Non-residential Asset	Apartments Convenience Store Fast Food Grocery Industrial Light Medical Office Non-Fast Food Office One-Story Recreation Religious Facilities Retail-Clothing Retail-Electronics Manufactured Home Schools Service Station Warehouse, Non-Refrigerated Warehouse, Refrigerated Retail-Furniture Hotel Hospital Protective Services Correctional Facility	General Office [10*] Medical Office Retail-Shoes Retail-Clothing Retail-Electronics Paper Products Hardware/Carpet Retail Misc Retail Furniture/Appliances Grocery Drugs Auto Hotel Restaurant Personal Services Financial Warehouse/industrial Theatres Institution Hospital	
Basement	Accounted for Residential asset	Accounted for Residential asset	Accounted for Residential asset

[7] FEMA (Federal Emergency Management Agency Department of Homeland Security), 2011.Supplement to the Benefit-Cost Analysis. Washington DC. 130 pages.

[8] IBI Group and Golder Associates Ltd. (2015). Provincial Flood Damage Assessment Study. Prepared for Government of Alberta ESRD - Resilience and Mitigation. 117 pages.

[9] Doyon et al (2021) Fonctions d'endommagement résidentiel relatives aux inondations de la rivière Richelieu. Unpublished.

[10] Within IBI 2015 the assets are different between Non-Residential curve for Structures and Contents. The table present the Non-residential curve for contents depict as Building Use within the toolkit.

Depth Damage Function			
Type	**USACE-Generic** [7]	**IBI 2015** [8]	**Doyon et al. 2021** [9]
Underground Parking	Not accounted	Accounted for Apartment and Non-Residential asset	Not accounted
Finished Basement	Accounted in the of the lowest floor Selection	Not accounted	Accounted
Number of Storeys	Accounted for Residential building	Accounted for Residential building and Apartment	Accounted
Access to Public Service	Not accounted	Not accounted	Accounted
Damage Unit	Percent	Dollar/ per square meters	Percent

Enter the Lowest Floor Elevation (LFE) of the Property (m)

If the **USACE-Generic** DDF is selected, the LFE is the elevation of the top of the lowest finished floor of the structure being studied. The elevation of an unfinished basement should not be used but finished basements should (walkout or non-walkout).

If **IBI (2015)** or **Doyon et al (2021)** DDF model is selected, the LFE refer to the elevation of the Main Floor.

How Many Meters is the Lowest Floor Raised?

This input is activated only for structure elevation projects. User should input the elevation of the structure with regard to the first floor.

Elevation of the Top Barrier

This input is activated only for Floodproofing measures. This is the elevation (Geodesic) for the top of the floodproofing or flood barrier. Assuming there is no basement, the difference between this elevation and the Lowest Floor Elevation equals the number of meters of flood depth that damage will be reduced in the depth damage function (DDF).

Enter Below the Recurrence Interval Corresponding with Surface Elevation (Before and after adaptation)

The Water Surface Elevation (WSE) for four flood recurrence intervals is suggested. The 10-, 50-, 100-, and 500-year flood period events (these may appear as the 10% annual chance, 2% annual chance, 1% annual chance, and 0.02% annual chance flood events in the flood data source) are suggested recurrence intervals, but they can be override by other value.

If only three recurrence intervals are available, users may enter zero values as recurrence and zero for the first WSE. Recurrence interval should be sorted from the most frequent to least frequent.

Table 3-3: Default Water Surface Elevation Recurrence Intervals suggested in the RoI Prototype

Recurrence Intervals	Water Surface Elevation
10	28 m
50	29 m
100	29.5 m
500	30 m

For the WSE after adaptation, the section will only display for project types like drainage or channel improvements that seek to lower the flood water surface elevations. An H&H study including adaptation project need to be conducted to fill the WSE after adaptation.

3.2.3 Building Information

A tab offers the possibility to enter multiple building information. User just has to click calculate all building information. The dark grey cell indicate that the information doesn't have to be filled.

Flood Hazard Type

The flood hazard type determines whether its pluvial or riverine flooding.

Use Quick assumption mode.

Several information could be modified in the quick assumption mode and will be filled in the building damage curve.

First floor elevation offset from grade (m)

The toolkit assumes a default value of 0.6m of offset from grade. This information can be useful when no data regarding first floor elevation exist, when only LiDAR topography are available.

Basement floor slab elevation from grade

This information is used to assess damage from groundwater flooding in case of pluvial flooding.

Building Replacement Value (BRV) unit cost

In large scale assessment when individual BRV is not available, the user can use sources of data such as RSMEAN to enter a BRV unit cost. The BRV for each building will be automatically calculated using the building size and number of storeys.

Damage Mode

This option guide the user to use the appropriate damage curve base on the available information. If the user select «*High level*» the toolkit will propose the IBI 2015 damage curve that doesn't require BRV value information for each building. The option «*Detailed percent of BRV*» will offer IJC 2021 damage curve or USACE damage curve that require has input BRV information.

Select Property Type

The Building Type selection determines the appropriate depth-damage function to use when calculating the amount of expected damage for different depths of flooding for structures and content. The building type combined with the presence of basement, the number of storeys, etc., will enable the selection of the appropriate DDF. The Table illustrates the different option of building for each of the DDF source.

Building Use

This option only applied if the IBI 2015 DDF is selected for Non-Residential Buildings. The Non-Residential DDF within IBI 2015 are separated by Structures and Contents (while for other models the asset is identical for both Structures and Contents). There are 5 DDF models for Structures within IBI 2015:

- Office/Retail
- Industrial/Warehouse
- Hotel/Motel
- Highrise
- Institutional

The Table 3-2 illustrates the 21 IBI 2015 Non-Residential Content DDFs depicted as Building use within the RoI Toolkit.

Reference City

The Reference City need to be selected by the user, to use the IBI 2015 DDFs. If the user location is not within the list of choices, the user needs to select the city that has similar construction cost. The indexes are used as per the RSMeans database which is one of the most reliable published data sources in the construction industry.

Living Space (square feet)

This option only applies for IBI 2015 Residential buildings. The IBI 2015 have a specific model for different category of residential home based on living space. The following option are available:

1) >=2400_<3999 square feet
2) >=1200_<2400 square feet
3) <1200 square feet

Stormwater management system

This option appeared only when pluvial flood is selected. When the user a level of service approach, if the modelling considers the minor system, groundwater damage and sewer backup damage will apply. When the user selects major system only overland flood damage will apply.

Building with a Basement?

Along with the Building Type input, this selection indicates the presence or absence of a basement and determines the proper Depth Damage Function that the model will use to correlate damages with flood depth inside the structure. See section 0, to correctly account for the presence of basement in the model specifically if USACE-Generic DDF is used.

Finished Basement?

This option only applied to Doyon et al 2021 DDF model. If model is USACE-Generic the choice of the LFE is impacted by the presence of a finished basement but cannot be accounted under this tab.

Access to Public Service?

This option is only available if Doyon et al 2021 DDF model is selected. Their model has a set of curves that applied to rural residential building, to include damage to sceptic tanks and individual water facilities.

Number of Storeys

One-storey: One finished floor level of habitable space, with the roof as the next higher structural member.

Two or More Storeys: Two or more finished floor levels of habitable space.

Split-level: The floor level of one part of the house is about halfway between the floor and ceiling of the other part of the house.

For IBI 2015 DDF model apartments can be separated by smaller than five storeys and greater or equal to five storeys.

Building Size (m^2)

For residential buildings, the Building Size consists of the enclosed area within the building, including the entire finished and livable space. It does not include unfinished basements, porches, garages, or other outside areas.

What is the Number of Residents?

This value is the number of people living in the structure being mitigated. This input is necessary to calculate the mental health and stress based on flooding.

How Many Residents Work?

This value is the number of people living in the structure being mitigated. This input is necessary to calculate the loss of productivity.

Building Replacement Value ($)

Detailed assessor data is best to use to estimate the building replacement value for each asset. To avoid including land values when accounting for avoided damages to assets, the value listed under the improvement component in the assessor data should be used as a proxy for the replacement value of each asset in analysis.

Where the improvement value is not known, standard values can be used to estimate the building replacement value.

3.2.4 Standard Benefits – Buildings

This section calculates the amount of building damage expected before adaptation and after adaptation. For USACE-GENERIC and Doyon et al 2021 it is percent of damage based on DDF multiply by the building replacement value. For IBI 2015 model, the damage is calculated as dollar per square metres. Doyon et al 2021 model combined the damage to structures and contents.

3.2.5 Standard Benefits – Contents

This section calculates the amount of contents damage expected before adaptation and after adaptation. For the USACE Generic model damage to content is calculated from the content-to-structure value ratio

(CSVR). The CSVR is applied (Table 3-4) from the BRV to calculate the content value for various types of assets, while Residential asset have a CSVR of 100%. The damage to content is calculated directly for the IBI 2015 DDF model as a dollar per square/metres. The damage to content is included in Standard Benefits-Buildings for Doyon et al 2021 model.

Table 3-4: Contents Value as a Percent of Asset Value

Asset	Engineered Building	Pre-engineered Building
Apartment	10%	12%
Clothing, Retail	29%	36%
Convenience Store	52%	62%
Correctional Facility	24%	27%
Electronics, Retail	65%	81%
Fast Food	15%	17%
Furniture, Retail	14%	18%
Grocery	85%	106%
Hospital	28%	30%
Hotel	15%	19%
Industrial Light	38%	47%
Medical Office	13%	15%
Non-Fast Food	23%	26%
Office One-Story	12%	14%
Protective Services	69%	88%
Recreation	25%	30%
Religious Facilities	7%	8%
Schools	6%	7%
Service Station	66%	83%
Warehouse, Non-Refrigerated	37%	47%
Warehouse, Refrigerated	36%	43%

3.2.6 Standard – Benefits – Injuries and Fatalities

The user has the option to include or not benefits associated with injuries and fatalities. He can also override the Value of Statistical Life, cost of major injury and minor injury.

3.2.7 Standard Benefits- Additional Living expenses

The user has the option to override default value of monthly rent, hotel cost, furniture storage, increase commuting cost. The user can also claim loss of rent. The additional living expenses benefits are calculated based on displacement DDF such as the one presented in Table 3-5.

Table 3-5: Residential displacement DDF

Flood Depth (meter)	Unit	Days Displacement
0.164	Day	22
0.328	Day	45
0.656	Day	90
0.984	Day	135
1.312	Day	180
1.640	Day	225

3.2.8 Standard Benefits – Business Interruption

The user has the ability to claim Business interruption benefits. The toolkit used Displacement DDF same as for Additional Living expenses. The user can calculate both direct and indirect business interruption. For the direct business interruption benefits, the user can choose between two options: to include business interruption by number of employees or affected surface. If the user selects number of employees, the loss of productivity will be calculated based on the number of employees. If the user selects «*affected surface*», the building interruption will be calculated from the building dimension based on assumptions of employees per square metres. The user has the ability to override the assumption presented in Table 3-6.

Table 3-6: Direct business Interruption Cost

Business Type	Employee per square metres	Operating hours per week	Labour productivity 2022 (per hour Chained 2012)	% of disruption during downtime	Labour productivity per hour 2023	Productivity loss per m^2 per day	Productivity loss per day per person	Ratio of direct to Indirect Business Interruption
General office	23	45	$ 49.00	70%	$60.69	$11.87	$273.12	0.02
Medical office	23	45	$50.10	100%	$62.06	$17.34	$398.93	0.50
Retail-Shoes	33	65	$37.90	100%	$46.94	$13.21	$435.92	0.04
Retail-Clothing	33	65	$37.90	100%	$46.94	$13.21	$435.92	0.04
Retail-Electronics	33	65	$41.50	100%	$51.40	$14.46	$477.32	0.04
Paper Products	33	65	$34.30	100%	$42.49	$11.95	$394.51	0.44
Hardware/Carpet	33	65	$34.80	100%	$43.11	$12.13	$400.26	0.04
Retail	33	65	$34.80	100%	$43.11	$12.13	$400.26	0.04
Misc Retail	33	65	$34.80	100%	$43.11	$12.13	$400.26	0.04
Furniture/Appliances	33	65	$31.40	100%	$38.89	$10.94	$361.15	0.04
Grocery	33	65	$25.90	100%	$32.08	$9.03	$297.90	0.04
Drugs	33	65	$39.50	100%	$48.93	$13.77	$454.32	0.06
Auto	50	45	$34.30	100%	$42.49	$5.46	$273.12	0.37
Hotel	50	45	$42.90	100%	$53.14	$6.83	$341.60	0.37
Restaurant	33	80	$17.70	100%	$21.92	$7.59	$250.56	0.64
Personal Services	23	45	$39.50	100%	$48.93	$13.68	$314.53	0.02
Financial	23	45	$86.20	70%	$106.77	$20.89	$480.47	0.02
Warehouse/industrial	70	65	$44.60	100%	$55.24	$7.33	$512.98	0.03
Theatres	70	65	$24.60	100%	$30.47	$4.04	$282.94	0.64
Institution	23	45	$53.10	100%	$65.77	$18.38	$422.82	0.05
Schools	23	45	$45.40	100%	$56.23	$15.72	$361.51	0.04
Convenience Store	23	45	$25.90	100%	$32.08	$8.97	$206.24	0.04
Fast Food	33	80	$17.70	100%	$21.92	$7.59	$250.56	0.64
Industrial Light	70	65	$44.60	100%	$55.24	$7.33	$512.98	0.44
Non-Fast Food	33	80	$17.70	100%	$21.92	$7.59	$250.56	0.64

Business Type	Employee per square metres	Operating hours per week	Labour productivity 2022 (per hour Chained 2012)	% of disruption during downtime	Labour productivity per hour 2023	Productivity loss per m^2 per day	Productivity loss per day per person	Ratio of direct to Indirect Business Interruption
Office One-Story	23	45	$49.00	100%	$60.69	$16.96	$390.17	0.02
Recreation	70	65	$24.10	100%	$29.85	$3.96	$277.19	0.64
Religious Facilities	23	45	$28.30	100%	$35.05	$9.80	$225.35	0.05
Service Station	23	45	$54.80	100%	$67.88	$18.97	$436.36	0.04
Warehouse, Non-Refrigerated	70	65	$44.60	100%	$55.24	$7.33	$512.98	0.03
Warehouse, Refrigerated	70	65	$44.60	100%	$55.24	$7.33	$512.98	0.03
Retail-Furniture	33	65	$31.40	100%	$38.89	$10.94	$361.15	0.04
Hospital	23	105	$35.40	100%	$43.85	$28.60	$657.72	0.50
Protective Services	23	105	$33.20	100%	$41.12	$26.82	$616.85	0.05
Correctional Facility	23	105	$33.20	100%	$41.12	$26.82	$616.85	0.05

The user can also include indirect business interruption. The Multihazard Mitigation Council (2019), has calculated multiplication coefficients of indirect impact to the general economy for both residential and Non-Residential buildings based on direct Business interruption. The user has the ability to include or not those benefits, For the residential Buildings a ratio of 0.47 apply for every dollar of additional Living expenses.

3.2.9 Standard Benefits – Social

The toolkit applies the Multihazard Mitigation council (2019) which assign an instance of PTSD equal to 0.15 per person flooded. The project team apply the instance of PTSD only when the first floor is flooded.

3.2.10 Standard Benefits – Insurance

The toolkit applies the Multi-Hazard Mitigation Council (2019) which evaluated that the cost transfer in the long run on the property owner represents 42% of property loss including damage to the structure, content and additional living expenses. The assumption is based on insurance savings regarding overhead and profit costs of the insurance premium.

3.2.11 Standard Benefits - Ecosystem Services

Ecosystem service benefits accrue when land use is changed or enhanced by an adaptation activity to provide a higher level of natural benefits.

Because natural systems are largely self-maintaining and tend to become more economically valuable over time, including ecosystem services provides a more complete accounting of a project's benefits.

The actual value present in the prototype were adapted from FEMA[11] using multiple sources to make them more precise for the Canadian context. Users can override the benefits value with regional value.

Table 3-7: Ecosystem Service Values (per Land Cover; $ per hectare per year)

Ecosystem Service	Forests	Urban Green Open Space	Rural Green Open Space	Riparian	Inland Wetlands
Air Quality	$909.63	$760.23	-	$597.80	-
Climate Regulation	$623.03	$167.26	$238.50	$297.35	$173.45
Erosion Control	$5,178.85	$241.60	$241.60	$42,815.34	-
Flood and Storm Hazard Reduction	$2,093.84	$978.78	-	$18,745.46	$3,915.11
Habitat	-	$18,243.68	$6,259.84	$7,889.07	$4,385.92
Pollination	-	$1,084.09	$1,084.09	-	-
Total Service Value	**$8,814.35**	**$20,496.85**	**$7,824.03**	**$51,599.56**	**$4,559.37**

[11] FEMA. (2022). Economic Benefit Values for Green Infrastructure. And FEMA. (2022). Ecosystem Service Value Updates.

Table 3-8:Ecosystem Service Values (for Urban Green Infrastructure; $ per m^2 or tree per year)

Ecosystem Service	Green Roofs	Permeable Pavements	Bioretention	Urban Trees
Avoided carbon emissions	$0.0065	$0.05	$0.23	$0.19
Carbon sequestration	$0.0023	-	$74.45	$28.65
Carbon sequestration and avoided emissions	$0.0088	$0.05	$74.67	$28.84
Building energy cost savings	$1.98	-	-	$31.19
Drought risk reduction	-	$0.10	$0.41	$4.41
Habitat	$0.04	-	$0.09	$32.05
Heat risk reduction	-	-	-	$726.19
Property value improvement	$0.15	-	$0.32	$42.40
Removal of air pollutants	$0.01	-	$0.076	$6.78
Stormwater volume and quality	$0.52	$4.37	$18.10	$14.89
Total Service Value	**$2.72**	**$4.57**	**$168.35**	**$915.59**

3.3 Wind Module

The present study focuses on strong winds that have destruction potential for infrastructure.

3.3.1 Input Data

The National Building Codes are developed by the Canadian Commission on Building and Fire Codes and published every five years by the National Research Council of Canada (NRCC). In the latest edition has been published in 2015 and presents historic data assuming a stationary climate including wind speeds.

The wind speeds and corresponding velocity pressures used in the Code are regionally representative or reference values. The reference wind speeds are nominal one-hour averages of wind speeds representative of the 10 m height in flat open terrain. These values were plotted on maps, then analyzed and abstracted for several locations across the country in Table C-2 of the National Building Codes. The data from this table were extracted and included in the RoI Toolkit.

3.3.2 Hazard Probability Parameter

Wind Gust Table

The Wind Gust Table (Table 3-9) shows an example of recurrence intervals and windspeeds for a given location based on user-provided Latitude and Longitude coordinates. The recurrence interval, also called “return period” or “expected frequency,” is a statistical probability of the occurrence of an event of a certain magnitude that typically is based on the frequency of historic events. The default windspeed values for each recurrence interval for the project location are displayed. It is possible to override the recurrence intervals and the wind gust table with other data. User should be aware that the gust unit are 1-minute wind speed to match the wind damage function unit. Five recurrence intervals are used in the actual version of the prototype, user cannot add more recurrence intervals in the actual version.

Table 3-9: Example of a Wind Gust Table

Recurrence Intervals	One-minute Sustained Wind Speed (m/s)
10	28.48
50	32.24
100	33.98
500	37.66
1000	39.26

Exposure

Exposure is the characteristics of the ground roughness and surface irregularities in the vicinity of a building. The categories are based on the natural topography, vegetation, and constructed facilities surrounding the project location. There are two categories available:

- **Urban/dense/treed:** Applies to urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.
- **Open**: Applies to the “open coast”, open terrain with scattered obstructions and areas adjacent to water surfaces in hurricane-prone regions, with the scattered obstructions generally less than 30 feet tall. This category includes flat open country, grasslands, and shorelines.

3.3.3 Building Information

This section establishes the before-adaptation and after-adaptation building performance metrics for the structure being mitigated. The wind damage functions change for each combination of inputs in the Building Properties section.

Select Building Type

Four option of Building type are available in the actual prototype:

- Residential (1-3 storeys).
- Commercial (1-3 storeys).
- Institutional (1-3 storeys).
- Mid-rise commercial (4-10 storeys).

Property Specific Item

The Building Property selections are determined by the Adaptation Type and Building Type users select, and the same properties will appear for the before-adaptation column and the after-adaptation sections. Before-adaptation properties consist of the existing building features and properties. After-adaptation properties are determined by the proposed adaptation project. Table 3-10 illustrates the different option for property specific item.

Table 3-10: Property Specific Item to Quantify Before and After Adaptation Project

Property Specific Item	Available Option in Current Prototype	
	Residential	Non-residential
Roof Shape	**Gable**: A ridged roof that slopes up from only two sides of a building **Hip Roof**: A roof that slopes up from all four sides of a building	**Flat:** A roof that is almost level in contrast to the many types of sloped roofs
Roof Cover Type	Apply only to non-residential building	**Built Up Roof (BUR)**: A flat roofing technique that uses multiple layers on top of the roof insulation, including a base layer, then several layers of roofing membranes or tar paper that are adhered to the base layer (often with hot asphalt), then topped with a reflective layer or ballast material like gravel. **Single Ply Membrane (SPM):** A flat roofing technique that uses a single layer of synthetic product that is installed over the roof insulation. The seams are glued or fused to prevent leakage and the slope is tapered toward roof drains.
Masonry Reinforcing	Apply only to non-residential building	Indicates if a structure has reinforced masonry walls.
Secondary Water Resistance	Identifies whether there is a secondary water resistance barrier to prevent water penetration through the roof decking after the loss of the roof covering	Apply only to Residential building
Roof-Wall Connection	Indicates if the structural system of a building can transfer loads from the roof to the foundation. In general, a **strap** would provide positive connection from the roof framing to the walls, better connections within the wall framing, and connections from the wall framing to the foundation system.	Same as residential
Roof Deck Attachment (wood)	Refers to the spacing of the nails that support the roof decking.	Same as residential
Roof Deck Attachment (Metal)	Apply only to non-residential building with **Steel Joist** roof frame system	Indicates if the structure has standard or above standard (superior) roof deck attachments for metal roofs. A “standard” metal roof deck attachment generally consists of an arc spot weld connection or screws that are most often #12 or ¼-inch diameter when fastening the roof deck to structural members. A “superior” metal roof deck attachment has increased fastener schedules to handle higher design pressures.
Shutters	Indicate the presence of Shutters for building or Garage	Indicate the presence of Shutters

Building Replacement Value

The Building Replacement Value (BRV) for a single building is the cost, to repair or to replace with a functionally equivalent building, based on the current cost of labor and materials.

What is the Number of Residents?

This value is the number of people living in the structure under evaluation. This input is necessary to calculate benefits associated with mental health and stress and anxiety.

How Many of the Residents Work?

This value is the number of people living in the structure under evaluation. This input is necessary to calculate benefits associated with loss of productivity.

Building Size (m^2)

For both residential and non-residential buildings, the total size consists of the total enclosed area within the building that is being mitigated. For residences, this includes finished and unfinished basements, and the entire living space; however, it does not include porches, garages, or other outside areas.

3.3.4 Standard Benefits — Building and Content

The DFA Module of the RoI Toolkit uses the user-entered recurrence interval and the present value of historic damages to calculate average annual damages. The expected annual benefits are the difference between the annualized damages to buildings before and after the implementation of the adaptation project.

3.3.5 Standard Benefits — Additional Living expenses

Loss of function and displacement is calculated based on the loss of function DDF for Residential and a generic for Commercial [12, 13]. The duration of displacement (in days) is multiplied by the daily evacuation and subsistence costs for residential assets and displacement costs per square meter for non-residential assets (see Table 3-6). The user has the option to override default value of monthly rent, hotel cost, increase commuting cost. The user can also claim loss of rent.

3.3.6 Standard Benefits — Insurance

The toolkit applies the Multi-Hazard Mitigation Council (2019) which evaluated that the cost transfer in the long run on the property owner represents 42% of property loss including damage to the structure, content and additional living expenses. The assumption is based on insurance savings regarding overhead and profit costs of the insurance premium.

3.3.7 Standard Benefits – Business Interruption

The Multihazard Mitigation Council (2019), has calculated multiplication coefficients of indirect impact to the general economy for both residential and Non-Residential buildings based on direct Business interruption. The user has the ability to include or not those benefits, For the residential Buildings a ratio of 0.47 apply for every dollar of additional Living expenses.

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[12] Federal Emergency Management Agency (FEMA) 2020. Hazus Earthquake Model Technical Manual – Hazus 4.2 Service Pack 3. 436 pages.

[13] Federal Emergency Management Agency (FEMA) 2021. *Hazus Hurricane Model Technical Manual* – Hazus 4.2 Service Pack 3. 624 pages.

3.4 Wildfire Module

A wildfire is an uncontrolled fire spreading through vegetative fuels, exposing and possibly consuming structures and causing massive population displacement. For areas with a wildfire risk, the Wildland-Urban Interface, or WUI, are areas where homes or other burnable community structures meet with or are interspersed within wildland fuels. Due to this proximity to the built environment, WUI fires have additional fuel loads from structures.

3.4.1 Input Data

In comparison to flood risk, there is no standardized approach for the estimation of wildfire risk. Several approaches exist and provide different ways to address wildfire risk. Also, wildfire risk can be analysed at multiple scales, namely at the landscape, community, or asset scales. The proposed risk adaptation measure or adaptation project will have more impact at the community scale than at the individual asset scale. The following are three approaches that can be used or combined within the RoI Toolkit to assess wildfire risk. The Burn Probability layer will be integrated in the toolkit, but special consideration mentioned below have to be considered.

FireSmart Approach: The FireSmart toolkit helps citizens and communities to assess their exposure to wildfire risk and provides risk adaptation strategies. Primary topics of FireSmart include the description of interface issues, evaluation of interface hazards, adaptation strategies and techniques, emergency response for agencies and individuals, training for interface firefighters, community education programs, and regional planning solutions. The wildland/urban interface is any area where industrial or agricultural installations, recreational developments, or homes are mingled with flammable natural vegetation. FireSmart also provides practical tools and information for use by interface residents, municipal officials, land use planners, structural and wildland firefighters, and industries that operate in the wildland/urban interface.

Wildland Urban Interfaces (WUI) Mapping (NRCAN): NRCAN has produced a Canada-wide map of wildland interface. This map provides a rough estimation of potential exposure to wildfire. This information can be used in conjunction with FireSmart principles. “Interface” are defined as areas of wildland fuels which are within a variable-width buffer (maximum distance: 2400 m) from potentially vulnerable structures or infrastructure.

Burn Probability Layer (**Ongoing work at NRCAN**): NRCAN is currently working on the calculation of Burn probability Canada-Wide. Again, Burn Probability (BP) data can be used in conjunction with FireSmart and WUI for a more precise evaluation of risk at the community level. The software BURN-P3 (probability, prediction, and planning) is used for the calculation of burn probability at the landscape-level. The model combines deterministic fire growth based on the Canadian Fire Behavior Prediction System and spatial data for forest fuels and topography with probabilistic fire ignitions and spread events derived from historical fire and weather data.

Limitations Related to data availability and format on Wildfire: It is worth mentioning that the three layers presented above are based on several static inputs. For example, the forest cover type is updated approximately at 10-year intervals. Also, a large wildfire occurring within a region can alter the risk level by potentially offering additional protection to a community through fuel reduction. Maps of BP and WUI should be used with caution as local knowledge might always prevail for wildfire risk evaluation. The wildfire risk calculated from BP applies only for a given landscape. If there is a change in the landscape (fire, harvesting, fuel reduction strategy etc.), the BP will not be as relevant.

3.4.2 Hazard Probability Parameters

Enter the average burn Recurrence Interval (Years)

With the availability of NRCAN Wildfire Hazard Burn Probability layer this input would be automatically populate based on entered coordinates.

Annual Probability

This is automatically calculated from the recurrence Intervals.

Do you want to apply Climate Change?

The approach of Wotton et al, (2020) depicting the increase in burn area over time, is used to evaluate climate change based on regression.

NRC Construction class recommendation
The user could then select between different option of construction classes mixed with forest fuel management, based on the level of risk. The owner has the choice to properly manage the fuel or use resistant construction material as recommended by NRC. The considered construction classes are the following:

- **Construction Class CC1**: Construction Class where, primarily through the use of non-combustible materials, a level of resistance to **direct flame** impingement and a **high level** of thermal irradiation and **burning embers;**
- **Construction Class CC2**: Construction Class where, through the use of a combination of noncombustible and ignition-resistant materials, a level of resistance to a **moderate level** of thermal irradiation and burning embers; and
- **Construction Class CC3**: Construction Class where, through the use of a combination of non-combustible materials, ignition-resistant materials, and other combustible materials, a **level of resistance to burning embers**.

Table 3-11: Recommended construction classes in listed priority zones

Global Exposure Level	Recommended Construction Classes for Use with Mitigation Measures Applied in the Listed Priority Zones				
	None	1A	1A and 1	1A to 2	1A to 3
Low	*CC1*(FR)(1) Baseline	*CC1* *Option 2*	*CC3* *Option 5*	*CC3* *Option 5*	*CC3* *Option 6*
Moderate	*CC1*(FR)(1) Baseline	*CC1*(FR)(2) Option 1	*CC2* *Option 4*	*CC2* *Option 5*	*CC3* *Option 6*
High	*CC1*(FR)(1) Baseline	*CC1(FR)*(2) *Option 1*	*CC1* *Option 3*	*CC1* *Option 4*	*CC3* *Option 6*

Enter Project Effectiveness

Project effectiveness refers to the extent to which the project will reduce wildfire damages, losses, and casualties. It is not possible to assume that a wildfire adaptation project will eliminate wildfire damages and losses, but only reduce them. The toolkit by default that indicates the compliance with NRC Construction class recommendation assumes a 90% project efficiency. The user can override this value.

Project Mitigation option

The user has the choice between four options:

- Property vulnerability: The user can also use the option 'property vulnerability' which uses the odds ratio based on the 2018 campfire observation (Hawks, 2020) and implemented by Porter et al, (2021). The user can then select the construction material before and after retrofitting. It is worth mentioning that this approach complies with American standards, not with Canadian standards. The Table 3-12 presents the property vulnerability function.
- Community level: No specific project effectiveness is associated with those measures.
- User entry: User need to enter project effectiveness.
- Follow NRC Recommendations: The toolkit by default that indicates the compliance with NRC Construction class recommendation assumes a 90% project efficiency.

Table 3-12: Property vulnerability function

Elements	Material	Odds Ratio
Elevated Deck or Porch	composite	0.5
	masonry or concrete	0.3
	none	0.5
	wood	2.5
Deck or Porch Grade	composite	0.3
	masonry or concrete	0.3
	none	2
	wood	2.7
Defensible Space	compliant	0.2
	noncompliant	5
Eaves	enclosed	0.8
	none	2
	unenclosed	1
Exterior Cladding	combustible	1.5
	ignition-resistant	0.6
Fence	combustible	1.8
	none	0.7
	non-combustible	1.1
Patio/Carport Cover	combustible	1.5
	none	0.7
	non-combustible	1.1
Roof	asphalt	0.9
	concrete	1.2

Elements	Material	Odds Ratio
	metal	1.2
	tile	0.4
	wood	6
Vent Screen	mesh < 4mm	0.7
	mesh >4mm	1.2
	no vents	1.1
	no screen	1.5
Windows	multi-pane	0.4
	single pane	3

3.4.3 Building Information

Enter the Number of Buildings Protected by Proposed Project

Users should count only the structures that are within the proposed wildfire adaptation project area. As for any adaptation project, function and occupancy levels are important factors for evaluating wildfire adaptation projects.

Total Building Replacement Value (BRV) for all Buildings within the Proposed Project Area ($)

The Building Replacement Value (BRV) for a single building is the cost, to repair or to replace with a functionally equivalent building, based on the current cost of labor and materials. The BRV is not the same as the market value or assessed value of the building. The Total BRV is the BRV for all structures protected by the project.

Value of Building Contents

Default at 50% of BRV. Building contents include items like furniture, office equipment, personal belongings, and non-permanent room dividers.

Value of Infrastructures Vulnerable to Fire in the Project Area

Infrastructure typically refers to assets that support an economy or an area, for example roads, water supply systems, wastewater systems, stormwater systems, and power supply systems.

Value of Timber to Be Sold within the Proposed Project Area ($)

The value of potential lumber in the project area that could be destroyed by wildfire.

Fire Suppression Costs for One Typical Fire Within the Project Area ($)

Fire suppression costs are the estimated costs for responding to and fighting a wildfire.

Other Costs ($)

The value of other costs associated with fire-related losses, which may include costs related to vehicle losses, cleanup costs for the structure or property.

What is the Number of Residents?

This value is the number of people living in the structure being mitigated. This input is necessary to calculate the mental health and stress based on wildfire.

How Many of the Residents Work?

This value is the number of people living in the structure being mitigated. This input is necessary to calculate the loss of productivity.

3.4.4 Standard Benefits — Building

This number establishes the risk exposure (in dollars) from buildings that will be reduced by the proposed project based on the project efficiency.

3.4.5 Standard Benefits — Contents

This number establishes the risk exposure (in dollars) for contents that will be reduced by the proposed project based on the project efficiency.

3.4.6 Standard Benefits —Injuries and fatalities

The user has the option to include or not benefits associated with injuries and fatalities. He can also override the Value of Statistical Life, cost of major injury and minor injury.

3.4.7 Standard Benefits — Social

The instance of PTSD is calculated based on Non-Fatal Injury as recommended by Porter et al, 2021.

3.4.8 Standard Benefits — Others

If the proposed project will result in reduced losses (other than to buildings and casualties), they can be considered here. This is the sum of fire suppression, vulnerable infrastructures, and other fire costs:

3.4.9 Standard Benefits – Insurance

The toolkit applies the Multi-Hazard Mitigation Council (2019) which evaluated that the cost transfer in the long run on the property owner represents 42% of property loss including damage to the structure, content and additional living expenses. The assumption is based on insurance savings regarding overhead and profit costs of the insurance premium.

3.4.10 Standard Benefits – Environmental Services

Burning an average house to the ground releases about 9 tons of CO_2. The user can override the price for the ton of carbon. The default value uses the social price of carbon at 247$ per ton[14].

[14] Environnement Canada. (2023). Social cost of greenhouse gas estimates—Interim updated guidance for the Government of Canada. https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/social-cost-ghg.html

3.5 Ice Storm Module

3.5.1 Input Data

Utility systems may be able to handle moderate ice accumulations, but stressed lines under wind forces are more likely to break. In that context, the RoI Toolkit includes the following inputs:

Ice Accretion

Researchers at the Climate Research Division of Environment and Climate Change Canada published a paper [15] in 2019 that project changes to extreme ice loads for future periods of specified global mean temperature change (GMTC), relative to the recent 1986–2016 period over the entire country. These researchers graciously granted permission to copy, use and reproduce 20- and 50-year return level radial ice accretion data for baseline and future periods from their paper and incorporate into the RoI Toolkit.

Canadian Wind Atlas

Environment and Climate Change Canadas Wind Atlas web site contains maps and data for wind energy over all of Canada at a resolution of 5 km [16]. This site also features colour maps representing the average wind velocity and power on the whole country, as well as corresponding geophysical characteristics. The wind velocity data from this web site were extracted and included in the RoI Toolkit to obtain the probability for different wind classes.

3.5.2 Hazard Probability Parameters

Radial Ice for Given Recurrence Intervals

In the actual prototype, this is the amount of Radial ice for recurrence 1/20 and 1/50 coming from Jeong et al (2019)[15].It is actually not possible to enter other recurrence intervals for the moment, but this feature could be added in a future version.

Ice Index Probability

The economic impact due to power outages is estimated using an extreme weather index known as the Sperry-Piltz Utility Ice Accumulation (SPIA) Damage Index [17]. This index categorizes damage potential in 5 levels through the use of radial ice thickness and wind speed (Table 3-13).

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[15] Jeong, D.I., A.J. Cannon, and X. Zhang, 2019. Projected changes to extreme freezing precipitation and design ice loads over North America based on a large ensemble of Canadian regional climate model simulations. Natural Hazards and Earth System Sciences, 19:857-872. doi:10.5194/nhess-2018-395

[16] http://www.windatlas.ca/index-en.php

[17] Piltz G.D., S.F., Sperry, S., McPherson, R.A., Gartside, A.D., McClain, D., Meyer, T., Fetsch, C., Shafer, M.A., 2009. *Development and testing of an ice accumulation algorithm*. August 2008 Conference: 17th Conference on Applied Climatology, American Meteorological Society, Whistler, B.C.

Table 3-13: Sperry-Piltz Utility Ice Accumulation Damage Index

Ice Index	Radial Ice Amount (mm)	Wind (km/h)	Damage and Impact Description
1	< 6.35	24-40	Some localized utility interruptions possible, typically lasting only 1 or 2 hours maximum.
	6.35 – 12.70	< 40	
2	< 6.35	≥ 40	Scattered utility interruptions expected, typically lasting less than 8-12 hours maximum.
	6.35 – 12.70	24 – 40	
	12.7 – 25.4	< 24	
3	6.35 – 12.70	≥ 40	Numerous utility interruption, with some damage to main feeder lines expected with outages lasting from 1-3 days.
	12.7 – 19.05	24 – 40	
	19.05 – 25.40	< 24	
4	12.7 – 19.05	≥ 40	Prolonged & widespread utility interruptions, with extensive damage to main distribution feeder lines and possibly some high voltage transmission lines. Outages expected to last more than 3 to 5 days.
	19.05 – 25.40	24 – 40	
	25.40 – 38.10	< 24	
5	19.05 – 25.40	≥ 40	Catastrophic damage to entire utility systems. Outages could last from one week to several weeks in some areas
	25.40 – 38.10	24– 40	
	> 38.10	< 24	

Source: McManus et al. 2009.

The RoI Toolkit output the joint annual probability of Radial Ice combined with wind class probability for recurrence interval of 20 years and 50 years.

Project Effectiveness

The quantification of damage after adaptation project is made through a user defined project efficiency value. For example, if a micro grid project is able to supplement power 80% of time during outage for 50% of the residents, the project efficiency could be set at 40%.

3.5.3 Building Information

Enter the Number of Residential Buildings Protected by Proposed Project

Users should count only the Residential structures that are within the adaptation project area.

Enter the Number of Residents Residing within Residential Buildings

This value is the number of people living in the structure being mitigated. This input is necessary to calculate the mental health and stress.

Enter the Number of Residents that Work?

This value is the number of people living in the area of the adaptation project. This input is necessary to calculate the loss of productivity.

Enter the Number of Commercial Buildings

Users should count only the Commercial structures that are within the adaptation project area.

3.5.4 Tree Removal

Enter the Number of Street Kilometres

This is the main input to qualify the magnitude of the tree removal.

Enter the Total Cost of Removal ($/m^3) (Default: $13.53)

Default at 13.53$ per m^3 [18]. If a different number is entered, the latter should incorporate collection and disposal cost.

Enter the Number of Tree Debris (m^3) per Street km per cm of Ice (Default: 51.8)

The default value is a city street distance factor of 51.8 m^3 tree debris per km city street distance per cm ice thickness.[19]

3.5.5 Standard Benefits — Additional living expense

The duration of displacement (in days) is multiplied by the daily evacuation and subsistence costs for residential assets and displacement costs per square meter for non-residential assets (see Table 3-6). The user has the option to override default value of monthly rent, hotel cost, increase commuting cost.

3.5.6 Standard Benefits — Business interruption

Commercial Disruption is the product of the number of days of disruption, the number of commercial buildings with the average operating budget.

3.5.7 Standard Benefits — Social

The Social Benefits only applied to very large power outage lasting multiple weeks (Ice Index greater than 5). The toolkit applies the Multihazard Mitigation council (2019) which assign an instance of PTSD equal to 0.15, same as the flood module. This number is in line with instances of PTSD occurrence of 18% for the power outage of Texas winter storm of 2021 (Grineski et al, 2022).

3.5.8 Standard Benefits — Tree Removal

Tree Removal benefits can only be accounted for certain adaptation projects, such as pruning and inspecting trees before winter.

3.6 Extreme Temperatures Modules

3.6.1 Input Data

Using gridded observations of the historical climate for the calibration of the downscaling method (i.e., a combination of several statistical methods), regional variations are derived from the coarser global climate simulations. Consequently, the projection for the period 2010-2023 will be computed as a baseline period to closely aligned with the observations and compared to a future period ranging from 2071 to 2100.

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[18] Federal Emergency Management Agency (FEMA) 2021. Hazus Hurricane Model Technical Manual – Hazus 4.2 Service Pack 3. 624 pages.

[19] Hauer, Richard J et al.2011. Rapid Assessment of Tree Debris Following Urban Forest Ice Storms. Arboriculture & Urban Forestry: 236-246.

From the 27 available climate models and the three emission scenarios (RCP2.6, RCP4.5, and RCP8.5), 12 models and one scenario (RCP8.5) have been be selected for the analyses (Table 3-14 and These simulations represent the full range and uncertainty of the climate simulations.

Table 3-14: Selected Global Climate Models (GCMs) for which downscaled climate data were obtained for this CCVA (PCIC, 2019).

Global climate models		
ACCESS1-0	CSIRO-mk3-6-0	IPSL-CM5A-MR
CanESM2	GFDL-CM3	MIROC5
CCSM4	GFDL-EMSM2G	MPI-ESM-LR
CNRM-CM5	inmcm4	MRI-CGCM3

Table 3-15: Short description of the different Representative Concentration Pathways (RCPs) (IPCC, 2001)[20].

RCP	Description
RCP2.6	**Stringent mitigation scenario**: representative of a scenario that aims to keep global warming likely below a 2°C increase above preindustrial temperatures. Ambitious reduction of GHG emissions required for this scenario for emissions to peak around 2020, then decline, and become net negative before 2100.
RCP4.5	**Intermediate mitigation scenario** consistent with relatively ambitious emissions reductions. The GHG emissions increase before starting to decline between 2040 and 2050. This scenario will likely fall short of the 2°C limit agreed upon in the Paris Agreement.
RCP6.0	**Intermediate to high emissions scenario** with emissions peaking in 2080 and declining for the rest of the century.
RCP8.5	**Very high GHG emissions**: consistent with no policy changes to reduce emissions.

3.6.2 Hazard Probability Parameters

Enter a reference City

The reference city is used to extract exposure-response function developed by Gasparrini et al 2015. The coefficients estimated excess deaths attributable to heat for 384 locations globally, including 21 Canadian cities. Excess deaths were defined as deaths attributable to mean daily temperatures above (heat) the “optimum temperature” (i.e., the mean daily temperature between the 2.5th and 97.5th percentiles that corresponded to the minimum daily mortality rate).

Do you want to include Climate Change?

The user can choose to include climate change or not. The exposure response function for mortality and morbidity will be recalculated accordingly.

[20] IPCC (2001). https://www.ipcc.ch/2001/

3.6.3 Project Information

Project Effectiveness

The project effectiveness is the average temperature reduction offer by the mitigation action. The exposure reduction function for mortality and morbidity will be recalculated based on the project effectiveness.

Enter the number of persons exposed

The number of people that will benefit from the mitigation measures should be entered. Those number will be used to estimate the average casualties and morbidity.

Enter the number of workers exposed at high risk occupancy

This input is used to estimate business interruption in terms of reduction of labour productivity on an hourly basis. High-risk industries considered are: (NAICS 11) Agriculture, Forestry, Fishing, and Hunting; (NAICS 21) Mining, Quarrying, and Oil and Gas Extraction; (NAICS 22) Utilities; (NAICS 23) Construction; (NAICS 31-33) Manufacturing; and (NAICS 48-49) Transportation and Warehousing.

3.6.4 Standard Benefits – Morbidity and Fatalities

Th user can override VSL and hospitalization cost.

Total hourly compensation during sick leaves

The user can input an average hourly compensation during sick leaves.

Percent of annual absence caused by health status

The default value of absenteeism for each instance of hospitalization for stroke, coronary and Hypertension is evaluated at 11% annually. The user can override this number.

3.7 Historical Damage — DFA

The damage frequency assessment (DFA) approach is applicable to all hazard types as long as a relationship can be established between how often the hazard event occurs and the extent of damages or losses that occur as a result of each hazard event. The DFA module events requires historical damage data for two or more hazard events in addition to the recurrence interval, or estimated annual probability, of each flood event recorded.

Regardless of the asset type being evaluated, the DFA module requires the user to enter the damage year and recurrence interval.

Damage Year: The DFA module requires the user to enter the year in which historical damages are incurred in order to inflate historical damages to the current dollar year.

Recurrence Interval (Years): The DFA module requires users to enter the recurrence interval, or estimated return period, of each historical event input into the DFA module. The recurrence interval is necessary to establish the relationship between how often the natural hazard occurs and the extent of damages or losses that occur as a result of each natural hazard event.

3.7.1 Building and Facilities

The building and facilities asset type calculates economic, social, and environmental impacts.

3.7.1.1 Economic Impact Calculation

Economic impacts calculated for building and facilities asset types include damages to buildings and their contents and volunteer costs.

Buildings and Contents

Physical Damage Costs (includes debris removal and site cleaning): The DFA module requires the user to enter the physical damage costs occurred for each historical event.

Average Annual Physical Damages: Average annual physical damages are calculated by the establishing the relationship between how often the natural hazard event occurs and the extent of damages. The RoI Toolkit calculates average annual physical damages automatically using the user-input recurrence interval and physical damage costs.

Expected Annual Volunteer Costs: Any hazard adaptation project that eliminates or reduces the need for volunteer labor can claim this benefit. A standard value for the hourly rate of a volunteer is used behind the scenes for these calculations. The DFA module requires users to enter the number of volunteers and number of volunteer days for each historical event input into the DFA module.

3.7.1.2 Social Impact Calculation

Social impacts calculated for buildings and facilities asset types include injuries and fatalities, costs associated with mental stress and anxiety and lost productivity, and displacement costs.

Injuries and Fatalities

Number of Fatalities: The DFA module requires users to enter the number of fatalities that occurred as a result of the historical event input into the DFA module. Damages are monetized using the value of a statistical life estimates.

Number of Major Injuries: The DFA module requires users to enter the number of major injuries that occurred as a result of the historical event input into the DFA module. Damages are monetized using the value of a statistical life estimates. Absent such injury classifications in historic records, hospitalizations can be used as a proxy to estimate the number of major injuries.

Number of Minor Injuries: The DFA module requires users to enter the number of minor injuries that occurred as a result of the historical event input into the DFA module. Damages are monetized using the value of a statistical life estimates. Absent such injury classifications in historic records, injuries that did not require hospitalizations can be used as a proxy to estimate the number of major injuries.

The DFA module uses the historic number of fatalities, major injuries, and minor injuries to calculate average annual injury damages.

Social Costs

Number of Residents: The DFA module requires users to enter the number of residents displaced as a result of each historical event input into the DFA module. The DFA module applies a standard value representing mental health and anxiety costs for each resident displaced.

Number of Residents that Work: Of the residents displaced as a result of each historical event input into the DFA module, the DFA module requires users to enter the number of residents who work. The DFA module applies a standard value representing lost productivity for each resident in the workforce displaced.

The DFA module uses number of residents and number of employed residents affected to calculate average annual social benefits.

3.7.1.3 Environmental Impact Calculation

Environmental impacts considered for building and facilities asset types include temporary adaptation of service interruption or clean up activities, water pollution, hazardous material storage, and Nature-Based Infrastructure. However, temporary adaptation of service interruption or clean up activities and water pollution are captured under economic impacts.

Water Pollution: The current version of the RoI Toolkit does not automatically calculate costs associated with water pollution. Instead, these should be captured under physical damage costs.

Hazardous Material Storage: The current version of the RoI Toolkit does not automatically calculate costs associated with hazardous material storage. Instead, these should be captured under physical damage costs.

The current version of the RoI Toolkit does not have line items to capture historic service interruption or clean up activities, potential water pollution, or hazardous material storage. Resultantly, these damages should be captured under physical damages.

Nature-based Infrastructure: The DFA module requires users to enter the area of habitat created or protected by an adaptation project (in hectares), and the type of habitat created or protected. The DFA module adds the average annual ecosystem services provided by the adaptation project to the other average annual benefits.

3.7.2 Transportation

The building and facilities asset type calculates economic, social, and environmental impacts.

3.7.2.1 Economic Impact Calculation

Economic impacts calculated for transportation asset types include damages to roads and bridges, loss of service/function, and volunteer costs.

<u>**Roads and Bridges**</u>

Physical Damage Costs (includes debris removal and site cleaning): The DFA module requires the user to enter the physical damage costs occurred for each historical event. Physical damage costs are used to measure the extent of damages.

Average Annual Physical Damage Costs: Average annual physical damages are calculated by the establishing the relationship between how often the natural hazard event occurs and the extent of damages. The RoI Toolkit calculates average annual physical damages automatically using the user-input recurrence interval and material damage costs.

Duration of Event: The DFA module requires users to entire the duration the event lasted, namely duration of road or bridge closure, for every historical event entered into the module.

<u>**Loss of Service/Function**</u>

Estimated Number of One-Way Traffic Detour Trips per Day: The FDA module requires the user to enter the estimated number of one-way traffic detour trips per day.

Additional Time per One-Way Detour Trip (minutes): The DFA module requires the user to enter the additional detour time travelers incur in the event of a road or bridge closure resulting from a natural hazard event.

Additional Distance per One-Way Detour Trip (km): The DFA module requires the user to enter the additional detour distance travelers incur in the event of a road or bridge closure resulting from a natural hazard event.

The DFA module uses the estimated number of one-way traffic detour trips per day, the additional time per one-way detour trip, and the additional distance per one-way detour trip to estimate the economic loss per day of loss of function; the DFA module multiples the loss of service per day by the duration of loss of service/function.

Volunteer Costs: Any hazard adaptation project that eliminates or reduces the need for volunteer labor can claim this benefit. A standard value for the hourly rate of a volunteer is used behind the scenes for these calculations. The DFA module requires users to enter the number of volunteers and number of volunteer days for each historical event input into the DFA module.

3.7.2.2 Social Impact Calculation

Social impacts calculated for transportation asset types include injuries and fatalities.

Injuries and Fatalities

Number of Fatalities: The DFA module requires users to enter the number of fatalities that occurred as a result of the historical event input into the DFA module. Damages are monetized using the value of a statistical life estimates.

Number of Major Injuries: The DFA module requires users to enter the number of major injuries that occurred as a result of the historical event input into the DFA module. Damages are monetized using the value of a statistical life estimates. Absent such injury classifications in historic records, hospitalizations can be used as a proxy to estimate the number of major injuries.

Number of Minor Injuries: The DFA module requires users to enter the number of minor injuries that occurred as a result of the historical event input into the DFA module. Damages are monetized using the value of a statistical life estimates. Absent such injury classifications in historic records, injuries that did not require hospitalizations can be used as a proxy to estimate the number of major injuries.

The DFA module uses the historic number of fatalities, major injuries, and minor injuries to calculate average annual injury damages.

3.7.2.3 Environmental Impact Calculation:

Environmental impacts calculated for building and facilities asset types include temporary mitigation of service interruption or clean up activities, potential water pollution, and Nature-Based Infrastructure.

Temporary mitigation of service interruption or clean up activities: The current version of the RoI Toolkit does not automatically calculate costs associated with temporary mitigation of service or clean up activities. Instead, these should be captured under physical damage costs.

Potential water pollution: The current version of the RoI Toolkit does not automatically calculate costs associated with potential water pollution. Instead, these should be captured under physical damage costs.

Nature-Based Infrastructure: The DFA module requires users to enter the area of habitat created or protected by an adaptation project (in hectares), and the type of habitat created or protected. The DFA module adds the average annual ecosystem services provided by the adaptation project to the other average annual benefits.

3.7.3 Utilities

The utilities asset type calculates economic, social, and environmental impacts.

3.7.3.1 Economic Impact Calculation

Physical Damage Costs: The DFA module requires the user to enter the physical damage costs occurred for each historical event. Physical damage costs are used to measure the extent of damages.

Average Annual Physical Damage Costs: Average annual physical damages are calculated by the establishing the relationship between how often the natural hazard event occurs and the extent of damages. The RoI Toolkit calculates average annual physical damages automatically using the user-input recurrence interval and material damage costs.

Loss of Service/Function

Number of Customers Served: The DFA module requires the user to enter the number of customers served by the utility in order to calculate benefits associated with loss of function.

Duration of Event: The DFA module requires the user to enter the duration of the event in order to calculate benefits associated with loss of function.

3.7.3.2 Social Impact Calculation

Social impacts calculated for water asset types include injuries and fatalities and displacement costs.

Injuries and Fatalities

Number of Fatalities: The DFA module requires users to enter the number of fatalities that occurred as a result of the historical event input into the DFA module. Damages are monetized using the value of a statistical life estimates.

Number of Major Injuries: The DFA module requires users to enter the number of major injuries that occurred as a result of the historical event input into the DFA module. Damages are monetized using the value of a statistical life estimates. Absent such injury classifications in historic records, hospitalizations can be used as a proxy to estimate the number of major injuries.

Number of Minor Injuries: The DFA module requires users to enter the number of minor injuries that occurred as a result of the historical event input into the DFA module. Damages are monetized using the value of a statistical life estimates. Absent such injury classifications in historic records, injuries that did not require hospitalizations can be used as a proxy to estimate the number of major injuries.

The DFA module uses the historic number of fatalities, major injuries, and minor injuries to calculate average annual injury damages.

Displacement Costs

Number of Households: The DFA module requires users to enter the number of households displaced as a result of each historical event input into the DFA module to estimate evacuation costs associated with displacement. Evacuation costs are estimated using the standard per diem rates for lodging.

Number of Residents: The DFA module requires users to enter the number of residents displaced as a result of each historical event input into the DFA module to estimate subsistence costs associated with displacement. Subsistence costs are estimated using the standard per diem rates for meals and incidentals.

Duration: The DFA module requires users to enter the duration of displacement (in days) as a result of each historical event input into the DFA module.

Average Annual Displacement Costs: Average annual displacement costs are calculated by the establishing the relationship between how often the natural hazard event occurs and the extent of displacement costs. The RoI Toolkit calculates average annual displacement costs automatically using the user-input recurrence interval, number of households, number of residents, and duration of displacement.

3.7.3.3 Environmental Impact Calculation

Environmental impacts calculated for water asset types include temporary mitigation of service interruption or clean up activities, potential water pollution, and Nature-Based Infrastructure.

Temporary Mitigation of Service Interruption or Clean-up Activities: The current version of the RoI Toolkit does not automatically calculate costs associated with temporary mitigation of service or clean up activities. Instead, these should be captured under physical damage costs.

Potential Water Pollution: The current version of the RoI Toolkit does not automatically calculate costs associated with potential water pollution. Instead, these should be captured under physical damage costs.

Nature-based Infrastructure: The DFA module requires users to enter the area of habitat created or protected by an adaptation project (in hectares), and the type of habitat created or protected. The DFA module adds the average annual ecosystem services provided by the adaptation project to the other average annual benefits.

3.8 Toolkit Outputs: Metrics and Evaluation

The Cost Benefit Analysis Metrics in the Toolkit Include NPV, benefit-cost ratio, and return on investments metrics. In addition to the Return on Investment (RoI) as is the main expected outcome, the benefit-cost ratio (BCA) and the Net Present Value (NPV) will complement and provide a more comprehensive overview of the project evaluation, supporting users and decision makers.

3.8.1 Net Present Value

One of the key variables that affect any cost benefit analysis is time. Adaptation projects or alternatives might incur costs and benefits that may occur in different years. Discounting is a measure used to convert future benefits and costs to a current year perspective. One of the most frequently used metrics when deciding whether a project can be justified is the Net Present Value (NPV). The NPV is the discounted monetized value of expected net benefits, using a discount rate. The discount rate is a key input that can affect the value over time of variables such as cost and benefits; therefore, it is used in many of the metrics evaluating projects.

The NPV is the total present value of all future benefits (PVB) minus the total present value of all future costs (PVC):

$$NPV = PVB - PVC$$

The present value is calculated by discounting each year's benefits or costs, and then adding all the benefits or costs in each year. This can be represented by the following formula:

$$PV = \sum_{y=0}^{n} \frac{B_y}{\prod_{i=base}^{y}(1 + r_i)}$$

Where:

$\sum$	=	the sum over the evaluation period from year "0" to year "n" and
$\prod$	:	the product of $(1 + r_i)$ over the range shown.
PV	:	present value
B_y	:	benefit or cost (C) under analysis
r_i	:	discount rate

Discount Rate

Discounting involves the use of a discount rate, which is the annual percentage change in the present value of a future dollar. The selection of a particular discount rate in the analysis can have a considerable impact.

In 2017, the Transportation Research Board updated its study on the social cost of carbon. The Interagency Working Group on the Social Cost of Greenhouse Gases recommends conducting sensitivity analysis for carbon emissions using a lower bound of 2.5% and an upper bound of 5.0%, along with a 3% central rate to reflect uncertainty associated with climate change and future economic growth, as well as with the long-time frames and intergenerational consequences associated with climate change.

In Canada, several agencies have stablished parameters to standardize discount rates for business cases and analysis. In Ontario, Metrolinx has recently (April 2019) published their Business Case Manual Volume 2: Guidance, where it presents parameters for a social discount rate and a financial case assumption discount rate. The social discount rate reflects society's time preference for money, and in such guidance, it is set at 3.5%. However, the financial case assumption discussed in the guidance sets a discount rate parameter at 5.5%. In 2007, the Treasury Board of Canada in its Canadian Cost-Benefit Analysis Guide for regulatory proposals [21], recommends a real rate of 8% to be used as the discount rate for the evaluation of regulatory interventions in Canada.

In a paper presented at the Transportation Association of Canada Technical Session: Investing in Road Construction: Building Canada's Economy in 2017, a review of the discount rates used by the provincial agencies ranged between 3% to 6%. The summary table below is an excerpt from the paper [22].

[21] Treasury Board of Canada Secretariat, Canadian Cost-Benefit Analysis Guide, Regulatory Proposals, 2007. https://www.tbs-sct.gc.ca/rtrap-parfa/analys/analys-eng.pdf

[22] Transportation Association of Canada, A Review and Recommendations for Canadian LCCA Guidelines, Mizan Moges et al., 2017. https://www.tac-atc.ca/sites/default/files/conf_papers/ayed.a-a_review_and_recommendations_for_canadian_lcca_guidelines.pdf

Table 3-16: Discount Rate Used by Provincial Agencies

Province	Agencies	Discount Rate
Alberta	Alberta's Benefit Cost Model Recommends that a real discount rate should be used to account for the time value of money, and bring all future dollar values back to the base year/ Accordingly, the model uses a real discount rate of 4%	4%
British Columbia	The British Columbia Ministry of Transportation & Infrastructure uses real discount rate prescribed by the B.C. Ministry of Finance. As of 2017, the discount rate used is 6%	6%
Manitoba	There is no fixed discount rate in Manitoba's LCCA guide. Manitoba's Transportation & Infrastructure uses the discount rate prescribed by the departments Financial Services. Currently a discount rate of 3% is used.	3%
Nova Scotia	The Nova Scotia Transportation & Public Works (NSTPW) uses a discount rate of 4%.	4%
Ontario	Ontario uses a social nominal discount rate, which reflects the social benefits forgone by not investing funds elsewhere in the economy. As of October, 2016, the discount rate used by MTO to convert future cost is set at 4.5% (from 0 to 30 years) and 4% (from 31 to 75 years).	4% - 4.5%
Quebec	Quebec's policy document recommends a discount rate of 5%.	5%
Saskatchewan	Saskatchewan's Ministry of Highways & Infrastructure uses a discount rate prescribed by Saskatchewan's Ministry of Finance. The discount rate mostly used is 4%.	4%

Source: Transportation Association of Canada, A Review and Recommendations for Canadian LCCA Guidelines, 2017, Mizan Moges et. al., Table 3

Through understanding the local and provincial preferences and justification for the discount rate, the RoI Toolkit will offer the flexibility to select the discount rate that the user will require for the adaptation project. This is intended not only to comply and adjust to provincial and local requirements, but also to support sensitivity analysis that can support the adaptation project to be assessed. However, **the RoI Toolkit provides a default discount rate of 3.5%** to account for social benefits and increase the present value of future benefits as aligned with some of the parameters and guidelines described above.

The RoI Toolkit outcomes will present the results using the default discount rate and the user's preferred discount rate, as an alternative. This will enhance the flexibility of the tool but will keep consistency for comparison and further evaluation of adaptation projects.

The NPV is complementary to the BCR. It communicates value for money in an alternative way by showing overall the net benefit from the project in absolute terms. It is common to focus on the BCR, but NPV is also important. If a project's NPV is greater than $0, it is considered cost-effective.

3.8.2 Benefit Cost Ratio

The Benefit Cost Ratio (BCR) is calculated by dividing the present value of the total benefit by the present value of the total cost as shown below:

$$BCR = \frac{PVB}{PVC}$$

Where:

BCR : Benefit Cost Ratio

PVB : Present Value of Benefits – The real, discounted value of the stream of benefits

PVC : Present Value of Costs – The real, discounted value of the stream of costs.

The placement of impacts into costs and benefits is crucial for BCR calculation. Considering that a positive benefit could be construed as a negative cost, and vice versa, an accounting and reporting standard is required. The present value of costs should only include the operating, maintenance, and capital costs of the adaptation project. This will enable decision makers to understand the proposed adaptation project and investment. If the BCR of an investment is greater than or equal to 1, it is considered economically viable.

3.8.3 Return on Investment

Return on Investment (RoI) is the benefit to the project from the investment of resources. As a performance measure, RoI is used to evaluate efficiency of an investment or investments. It is *equivalent to:*

$$ROI = \frac{(PVB - PVC)}{PVC}$$

It communicates the relative value of an investment's benefits to the resources required to deliver it. A positive RoI indicates the project's benefits exceed its costs.

The RoI Toolkit will include these three metrics—NPV, BCR, and RoI, and will use a 3.5% discount rate as a default input for discounting cost and benefits. The tool will allow users to select a different discount rate to compare results and follow local guidance or parameters, but the default discount rate will offer consistency among adaptation project evaluation and will be visible on every RoI toolkit outcome.

4. Climate Change Consideration

The effects of widespread warming are evident in many parts of Canada and are projected to intensify in the future [23]. This means that Canadian cities can expect to be confronted more often with natural hazards. In that context, a module was added in the RoI Toolkit for each hazard in order to help cities to test their resilience and help them adapt to the new climatic conditions.

4.1 Timeframes: Baseline Period and Future Horizons

The most relevant timeframe for each of the assets evaluated has been identified in the RoI Toolkit. For example, the most appropriate timeframe to carry out an assessment to may be 2080 for a newly constructed infrastructure as its life expectancy is expected to be several decades. On the contrary, a shorter timeframe (e.g., 2035) may be appropriate for an infrastructure whose replacement is planned shortly. The default climate change mode automcatically select the appropriate timeframe based on the expected construction end combined with the project useful life.

4.2 Climate Change Scenarios

Climate projections are based on assumptions regarding the evolution of GHG emissions. These are referred to as Representative Concentration Pathways (RCP) and are named after their associated level of radiative forcing or difference between sunlight absorbed on Earth and what is radiated back to space. For instance, RCP 2.6, RCP 4.5, RCP 6, and RCP 8.5 correspond to 2.6, 4.5, 6 and 8.5 W/m² of radiative forcing, respectively for each scenario. Projected carbon dioxide (CO_2) concentration levels are predicted from the anticipated growth in population and energy demand (the type of energy is an important factor), as well as by the anticipated changes vegetation cover and type. High level descriptions of the RCPs are shown below in Table 4-1.

Table 4-1: RCPs Scenario

RCP	Description
RCP 2.6	**Stringent mitigation scenario:** representative of a scenario that aims to keep global warming likely below 2 °C increase above preindustrial temperatures. Ambitious reduction of GHG emissions peak around 2020, then decline and become net negative before 2100.
RCP 4.5	**Intermediate mitigation scenario** consistent with relatively ambitious emissions reductions and GHG emissions increasing slightly before starting to decline ~2040. This falls short of the 2 °C limit agreed upon in the Paris Agreement.
RCP 6.0	**High to intermediate emissions scenario** with emissions peaking in 2060 and declining for the rest of the century.
RCP 8.5	**Very high GHG emissions:** consistent with no policy changes to reduce emissions (current policies or business as usual).

[23] Bush, E. and Lemmen, D.S., editors (2019): Canada’s Changing Climate Report; Government of Canada, Ottawa, ON. 444 p.

The high carbon future (RCP 8.5) scenario was selected as default Climate Change mode in the RoI Toolkit as it represents the worst-case scenario, which would overestimate the associated risk. The RCP 8.5 has been chosen in the toolkit, because it will depict the upper damage band. The user can perform an analysis with and without climate change to quantify damage associated to the magnitude of Climate Change uncertainty. Table 4-2 shows the year at which the indicated global mean warming ΔT relative to 1986-2016 reference period [24].

Table 4-2: Global Mean Warming Relative to 1986-2016 Reference Period

Δ Temperature	Year
+ 1.0°C	2035
+ 1.5°C	2047
+ 2.0°C	2059
+ 2.5°C	2069
+ 3.0°C	2080
+ 3.5°C	2090

Specific climate models will be used for flood and wildfire risks, the following subsections present data requirements for each climate hazard.

4.3 Riverine Flood

For Stormwater and pluvial project user is encouraged to use the intensity-duration-frequency(IDF) tool of the university of Western Ontario[25].

The user can override any-time the default mode with the availability of better data accounting for climate change.

4.4 Wildfire

The updated Burn Probability with regards to climate change are supposed to be included in the upcoming NRCAN project (see section 4.2). For now, the approach of Wotton et al, (2020) depicting the increase in burn area over time, will be used to evaluate climate change based on the following regression:

$$f1(t) = a * (t - 2000)^b$$

where: a=0.562

b=0.2436

t=target year

4.5 Wind

Cannon et al. (2020) projected wind speed value for 675 locations across Canada for 6 global mean temperature change level above the baseline, namely 0.5 °C; 1°C, 1.5 °C, 2 °C, 2.5 °C, 3 °C, and 3.5 °C. Briefly, the authors used the wind speed values presented in the Table C-2 of the 2015 National Code of Building as baseline level and projected the variation of these baseline values for two return periods (10 and

[24] Cannon et al. 2020. Climate-resilient buildings and core public infrastructure 2020 : an assessment of the impact of climate change on climatic design data in Canada. 106 pages.

[25] ICLR (Institute of Catastrophic Loss), FIDS - Western University – 2021. https://www.idf-cc-uwo.ca/. Accessed 2021-09-24.

50-year) by using the Canadian Regional Climate Model Large Ensemble (CanRCM4). Results from this modeling were downloaded (https://climate-scenarios.canada.ca) and included in the RoI Toolkit.

4.6 Ice Storm

As stated in 3.5.2, the researchers from the Climate Research Division of Environment and Climate Change Canada graciously grant permission to the RoI project to copy, use and reproduce 20- and 50-year return period level radial ice accretion data for future periods from their paper. They used a global mean temperature change level (0.0 °C to 3.5 °C) above the baseline. The Sperry-Piltz Radial Ice accretion indices (see section 3.5.2), was generated for each climate change scenarios.

4.7 Extreme Temperature

Using gridded observations of the historical climate for the calibration of the downscaling method (i.e., a combination of several statistical methods), regional variations are derived from the coarser global climate simulations. Consequently, the projection for the period 2010-2023 will be computed as a baseline period to closely aligned with the observations and compared to a future period ranging from 2071 to 2100.

From the 27 available climate models and the three emission scenarios (RCP2.6, RCP4.5, and RCP8.5), 12 models and one scenario (RCP8.5) have been selected for the analyses (Table 4-4 and These simulations represent the full range and uncertainty of the climate simulations.

Table 4-3: Selected Global Climate Models (GCMs) for which downscaled climate data were obtained for this CCVA (PCIC, 2019).

Global climate models		
ACCESS1-0	CSIRO-mk3-6-0	IPSL-CM5A-MR
CanESM2	GFDL-CM3	MIROC5
CCSM4	GFDL-EMSM2G	MPI-ESM-LR
CNRM-CM5	inmcm4	MRI-CGCM3

Table 4-4: Short description of the different Representative Concentration Pathways (RCPs) (IPCC, 2001)[26].

RCP	Description
RCP2.6	**Stringent mitigation scenario**: representative of a scenario that aims to keep global warming likely below a 2°C increase above preindustrial temperatures. Ambitious reduction of GHG emissions required for this scenario for emissions to peak around 2020, then decline, and become net negative before 2100.
RCP4.5	**Intermediate mitigation scenario** consistent with relatively ambitious emissions reductions. The GHG emissions increase before starting to decline between 2040 and 2050. This scenario will likely fall short of the 2°C limit agreed upon in the Paris Agreement.
RCP6.0	**Intermediate to high emissions scenario** with emissions peaking in 2080 and declining for the rest of the century.
RCP8.5	**Very high GHG emissions**: consistent with no policy changes to reduce emissions.

[26] IPCC (2001). https://www.ipcc.ch/2001/

5. Adaptation Library

The Toolkit hosts a default adaptation project for each type of hazard; therefore, options will depend on the Hazard Type selection (flooding, wildfires, wind, extreme temperatures, and ice storms). The table in Appendix C presents the adaptation project library. The adaptation projects library classifies the adaptation according to the type of hazard, the components that are targeted by the adaptations and the different stakeholders that could be involved. The adaptation projects are also classified according to three categories: Design, Operation and Maintenance and Policy.

The design category refers to structural measures or projects to adapt the asset so that it withstands future climate conditions, while the operation and maintenance and policy categories are non-structural measures that refer to planning additional operations and maintenance measures or projects or the development of policies to ensure resiliency to future climate change impacts.

The adaptation projects within the RoI Toolkit are adapted to the Canadian reality and Canadian standards, such as CSA standards, Fire Smart, etc. The calculation of adaptation project costs will be undertaken for structural measures within the RoI Toolkit by considering their costs and the project or structure's useful life. For non-structural adaptation projects, it is hard to establish default costs, therefore the user will have to input their own data for non-structural project costs.

The following sections will provide an overview of adaptation projects according to the hazard (riverine flooding, wildfire, strong wind, extreme temperature, and ice storms) and categorized by type. These descriptions can help the user input the appropriate adaptation project into the RoI Toolkit.

5.1 Riverine Flood

5.1.1 Acquisition

This is the purchase of a structure and its associated land parcel. Acquisition may be combined with demolition or the relocation of the structure to an area not prone to flooding. In both cases, the acquired land is deed restricted in order to eliminate future damage.

5.1.2 Property Enhancement

Adaptation projects for the property enhancement include avoiding the construction of buildings in flood prone areas or relocation and using flood-damage-resistant building materials (CSA Z800-18). For electrical installations and infrastructures for buildings and facilities, these should be relocated outside areas at risk of flooding or erosion, their elevation should be required, stainless steel transformers should be used to avoid and delay corrosion and incorporating the use of water sensors in basements to shut off power and/or isolate connections.

Non-structural property enhancement measures are related to operation and maintenance and inspections following CSA standard Z800-18.

5.1.3 Flood Control Measures and Drainage Improvements

Drainage improvement through flood control measure include the construction or modification of physical flood control measures or the alteration of channels. Examples of flood control measures include the building of dams, detention and retention ponds, or by-pass channels. Channel relocation, widening, and straightening also are major flood control measures. Examples of drainage improvements include culvert replacement and stream bank stabilization. There are two types of drainage improvement: structural flood control measures and alteration of a watercourse.

- Structural Flood control measures are drainage projects reduce flooding through the construction of flood storage areas, either detention and retention ponds or behind dams.
- Alteration of watercourse control measures are often made to the channels of rivers, streams, ditches or drainageways, usually to improve drainage, to relocate the channel, or to increase its conveyance capacity. There are three requirements when altering the conveyance capacity of a watercourse: (1) The altered or relocated watercourse must have the same or greater capacity than the original watercourse; (2) Once the alterations is made, the capacity of the altered or relocated watercourse must be maintained over time; and (3) The altered watercourse cannot adversely affect other property owners through increased or changed floodplains or floodplains.

Drainage improvements can also focus on sanitary and storm sewers by increasing the capacity of storm sewers, separating sanitary and storm sewer systems, improving the pumping capacity of the drainage system, protecting from sewer backup by never directing downspout, foundation drain and sump pump discharge toward the sanitary sewers (CSA W204:19), minor and major drainage systems should be designed concurrently to a minimum 1-in-100-year major storm design event (CSA W204:19) and major drainage systems should be designed to convey runoff for rainfall events, which exceed the capacity of the minor system and serve up to the major design storm (CSA W204:19).

Non-structural drainage improvements measures are related to operation and maintenance practices such as the clearing of debris in the drainage system and the management of vegetation and riparian buffer zones along water courses.

5.1.4 Elevation of Structures

Raising a building to place the lowest floor at or above the designated Base Flood Elevation (BFE) according to designs that may include extended foundation walls, fill, piles, piers, or other techniques. Local building codes or floodplain management ordinances may require that the lowest floor be elevated to a specified freeboard elevation that is higher than only raising the building to the BFE.

5.1.5 Floodproofing Measures

Any combination of adaptation projects added to or incorporated into an asset to prevent flood damages. This approach completely seals the interior of a building by making the exterior walls substantially impermeable to the passage of floodwater. Although floodwater may touch or surround the asset, the asset is not damaged, and the interior remains dry. For existing assets, this is considered as a type of retrofitting. Dry floodproofing is typically most suitable for areas subject to short-duration, low-level flooding.

Floodproofing Measures also includes flood barriers, which is defined as a constructed barrier between an asset and the flood source that blocks floodwaters from meeting the asset. Examples include earthen levees and concrete or masonry floodwalls. Levees or floodwalls may surround an asset or tie into high ground at each end.

5.1.6 Nature Based Infrastructure

Nature based infrastructure adaptations concerns enhanced assets, natural assets, and engineered assets. This includes structural adaptations such as stream bank stabilization, avoiding encroachment of riparian buffers, and floodplain and stream restoration, bioretention planters, bioswales, berms and dikes.

Floodplain and Stream Restoration (FSR) projects are used primarily to reduce flood risk and erosion by providing stable reaches but can also be used to help mitigate drought. These projects restore and enhance the floodplain, stream channel and riparian ecosystem’s natural function. They provide baseflow recharge, water supply augmentation, floodwater storage, water quality renovation, terrestrial and aquatic wildlife habitat, and recreation opportunities, by restoring the site’s soil, hydrology and vegetation conditions that mimic the pre-development, or pre-alteration natural channel/floodplain connectivity. FSR projects typically encompass the restoration of the stream's active channel and streambanks, as well as the adjacent floodplain and riparian zones.

Non-structural nature-based infrastructure measures are related to operation and maintenance and include water level monitoring, keeping updated and accessible floodplain maps and developing an operational and maintenance plan that identifies potential areas of risk related to flooding of riverine zones and specify measures and procedures to address any such risks.

5.1.7 Transportation

The transportation sector adaptations focus on the use of appropriate materials to prevent cracking and that are well sealed and less susceptible to water damage, the increase of base strength to protect the subgrade layers of roads, the reinforcement of bridges through the incorporation of design requirements from the CSA S6-18 Canadian Highway Bridge Design Code in order to increase resiliency of bridges to erosion caused by flooding.

Non-structural transportation measures are related to operation and maintenance.

5.1.8 Policy

Policy adaptation projects are non-structural measures to help prepare appropriately to flood risks. Policy adaptation projects include laws, regulations, procedures, administrative actions, incentive of voluntary practices of government and other institutions in order to provide guidance. They are rules, principles, guidelines, and frameworks that are adopted or designed to achieve long-term goals.

Riverine flood policies include the implementation of flood forecasting, the implementation of emergency response protocols and flood preparedness and prevention education. This will help prepare appropriately to flood risks.

5.2 Wildfire

5.2.1 Property Enhancement

Adaptation projects for the property enhancement, focus on location and avoiding areas that are at risk of wildfire and where fire burns more rapidly such as sloped areas. Vulnerable communities should also be designed in a way that facilitate proper access to help emergency responders arrive in a timely manner, and burry their electrical grid to protect it.

Non-structural property enhancement measures are related to operation and maintenance including replacing worn or missing weather stripping and keeping buildings cleared of combustible materials and overhanging vegetation.

5.2.2 Defensible Space

Defensible space adaptation projects involve the creation of perimeters in and around both residential and non-residential structures through the removal or reduction of flammable vegetation. This can be undertaken by minimizing the volume of vegetation, replacing flammable vegetation with less flammable species, and clearing all combustibles in the safety zone surrounding the structure.

Non-structural defensible space measures are related to operation and maintenance of the defensible space by keeping it clear of vulnerable vegetation.

5.2.3 Policy

Policy adaptation projects are non-structural measures that include laws, regulations, procedures, administrative actions, incentive of voluntary practices of government and other institutions to provide guidance. They are rules, principles, guidelines, and frameworks that are adopted or designed to achieve long-term goals.

Wildfire policies include making sure that emergency plans are current and that people responsible for the implementation of the plans are emergency-ready, developing guidelines for development, implementing evacuation plans and preparing the communities to properly handle emergencies and implementing public awareness, engagement, and community participation to risk reduction activities. This will help prepare appropriately to wildfire risks.

5.2.4 Reduction of Hazardous Fuels

Hazardous Fuels Reduction is the action to remove vegetative fuels that if ignited pose significant threat to human life and property. The following measures are non-structural and are related to operation and maintenance. Vegetation management reduces hazardous fuels, vegetation thinning, and the reduction of flammable materials to protect life and property beyond defensible space perimeters but proximate to at-risk structures. Activities may include vegetation management or the removal of vegetative fuels, vegetation clearing or thinning, slash removal, vertical clearance of tree branches, biomass conversion or removal.

5.3 Strong Wind

5.3.1 Property Enhancement

Adaptation projects for the property enhancement focus on retrofit projects and on protecting electrical infrastructure. Retrofit projects include retrofitting windows and doors to prevent damage and injury from debris, retrofit projects to transfer wind leads from the roof to the foundation, retrofit projects to secure the building envelope and integrity wind event, roof diaphragm retrofit by roof hardening and incorporating roof clips. Furthermore, during the planning phase of construction buildings should be planned with hip-roofs of a cubical form and by avoiding building elevation forms that are thinner at the bottom and wider at the top.

5.3.2 Policy

Policy adaptation projects are non-structural measures that include laws, regulations, procedures, administrative actions, incentive of voluntary practices of government and other institutions to provide guidance. They are rules, principles, guidelines and frameworks that are adopted or designed to achieve long-term goals.

Strong win policies call for the establishment of new codes to upgrade building requirements for strong wind/hurricane resistance and establishing new codes and standards for construction zones where debris and objects that can be blown away are properly tied down and stored away. This will help prepare appropriately to strong wind risks.

5.3.3 Transportation

Design roadside infrastructure and bridges to withstand higher wind speed are structural measures that can be undertaken for transportation.

Non-structural measures are related to operation and maintenance and include clearing sidewalks, roads and construction sites of debris and tying down materials, debris and objects that are susceptible of being blown away and considered as projectiles.

5.3.4 Nature Based Infrastructure

Nature based infrastructure adaptation projects include enhanced assets, natural assets and engineered assets.

Adaptation projects for nature-based infrastructure include incorporating wind breaks in the landscaped design of a project and the addition of “snow fences” which are rows of trees to reduce the impact of blowing snow or blowing rain on roadway visibility.

5.4 Extreme Temperatures

5.4.1 Property Enhancement

Adaptation projects for the property enhancement include the installation of window shades and the incorporation of heat island reduction strategies such as green roofs or cool roofs.

Some adaptation projects focus on electricity infrastructure and include burying the electrical grid to avoid damage from extreme heat, replacing overhead lines with underground cables, adding supplementary transmission lines to re-route electricity in case of failure, investment in smart grids, microgrids and circular grids, building retrofits and plan building designs that promote electricity and energy conservation, such as passive cooling systems, window shading and insulation and considering electricity mix diversification by having centralized and decentralized options and by promoting an increase in renewable energy.

Non-structural adaptation projects are related to operation and maintenance and include the increase of monitoring of HVAC cooling demand during heat wave periods to avoid overheating of the systems.

5.4.2 Nature Based Infrastructure

Nature based infrastructure adaptations projects include enhanced assets, natural assets, and engineered assets. Structural measures include aquifer storage and recovery projects which is constructing a system for injecting water into an aquifer during periods of excess rainfall, then pumping it back to the surface during periods of water deficit and planting local species that have a greater heat tolerance or are drought resistant.

5.4.3 Policy

Policy adaptation projects are non-structural measures that include laws, regulations, procedures, administrative actions, incentive of voluntary practices of government and other institutions in order to provide guidance. They are rules, principles, guidelines and frameworks that are adopted or designed to achieve long-term goals.

Policies to mitigate the effects of extreme temperatures include regularly evaluating de local forecast and monitor heat, tracking impacts of extreme heat to identify "hot-spots" that may require an increased rate of inspection, and implementing formal systems for notifying the public of heat waves which would include the communication of its arrival, duration and severity. During prolonged episodes of extreme temperatures and heat waves, establish a secure area where the community and vulnerable populations can cool off. Community education on best practices in urban greening and the implementation of urban planning standards and climate adaptation such as tree cover minimums, green spaces standards, fresh air corridor standards, etc., is encouraged. This will help prepare appropriately to extreme temperature risks.

5.4.4 Transportation

Structural adaptation projects for transportation assets include increasing roadside vegetation and trees to increase shade and decrease exposure, considering the use of additives in asphalt mix to reduce shoving/rutting, using solar heating reflective coating layer, using materials that are resistant to or limit the accumulation of heat, such as light-colored materials such as white (high albedo), using more durable materials for bridge deck, including reinforced concrete and using heat resistant paving materials with higher solar reflectance to reduce damages (e.g., potholes and cracks) and UHI effect. Also consider use of additives in asphalt mix to reduce shoving/rutting.

Non-structural measures are related to operation and maintenance and include conducting more frequent inspections and maintenance of bridges, replacing bridge expansion joints and ensure joints can accommodate thermal expansion and implementing proactive traffic management plans to reduce risk of rutting.

5.5 Ice Storm

5.5.1 Property Enhancement

Structural adaptation projects for the property enhancement focus on maintaining electricity in the event of power a power outage, such as adding solar panels and energy storage sources as an alternative source of power and the addition of back-up generator or battery backup systems. There are also measures such as adding supplementary transmission lines to re-route electricity in case of failure, burying electrical lines, smart grids, microgrids and circular grids and the use of thicker overhead wires in areas prone to severe icing.

Non-structural adaptation projects are related to operation and maintenance and include the upgrade of structures such as the insulation at building corners and seal joints between panels, the increase of wall condition monitoring frequency, the regular inspection of snow/ice removal on building roofs and increased maintenance for tree cover (trimming tree branches) to minimize ice incrusted branches that fall on power lines.

5.5.2 Policy

Policy adaptation projects are non-structural measures that include laws, regulations, procedures, administrative actions, incentive of voluntary practices of government and other institutions in order to provide guidance. They are rules, principles, guidelines, and frameworks that are adopted or designed to achieve long-term goals.

Ice storm policies include the implementation of a storm preparedness plan and emergency response protocols and/or making sure that emergency plans are current and that people responsible for the implementation of the plans are emergency ready.

Measures for regularly evaluating the local forecast and regularly reviewing and updating ice loading maps and loading criteria and community measures such as establishing reception center sites across the city and educating the community on the best practices and how to prepare for ice storms. This will help prepare appropriately to ice storm risks.

5.5.3 Transportation

Adaptation projects for the transportation asset type are non-structural and are related to operation and maintenance. They include frequent inspections of pavement surfaces to ensure cracks are properly sealed, increasing maintenance of pavement surfaces to monitor the accumulation of ice and the formation of black ice and the spreading of de-icing agents to eliminate icy roads and hazardous conditions.

5.5.4 Nature Based Infrastructure

Nature based infrastructure adaptations concerns enhanced assets, natural assets and engineered assets.

Adaptation projects for nature-based infrastructure include use vegetation that has a higher resilience to ice storms in landscaping.

6. Resources

6.1 Specific Hazard Resources

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Appendix A: Standard Values and Sources

Table A1: Standard Data Types and Corresponding Values and Sources

Data Type	FEMA Value	RoI	Source
Discount Rate	3.5%	User entry (default at 3.5%)	
BCA Parameters for Utility Services			
Electrical (US$/Person/Day)	US$ 174	$221	FEMA Benefit-Cost Analysis Toolkit Version 6.0
Potable Water (US$/Person/Day)	US$ 114	$145	FEMA Benefit-Cost Analysis Toolkit Version 6.0
Wastewater (US$/Person/Day)	US$ 58	$74	FEMA Benefit-Cost Analysis Toolkit Version 6.0
Vehicle Occupancy and Unit Cost for Time Parameters			
Passenger Vehicle (Occupancy)	1.67	1.7	Alberta Transportation Benefit Cost Model – Version 201811120.
Time value of money work travel (per hour)	US$ 27.90	$ 26.00	Alberta Transportation Benefit Cost Model – Version 201811120.
Time value of money leisure travel (per hour)	US$ 16.50	$ 13.00	Alberta Transportation Benefit Cost Model – Version 201811120.
Safety Parameters			
Cost of fatality	7,500,000	$11.80M	Multihazard Mitigation Council (2019) VSL from Bergeron (2014)
Cost of serious injury	N/A	$4.4M	
Cost of minor injury	N/A	$66,109	
FEMA value of a hospitalization (2021$)	US$ 2,300,000	N/A	
FEMA value of treat & release (2021$)	US$ 61,000	N/A	
FEMA value of self-treatment (2021$)	US$ 14,000	N/A	
Wildfire casualty rate	8.94 death per million	0.009 per person	Calfire database
Wildfire injury rate	NA	0.033	Calfire database
Flood minor injury rate per households		0.1275	Multihazard Mitigation Council 2019
Flood moderate injury rate per households		0.04	Multihazard Mitigation Council 2019
Flood death rate per house per households		0.0008	Multihazard Mitigation Council 2019
Mental Health Parameters			
Treatment Cost per Person (per event)	US$ 2,443	$90,000	FEMA BCA Help, "How are mental health treatment costs and productivity losses calculated?"
Instance of PTSD		0.15 per person	Multihazard Mitigation Council 2019

Data Type	FEMA Value	RoI	Source
Loss of Productivity Parameters			
Productivity loss per Person (per event)	US$ 8,736	$15,634	FEMA BCA Help, "How are mental health treatment costs and productivity losses calculated?"
Average number of workers per household	1.22	User entry	
Ecosystem Services Parameters (Value per acre per year [U.S.]/hectare per year [Can])			
Forest	US$ 554	$8,814.35	Multiple sources
Urban Green Open Space	US$ 8,308	$20,496.85	Multiple sources
Rural Green Open Space		$7,824.03	Multiple sources
Riparian	US$ 39,545	$51,599.56	Multiple sources
Inland wetland	US$ 6,010	$4,559.37	Multiple sources
Volunteer Costs			
Volunteer costs per person per day	US$ 198	N/A	FEMA Benefit-Cost Analysis Toolkit Version 6.0

Table A2: tandard Data Types and Corresponding Values of Ecosystem Services (Urban Green Infrastructure)

Data Type	Green Roofs	Permeable Pavements	Bioretention	Urban Trees
Avoided carbon emissions	$0.0065 m^{-2}	$0.05 m^{-2}	$0.23 m^{-2}	$0.19 tree^{-1}
Carbon sequestration	$0.0023 m^{-2}	-	$74.45 m^{-2}	$28.65 tree^{-1}
Carbon sequestration and avoided emissions	$0.0088 m^{-2}	$0.05 m^{-2}	$74.67 m^{-2}	$28.84 tree^{-1}
Building energy cost savings	$1.98 m^{-2}	-	-	$31.19 tree^{-1}
Drought risk reduction	-	$0.10 m^{-2}	$0.41 m^{-2}	$4.41 tree^{-1}
Habitat	$0.04 m^{-2}	-	$0.09 m^{-2}	$32.05 tree^{-1}
Heat risk reduction	-	-	-	$726.19 tree^{-1}
Property value improvement	$0.15 m^{-2}	-	$0.32 m^{-2}	$42.40 tree^{-1}
Removal of air pollutants	$0.01 m^{-2}	-	$0.076 m^{-2}	$6.78 m^{-2} tree^{-1}
Stormwater volume and quality	$0.52 m^{-2}	$4.37 m^{-2}	$18.10 m^{-2}	$14.89 tree^{-1}

Table A3: Standard Data Types and Corresponding Values of Ecosystem Services (per Land Cover)

Data Type	Forests	Urban Green Open Space	Rural Green Open Space	Riparian	Inland Wetland
Air quality	$909.63 ha^{-1}	$760.23 ha^{-1}	-	$597.80 ha^{-1}	-
Climate regulation	$623.03 ha^{-1}	$167.26 ha^{-1}	$238.50 ha^{-1}	$297.35 ha^{-1}	$173.45 ha^{-1}
Erosion Control	$5,178.85 ha^{-1}	$241.60 ha^{-1}	$241.60 ha^{-1}	$42,815.34 ha^{-1}	-
Flood and storm hazard reduction	$2,093.84 ha^{-1}	$978.78 ha^{-1}	-	$18,745.46 ha^{-1}	$3,915.11 ha^{-1}
Habitat	-	$18,243.68 ha^{-1}	$6,259.84 ha^{-1}	$7,889.07 ha^{-1}	$4,385.92 ha^{-1}
Pollination	-	$1,084.09 ha^{-1}	$1,084.09 ha^{-1}	-	-

Appendix B: Average Expected Useful Life for Publicly Owned New Assets

Table B1: RoI Toolkit - Average Expected Useful Life of New Publicly Owned Potable Water Assets [1, 2]

Geography	Type of Municipality by Population Size	Water Treatment Facilities	Water Reservoirs (Including dams) Before Intake[3]	Storage Tanks after Intake not part of a Treatment Plant	Water Pump Stations[4]	Local Water Pipes (diameter less than 416 mm)[5]	Transmission Pipes (Diameter greater than/or equal to 416 mm)[63]	Pipes of unknown diameter
Canada	All municipalities	37	38	41	33	54	62	44
	All urban municipalities	41	44	45	37	63	71	57
	All rural municipalities	35	35	38	32	50	51	38
Newfoundland and Labrador	All municipalities	26	35	29	27	39	54	38
	All urban municipalities	37	47	36	38	50	57	43
	All rural municipalities	25	33	27	25	38	54	38
Prince Edward Island	All municipalities	36	22	28	30	55	89	10
	All urban municipalities	55	40	47	52	84	89	100
	All rural municipalities	32	20	21	25	51	NA[7]	NA
Nova Scotia	All municipalities	38	50	38	36	58	62	16
	All urban municipalities	36	44	47	40	64	66	20
	All rural municipalities	45	58	31	44	58	69	NA
New Brunswick	All municipalities	36	42	39	36	53	67	44
	All urban municipalities	37	40	38	36	59	72	68
	All rural municipalities	36	44	39	36	49	62	36
Quebec	All municipalities	38	38	41	NA	NA	60	46
	All urban municipalities	43	43	47	38	68	76	53
	All rural municipalities	37	37	40	34	51	46	45
Ontario	All municipalities	46	46	49	42	67	72	63
	All urban municipalities	49	46	51	49	71	75	69
	All rural municipalities	44	48	46	39	64	64	56
Manitoba	All municipalities	36	36	35	32	47	43	32
	All urban municipalities	39	33	46	35	52	87	67
	All rural municipalities	35	37	28	32	45	35	25
Saskatchewan	All municipalities	34	30	38	28	44	51	30
	All urban municipalities	39	43	42	37	59	67	43
	All rural municipalities	33	26	36	26	40	44	27
Alberta	All municipalities	35	38	40	32	53	58	44
	All urban municipalities	38	42	39	35	53	63	54
	All rural municipalities	33	34	39	29	53	49	36

Geography	Type of Municipality by Population Size	Water Treatment Facilities	Water Reservoirs (Including dams) Before Intake[3]	Storage Tanks after Intake not part of a Treatment Plant	Water Pump Stations[4]	Local Water Pipes (diameter less than 416 mm)[5]	Transmission Pipes (Diameter greater than/or equal to 416 mm)[63]	Pipes of unknown diameter
British Columbia	All municipalities	38	48	46	35	68	71	63
	All urban municipalities	40	49	49	34	71	74	65
	All rural municipalities	36	46	42	38	65	71	58
Yukon	All municipalities	47	45	45	NA	57	NA	NA
	All urban municipalities	45	45	45	NA	75	NA	NA
	All rural municipalities	48	NA	NA	NA	49	NA	NA
Northwest Territories	All municipalities	26	27	NA	24	31	15	NA
	All urban municipalities	27	27	NA	24	31	15	NA
	All rural municipalities	25	NA	NA	NA	NA	NA	NA
Nunavut	All municipalities	36	45	20	37	75	75	20
	All urban municipalities	40	45	20	37	75	75	NA
	All rural municipalities	33	NA	NA	NA	NA	NA	20

Note:

1. *Expected useful life of an asset refers to the service life or the productive life of the asset at the time of its acquisition regardless of their lives reported for income tax purposes.*
2. *Estimates for 2018 may not be comparable to those for 2016 due to improved coverage and definitions as well as changes in survey methodology.*
3. *Reservoir: A pond, lake, or basin (natural or artificial) that stores, regulates, or controls water. Includes the number of reservoirs and water towers within the distribution, transmission, or integrated system.*
4. *Pump stations include pump stations within the non-linear potable water system.*
5. *Local water pipes include all connecting pipes, of diameter less than 416 mm, between pump stations, rechlorination facilities and storage facilities if these are located within the distribution system.*
6. *Transmission pipes include all connecting pipes, of diameter greater than or equal to 416mm, between pump stations, rechlorination facilities and storage facilities when located between the source and the treatment plant or between the treatment plant and the distribution system.*
7. *Not available for a specific reference period*

TableB2: RoI Toolkit - Average Expected Useful Life of New Publicly Owned Wastewater Assets [1, 2]

Geography	Type of municipality by population size	Wastewater Treatment Plants (Incl. sludge handling plants)	Lagoon Systems	Wastewater Pump Stations	Wastewater Lift Stations	Wastewater Storage Tanks	Sewer pipes (diameter: less than 450 mm)	Sewer Pipes (diameter: greater than or equal to 450 mm to less than 1,500 mm)	Sewer Pipes (diameter: greater than or equal to 1,500 mm)	Sewer Pipes (of unknown diameter)	Sanitary Forcemains
Canada	All municipalities	34	42	35	32	42	53	61	52	54	55
	All urban municipalities	36	44	38	34	53	62	65	67	64	62
	All rural municipalities	33	42	34	31	40	50	53	38	50	51
Newfoundland and Labrador	All municipalities	24	54	31	22	34	40	46	62	67	44
	All urban municipalities	26	51	60	31	NA[3]	47	45	NA	83	52
	All rural municipalities	22	60	28	21	34	39	50	62	58	41
Prince Edward Island	All municipalities	37	31	24	27	NA	53	68	NA	72	52
	All urban municipalities	37	30	30	38	NA	74	64	NA	72	67
	All rural municipalities	37	31	23	27	NA	51	75	NA	NA	49
Nova Scotia	All municipalities	36	48	34	31	35	48	56	NA	53	43
	All urban municipalities	37	56	28	29	28	50	65	NA	40	42
	All rural municipalities	35	45	38	32	41	47	25	NA	75	44
New Brunswick	All municipalities	36	38	36	35	45	56	48	31	57	51
	All urban municipalities	35	39	48	34	NA	61	75	85	75	59
	All rural municipalities	36	38	35	36	45	55	27	10	50	48
Quebec	All municipalities	33	44	35	30	46	56	60	47	58	55
	All urban municipalities	35	46	35	32	76	65	65	54	62	64
	All rural municipalities	33	44	34	29	44	54	54	42	57	51
Ontario	All municipalities	37	52	42	38	53	67	70	74	63	64
	All urban municipalities	39	59	45	41	55	73	73	74	75	70
	All rural municipalities	36	50	40	37	51	63	66	NA	54	61
Manitoba	All municipalities	30	36	26	30	50	38	41	42	39	42
	All urban municipalities	37	35	25	31	NA	50	63	75	75	50
	All rural municipalities	26	36	27	29	50	33	26	20	34	36
Saskatchewan	All municipalities	26	42	29	34	25	40	52	36	35	52
	All urban municipalities	34	43	40	36	43	52	62	75	52	60
	All rural municipalities	22	41	26	33	21	36	29	29	34	47
Alberta	All municipalities	36	41	33	33	33	48	61	76	49	54
	All urban municipalities	35	46	45	35	51	53	63	76	51	56
	All rural municipalities	39	37	20	32	26	44	55	NA	47	53

Geography	Type of municipality by population size	Wastewater Treatment Plants (Incl. sludge handling plants)	Lagoon Systems	Wastewater Pump Stations	Wastewater Lift Stations	Wastewater Storage Tanks	Sewer pipes (diameter: less than 450 mm)	Sewer Pipes (diameter: greater than or equal to 450 mm to less than 1,500 mm)	Sewer Pipes (diameter: greater than or equal to 1,500 mm)	Sewer Pipes (of unknown diameter)	Sanitary Forcemains
British Columbia	All municipalities	34	48	32	36	37	64	62	60	61	62
	All urban municipalities	36	37	32	34	38	68	62	74	60	67
	All rural municipalities	32	58	31	39	37	58	63	50	61	54
Yukon	All municipalities	NA	0	NA	NA	NA	38	45	45	NA	35
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	0	NA	NA	NA	38	45	45	NA	35
Northwest Territories	All municipalities	NA	32	NA	24	NA	40	NA	NA	NA	40
	All urban municipalities	NA	35	NA	24	NA	40	NA	NA	NA	40
	All rural municipalities	NA	30	NA	NA	NA	NA	NA	NA	NA	NA
Nunavut	All municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note:

1. *Expected useful life of an asset refers to the service life or the productive life of the asset at the time of its acquisition regardless of their lives reported for income tax purposes.*
2. *Estimates for 2018 may not be comparable to those for 2016 due to improved coverage and definitions as well as changes in survey methodology.*
3. *Not available for a specific reference period*

Table B3: RoI Toolkit - Average Expected Useful Life of New Publicly Owned Stormwater Assets [1, 2]

Geography	Type of Municipality by Population Size	Stormwater Drainage Pump Stations[3]	Stormwater Management Facilities, Stormwater Management Ponds and Stormwater Wetlands[4]	Stormwater Management Facilities all other Permitted, End-of-Pipe Facilities[5]	Culverts (diameter less than 3 m)	Open Ditches	Stormwater pipes (diameter: less than 450 mm)	Stormwater Pipes (diameter: greater than or equal to 450 mm to less than 1,500 mm)	Stormwater Pipes (diameter: greater than or equal to 1,500 mm)	Stormwater Pipes (of unknown diameter)
Canada	All municipalities	45	56	42	39	45	56	59	73	52
	All urban municipalities	47	57	48	46	51	63	65	79	60
	All rural municipalities	43	55	36	36	43	51	53	60	47
Newfoundland and Labrador	All municipalities	44	57	39	29	37	48	45	51	32
	All urban municipalities	45	56	42	34	49	51	47	68	53
	All rural municipalities	44	59	30	28	33	46	43	43	25
Prince Edward Island	All municipalities	NA[6]	50	NA	28	28	51	50	61	66
	All urban municipalities	NA	50	NA	23	28	62	50	61	66
	All rural municipalities	NA	NA	NA	30	27	50	NA	NA	NA
Nova Scotia	All municipalities	30	42	37	45	47	48	52	64	42
	All urban municipalities	30	43	50	44	49	61	48	70	38
	All rural municipalities	NA	41	30	47	45	39	56	50	54
New Brunswick	All municipalities	44	67	24	40	41	52	52	57	56
	All urban municipalities	40	76	20	49	52	57	56	62	58
	All rural municipalities	45	58	25	39	38	51	51	52	56
Quebec	All municipalities	43	57	43	40	37	58	61	89	54
	All urban municipalities	44	62	49	53	40	74	80	98	71
	All rural municipalities	41	53	38	37	37	53	52	71	51
Ontario	All municipalities	48	56	50	42	52	60	64	73	63
	All urban municipalities	51	51	54	53	63	67	70	76	76
	All rural municipalities	42	59	45	38	48	57	59	68	56
Manitoba	All municipalities	36	48	39	31	47	44	49	40	40
	All urban municipalities	34	52	45	38	42	52	54	75	44
	All rural municipalities	38	44	35	29	50	36	45	18	37
Saskatchewan	All municipalities	48	56	24	34	54	48	50	57	32
	All urban municipalities	48	64	28	38	55	53	51	70	38
	All rural municipalities	48	50	21	32	54	46	48	20	30
Alberta	All municipalities	46	56	37	37	51	52	56	67	51
	All urban municipalities	46	55	37	41	53	56	59	67	52
	All rural municipalities	46	59	38	32	48	45	45	66	49
British Columbia	All municipalities	49	55	57	47	55	64	65	68	65

Geography	Type of Municipality by Population Size	Stormwater Drainage Pump Stations[3]	Stormwater Management Facilities, Stormwater Management Ponds and Stormwater Wetlands[4]	Stormwater Management Facilities all other Permitted, End-of-Pipe Facilities[5]	Culverts (diameter less than 3 m)	Open Ditches	Stormwater pipes (diameter: less than 450 mm)	Stormwater Pipes (diameter: greater than or equal to 450 mm to less than 1,500 mm)	Stormwater Pipes (diameter: greater than or equal to 1,500 mm)	Stormwater Pipes (of unknown diameter)
	All urban municipalities	52	56	57	50	54	68	69	72	69
	All rural municipalities	34	46	60	44	57	58	60	40	52
Yukon	All municipalities	25	40	20	53	75	60	50	75	41
	All urban municipalities	NA	NA	NA	30	75	60	50	75	50
	All rural municipalities	25	40	20	75	NA	NA	NA	NA	32
Northwest Territories	All municipalities	NA	NA	NA	30	40	27	27	30	22
	All urban municipalities	NA	NA	NA	30	40	27	27	30	22
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nunavut	All municipalities	NA	NA	NA	30	30	49	NA	NA	46
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	30	30	49	NA	NA	46

Note:

1. *Expected useful life of an asset refers to the service life or the productive life of the asset at the time of its acquisition regardless of their lives reported for income tax purposes.*
2. *Estimates for 2018 may not be comparable to those for 2016 due to improved coverage and definitions as well as changes in survey methodology.*
3. *Stormwater drainage pump stations include stormwater drainage pump stations that are connected to drainage swales, ditches, and storm sewers. Exclude combined pump stations which convey combined sewage/stormwater to wastewater treatment plants.*
4. *Stormwater management facilities – Stormwater management ponds and stormwater wetlands includes engineered end-of-pipe facilities that have received a permit or approval to operate, and which may provide peak flow control, runoff quality control, runoff control for downstream erosion, runoff volume control, etc. Includes dry ponds, wet ponds, and stormwater wetlands etc.*
5. *Stormwater management facilities – All other permitted end-of-pipe facilities includes engineered end-of-pipe facilities that have received a permit or approval to operate, and which are not stormwater ponds or wetlands (e.g.: oil-grit separators, etc.).*
6. *Not available for a specific reference period*

Table B4: RoI Toolkit - Average Expected Useful Life of New Publicly Owned Road Assets

Geography	Type of municipality by population size	Highways[3]	Rural Highways[4]	Arterial Roads[5]	Collector Roads[6]	Local Roads[7]	Lanes and Alleys	Sidewalks
Canada	All municipalities	28	35	30	31	31	31	31
	All urban municipalities	28	35	30	30	31	30	34
	All rural municipalities	28	35	30	31	31	31	29
Newfoundland and Labrador	All municipalities	30	16	22	20	22	30	24
	All urban municipalities	NA[8]	NA	23	20	21	24	24
	All rural municipalities	30	16	20	15	22	32	24
Prince Edward Island	All municipalities	NA	NA	15	17	23	NA	34
	All urban municipalities	NA	NA	15	17	25	NA	33
	All rural municipalities	NA	NA	NA	NA	23	NA	34
Nova Scotia	All municipalities	28	28	26	25	28	33	27
	All urban municipalities	NA	25	23	25	30	20	29
	All rural municipalities	28	29	32	25	27	40	25
New Brunswick	All municipalities	29	22	31	36	28	34	26
	All urban municipalities	NA	33	38	31	26	15	29
	All rural municipalities	29	20	25	39	28	37	26
Quebec	All municipalities	25	26	28	27	29	32	28
	All urban municipalities	30	32	29	28	31	28	32
	All rural municipalities	20	26	26	27	29	33	27
Ontario	All municipalities	25	32	31	32	30	30	35
	All urban municipalities	25	26	33	35	36	31	37
	All rural municipalities	25	33	27	28	28	30	34
Manitoba	All municipalities	35	36	34	35	38	31	30
	All urban municipalities	30	25	36	33	35	30	33
	All rural municipalities	40	37	33	37	39	31	28
Saskatchewan	All municipalities	25	44	34	36	37	33	31
	All urban municipalities	24	25	27	25	30	34	36
	All rural municipalities	26	45	37	40	38	32	29
Alberta	All municipalities	32	30	30	31	32	26	29
	All urban municipalities	30	33	28	30	29	24	30
	All rural municipalities	35	29	32	32	35	28	29
British Columbia	All municipalities	33	58	30	32	34	31	39
	All urban municipalities	32	86	31	32	35	36	43
	All rural municipalities	40	50	26	32	34	25	34

Geography	Type of municipality by population size	Highways[3]	Rural Highways[4]	Arterial Roads[5]	Collector Roads[6]	Local Roads[7]	Lanes and Alleys	Sidewalks
Yukon	All municipalities	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA
Northwest Territories	All municipalities	NA	NA	25	25	32	25	23
	All urban municipalities	NA	NA	25	25	25	25	23
	All rural municipalities	NA	NA	NA	NA	40	NA	NA
Nunavut	All municipalities	NA	NA	NA	NA	23	NA	NA
	All urban municipalities	NA	NA	NA	NA	30	NA	NA
	All rural municipalities	NA	NA	NA	NA	20	NA	NA

Note:

1. *Expected useful life of an asset refers to the service life or the productive life of the asset at the time of its acquisition regardless of their lives reported for income tax purposes.*
2. *Estimates for 2018 may not be comparable to those for 2016 due to improved coverage and definitions as well as changes in survey methodology.*
3. *As of 2018, highways are defined as roads that move high volumes of traffic and have controlled entrance and exit, a dividing strip between the traffic in opposite directions, and typically two or more lanes in each direction. Highways do not provide access to property, and generally do not accommodate cyclists or pedestrians.*
4. *As of 2018, rural highways are defined as roads that move varied traffic volumes depending on location, are medium to high speed, and are usually one, but sometimes two lanes in each direction. These highways usually have no dividing strip and allow for direct access from adjacent developments.*
5. *As of 2018, arterial roads are defined as roads that move moderate to high traffic volumes over moderate distances between principal areas of traffic generation and gather traffic from collector roads and local roads and move it to the highway system. Arterial roads are generally designed for medium speed, have capacity for 2 to 6 lanes, and may be divided, with limited or controlled direct access from adjacent developments and with on-street parking discouraged.*
6. *As of 2018, collector roads are defined as roads that move low to moderate traffic volumes within specific areas of a municipality and collect local traffic for distribution to the arterial or highway system. Collector roads are generally designed for medium speed, have capacity for 2 to 4 lanes, are usually undivided, with direct access from adjacent development permitted but usually controlled, and with controlled on-street parking usually permitted.*
7. *As of 2018, local roads are defined as roads that provide for low volumes of traffic and access to private properties; local roads are designed for low speeds, have capacity for 2 undivided lanes of traffic; through traffic is discouraged and parking is usually permitted though often controlled.*
8. *Not available for a specific reference period*

Table B5: RoI Toolkit - Average Expected Useful Life of New Publicly Owned bridge and Tunnel Assets [1, 2]

Geography	Type of municipality by population size	Highway Bridges[3]	Rural Highway Bridges[4]	Arterial Bridges[5]	Collector Bridges[6]	Local Bridges[7]	Foot Bridges	Culverts diameter greater than or equal to 3 m	Tunnels
Canada	All municipalities	55	46	56	56	48	40	39	65
	All urban municipalities	52	41	56	57	49	45	55	68
	All rural municipalities	57	47	57	54	47	35	34	50
Newfoundland and Labrador	All municipalities	50	NA[8]	50	..	41	10	15	..
	All urban municipalities	..	..	50	..	42	..	..	..
	All rural municipalities	50	..	..	..	35	10	15	..
Prince Edward Island	All municipalities	NA	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA
Nova Scotia	All municipalities	NA	NA	48	NA	50	NA	NA	NA
	All urban municipalities	NA	NA	48	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	50	NA	NA	NA
New Brunswick	All municipalities	NA	20	NA	NA	70	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	20	NA	NA	70	NA	NA	NA
Quebec	All municipalities	NA	99	30	30	46	NA	59	70
	All urban municipalities	NA	NA	NA	NA	NA	NA	55	70
	All rural municipalities	NA	99	30	30	46	NA	62	NA
Ontario	All municipalities	75	57	65	65	63	46	46	50
	All urban municipalities	NA	40	63	63	59	46	76	NA
	All rural municipalities	75	62	75	75	65	46	41	50
Manitoba	All municipalities	NA	40	35	72	37	37	32	NA
	All urban municipalities	NA	NA	NA	NA	NA	25	NA	NA
	All rural municipalities	NA	40	35	72	37	40	32	NA
Saskatchewan	All municipalities	75	42	75	75	39	40	33	NA
	All urban municipalities	75	NA	75	75	20	40	48	NA
	All rural municipalities	NA	42	NA	NA	40	NA	31	NA
Alberta	All municipalities	NA	41	56	56	51	45	22	NA
	All urban municipalities	NA	41	30	NA	NA	35	10	NA
	All rural municipalities	NA	NA	63	56	51	50	26	NA
British Columbia	All municipalities	44	NA	57	46	47	39	55	67
	All urban municipalities	44	NA	54	51	51	49	61	67
	All rural municipalities	NA	NA	75	25	35	27	25	NA
Yukon	All municipalities	NA	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA

Geography	Type of municipality by population size	Highway Bridges[3]	Rural Highway Bridges[4]	Arterial Bridges[5]	Collector Bridges[6]	Local Bridges[7]	Foot Bridges	Culverts diameter greater than or equal to 3 m	Tunnels
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA
Northwest Territories	All municipalities	NA	NA	NA	40	NA	30	40	NA
	All urban municipalities	NA	NA	NA	40	NA	30	40	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA
Nunavut	All municipalities	NA	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA

Note:

1. *Expected useful life of an asset refers to the service life or the productive life of the asset at the time of its acquisition regardless of their lives reported for income tax purposes.*
2. *Estimates for 2018 may not be comparable to those for 2016 due to improved coverage and definitions as well as changes in survey methodology.*
3. *As of 2018, highways are defined as roads that move high volumes of traffic and have controlled entrance and exit, a dividing strip between the traffic in opposite directions, and typically two or more lanes in each direction. Highways do not provide access to property, and generally do not accommodate cyclists or pedestrians.*
4. *As of 2018, rural highways are defined as roads that move varied traffic volumes depending on location, are medium to high speed, and are usually one, but sometimes two lanes in each direction. These highways usually have no dividing strip and allow for direct access from adjacent developments.*
5. *As of 2018, arterial roads are defined as roads that move moderate to high traffic volumes over moderate distances between principal areas of traffic generation and gather traffic from collector roads and local roads and move it to the highway system. Arterial roads are generally designed for medium speed, have capacity for 2 to 6 lanes, and may be divided, with limited or controlled direct access from adjacent developments and with on-street parking discouraged.*
6. *As of 2018, collector roads are defined as roads that move low to moderate traffic volumes within specific areas of a municipality and collect local traffic for distribution to the arterial or highway system. Collector roads are generally designed for medium speed, have capacity for 2 to 4 lanes, are usually undivided, with direct access from adjacent development permitted but usually controlled, and with controlled on-street parking usually permitted.*
7. *As of 2018, local roads are defined as roads that provide for low volumes of traffic and access to private properties; local roads are designed for low speeds, have capacity for 2 undivided lanes of traffic; through traffic is discouraged and parking is usually permitted though often controlled.*
8. *Not available for a specific reference period*

Table B6: RoI Toolkit - Average Expected Useful Life of New Publicly Owned Public Transit Assets[1,2]

Geography	Type of municipality by population size	Diesel Buses	Bio-diesel Buses	Hybrid Buses (Includes diesel, biodiesel & natural gas)	Heavy Railcars (subway)[3]	Commuter Railcars (locomotives and passenger)[4]	Light Railcars[5]	Specialized Transit (Para or handi transpo and dial a ride)[6]	Passenger Stations/ Terminals	Transit Shelters	Exclusive Rights-of-ways[7]	Parking Lots (Park & ride)[8]	Passenger Drop-off Facilities (Kiss & Ride)
Canada	All municipalities	15	x[9]	15	x	x	30	10	41	22	21	19	23
	All urban municipalities	x	x	15	x	x	30	9	41	x	21	19	x
	All rural municipalities	x	NA[10]	17	NA	NA	NA	10	38	x	NA	20	x
Newfoundland and Labrador	All municipalities	20	NA	NA	NA	NA	NA	NA	NA	30	NA	NA	NA
	All urban municipalities	20	NA	NA	NA	NA	NA	NA	NA	30	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Prince Edward Island	All municipalities	10	NA	NA	NA	NA	NA	NA	NA	23	NA	NA	NA
	All urban municipalities	10	NA	NA	NA	NA	NA	NA	NA	26	NA	NA	NA
	All rural municipalities	10	NA	NA	NA	NA	NA	NA	NA	20	NA	NA	NA
Nova Scotia	All municipalities	11	NA	NA	NA	NA	NA	10	30	20	NA	NA	NA
	All urban municipalities	12	NA	NA	NA	NA	NA	NA	30	10	NA	NA	NA
	All rural municipalities	10	NA	NA	NA	NA	NA	10	NA	25	NA	NA	NA
New Brunswick	All municipalities	18	NA	NA	NA	NA	NA	8	NA	19	NA	16	15
	All urban municipalities	17	NA	NA	NA	NA	NA	8	NA	19	NA	16	15
	All rural municipalities	20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Quebec	All municipalities	23	x	16	x	x	NA	9	33	29	15	20	17
	All urban municipalities	x	x	16	x	x	NA	8	33	x	15	22	x
	All rural municipalities	x	NA	NA	NA	NA	NA	10	NA	x	NA	19	x
Ontario	All municipalities	14	16	13	30	NA	30	8	50	21	25	19	25
	All urban municipalities	13	16	13	30	NA	30	8	50	21	25	18	25
	All rural municipalities	14	NA	NA	NA	NA	NA	9	50	23	NA	20	NA
Manitoba	All municipalities	14	NA	NA	NA	NA	NA	10	25	30	25	20	60
	All urban municipalities	16	NA	NA	NA	NA	NA	5	25	30	25	20	60
	All rural municipalities	10	NA	NA	NA	NA	NA	11	NA	NA	NA	NA	NA
Saskatchewan	All municipalities	13	NA	16	NA	NA	NA	11	22	24	25	NA	NA
	All urban municipalities	13	NA	16	NA	NA	NA	10	22	24	25	NA	NA
	All rural municipalities	13	NA	NA	NA	NA	NA	11	NA	NA	NA	NA	NA
Alberta	All municipalities	16	NA	17	NA	NA	30	8	24	24	NA	20	23
	All urban municipalities	15	NA	NA	NA	NA	30	8	24	24	NA	20	20
	All rural municipalities	16	NA	17	NA	NA	NA	8	25	23	NA	20	25
British Columbia	All municipalities	11	10	NA	NA	NA	NA	13	48	18	25	20	30

Geography	Type of municipality by population size	Diesel Buses	Bio-diesel Buses	Hybrid Buses (Includes diesel, biodiesel & natural gas)	Heavy Railcars (subway)[3]	Commuter Railcars (locomotives and passenger)[4]	Light Railcars[5]	Specialized Transit (Para or handi transpo and dial a ride)[6]	Passenger Stations/ Terminals	Transit Shelters	Exclusive Rights-of-ways[7]	Parking Lots (Park & ride)[8]	Passenger Drop-off Facilities (Kiss & Ride)
	All urban municipalities	12	10	NA	NA	NA	NA	13	48	19	25	20	30
	All rural municipalities	10	NA	NA	NA	NA	NA	NA	NA	13	NA	20	NA
Yukon	All municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Northwest Territories	All municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nunavut	All municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note:

1. *Expected useful life of an asset refers to the service life or the productive life of the asset at the time of its acquisition regardless of their lives reported for income tax purposes.*
2. *Estimates for 2018 may not be comparable to those for 2016 due to improved coverage and definitions as well as changes in survey methodology.*
3. *Heavy rail (subways): Heavy rail (subways) usually operate in tunnels but may also operate at grade. Includes rail or guided tire based heavy rail (subways) owned by an organization, as well as all heavy rail (subways) leased by an organization through a capital lease agreement and used for revenue service.*
4. *Commuter rail (locomotive and passenger): Commuter rail (locomotive and passenger) link regional centres with outlaying communities and may operate along some of the same corridors and track used by freight and inter-city passenger rail services. Includes commuter rail (locomotive and passenger) owned by an organization, as well as all the commuter rail (locomotive and passenger) leased by an organization through a capital lease agreement and used for revenue service.*
5. *Light rail transit (LRT)/Advanced light rail transit (ALRT): LRT/ALRT usually operates above ground in their own rights-of-way, however, some systems are operated in tunnels and on elevated guideways. Includes LRT/ALRT owned by an organization, as well as all the assets leased by an organization through a capital lease agreement and used for revenue service.*
6. *Specialized transit services are transit services for persons with disabilities.*
7. *Exclusive right-of-way include roadways reserved at all times for transit use and/or other high occupancy vehicles only. Exclude transit exclusive lanes that are only transit exclusive during rush hour.*
8. *Park and ride parking lots: Park and ride parking lots provided parking spaces with direct connections to the transit system that allow commuters to leave their personal vehicle and transfer to transit. Includes park and ride parking lots owned by an organization, as well as all park and ride parking spaces leased by an organization through a capital lease agreement.*
9. *suppressed to meet the confidentiality requirements of the Statistics Act*
10. *Not available for a specific reference period*

Table B7: RoI Toolkit - Average Expected Useful Life of New Publicly Owned Culture, Recreation and Sport Facilities

Geography	Type of municipality by population size	Indoor ice arenas, single pad	Indoor ice arenas: multiple pads (two or more)	Indoor ice arenas: Performance/spectator	Outdoor ice arenas	Curling rinks	Indoor pools, 25 metres	Indoor pools, 50 metres or longer	Indoor pools, leisure pools 3	Outdoor pools	Outdoor spray parks/splash pads/wading pools	Galleries	Libraries	Museums and archives	Presentation and performance spaces	Indigenous culture facilities	Community centres (senior and youth centres)	Indoor gymnasiums	Indoor racquet courts	Indoor walking/jogging tracks	Indoor fitness areas	Indoor fields	Outdoor specialty areas	Playgrounds	Outdoor tennis and/or pickleball courts	Ball diamonds	Rectangular sports fields (natural turf)	Artificial turf sports fields	Paved pathways	Trails (non-paved)
Canada	All	36	44	39	27	36	37	46	36	27	23	41	37	35	36	NA	40	34	31	34	29	32	28	22	21	28	30	20	25	29
	All urban	38	44	40	26	38	36	NA	NA	30	25	45	40	38	42	NA	43	35	31	36	33	35	31	21	23	27	30	21	26	30
	All rural	36	43	38	27	35	38	NA	NA	25	22	37	35	33	33	NA	39	33	31	32	28	29	26	22	21	28	29	19	24	28
Newfoundland and Labrador	All	39	55	18	28	37	26	NA	40	21	23	51	24	31	68	NA	38	23	51	29	19	NA	26	23	24	36	30	37	38	29
	All urban	30	55	18	15	29	22	NA	NA	60	25	55	27	29	55	NA	41	36	52	28	68	NA	30	20	20	26	34	43	50	30
	All rural	42	NA	NA	30	40	46	NA	40	18	20	50	23	32	77	NA	38	21	50	29	14	NA	25	24	25	38	29	20	33	29
Prince Edward Island	All	30	50	32	22	50	50	NA	NA	30	33	36	23	22	31	NA	37	26	50	52	27	NA	20	22	19	25	24	29	25	26
	All urban	46	50	50	50	NA	50	NA	NA	40	46	50	50	50	NA	NA	61	75	50	61	50	NA	50	39	39	41	46	50	39	43
	All rural	29	NA	30	17	50	50	NA	NA	25	30	35	22	20	31	NA	36	20	NA	50	25	NA	19	21	18	24	21	15	22	26
Nova Scotia	All	31	NA	23	38	20	40	NA	NA	18	16	23	36	47	35	NA	34	33	10	27	39	NA	37	19	15	35	39	20	15	33
	All urban	25	NA	25	25	NA	50	NA	NA	25	21	NA	45	31	50	NA	33	38	10	25	50	NA	38	18	16	39	42	NA	15	32
	All rural	32	NA	20	45	20	35	NA	NA	17	12	23	34	53	27	NA	35	31	NA	28	35	NA	36	19	15	32	37	20	15	34
New Brunswick	All	36	40	38	25	38	40	25	25	23	21	43	46	28	31	NA	40	37	30	31	30	NA	38	20	19	24	18	17	21	28
	All urban	35	40	35	24	40	44	25	25	30	24	42	44	48	36	NA	40	45	30	41	35	NA	48	18	22	20	21	14	27	33
	All rural	37	NA	43	25	37	34	NA	NA	20	19	44	47	20	26	NA	41	32	NA	29	27	NA	33	20	17	27	17	30	16	27
Quebec	All	37	42	46	26	32	34	37	35	27	24	34	37	35	31	NA	39	37	32	31	29	31	25	24	22	29	29	21	28	28
	All urban	42	41	43	28	31	36	NA	NA	31	25	32	40	35	35	NA	43	34	38	30	27	35	32	25	24	27	28	21	29	27
	All rural	35	44	48	26	34	31	NA	NA	23	24	35	37	35	30	NA	39	38	27	31	30	30	22	24	21	29	30	20	27	29
Ontario	All	44	48	45	29	40	40	52	41	34	23	53	45	47	51	40	49	41	32	35	35	24	28	20	22	26	30	21	25	29
	All urban	47	49	46	33	42	39	48	37	34	23	56	50	51	52	40	52	35	31	37	35	28	25	20	21	25	28	21	25	25
	All rural	43	45	44	28	40	44	63	52	33	23	44	43	45	51	NA	48	46	33	33	34	20	30	19	22	27	31	23	25	32
Manitoba	All	32	40	36	26	35	32	50	NA	18	24	29	30	30	26	9	34	29	NA	26	23	47	40	20	19	22	23	10	24	29
	All urban	31	33	NA	24	36	40	50	NA	19	28	10	37	42	39	NA	37	33	NA	35	29	50	53	23	22	22	23	10	22	27
	All rural	32	47	36	28	34	21	NA	NA	17	20	38	27	26	20	9	34	27	NA	22	22	45	35	19	16	22	23	NA	26	29
Saskatchewan	All	32	35	37	25	34	38	40	38	26	19	29	29	28	25	74	35	27	35	35	28	27	29	21	21	28	37	10	21	27
	All urban	33	29	37	22	32	36	40	38	25	22	29	31	26	26	22	33	28	30	37	29	28	31	18	23	26	34	NA	17	22
	All rural	32	50	36	30	35	40	NA	NA	26	16	NA	29	29	23	99	36	27	40	32	27	25	28	23	19	28	40	10	28	30

Geography	Type of municipality by population size	Indoor ice arenas, single pad	Indoor ice arenas: multiple pads (two or more)	Indoor ice arenas: Performance/spectator	Outdoor ice arenas	Curling rinks	Indoor pools, 25 metres	Indoor pools, 50 metres or longer	Indoor pools, leisure pools 3	Outdoor pools	Outdoor spray parks/splash pads/wading pools	Galleries	Libraries	Museums and archives	Presentation and performance spaces	Indigenous culture facilities	Community centres (senior and youth centres)	Indoor gymnasiums	Indoor racquet courts	Indoor walking/jogging tracks	Indoor fitness areas	Indoor fields	Outdoor specialty areas	Playgrounds	Outdoor tennis and/or pickleball courts	Ball diamonds	Rectangular sports fields (natural turf)	Artificial turf sports fields	Paved pathways	Trails (non-paved)
Alberta	All	35	41	36	23	36	36	47	32	28	27	39	36	35	37	42	40	35	27	34	30	41	28	19	21	24	29	15	22	23
	All urban	37	39	41	23	40	35	47	32	32	27	39	39	35	39	63	41	37	29	34	34	45	28	20	22	28	31	20	22	26
	All rural	34	48	24	23	30	40	NA	NA	22	25	38	32	34	36	33	40	31	20	35	27	33	28	17	18	20	24	10	21	19
British Columbia	All	35	40	39	34	42	36	52	26	37	22	53	35	39	48	60	45	36	24	38	31	27	28	21	25	26	34	20	27	36
	All urban	38	45	40	34	42	39	52	26	31	24	55	37	42	49	NA	47	34	20	38	31	27	30	20	25	26	35	18	31	41
	All rural	31	33	35	34	42	31	NA	NA	46	19	42	32	29	43	60	43	44	50	40	31	NA	24	23	24	25	32	29	15	28
Yukon	All	20	NA	NA	NA	10	NA	NA	24	NA	NA	NA	NA	NA	NA	NA	21	22	19	NA	10	NA	NA	5	NA	10	NA	NA	NA	25
	All urban	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	All rural	20	NA	NA	NA	10	NA	NA	24	NA	NA	NA	NA	NA	NA	NA	21	22	19	NA	10	NA	NA	5	NA	10	NA	NA	NA	25
Northwest Territories	All	31	45	NA	28	35	30	NA	NA	NA	NA	NA	30	NA	NA	NA	27	NA	NA	50	25	45	36	21	14	32	NA	NA	50	26
	All urban	50	45	NA	28	50	30	NA	NA	NA	NA	NA	30	NA	NA	NA	50	NA	NA	50	NA	45	36	30	20	45	NA	NA	50	38
	All rural	21	NA	NA	NA	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	21	NA	NA	NA	25	NA	NA	15	10	15	NA	NA	NA	10
Nunavut	All	45	NA	NA	NA	20	NA	NA	30	NA	NA	NA	27	40	10	30	23	24	NA	10	30	NA	NA	16	15	34	20	15	NA	28
	All urban	40	NA	NA	NA	20	NA	NA	30	NA	NA	NA	30	NA	NA	30	26	50	NA	NA	30	NA	NA	17	15	36	NA	NA	NA	35
	All rural	50	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	25	40	10	NA	21	18	NA	10	NA	NA	NA	15	NA	30	20	15	NA	25

Table B8: RoI Toolkit - Average Expected Useful Life of New Municipally Owned Social and Affordable Housing Assets [1,2]

Geography	Type of municipality by population size	Single Detached House[3]	Semi-detached House[4]	Row House[5]	Apartment Building (fewer than five storeys)[6]	Apartment Building (five or more storeys)[7]
Canada	All municipalities	65	NA[8]	65	42	80
	All urban municipalities	NA	NA	65	40	80
	All rural municipalities	65	NA	NA	45	NA
Newfoundland and Labrador	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Prince Edward Island	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Nova Scotia	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
New Brunswick	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Quebec	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Ontario	All municipalities	NA	NA	65	38	NA
	All urban municipalities	NA	NA	65	38	NA
	All rural municipalities	NA	NA	NA	NA	NA
Manitoba	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Saskatchewan	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Alberta	All municipalities	65	NA	NA	45	NA
	All urban municipalities	NA	NA	NA	45	NA
	All rural municipalities	65	NA	NA	NA	NA
British Columbia	All municipalities	NA	NA	NA	45	80
	All urban municipalities	NA	NA	NA	NA	80

Geography	Type of municipality by population size	Single Detached House[3]	Semi-detached House[4]	Row House[5]	Apartment Building (fewer than five storeys)[6]	Apartment Building (five or more storeys)[7]
	All rural municipalities	NA	NA	NA	45	NA
Yukon	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Northwest Territories	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA
Nunavut	All municipalities	NA	NA	NA	NA	NA
	All urban municipalities	NA	NA	NA	NA	NA
	All rural municipalities	NA	NA	NA	NA	NA

Note:

1. *Expected useful life of an asset refers to the service life or the productive life of the asset at the time of its acquisition regardless of their lives reported for income tax purposes.*
2. *Public social and affordable housing estimates for Canada were produced excluding Quebec.*
3. *Single-detached house: A single dwelling not attached to any other dwelling or structure (except its own garage or shed). A single-detached house has open space on all sides and has no dwellings either above it or below it. A mobile home fixed permanently to a foundation is also classified as a single-detached house.*
4. *One of two dwellings attached side by side (or back-to-back) to each other, but not attached to any other dwelling or structure (except its own garage or shed). A semi-detached dwelling has no dwellings either above it or below it, and the two units together have open space on all sides.*
5. *Row house: One of three or more dwellings joined side by side (or occasionally side to back), such as a townhouse or garden home, but not having any other dwellings either above or below. Townhouses attached to a high-rise building are also classified as row houses. A set of row houses represents one structure.*
6. *Apartment building (fewer than five storeys): A high-rise apartment building which has five or more storeys.*
7. *Apartment building (five or more storeys): A building that has fewer than five storeys.*
8. *Public social and affordable housing data for Quebec are not available.*

Table B9: Standard Value for Hazard and Project Types (Source: FEMA BCA Toolkit)

Project Useful Life			
Project Type	**Standard Value**	**Acceptance Limits**	**Comments**
Flood			
Acquisition / Relocation			
Acquisition / relocation	100	100	
Building Elevation			
Residential building	30	30-50	
Non-residential building	25	25-50	
Public building	50	50-100	
Historical building	50	50-100	
Mitigation Reconstruction			
Mitigation reconstruction	50	50	
Infrastructure Project			
Major infrastructure (Dams, levees)	50	35-100	
Concrete infrastructure, flood walls, roads, bridges, major drainage system	50	35-50	
Culverts (Concrete, PVC, CMP, HDPE, etc.	30	25-50	Culvert with end treatment (i.e.: wing, walls, end sections, head walls, etc.)
	10	5-20	Culvert without end treatment (i.e.: wing, walls, end sections, head walls, etc.)
Pump stations, substations, wastewater systems, or equipment such as generators	50	50	Major (Power lines, cable, hardening gas, water, sewer lines, etc.)
	5	5-30	Minor (Backflow valves, downspout disconnect, etc.)
Other Flood Adaptation Project Types			
Floodplain and Stream Restoration	30		Higher values acceptable
Flood diversion and storage	30		Higher values acceptable
Tornado and Hurricane Safe Room			
Tornado safe room - residential	30	30	
Tornado safe room - community	30	30-50	Retrofit or small community safe room ≤ 16 people (30 yr.), new (50 yr.)
Hurricane safe room	30	30-50	
Hurricane Wind			
Roof diaphragm retrofit	30	30	Roof hardening and roof clips

Project Useful Life			
Project Type	**Standard Value**	**Acceptance Limits**	**Comments**
Hurricane storm shutters	15	15-30	Depends on type of storm shutter
Wildfire			
Defensible space/hazardous fuels reduction (Vegetation management)	4	1-4	Brush - Depends on drought conditions
	1	1	Grass - Depends on geographic location and precipitation
	20	3-20	Forest Canopy - Must be maintained every 3 years
Ignition resistant construction	10	10-30	Depends on type of construction and materials used
Building Retrofit Projects			
Residential building retrofit	30	30	
Non-residential building retrofit	25	25-50	
Public building retrofit	50	50-100	
Historic building retrofit	50	50-100	
Utility Adaptation Projects			
Utility adaptation projects	50	50-100	Major (Power lines, cable, hardening gas, water, sewer lines, etc.)
	5	5-30	Minor (Backflow values, downspout disconnect, etc.)
Generators and Miscellaneous Equipment			
Equipment purchases	2	2-10	Small, portable equipment (e.g., computer)
	30	5-30	Heavy equipment
Generators	19		The Project Useful Life may be altered based on manufacturer warranty or other documentation that can demonstrate that the generator life may be able to provide service longer than 19 years
Drought			
Aquifer storage and recovery	30		Higher Project Useful Life values acceptable with documentation

Appendix C: Adaptation Library Summary Table

Flooding (Riverine)				
Scale	Stakeholders	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-structural)	Policy (Non-structural)
Roads	Local transportation authorities and transportation agencies	• Use appropriate materials to prevent cracking of the surface layer of roads • Use pavement materials that are well sealed and less susceptible to moisture • Increase base strength (thickness and/or quality) to increase protection of subgrade layers • Use subgrade materials that withstand higher moisture content and/or use hydraulic binding agents in road foundation • If possible, raise road surface level to reduce flood damage and ensure continued access during flood event	• Increase crack sealing, especially prior to flooding season	
Bridges and Culverts	Local transportation authorities and transportation agencies	• Raise bridge decks to accommodate increase in flood volumes • Reinforce bridge piers and abutments and strengthen foundation to protect from erosion risks. • Incorporate design requirements from the CSA S6-18 Canadian Highway Bridge Design Code in order to increase resiliency of bridges to erosion caused by flooding • Culvert design should account for the possibility of partial blockage by debris and sediments (CSA W204:19)	• Cleaning out debris from clogged culverts and increase its frequency • Inspect bridges for erosion before and after flooding events	
River Basin	Local, regional, provincial, and territorial governments AND landowners	• Floodplain and stream restoration (FSR): Land purchase of flood prone areas by the government to relocate on safer grounds and restore the land to natural floodplain functions	• Monitor water level to assess the risk or flooding during heavy rainfall (see TRCA's real-time flood monitoring website and Calgary's flood and rive monitoring program)	
	Local, regional, provincial, and territorial governments AND watercourse experts	• Watercourse alteration: o Channel relocation o Widening or straightening o Culvert replacement o Stream bank stabilization	• Keep floodplain information and maps up to date and make sure they are accessible • Develop an operational and maintenance plan that identifies potential areas of risk related to flooding of riverine zones and specify measures and procedures to address any such risks	
Buildings	Architects, developers, builders, and renovation specialists and building owners	• Dry floodproofing • Wet floodproofing • Elevation of assets • Flood barriers • Levees • Floodwalls • Anti-return valve • Site-grading • Use flood-damage-resistant building materials (CSA Z800-18) • Ensure that buildings are not located in flood prone areas and prioritize sites that are at lower risks of flooding when choosing sites • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	• Ensure proper testing and maintenance of sump pump and backwater valve systems • Residential buildings should conduct sewer connection inspections, maintenance, repairs, or replacements when appropriate (CSA Z800-18) • Proper construction should be conducted during pre-construction, construction, and post construction phases in order to prevent erosion as per CSA W202-18	Increase minimum building elevations during development and construction

Flooding (Riverine)				
Scale	Stakeholders	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-structural)	Policy (Non-structural)
	Homeowners and building owners		• Increase routine and proactive maintenance measures that should be regularly completed by homeowners to reduce water damage and flood risk (CSA Z800-18)	
Critical Infrastructure	Local, regional, provincial, and territorial governments AND engineers	• Drainage improvement by: o Retention ponds o By-pass channels o Higher capacity storm sewers o Separating storm sewers and sanitary sewers o Improve pumping capacity of drainage systems • Sewer backwater protection by never directing downspout, foundation drain and sump pump discharge toward the sanitary sewers (CSA W204:19) • Stormwater system should be designed according to a dual drainage concept, taking into account the minor and major system • As per CSA W204:19: o Minor and major drainage systems should be designed concurrently to a minimum 1-in-100-year major storm design event. o Minor drainage systems should be designed to convey runoff for the 1-in-2-year to 1-in-10-year return period flows and more frequent rainfall events. o Major drainage systems should be designed to convey runoff for rainfall events, which exceed the capacity of the minor system and serve up to the major design storm	• Designated authorities shall develop an operational and maintenance plan that identifies potential areas of risk to proper system functioning and specify measures and procedures to address any such risks. (CSA W204:19) • Clear drainage systems of debris (e.g.: objects, leaves, etc.) to prevent flooding and sewer backup • Increase regular inspections and maintenance of drainage systems	Implement a flood emergency response plan to manage facilities impacted during flood events (CSA W204:19)
	Local, regional, provincial, and territorial governments AND engineers AND the energy/electricity sector	• Require elevation of electrical panels above the ground or ensure the ability to disconnect power above ground • Incorporate the use of water sensors in basements to shut off power and/or isolate connections • Consider using stainless steel transformers to avoid and delay corrosion	Increase regular inspections and maintenance after heavy rainfall events and introduce more guidance on monitoring and maintenance of critical assets	
City	Local, regional, provincial, and territorial governments AND	• In high-risk areas, build community-scale structural flood Adaptation works (such as berms and dikes) to supplement other flood-proofing measures • Relocate critical energy infrastructure outside of areas at risk of flooding or erosion now or within the infrastructure's lifetime		• Implement flood forecasting and warning systems protocols • Implement emergency response protocols
Community	Neighborhood associations and local community groups			• Flood prevention/ preparedness education • Teach about local flood forecasting and warning systems and help residents prepare emergency plans and emergency kits
Landscape	Landscapers and landowners	• Incorporate low impact development practices or nature-based solutions to manage stormwater runoff and prevent flood damages. Some examples include, bioretention platers, bioswales, etc. o The strategic use of natural infrastructure, low impact development measures and grey infrastructure to manage flood risk in new residential communities should be considered in the planning and design (CSA W204:19) o Natural infrastructure should be assessed at the watershed/sub-watershed level as well as the site level (CSA W204:19) o Measures should be planned and designed to retain, infiltrate, evapotranspiration, or filter runoff close to its source and in the conveyance system so that discharges from frequent events are treated and runoff volumes are minimized (CSA W204:19)		

Flooding (Riverine)				
Scale	Stakeholders	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-structural)	Policy (Non-structural)
		o Adaptable configurations of natural infrastructure and LID measures should be spatially distributed through the watershed to ensure redundancy and increase resilience of the systems (CSA W204:19)		
	Local, regional, provincial, and territorial governments AND landowners AND landscapers	Avoid encroachment on riparian buffers	Proactively manage vegetation and maintain riparian buffer zones along water coursers, including debris removal	
Wildfire				
Community	Local, regional, provincial, and territorial governments, architects, developers, builders, and renovation specialists	• Minimize development where fire risk is high and prioritize the selection of areas at lower risk • Create a defensible fuel break around vulnerable areas • Bury the electrical grid to avoid damage from extreme heat and fire • Design community with good and proper access to helps emergency responders arrive in a timely manner • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit		• Develop and follow guidelines for development such as those presented in Development Permit Areas for hazards in British Columbia • Implement evacuation planning and prepare community to properly handle emergencies • Make sure that emergency plans are current and that people responsible for the implementation of the plans are emergency-ready
	Neighborhood associations and local community groups			Implement public awareness, engagement and community participation to risk reduction activities
	Architects, developers, and builders	Consider the location of developments or of a building on flat or rising ground. Avoid slopes because fire will burn more rapidly uphill than on a flat or level surface		
Individual Assets	Homeowners, architects, developers, builders, and renovation specialists	• Use ignition-resistant construction o Fire resistant roofing (metal, clay tiles and asphalt shingles) o Exterior walls made of stucco, metal, brick, and concrete o Metal railings or tempered glass o Non-combustible patio furniture • Clearing all combustibles in the safety zone surrounding the asset • Installing non-combustible ground surfaces within 1.5m of the house (mineral soil, rock, concrete, or stone) • Create a 15-cm ground-to-siding non-combustible clearance (cement board or metal skirting) • Residential Building Retrofit		
	Residents, homeowners, and tenants		• Maintain roof cleanliness by making sure gutters are unclogged and there is no accumulation of combustible materials and debris • Increase frequency of clearing roofs of overhanging trees or vegetation that can provide fuel for airborne sparks and embers • Firewood must be stored at least 50 feet from the home and any other asset • Keep vegetation cleared well back of all electrical lines, propane tanks and other fuel supplies • It is recommended that pea gravel, lava rock or other non-combustible material be used as ground cover rather than bark mulch • Replace worn or missing weather stripping on all doors, including garage doors	
Landscape	Landowners and landscapers	• Minimizing the volume of vegetation • Remove conifer trees that are within 10m of the house • Replacing flammable vegetation with less flammable species	• Vegetation management or the removal of vegetative fuels that, if ignited, pose significant threat to human life and property • Vegetation clearing or thinning • Slash removal	

Flooding (Riverine)				
Scale	**Stakeholders**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-structural)**	**Policy (Non-structural)**
		o Avoid cedar, juniper, pine, tall grass, and spruce because they have high flammability	• Vertical clearing of tree branches • Mow the lawn under 10cm and plant low-growing, well-spaced shrubs, and other vegetation *FireSmart Canada Guidelines to Landscaping provides information on appropriate plant selection and landscaping practices to reduce wildfire threatening	
	Community, landowners, and local utility companies		Power lines should be clear of branches and other vegetation. Contact your local utility company to discuss removing any branches or vegetation around overhead electrical installations.	
Wind				
Landscape	Landscapers, landowners	Incorporate windbreaks (e.g.: vegetation) in the landscape design		
Buildings	Architects, developers, builders, and renovation specialists	• Retrofit window and door protection to prevent damage and injury from debris • Retrofit project to transfer wind loads from the roof to the foundation • Retrofit project to secure the building envelope and integrity during a wind event • Avoid building elevation forms that are thinner at the bottom and wider at the top • Buildings supported on columns in their first story should have these columns stiffened by bracing • A hip-roofed home of a cubical form is considered as one of the best configurations to use in high wind or hurricane prone areas • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit • Roof Diaphragm Retrofit - Roof hardening and roof clips		
	Local, regional, provincial, and territorial governments			Establish new code to upgrade building requirements for strong wind/hurricane resistance
Critical Infrastructure	Local, regional, territorial government, and energy authorities	• Install a generator to ensure minimal power loss to the building before, during and after a power outage • Burying electrical lines when possible to prevent vulnerability to winds and power outages in areas that are not vulnerable to flooding. • Incorporate a range of clean energy technologies such as renewable energy, energy storage, and distributed generation • Roof Diaphragm Retrofit - Roof hardening and roof clips		Provincial and federal policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures, such as renewable electricity standards.
Roads	Local transportation authorities and transportation agencies	• Construct strategic wind breaks • Design roadside infrastructure and bridges to withstand higher wind speed	Increase clearing of sidewalks and roads of debris or objects that may be blown away.	
	Landscapers and Local, regional, provincial, and territorial governments and transportation agencies	Put “snow fences” which are rows of trees, to reduce impacts of blowing snow or blowing rain on roadway visibility		
Community	Construction workers		Increase clearing of all types of construction sites of debris that can be blown away. Tie down materials, debris and objects from construction sites that can potentially be blown away and considered	Establish new codes and standards for construction zones where debris and objects that can be blown away are properly tied down and stored away.

Flooding (Riverine)				
Scale	Stakeholders	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-structural)	Policy (Non-structural)
			as projectiles	
Extreme Temperature/ Heat Waves				
Roads	Local transportation authorities and transportation agencies	• Use heat resistant paving materials with higher solar reflectance to reduce damages (e.g.: potholes and cracks) and UHI effect. • Solar heating reflective coating layer • Using white materials (e.g., pigments, binders, light aggregates, white topping, reflective paints) for surface layer of road pavement • consider use of additives in asphalt mix to reduce shoving/rutting • Increase roadside vegetation and trees to increase shade and decrease exposure	Increase frequency of inspections of pavement surfaces to ensure cracks are properly sealed	Implement proactive traffic management plans to reduce risk of rutting
Bridges	Local transportation authorities and transportation agencies	• Use more durable materials for bridge deck, including reinforced concrete	• Replace bridge expansion joints and ensure joints can accommodate thermal expansion • Conduct more frequent inspections and maintenance	
Landscape	Landscapers, landowners	• Consider nature-based solutions, such as planting local species that have a greater heat tolerance or are drought resistant, retaining water.		
Buildings	Architects, developers, builders, and renovation specialists	• Use materials that are resistant to or limit the accumulation of heat, such as light-colored materials such as white (high albedo) • Building retrofit and plan building designs that promote electricity and energy conservation, such as passive cooling systems, window shading and insulation • Incorporated heat island reduction strategies such as green roofs or cool roofs. • Install window shades • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	Upgrade ventilation system	
	Inspectors, building managers and owners		• Weekly monitoring of energy demand on mechanical HVAC and cooling systems, during the high temperature periods in July/August • Increase monitoring of HVAC cooling demand during heat wave periods to avoid overheating of the systems.	

Critical infrastructure	Local, regional, provincial, and territorial governments and energy sector stakeholders	• Consider electricity mix diversification by having centralised and decentralised options and by promoting an increase in renewable energy. Diversification minimises the magnitude of impacts and makes electricity systems less prone to failures
		• Bury the electrical grid to avoid damage from extreme heat
		• Improving the electricity grid by retrofitting current assets and introducing new technologies and new design asset
		  o Replacing overhead lines with underground cables
		  o Supplementary transmission lines to re-route electricity in case of failure
		  o Invest in smart grids, microgrids and circular grids
		• Aquifer Storage and recovery project
				Policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures

Flooding (Riverine)				
Scale	Stakeholders	Examples of Adaptation Projects		
		Design (Structural)	Operation and Maintenance (Non-structural)	Policy (Non-structural)
City	Local, regional, provincial, and territorial governments		• Track impacts of extreme heat to identify "hot-spots" that may require an increased rate of inspection. • Regularly evaluate de local forecast and monitor heat	• Implement urban planning standards and adaptation such as tree cover minimums, green spaces standards, fresh air corridor standards, etc. • Implement formal systems for notifying the public of heat waves which would include the communication of its arrival, duration and severity
Community	Neighborhood associations and local community groups	Planting trees and other vegetation to create shade in urban and open spaces		• During prolonged episodes of extreme temperatures and heat waves, establish a secure area where the community and vulnerable populations can cool off • Educate the community on best practices in urban greening
	Local, regional, provincial, and territorial governments and workers		• Improve or develop outreach strategies for communication risks to vulnerable communities • Training employers and workers in industries where work is conducted outside, including water availability, shade, rest breaks and training on heat risks	• Implement strategies to increase community resilience by improving social infrastructure, such as places and organizations that foster cohesion and support • Improve, promote and implement coordination by government, local agencies, industries, schools, clinics, hospitals for better worker protection measures
Ice Storm				
Roads	Local transportation authorities and transportation agencies		• Increase maintenance of pavement surfaces to monitor the accumulation of ice and the formation of black ice • Spread de-icing agents to eliminate icy road hazardous conditions	
Buildings	Architects, developers, builders, and renovation specialists	• Add a back-up generator or battery backup system and check-up regularly to provide emergency power • Add solar panels accompanied of a power storage source (e.g.: battery) as an alternative source of power • Residential Building Retrofit • Non-Residential Building Retrofit • Public Building Retrofit • Historic Building Retrofit	Upgrade insulation at building corners to reduce heat loss; seal joints between panels to address insulation discontinuity issues	
	Inspectors, building owners		• Increase the frequency of wall condition monitoring in critical areas • Regular inspection of snow/ice removal on building roofs	

Flooding (Riverine)				
Scale	**Stakeholders**	**Examples of Adaptation Projects**		
		Design (Structural)	**Operation and Maintenance (Non-structural)**	**Policy (Non-structural)**
Critical Infrastructure	Architects, developers, builders, and renovation specialists AND engineers AND energy/electricity sector	• Add a back-up generator or battery backup system and check-up regularly to provide emergency power so that operations and services are not disrupted during an outage • Improving the electricity grid by retrofitting current assets and introducing new technologies and new design asset o Replacing overhead lines with underground cables o Supplementary transmission lines to re-route electricity in case of failure • Invest in smart grids, microgrids and circular grids • Add solar panels accompanied of a power storage source (e.g.: battery) as an alternative source of power • Burying power lines when possible, in areas that are not vulnerable to flooding. • Use thicker overhead wires in areas prone to severe icing		Policymakers should adopt and strengthen programs that support the timely expansion of renewable energy and energy efficiency measures
Landscape	Landscapers, landowners,	• Use vegetation that have a higher resilience to ice storms. For example, some tree species are more prone to having ice accumulate on the entire branches, while others will only see the tip of the branches covered in ice and tend to perform better during ice storms. This will minimize the number of tree branches falling on power lines and roads.	• Increased maintenance for tree cover (trimming tree branches) to minimize ice incrusted branches that fall on power lines • Offer clients advice of adequate vegetation coverage to prevent and/or minimize risk associated with ice storms	
City	Local, regional, provincial, and territorial governments		• Regularly evaluate de local forecast and increase its frequency • Regular review and increase frequency of updating ice loading maps and loading criteria	• Implement a storm preparedness plan • Implement emergency response protocols • Establishing reception centre sites across the city • Make sure that emergency plans are current and that people responsible for the implementation of the plans are emergency-ready
Community				Educate the community on best practices and how to prepare for ice storms

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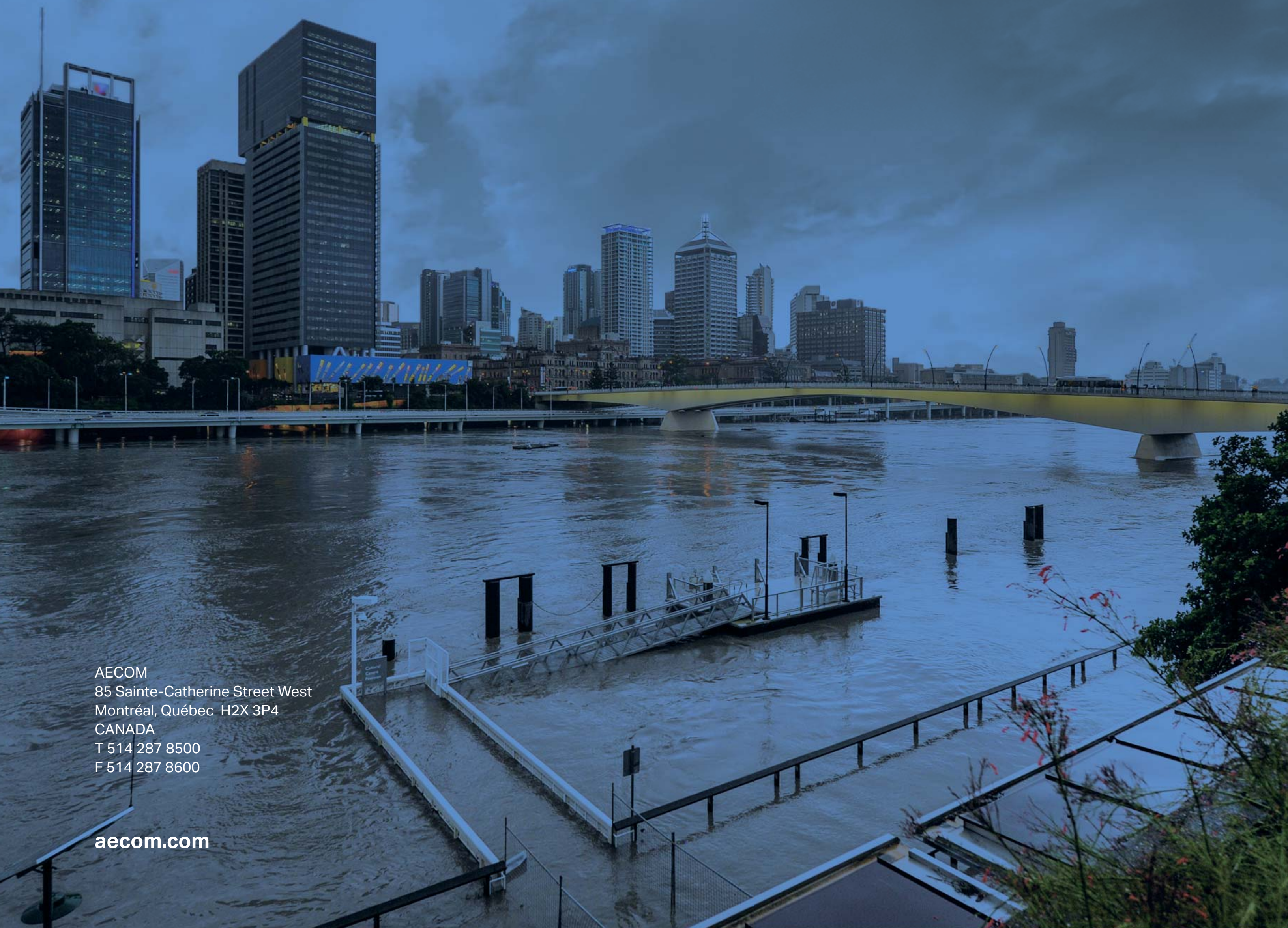

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