APPENDIX Q – Climate Change Report

MORRISON HERSHFIELD now Stantec

Final Report

York Region - Comprehensive Environmental Assessment for the Teston Road Area Transportation Improvements

Report No. 135800052
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1. INTRODUCTION

1.1 Background

The Regional Municipality of York (the Region) is seeking to complete the Individual Environmental Assessment (IEA) for Teston Road Area Transportation Improvements between Highway 400 and Bathurst Street. The IEA is to be done in accordance with the Ministry of Environment, Conservation and Parks (MECP) approved IEA Terms of Reference (ToR) which includes a commitment that climate change be considered as part of the IEA study.

Environmental assessment provides a structured process for decision-making that helps a proponent go from problem to a preferred solution while ensuring that a full range of alternatives are considered and that the decision-making process considers all environmental factor areas. The overall intent is to provide a clear, traceable, defensible, and replicable process so that all stakeholders can understand the rationale behind the decision-making process. Another key component of the process is that it involves a staged sequence of decision-making where the level of engineering and environmental investigations increases as the study progresses.

1.1.1 Provincial Guidance

Based on increased knowledge and understanding of the relationship between human generated greenhouse gas (GHG) emissions and rising GHG concentrations in the atmosphere, there is greater emphasis on the need to consider potential impacts of Project development on climate change. Climate change impacts are occurring with more frequent and intense weather extremes and climate-related events causing damage to infrastructure, property, and ecosystems. Therefore, climate change adds additional challenges and environmental risks to implementing the proposed Teston Road Area Transportation Improvements IEA.

The MECP (formerly the Ministry of the Environment and Climate Change) released a guide in 2017 titled "Considering Climate Change in the Environmental Assessment Process" (the Guide) which was updated in 2021 and which outlines how Proponents (York Region) can incorporate consideration of climate change impacts into the EA process. Per the Guide, the MECP advises that climate change impact considerations are part of responsible planning and due diligence, and that consideration of climate change impacts includes assessing the:

- Effects of a project on climate change.
- Effects of climate change on a project.

This entails consideration of specific mitigation measures to reduce the project's effect on climate change (e.g., reducing GHG emissions) and measures to adapt to climate change or make the project more resilient to the effects of climate change.

The Provincial Policy Statement (PPS, 2020) also requires that planning authorities support climate change mitigation and adaptation through land use and development.

In keeping with the above, this IEA study will integrate consideration of climate change impacts of alternatives as part of the evaluation and selection process and report on the expected performance of the preferred alternative with respect to climate change impacts.

1.1.2 York Region Climate Change Action Plan

York Region is already experiencing impacts of a changing climate: warmer temperatures leading to an increase in blacklegged ticks, flooding due to more frequent and powerful rainstorms, and power outages and tree loss because of ice storms. The Climate Change Action Plan, adopted in 2022, is York Region's plan to fight climate change by reducing greenhouse gas pollution, transitioning to a low-carbon way of living, and building resilient communities. The Action Plan identifies 20 actions that focus on reducing emissions that cause climate change and managing the risks of climate change impacts. The intent of these actions is to maintain residents' and workers' quality of life, minimize disruptions to the natural environment, avoid significant costs over the coming decades and to ensure communities in York Region continue to thrive under changing climate conditions. York Region's approach to climate change centers around an integrated, low impact development approach to adaptation and mitigation.

The Action Plan sets out three priority action areas and sets action items within each area. The three areas are: Resilient Communities and Infrastructure, Low Carbon Living, and Supporting an Equitable Transition. Two of the actions identified under Resilient Communities and Infrastructure are particularly relevant to the IEA study:

- **Action 2:** Integrate climate change considerations into existing and new municipal planning and development tools.
- **Action 7:** Undertake climate change vulnerability and risk assessments on all regional infrastructure, systems and assets using a common methodology.

Additionally, Action 9 of Low-Carbon Living priority action area will be relevant to the IEA study given that the project centers around transportation infrastructure: "Increased use of more sustainable modes of transportation, such as walking, cycling and transit, and community adoption of electric and low-emissions vehicles".

2. CONTEXT

2.1 Study Area

The study area for this project was determined during the Terms of Reference (ToR) stage completed in 2018. As shown in **Figure 1** the study area is bound by Kirby Road to the north, Bathurst Street to the east, Major Mackenzie Drive West to the south, and Highway 400 to the west. This study area includes several north/south and east/west arterial roads as well as collector roads. Additionally, the western extent of the study area includes Highway 400. Highway 400 is a Controlled Access Highway under the jurisdiction of the Ministry of Transportation of Ontario (MTO), which traverses through the study area in a north/south direction. Highway 400 is considered regionally and provincially significant, serving as an important link between the Greater Golden Horseshoe (GGH) area and Simcoe County to the north. It also connects Highway 401 in southern Ontario to central and northern Ontario/western Canada via Highway 69 and Highway 11. Highway 400 includes two interchanges within the study area at Major Mackenzie Drive West and Teston Road. The study area is situated within the City of Vaughan. The City of Vaughan is one of nine local municipalities within York Region, with local government organized in a two-tier structure.

Figure 1: Study Area

2.2 Regional Climate Context

2.2.1 Mixedwood Plains Ecozone

The climate in the Mixedwood Plains Ecozone is characterized by cool winters with warm summers and is described as one of the mildest in Canada (Crins et al., 2009). The mean daily winter temperatures for the ecozone (January)) range between -3°C and -12°C, while the mean daily summer temperatures (July) range between 18°C and 22°C (Crins et al., 2009). It is noted that temperatures in this ecozone are known to vary due to the moderating influence of the Great Lakes (Crins et al., 2009). The relatively moist ecozone receives approximately 720 – 1,000 mm of precipitation per year (Crins et al., 2009).

Climate change is expected to combine with other types of impacts such as habitat fragmentation and smog to affect the overall ecosystem composition, structure, and function, with climate model projections suggesting that this ecozone may be more susceptible to drought in the 21st century (Crins et al., 2009).

2.2.2 Ecoregion – Lake Simcoe – Rideau

The regional climate for the Lake Simcoe – Rideau Ecoregion is described as mild and moist (Crins et al., 2009). The mean annual temperature ranges from approximately 5 – 8 °C, with mean annual precipitation ranging from roughly 760 mm to 1,100 mm (Crins et al., 2009). The region has a growing season with a mean of 205 to 230 days annually (Crins et al., 2009).

More than 57% of the ecoregion exists as cropland, pasture, and abandoned fields, with forest cover accounting for approximately 30% of land cover (Crins et al., 2009). Water covers 4% of the ecoregion and forest fire is not considered a significant natural force, historically (Crins et al., 2009).

2.2.3 Ecodistrict: Oakridges 6E-7

The project site is located within Ontario's Ecodistrict 6E-7 which is approximately 7% of the Ecoregion and forms a narrow area between Orangeville in the west and Hilton in the east (Wester et. al., 2018). The Ecodistrict is comprised primarily of a gently rolling to a hilly landscape dominated by deep morainal material, with over half of the land use being described as cropland and pasture (Wester et. al., 2018). Settlement and associated built infrastructure cover approximately 2% of the eco-district and includes the communities of Vaughan, Halton Hills, Caledon, Georgetown, and Orangeville (Wester et. al. 2018).

3. EFFECTS OF PROJECT ON CLIMATE CHANGE

3.1 Methodology

The effects of the project on climate change are determined by completing a GHG assessment for embodied emissions associated with the construction of the project. The overall approach is quantitative.

3.1.1 Emissions Sources and Scope

GHG emissions are divided into three categories, known as Scope 1, 2 and 3. Scope 1 refers to direct sources owned or controlled by the proponent. Indirect emissions are divided into Scope 2 and Scope 3 emissions. Scope 2 refers to indirect emissions from the consumption of electricity, natural gas, steam, and/or heating and cooling. Scope 3 refers to all other indirect emissions both upstream and downstream (Government of Canada, 2024).

The emission sources and scopes considered in this assessment are generally limited to the construction of major project elements and major mid-life refurbishments/ rehabilitations of the roadway as can be seen below in **Error! Reference source not found.**.

Table 1: Emissions Sources and Scopes Considered in Assessment

EMISSION SOURCE	EMISSION SCOPE
Construction Materials (Embodied Carbon)	Scope 3
Fuel Consumption (Construction Equipment)	Scope 1

The GHG assessment considered scopes 1 and 3 for GHG emissions associated with the following phases: earthworks and mass hauling, construction materials, construction site operations and material replacement and refurbishment during the in-use phase. Results were reported as a mass of carbon dioxide equivalent (CO_2e) in tonnes. The calculations were performed using OneClick LCA's Infrastructure Carbon LCA tool based on the EN 17472 Standard for the Sustainability of Construction works - Sustainability Assessment Civil Engineering Works - Calculation Methods.

3.1.2 Greenhouse Gases Considered

A range of GHGs contribute to global warming potential. According to Canada's National Inventory Report, the following three GHGs relevant for this project were considered in the assessment.

- Carbon Dioxide (CO_2)
- Nitrous Oxide (N_2O)

- Methane (CH_4)

Other GHGs included in the Inventory report such as hydrofluorocarbons, sulfur hexafluoride, and nitrogen trifluoride were not applicable to this project and are not included in this assessment.

3.1.3 Boundary of the Assessment

The project boundaries consider the physical and temporal limits of the project including construction, and maintenance phases. The physical limit is Teston Road from west of Keele Street to Bathurst Street and includes a 40 m bridge over the East Don River tributary. The assessment considers the full roadway width development, and a 75-year project lifespan.

3.1.4 Whole Life Cycle Carbon Assessment

Whole life carbon emissions include those operational emissions from regulated and unregulated energy use, and embodied carbon. Embodied carbon covers the carbon emissions from:

- Raw material extraction
- Manufacture of products
- Transport of materials
- Construction
- Major repair and replacement

The figure below outlines the scope of a Whole Life Carbon assessment and refers to the emissions associated with the different life cycle stages. While the figure is based on the life cycle of a typical buildings project (intended for human occupancy), the carbon life cycle stages and elements are appropriate to consider for this project.

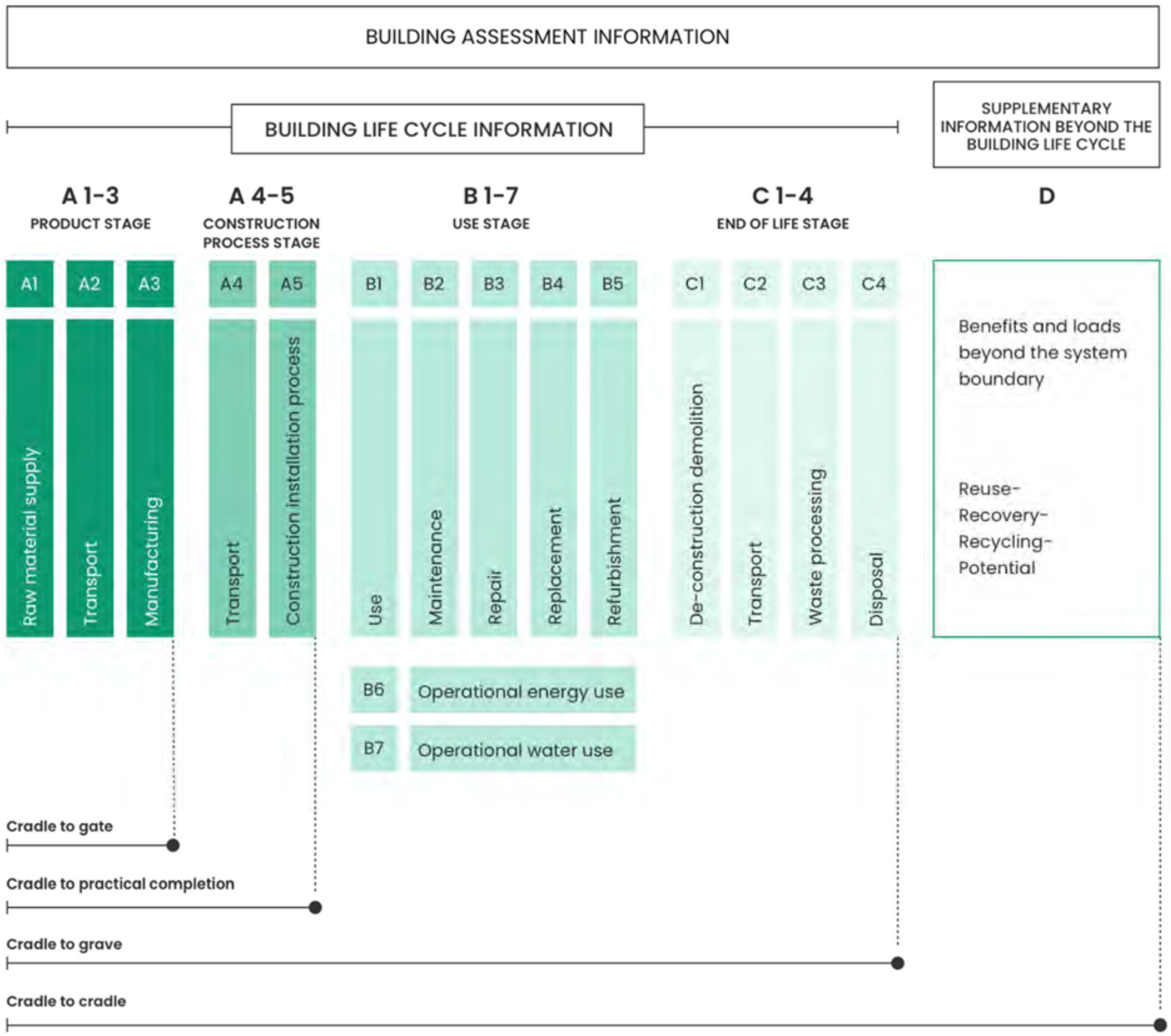

Figure 2: Life Cycle Stages, One Click LCA

Life-cycle stages according to the EN 17472 Standard:

- A1: Raw material extraction and processing, processing of secondary material input (e.g. recycling processes)
- A2: Transport to the manufacturer
- A3: Manufacturing

A1-A2 stages include the provision of all materials, products, and energy, as well as waste processing up to the end-of-waste state or disposal of final residues during the product stage.

- A4: Transport to the building site
- A5: Installation into the building.

Stages A4 and A5 include all impacts and aspects related to any losses during this construction process stage (i.e. production, transport, and waste processing, and disposal of the lost products and materials).

- B1: Use or application of the installed product.
- B2: Maintenance
- B3: Repair
- B4: Replacement
- B5: Refurbishment
- B6: Operational energy use (e.g. operation of the heating system and other building-related installed services)
- B7: Operational water use

Stages B6 and B7 also include provision and transport of all materials, products, as well as energy and water provisions, waste processing up to the end-of-waste state or disposal of final residues during this part of the use stage.

- C1: De-construction, demolition
- C2: Transport to waste processing
- C3: Waste processing for reuse, recovery and/or recycling
- C4: Disposal

All C stages include provision and transport, provision of all materials, products and related energy and water use.

- D: Reuse, recovery and/or recycling potentials, expressed as net impacts and benefits

3.1.5 Data Sources and Assumptions

The assessment process involved inputting data related to construction materials estimated by MH staff used for roadway, bridge, surface & pavement layers into the OneClick LCA software program along with transportation equipment and materials required for repair during the use phase. OneClick LCA has an internal database of global warming potentials for a diversity of materials and equipment. For some elements, assumptions are made due to lack of specific information available currently. Assumptions included:

- Fill and riprap material will be imported to the site from 100 km.
- Relocated fill used on site will be transported an average distance of 2 km.
- Aggregate will be transported to the site from 100 km.
- Concrete will be transported to the site from 100 km.
- Asphalt will be transported to the site from 100 km.
- Rebar will be all new material.
- Bridge girders will be supplied from a plant within 60 km of the site.
- Repaving will be every 20 years with full depth repaving at 40 years.

3.1.6 Exclusions

The scope of the assessment is limited to the construction and major re-construction of the roadway. Thus, user emissions (covered in a separate report), routine maintenance and decommissioning have been excluded from this assessment. Specific elements not included in this assessment are:

- Subsurface works such as sewer, water, drainage, and other buried utilities
- Roadway lighting
- Landscaping
- Routine maintenance, such as snow plowing & removal, sweeping, line painting, crack repair, landscape maintenance, etc.

3.2 GHG Emissions Estimate Results

GHG emissions result from both the embodied emissions of the material (production and delivery to the site) and emissions resulting from construction activities on site. Details of these emissions are provided below.

3.2.1 Construction Materials and Earthworks Emissions

The GHG emissions of the various project materials are presented in the tables below. As noted above only Scope 3 emissions limited to the materials production/manufacturing (embodied emissions) were considered. These emissions include A1-3 Product Stage and A4 Transport to site.

Table 2: GHG Emissions by Materials

Description	Material Type	Quantity	Units	CO_2e (Tonnes)
Earthworks and Mass hauling				
Masses sourced for the project - A1-A4				
Earth borrow (imported fill)	Soil	103,000	m^3	1,920
Quarry Stone- Bridge riprap	Stone	700	m^3	13
Masses that can be reused in the project - A4 only				
Earth Excavation and Grading (Cut & Fill)	Earth/Gravel	90,000	m^3	22
Construction Materials				
Foundations and geotechnical structures				
Roadway Granular 'A' Base Course	Gravel	9,000	m^3	131
Roadway Granular 'B' Base Course	Gravel	27,000	m^3	393
Driveway Granular 'A' Base Course	Gravel	640	m^3	9
Curb Granular 'B' Base Course	Gravel	2,100	m^3	31
Technical structures, construction works and systems				
Bridge - Reinforcing steel black	Steel	16	t	360
Bridge - Reinforcing steel black	Steel	8.5	t	193
Bridge - superstructure (45 MPA)	Concrete	660	m^3	283
Bridge - substructure (35 MPA)	Concrete	1,045	m^3	461
Precast arch culvert - assumed volume of concrete	Concrete	18	m^3	7

Description	Material Type	Quantity	Units	CO_2e (Tonnes)
Concrete in bridge girders	Concrete	5,620	m^3	117
Surface and pavement layers				
Concrete Sidewalk	Concrete	1,410	m^3	603
Concrete Median Islands	Concrete	203	m^3	62
Concrete Curb and Gutter	Concrete	566	m^3	172
SP12.5 Asphalt Pavement	Asphalt	3,900	m^3	2,180
SP25.0 Asphalt Pavement	Asphalt	6,240	m^3	1,302
SP19.0 Asphalt Pavement	Asphalt	3,900	m^3	814
Asphalt Multi-Use Trail / Cycle Track	Asphalt	1,380	m^3	386
SP12.5 Driveway Asphalt Pavement	Asphalt	160	m^3	45
SP19.0 Driveway Asphalt Pavement	Asphalt	160	m^3	33
Bridge Asphalt	Asphalt	120	m^3	61
Total Emissions:				**9,595**

3.2.2 Construction Site Operations Emissions

Construction GHG emission will also result from operating heavy machinery and vehicles to construct both the roadway and bridge. A preliminary estimate of heavy equipment and vehicles anticipated to be used for the roadway and the bridge construction are detailed as follows. These are high level estimates based on professional judgement and experience based on similar projects.

Table 3: Construction Site Operations – Roadway

Equipment	Quantity	Unit	Emissions (t CO_2e)
Loader	804	h	22
Grader	2,580	h	292
Paver	247,800	m^2	15
Soil Compactor	92,500	m^2	5
Asphalt Roller	247,800	m^2	18
Soil Compactor - Fill	3,011	h	40
Water Truck	3,026	Liters of fuel	10
Pick-up Truck	20,808	Liters of fuel	70
Dump Truck	9,684	h	

Equipment	Quantity	Unit	Emissions (t CO_2e)
Scraper	2,272	h	Included in materials emissions in Table 2.
Total Emissions:			**472**

Table 4: Construction Site Operations – Bridge

Equipment	Quantity	Unit	Emissions (t CO_2e)
Dump Truck	1,920	h	Included in materials emissions in Table 2.
Excavator	1,440	h	44
Bulldozer	240	h	10
Loader	960	h	29
Water Truck	21,600	Liters of fuel	73
Compactor	960	h	13
Pick-up Truck	96,000	Liters of fuel	324
Paver	120	h	3
Asphalt Roller	120	h	2
Crane	480	h	12
Service Truck	12,000	Liters of fuel	41
Compressor	1,200	h	49
Generator	1,200	h	21
Aerial Platform	1,440	h	17

Equipment	Quantity	Unit	Emissions (t CO_2e)
Zoom Boom	1,920	h	11
Concrete Truck	1,920	h	Included in materials emissions in Table 2.
Skid-steer	1,440	h	12
Flat Deck Truck	24,000	Liters of fuel	81
Fuel Truck	54,000	Liters of fuel	183
Total Emissions:			**925**

3.2.3 Emissions Summary

The development of the Project is estimated to result in a whole life cycle net release of 10,920 tCO_2e. This includes construction and major rehabilitation/refurbishment (repaving) of the roadway. Emissions by life cycle phase, for the elements included in this assessment, are as follows.

Table 5: Summary of GHG Emissions, by Life Cycle Stage

Life Cycle Stage	Emissions (t CO_2e)	% of Project Total Emissions
A1-A3: Product Stage	4,397	40%
A4: Transportation to Site	2,142	20%
A5: Construction Process	1,484	14%
B1: Use Phase	-73	-1%
B4-5: Replacement & Refurbishment – Materials	2,569	24%
B4-5: Replacement & Refurbishment – Transportation to Site	401	4%

Initial construction related emissions account for 73% of the emissions included in this assessment. Repaving activities account for the remaining 27% of the emissions over the roadway's lifetime. Most of the emissions during construction come from the embodied carbon from the materials. Transportation of materials to site, including hauling of earth and fill to site accounts for 20% of the total estimated emissions from the project.

For the purposes of this embodied carbon assessment, B1 Use Phase Emissions are limited to carbonization of cementation materials. Cementitious materials, such as concrete, cement and mortar, absorb carbon dioxide when exposed to air. This process is the chemical reversal of the cement production process calcination phase. The amount of carbon dioxide absorbed depends on exposure of the material, duration of the exposure as well as the initial amount of cement.

The following summarized emissions by project component:

Table 6: Emissions by Project Component

Project Component	Emissions (t CO_2e)	% of Project Total Emissions
Asphalt	4,819	44%
Earth fill / Earth Moving	2,497	23%
Concrete used on Roadway	892	8%
Concrete used in Bridge	811	7%
Equipment Used On-Site	1,397	13%
Rebar	552	5%

4. POTENTIAL GHG EMISSIONS MITIGATION MEASURES

Understanding major sources of emissions associated with the Project helps identify opportunities to reduce its GHG emissions. The following are some strategies that should be considered to reduce emissions:

General

Project documentation including design briefs, specification and tender documents should communicate a goal of reducing whole life-cycle carbon emissions form the Project. Some strategies can include:

- Select long-lived solutions that reduce maintenance and refurbishment needs.
- State emission reduction goals in drawings and specifications.
- Consider preferential procurement for lower carbon solutions.
- Use performance-based specification where possible to allow suppliers and contractors to innovate to achieve carbon reduction goals.
- Collaborate with suppliers and contractors to identify carbon reduction opportunities.
- Communicate carbon reduction goals in pre-bid meeting(s)
- Ensure good quality control and assurance.

Asphalt

Asphalt is the single largest GHG emission source on this project. Thus, focusing on optimizing the asphalt design to reduce emissions should be a priority. Some strategies can include:

- Reduce the amount of paving required.
- Design for longer life of asphalt to reduce frequency of repaving need. Evaluate life-cycle benefit of perpetual pavement.
- Use warm mix asphalt instead of hot mix asphalt.
- Increase recycled content (RAP) in asphalt mix.

Earth fill

Use of natural materials such as earth and rock are inherently lower carbon. For this project, the large volume of fill being imported has a potentially significant impact on emissions, currently estimated at about 1,900 t CO2e, or 18% of the project emissions.

For this assessment, it has been assumed that earth fill haulage is 100 km. Reducing the haulage distance will significantly reduce emissions.

Concrete

Concrete is a high-emission material, and total concrete usage on this project is estimated to represent 15% of project emissions. Some strategies can include:

- Efficient concrete design to reduce volume of concrete required.
- Allow for later strength concrete where early strength is not required. For example, in curbs and sidewalks.
- Allow for increased use of innovative cements with lower global warming potential, such as use of general use limestone (GUL) cement and increase supplementary cementitious material (SCM) content. Specify admixtures to reduce cement content.
- Avoid limiting ingredients were possible, while achieving performance requirements.

Construction Equipment

Light duty vehicles are a major source of construction equipment related emissions. Develop strategies to reduce fuel usage of these vehicles. Develop and implement aggressive anti-idling measures during construction.

Carbon Removals

Look for opportunities to create carbon removals as part of the project. A key strategy would be including significant tree planting as part of the roadway project. This could be extensive planting both along the roadway and the affected construction footprint, such as through the East Don River tributary area.

5. EFFECTS OF CLIMATE CHANGE ON PROJECT

5.1 Methodology

The effects of climate change on the project were determined by conducting a planning (or screening) level climate vulnerability risk assessment (CVRA).

The Project Definition component of the CRVA process includes the identification of the elements of study to be included in the assessment with regards to the asset components and the climate parameters.

5.1.1 Risk Assessment Process

The overall process is consistent with the PIEVC Protocol High Level Screening Guide (HLSG) process, as illustrated below in **Error! Reference source not found.**. The PIEVC HLSC aligns with international risk management standards ISO 31000 and ISO 14090, and other risk assessment processes.

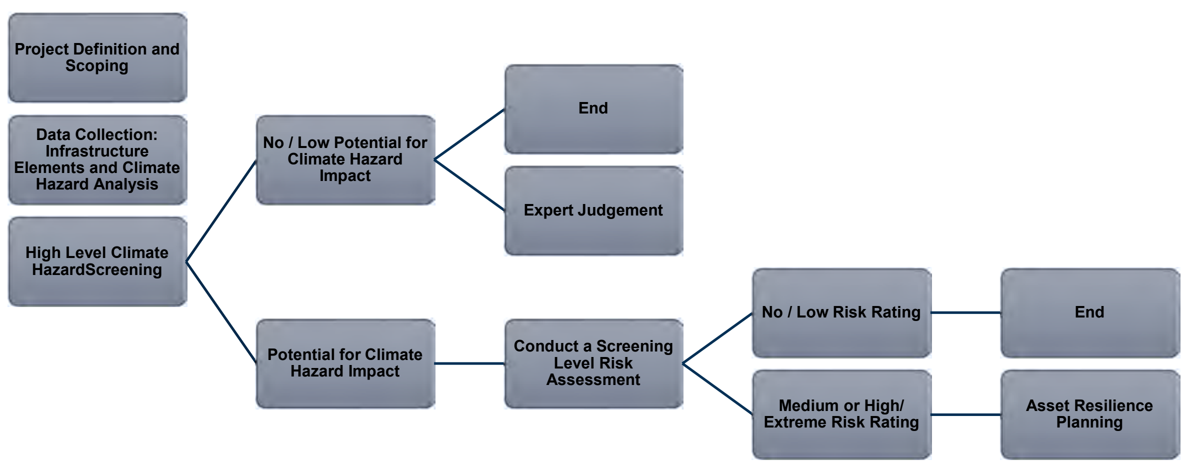

Figure 3: Climate Risk and Vulnerability Assessment Process

5.1.1 Climate Data Timeframes

Historical and projected future climate information on relevant climate factors for locations at or near the infrastructure have been compiled.

The baseline timeframe of 1976-2005 was used for all historical data unless otherwise stated. This was chosen to reflect a three-decade period relative to the most current available historical data for the area (2005).

Future climate projections have been compiled for a projected 2080s (2071-2100) timeline based on climate models for the Intergovernmental Panel on Climate Change's (IPCC's) Fifth Assessment Report (AR5) Representative Concentration Pathway 8.5 (RCP8.5) for a high greenhouse gas emissions scenario.

RCP8.5 high emissions scenario was chosen for all climate projections due to this being a conservative approach to climate projections and at this time the most accurate to current global emissions trends. 2080 timeline was chosen as project assets have lifespans exceeding 60 years and therefore should be assessed for projected impacts during the lifespan of the project.

5.1.2 Screening of Potential Climate Hazards

Climate change related hazards considered relevant to Ontario are listed in **Table 7**. This list was used for the preliminary screening process, to determine which hazards were specifically applicable to the project and merited further review. For each hazard, a comment is included to capture the rationale behind its inclusion in or exclusion from the assessment. The list of climate hazards was developed using the following key resources.

- *The Ecosystems of Ontario – Part 1: Ecozones and Ecoregions (2009)*
- *The Ecosystems of Ontario - Part 2: Ecodistricts (2018)*
- *Canada's Changing Climate Report (2019)*
- *Climate change projections for Ontario: An updated synthesis for policymakers and planners (2015)*
- *Climate Change Information for Adaptation: Climate Trends and Projected Values for Canada from 2010 to 2050 (2011)*

Localized and small-scale weather phenomena such as thunderstorms, tornadoes, hail, and lightning, are not simulated in climate models, as the models currently lack the spatial detail required to make confident projections (IPCC, 2001). The following hazards are not relevant due to the location and associated environmental conditions of the project: thawing permafrost, melting glaciers and sea ice, storm surges, higher tides, sea-level rise, coastal erosion, salt-water intrusion, and hurricanes.

For each of the climate change hazards that were found to be directly relevant to the project, projections for future values have been extracted from published sources. These projections have been shown as they relate to changes from existing conditions.

Table 7: Climate Hazard Preliminary Screening

Climate Change Related Hazard	Inclusion in Assessment			Rationale
	Planning	Construction	Operation	
Increased average temperatures	✓	✓	✓	An increase in average temperatures is predicted to occur.
Increase in warm extreme temperatures	✓	✓	✓	Potential interactions include the potential for heat stress for various roadway elements.
Decrease in cold extreme temperatures	×	×	×	Extreme Cold temperatures have the potential to deteriorate roadway elements. A reduction in extreme cold temperatures has the potential to increase the lifespan of these materials in comparison to baseline conditions. This is considered a potential benefit to the asset.
Increased average precipitation	✓	✓	✓	Annual precipitation may contribute to general wear and tear on the roadway and associated components.
Decreased average snowfall	×	×	×	Canada's Changing Climate Report (2019) projects a reduction of 5-10% per decade in seasonal snow accumulation for much of southern Canada (Bush and Lemmon, 2019). This condition is not considered to be a hazard for the project components identified.

Climate Change Related Hazard	Inclusion in Assessment			Rationale
	Planning	Construction	Operation	
Increased average winter precipitation – Freezing Rain	✓	✓	✓	Freezing rain may result in the deterioration of exposed roadway elements.
Increased variability in precipitation – Intense Snowfall	✓	✓	✓	While overall snowfall amounts may be declining, heavy snowstorms are still expected.
Riverine Flooding	✓	✓	✓	Flooding has been noted as a risk in the area in the York Region Climate Action Plan.
Overland Flooding/ Rainfall Intensity Duration Frequency	✓	✓	✓	Directly relevant to all identified project components. Design and service life and service connections considered.
Water Balance – Drought / Dry Conditions	✓	✓	✓	Drought / dry conditions may deteriorate roadway elements.
Decreased Freeze Thaw Cycles	✓	✓	✓	Freeze-thaw cycles have the potential to deteriorate roadway elements. A reduction in freeze-thaw cycles has the potential to increase the lifespan of these materials in comparison to baseline conditions. This is considered a potential benefit to the asset.

Climate Change Related Hazard	Inclusion in Assessment			Rationale
	Planning	Construction	Operation	
Increase in extreme weather –Tornadoes, storms, etc.	✓	✓	✓	Directly relevant to all project components identified. Design and service life considered. Though not considered in climate model projections, the high consequence of this risk determined further investigation should be completed.
				Directly relevant to various project components identified. Design and service life considered.
Forest fires: increased severity and frequency (Direct Impacts)	×	×	×	Due to land use patterns, a forest fire is not a significant natural force within the region.
				Wildfires in neighboring areas may decrease air quality in the York region.
Terrain risks	×	×	×	TRCA Environmentally Sensitive Area Ecologically significant/regional green lands system. McGill Area Don River Watershed
	✓	✓		Changing climatic conditions make it possible for invasive plant and animal species to thrive (RSI, 2018).

Based on the preliminary screening, the following are the key climate hazards requiring assessment for the Teston Road IEA:

1) Increased Average Temperature
2) Increases in Extreme Warm Temperatures
3) Increased Average Precipitation
4) Increased Average Winter Precipitation – Freezing Rain
5) Increased Variability in Winter Precipitation – Intense Snowfall
6) Riverine Flooding
7) Overland Flooding / Rainfall Intensity Duration Frequency
8) Water Balance – Increased Drought and Dry Conditions
9) Decreased Freeze – Thaw Cycles
10) Increase in extreme weather – Tornadoes, storms, etc.
11) Wind Gusts
12) Indirect Wildfire / Air Quality Impacts
13) Invasive Species

5.1.3 Timeframe of the Study

5.1.3.1 Climate Projection Timeframe

Historical and projected future climate information on relevant climate factors for locations at or near the Teston Road project have been compiled.

Future climate projections have been compiled for a period of approximately 60 years into the future (+/- 2080) based on climate models for the Intergovernmental Panel on Climate Change's (IPCC's) Fifth Assessment Report (AR5) Representative Concentration Pathway 8.5 (RCP8.5) for a high greenhouse gas emission scenario. Projections are also shown for reference for the 2050 timeframe as well.

5.1.3.2 Historic and Future Climate Hazard Data Collection and Analysis

The data used to create this climate profile were gathered from the Climate Atlas of Canada (2019) and ClimateData.ca (2019) unless otherwise noted below. Where available, data was gathered specifically for the City of Vaughan, York Region, Ontario from the ClimateData.ca web portal, and for the Lake Simcoe Region from the Climate Atlas web portal.

The data depicts the average of the statistically downscaled data from 24 climate models. The data is representative of a range of models which encompasses the uncertainty associated with the climate modeling process. Each of the climate models simulates the climate for the historical period (1976-2005), and plausible future scenarios (2071-2100), in response to high emission scenario RCP8.5 (ClimateData.ca, 2019).

Climate change projections are developed using varying future emissions scenarios, also called Representative Concentration Pathways, (RCPs) (Charron, 2016). When possible, projections corresponding to high emissions scenario (RCP 8.5 or equivalent) were selected for this analysis. The high emissions scenario is considered a conservative approach for climate hazards analysis and specifically for potentially long-lived project assets.

5.1.4 Historic and Future Climate Hazard Data Collection and Analysis

The most current, publicly available climate information was used to guide this Climate Risk and Vulnerability Assessment (CRVA). No primary research or additional site-specific climatological analyses (climate modeling or downscaling of climate projections) was conducted for this report. As climate science evolves and emissions patterns shift, climate projections may change. This could result in variations to the overall climate risk profile for the project. For this reason, the assessment should be reviewed periodically to identify potential deviations resulting from evolving climate science.

When possible, projections corresponding to the high emissions scenario (RCP8.5 or equivalent) were selected for this analysis, as this is considered a conservative approach for the relevant climate hazards and the potentially long remaining life of the project asset. The data used in this assessment were gathered primarily from ClimateData.ca (2019) and the Climate Atlas of Canada (Prairie Climate Centre, 2019) unless otherwise noted.

Given the ensemble of models and associated data used to analyze the climate hazards in York Region, there is some variability in the median and mean values projected. Tabular presentation of data includes the ensemble mean of median data (50^{th} percentile), along with the lower and upper range (10^{th} to 90^{th} percentile) of the model ensemble. The 10^{th} and 90^{th} percentile ranges describe the range of uncertainty among the models and natural climate variability. This is presented as "*median (lower range (i.e.10^{th} percentile), upper range (i.e. 90^{th} percentile))*".

Graphical presentation of data, similarly, includes the median and range of the model ensemble. The bar on the graph represents the mean of medians of the climate modeling ensembles, while the lower error bar represents the 10^{th} percentile and the upper error bar representative of the 90^{th} percentile. Error bars are used to indicate uncertainty among models, and climate variability and reiterate the range in climate projection data.

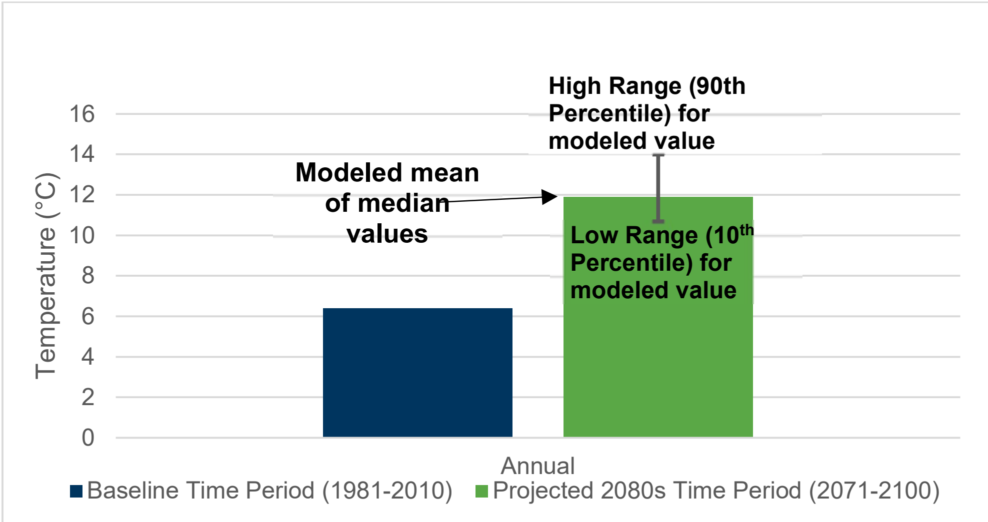

Figure 4: Graphical Representation of Climate Data

Graphical presentation of data, similarly, includes the median and range of the model ensemble. The bar on the graph represents the median of the climate modeling ensembles, while the low error bar represents the 10^{th} percentile and the high error bar representative of the 90^{th} percentile. Error bars are used to indicate uncertainty among models, and climate variability and reiterate the range in climate projection data.

5.2 Climate Parameters

5.2.1.1 Increased Average Temperature

Historically, the average annual temperatures for the City of Vaughan are recorded as 6.8°C, from 1951-1980, and more recently 7.7°C from 1981-2010 (ClimateData.ca). Increased air temperatures because of climate change are well documented, and air temperature is one of the principal indicators of climate change. For this climate change hazard, predicted future annual and seasonal temperatures were retrieved from the Climate Atlas and are representative of the Lake Simcoe Region data set (Climate Atlas, 2019). Downscaled regional climate models show future projections of an average annual temperature between 9.6 and 10.2 °C (York Region, 2016) which is consistent with the York Region Climate Action plan (York Region, 2022)

Table 8 shows the projected mean temperatures for each season for the periods of 2021-2050 and 2051-2080 for the high (RCP8.5) GHG emissions scenario (Climate Atlas, 2019). These projections show an increase in mean temperatures year-round for both future periods, with the most pronounced increase in the winter, followed by the summer. The increase is projected to become greater with time.

Table 8: Projected Temperatures (°C) Changes from Historic Annual and Seasonal Means for the Lake Simcoe Region (Climate Atlas, 2019)

Temperature Variable (C)	Historical Mean (1976 2005)	Projected Future Mean	
		RCP8.5 (2021 2050)	RCP8.5 (2051 2080)
Mean Annual*	6.4	8.5	10.7
Mean Spring	5.1	7.0	9.0
Mean Summer	18.7	20.8	23.1
Mean Fall	8.4	10.6	12.6
Mean Winter	-7.0	-4.6	-2.0

5.2.1.2 Extreme Warm and Cold Temperature Changes

Projections from ClimateData.ca indicate an increase in both the maximum annual temperature and the minimum annual temperatures under the RCP8.5 climate scenario (high GHG emissions) **(Table 9**). This is also seen in regional projections (York region, 2016). Under the RCP8.5 High GHG Emissions Climate Future, very hot days (+30°C) are predicted to increase, and very cold days are predicted to decrease (Climate Atlas, 2019). Compared to historical means, 2021-2050 will see a projected increase of 192% for very hot days (+30°C), and a decrease of 75% for very cold days under a high GHG emissions scenario (RCP8.5) (Climate Atlas, 2019). During the 2051-2080 time, very hot days (+30°C) have a projected increase of 488%, and very cold days are predicted to decrease by 100%, compared to historical means (Climate Atlas, 2019).

Increase in extreme heat events are considered very likely for York Region (York Region, 2016). The number of heat waves per year, is defined as three or more consecutive days with a temperature of +30°C or more. Compared to historical means, 2021-2050 will see a projected increase of 240% in the number of annual heatwaves, and a decrease of 37% for winter days under a high GHG emissions scenario (RCP8.5), where winter days are defined as days with a temperature equal to or less than -15°C (Climate Atlas, 2019). During the 2051–2081-time, heat waves are projected to increase by 480% and winter days are predicted to decrease by 69%, compared to historical means (Climate Atlas, 2019).

Increases in extremely hot days are projected to become more pronounced in future with approximately three times as many days above 30°C by the 2050s (York Region, 2022). Climate Atlas shows projected increases of 1033% for extremely hot days (+34°C) under the high emissions scenario (RCP8.5) for the 2021–2050-time horizon (Climate Atlas, 2019). The 2051–2080-time horizon sees a projected increase of

4400% in extremely hot days (+34°C) under the high emissions scenario (RCP8.5) (Climate Atlas, 2019).

Table 9: Projected Extreme Temperature (°C) Changes from Historic Annual and Seasonal Means for the Lake Simcoe Region (Climate Atlas, 2019)

Temperature Variable	Historical Mean (1976 2005)	Projected Change in Extreme Temperature Variables from Historical Mean	
		RCP8.5 (2021 2050)	RCP8.5 (2051 2080)
Number of Heat Waves/year*	1.0	3.4	5.8
Average Length of Heat Waves (days)	2.4	4.8	7.3
Very Hot Days (+30°C)	8.4	24.5	49.4
Extremely Hot Days (+32°C)	2.3	10.5	28.2
Extremely Hot Days (+34°C)	0.3	3.4	13.5
Number of Winter Days/year	34.7	22.0	10.8
Very Cold Days / Year	1.2	0.3	0.0

5.2.1.3 Freeze-Thaw Cycles

Freeze-thaw data refers to the number of days when the air temperature fluctuates between freezing and non-freezing temperatures (Climate Atlas, 2019). Under freeze-thaw conditions, it is likely that some water at the surface was both liquid and ice at some point during the 24-hour reporting period (Climate Atlas, 2019)**.** The number of annual freeze-thaw days is anticipated to decrease under high GHG emissions scenarios (RCP8.5). Historically the Lake Simcoe Region has had an average of 74 freeze-thaw days reported annually (Climate Atlas, 2019).

Under RCP8.5 GHG emissions scenarios, the number of cycles is projected to decrease to 68.8 days (decrease of 5.2 days) in the 2021-2050 timeframe and decrease to 62.2 (decrease of 11.7 days) in the 2051-2080 timeframe (Climate Atlas, 2019), as illustrated in **Figure 5**.

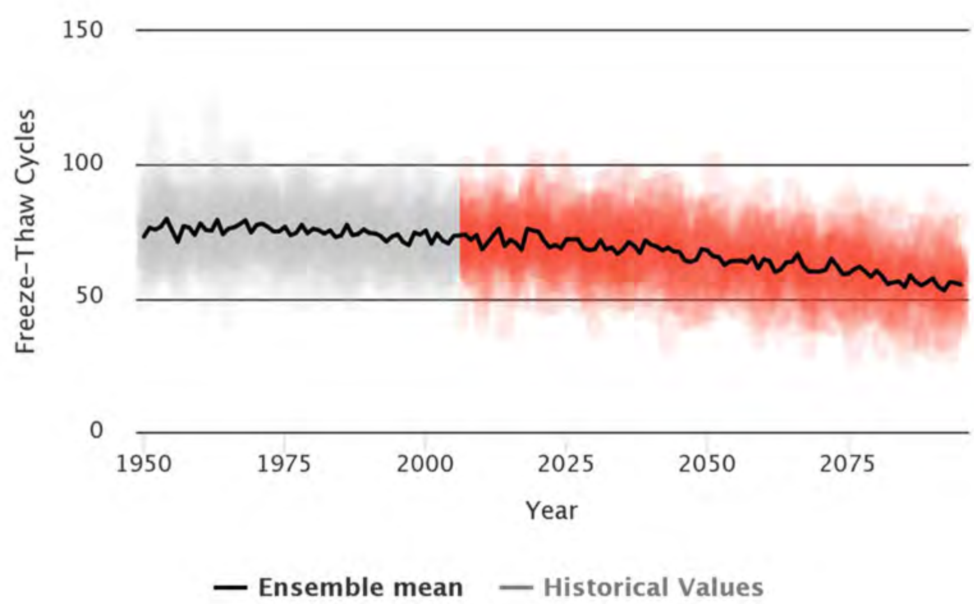

Figure 5: Freeze-Thaw Cycles (Days Annually) for Lake Simcoe Region using High GHG Climate Future (RCP8.5)

5.2.1.4 Increased Average Precipitation

Precipitation in Vaughan is projected to increase in the future under higher GHG climates (RCP 8.5). **Table 10** demonstrates that mean annual precipitation has a projected percentage increase of approximately 6.3-9.6% from historical means when considering the 2051-2080-time horizon (Climate Atlas, 2019). Historically York Region has seen more rainfall in the north and lesser amounts in the south (York Region, 2016). The duration of precipitation events is likely to increase which may impact urban infrastructure systems (York Region, 2016).

As illustrated in **Table 10**, winter and spring are projected to have greater rates of precipitation increase than annual averages, indicating these seasons will see a greater proportion of precipitation than summer and fall months in the future (ClimateData.ca, 2019). These predictions are consistent with regional analysis (York Region, 2016). Though increased winter precipitation may be inferred to relate to increased snowfall (and thus snow load), snowfall trends are decreasing in the region, as further described below.

Table 10: Projected Percent Change in Precipitation (mm) from Historic Annual and Seasonal Means for Lake Simcoe Region (Climate Atlas, 2019)

Precipitation (mm)	Historical Mean (1976 2005)	Projected % Change from Historical Mean	
		RCP8.5 (2021 2050)	RCP8.5 (2051 2080)
Mean Annual	885	6.3%	9.6%
Mean Spring	209	9.6%	16.7%
Mean Summer	220	0.9%	-0.9%
Mean Fall	245	4.5%	5.3%
Mean Winter	211	10.4%	18.5%

Extreme precipitation is one of the most difficult climate change variables to project, however, it is also one of the most important in terms of potential impacts on infrastructure. In general, according to current projections under the RCP8.5 climate scenario:

- Total annual precipitation will increase; and
- Extreme/heavy precipitation will increase at a faster rate than total annual precipitation.

Increases in extreme precipitation events in the future are likely with no significant increase in intensity predicted (York Region, 2016). **Table 11** provides historic and projected mean extreme precipitation events for high GHG emission (RCP8.5) climates in the future. The data indicates that though the total number of wet days will remain relatively stable, heavy precipitation days are anticipated to increase (Climate Atlas, 2019). York Region has predicted a 33% increase in heavy precipitation events by the 2050s (York Region, 2020).

Table 11: Historic and Projected Mean Extreme Precipitation Events for the Lake Simcoe Region (Climate Atlas, 2019)

Precipitation (mm)	Historical Mean (1976 2005)	Projected % Increase from Historical Mean			
		RCP4.5 (2021 2050)	RCP8.5 (2021 2050)	RCP4.5 (2051 2080)	RCP8.5 (2051 2080)
Annual Number of Wet Days	168.3	0%	0%	0%	0%

Precipitation (mm)	Historical Mean (1976 2005)	Projected % Increase from Historical Mean			
		RCP4.5 (2021 2050)	RCP8.5 (2021 2050)	RCP4.5 (2051 2080)	RCP8.5 (2051 2080)
Annual Heavy Precipitation Days (10mm +)	24.9	8%	11%	13%	15%
Annual Heavy Precipitation Days (20mm +)	5.5	16%	20%	29%	38%
Max. 1 Day Precipitation (mm)	39	8%	8%	10%	15%
Max. 3 Day Precipitation (mm)	50	8%	10%	14%	16%
Max. 5 Day Precipitation (mm)	60	8%	10%	15%	17%

5.2.1.5 Increased Average Winter Precipitation – Freezing Rain/Ice Storms

Certain climate variables, such as freezing rain, cannot be derived directly from temperature or precipitation and require regional modelling with higher resolution. ClimateData.ca and the Climate Atlas of Canada do not project this climate variable. However, several studies have been conducted to look at the impacts of climate change on freezing rain. An Environment and Climate Change Canada study by Cheng et al. (2007) concluded that freezing rain events are very likely to increase in northern, eastern, and southern Ontario in the coming century. The study concluded that southern Ontario is projected to see a 10-50% increase in freezing rain events for all future projected time periods (2016-2035, 2046-2065, 2081-2100) (Cheng et al. 2007). The largest projected increases in freezing rain events are in January, with moderate increases in December and February (Cheng et al. 2007). The study projected that the frequency of freezing rain events would remain unchanged for November, March, and April (Cheng et al. 2007).

Proxy information for the likelihood of an ice storm occurring in the future was based on the "ice potential" indicator (York region, 2016) which determines trends in favorable conditions for the formation of ice storms to occur. From this indicator these conditions are expected to remain consistent, however, it is noted that this is with considerable uncertainty due to the proxy information being used (York Region, 2016).

5.2.1.6 Average and Extreme Snowfall

The Climate Atlas of Canada and ClimateData.ca does not provide the analysis required for average and extreme snowfall projections. Below are the historical total annual snowfalls for Woodbridge Station (approx. 1.3 km from Vaughan proximity search) (Government of Canada, 2020).

A downward trend can be identified in the average snowfall totals in representative historical data (**Figure 6**). This trend generally aligns with projections for annual temperature increases. Further, the increase in annual daily average temperature is not distributed evenly throughout the year, but rather will impact the winter season disproportionately compared with other seasons, as previously presented in **Table 8**.

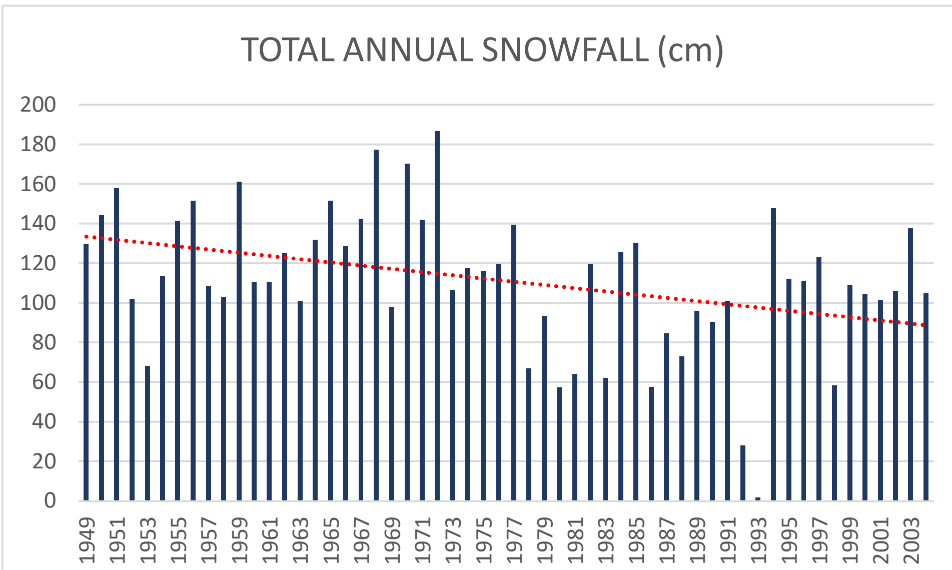

Figure 6: Historical Annual Total Snowfall (cm), Woodbridge Station (Govt. of Canada, 2020)

While overall snowfall amounts may be declining, heavy snowstorms are still expected. A National Climate Assessment Report completed by the U.S. Global Change Research Program (2014) notes that there is evidence of an increase in both storm frequency and intensity during the cold season since 1950 for the entire Northern Hemisphere. Winter storm tracks have also notably shifted slightly toward the poles (U.S. Global Change Research Program (2014). Extremely heavy snowstorms have also increased in number during the last century in northern and eastern parts of the United States (2014).

5.2.1.7 Rainfall Intensity Duration Frequency

Intensity Duration Frequency (IDF) curves relate short-duration rainfall intensity with the frequency of occurrence. Historic IDF curves show the probability of occurrence for short periods based on historical rainfall data, recorded at a specific weather station. The limitations of these curves are that they do not explicitly incorporate any projected future trends resulting from a changing climate. Environment and Climate Change Canada does not produce future IDF curves due to the sparsity of suitable data and high levels of uncertainty associated with future projections of extreme events at a specific location over short period (ClimateData.ca, 2019).

Natural Resources Canada (NRCan) notes that projected increases in the frequency, and possibly the intensity, of extreme rainfall events, have implications for urban drainage systems (NRCan, 2016). NRCan states that adaptation strategies related to infrastructure maintenance, upgrading, and design are key considerations related to the uncertainties in the changing frequency and magnitude of extreme climate events (NRCan, 2016).

The Ministry of Transportation Ontario (MTO) has created an IDF Curve Lookup with the assistance of the University of Waterloo. The tool is intended to assist MTO staff and consultants working on MTO projects, who may wish to use the information for drainage management purposes. The IDF curves generated for the study area, using the MTO IDF Curve Lookup tool indicate that overall, the intensity of rainfall (total 24-hour precipitation) is projected to increase in the future, with potentially greater increases seen for shorter return periods (2-year events) than for larger return periods (100-year events).

Various tools are available to compare historic and projected IDF curves under various GHG scenario futures. The IDF-CC Tool 6.0, developed by Western University was used to provide a high-level understanding of what potential changes in the probability of extreme rainfall events might look like in the vicinity of the Teston road project area. The "IDF curve for ungauged locations" tool was selected to populate historic and projected curves. Median total precipitation is shown in **Table 12** for a 1-hour and a 24-hour duration rainfall event with return periods of T:50 and T:100, both historically and in the future ((ICLR, FIDS - Western University, 2021).

Table 12: IDF Precipitation Projections (mm)

	Historical Mean(1976 2005)	Projected Mean	
		RCP8.5 (2021 2050)	RCP8.5 (2051 2080)
Total PPT 1hr T50	51	56	60
Total PPT 24hr T50	111	120	130
Total PPT 1hr T100	59	63	68
Total PPT 24hr T100	133	143	155

5.2.1.8 Water Balance

The projected change in mean dry days under medium (RCP4.5) and high (RCP8.5) GHG future remains relatively stable compared to historic trends. For example, the mean number of annual dry days is projected to be less than 0.8 days in the 2021–2050-time horizon and increase by 0.6 days in the 2051-2080 time horizon (Climate Atlas, 2019). It is noted, however, that dry days (days without precipitation) are not the only factor that affects water balance. The regional analysis predicts a likely overall drier growing season (York Region, 2016).

ClimateData.ca includes projections for the Standardized Precipitation Evapotranspiration Index (SPEI). The index presents the difference between precipitation and potential evapotranspiration (to account for the effects of increased temperatures on water demand) as a drought index. SPEI-12 refers to the SPEI of one month and the 11 previous months, for example, December was selected, giving an annual 12-month projection. SPEI-3 refers to the SPEI of one month and the two previous months. Negative values indicate a water deficit, while positive values indicate a water surplus in the information presented in **Table 13**. Seasonal projections were not available on ClimateData.ca for the City of Vaughan at the time of writing.

Table 13: SPEI-12 Index under RCP4.5 and RCP8.5 GHG Emissions Scenarios

	Historical Mean (1976 2005)	Projected Mean Increase from Historical Mean	
		RCP8.5 (2021 2050)	RCP8.5 (2051 2080)
SPEI-12	(-) 0.03	(+) 0.07	(+) 0.48
SPEI-3 (Spring)	(+) 0.02	(+) 0.18	(+) 0.16
SPEI-3 (Summer)	(-) 0.08	(-) 0.48	(-) 1.04
SPEI-3 (Fall)	(-) 0.01	(-) 0.08	(-) 0.36
SPEI-3 (Winter)	(+) 0.05	(+) 0.48	(+) 0.76

5.2.1.9 Tornado Events

Though tornado events can be highly destructive and result in fatalities, regional characterization of tornado activity in relation to large-scale climatic processes remains highly uncertain (Cheng et al. 2016). The spatial variability of tornado occurrence during warm summer months may be explained by convective available potential energy and storm-relative helicity (Cheng et al. 2016). Hierarchical models are being developed as a means of understanding regional tornadic environments, and as a means of establishing tornado prognostic tools in North America (Cheng et al, 2016).

The Northern Tornadoes Project was created in 2017 as a means of better detecting tornado occurrence throughout Canada, particularly in sparsely populated areas. An improved understanding of existing tornado patterns will improve extreme weather prediction, mitigate against harm to people and property, and will support investigations related to future implications of climate change (Western University of Canada, 2021). Tornadoes have been reported in the areas as recently as September 2021 (Western University of Canada, 2021).

5.2.1.10 Hail Events

An increase in severe thunderstorm potential is anticipated resulting from climate change, but the resulting changes in the associated convective hazards (such as hail) are not well known (Brimelow et al., 2017). A North American study conducted by Brimelow et al. (2017) notes that generally, fewer hail days are expected over most areas, though an increase in the mean hail size is projected, with fewer small hail events and a shift toward a more frequent occurrence of larger hail. Regional variability may not be consistent with the projections and some levels of uncertainty are associated with the data given the convective nature of hail, though projections are in line with those demonstrated for other regions (Brimelow et al. 2017). Factors such as the total mass of the hail from the storms and hail swath properties were not included in the study.

5.2.1.11 Wind Gusts

Similar to freezing rain, the wind is considered a complex climate variable, requiring more complex modelling. Therefore, the number of projection sources for this climate variable is limited. One Environment and Climate Change Canada study by Cheng et al. (2012) looked at increases in daily and hourly wind gusts for various regions of Ontario, including the Toronto and Lake Simcoe Regions. The study analyzed projected climate data from eight Global Climate Models under two climate change scenarios. Like RCPs but developed for the IPCC's fourth assessment report (AR4), different scenarios represent alternative future greenhouse gas emissions. Under AR4, scenario A2 assumes higher GHG emissions, while scenario B1 assumes less.

The results of the 2012 study (Toronto Region) suggest modest increases in wind gusts are likely in the coming decades (**Table 14**). Wind gusts over 70 km/h will see the highest increase in frequency, occurring 17% to 19% more often than current conditions in the Toronto Region.

Table 14: Daily and Hourly Wind Gust Projections (Cheng et al., 2012)

Wind Gust Event	Daily wind gust (% increase in frequency)				Hourly wind gust (% increase in frequency)			
	2046-2065		2081-2100		2046-2065		2081-2100	
	A2	B1	A2	B1	A2	B1	A2	B1
≥28 km/h	4	3	6	3	8	7	15	8
≥40 km/h	7	6	11	6	13	12	21	12
≥70 km/h	14	12	22	11	17	13	19	11

High wind speeds and wind gusts, which are not the result of a tornado, are significant meteorological hazards, known to cause significant damage to trees, property, and infrastructure (Cheng et al, 2012). In Ontario, damaging high winds are often associated with intense synoptic storms or convective activity, or a combination of both (Cheng et al, 2012).

5.2.1.12 Wildfire (Direct and Indirect Impacts)

Fire weather in eastern Canada is expected to increase by 200-300% in future projections (Climate Atlas, 2019). Direct wildfire interface may not impact the roadway infrastructure due to its location and proximity to wooded areas. Indirect Impacts on air quality may be impacted from neighboring wildfires producing smog and ash.

5.2.1.13 Invasive Species

Changing climatic conditions make it possible for invasive plant and animal species to thrive (RSI, 2018). Expansion rates are difficult to predict, and invasive species are generally target- and ecosystem-specific (e.g., Emerald Ash Borer for ash trees and Phragmites for wetlands). Ecosystems weakened by invasive species may become more susceptible to other climate parameters such as high winds and ice storms (RSI, 2018). Urban ecosystems are particularly vulnerable to the arrival of a growing number of invasive species as changing climatic conditions make it possible for them to thrive, including non-native plants and animals that have no natural predators (Ledwell, 2017).

5.3 Limitations

The most current, publicly available climate information was collected for use in the Teston Road Individual Environmental Assessment (IEA) Project climate risk assessment. References to sources used are included at the end of this report. No primary research or additional site-specific climatological analyses were conducted. As climate science evolves, climate projections may change. This could result in variations to the overall climate risk profile for the facility. For this reason, the assessment should be reviewed periodically to identify potential deviations resulting from newer, better climate information.

6. CLIMATE CHANGE RISK ASSESSMENT

6.1 Risk Assessment

The overall assessment process utilized for this assessment is consistent with the PIEVC Protocol High Level Screening Guide (HLSG). The PIEVC HLSG aligns with international risk management standards ISO 31000 and ISO 14090, and other risk assessment processes.

6.1.1 Risk Assessment Methodology

For the purposes of this assessment risk scores were calculated based on exposure of an element to a climatic condition (exposure), the likelihood of a particular climate event occurring under existing and future climate conditions (likelihood), and the potential consequences/severity of an interaction arising from the climate event exposure (consequence).

The risk analysis conducted for this assessment was based on a standard proxy risk calculation, as outlined in the PIEVC HLSG. For the purposes of this report:

Risk = Exposure (E) x Likelihood (L) x Consequence (C)

6.1.1.1 Exposure

Exposure is determined by examining the relationship between the element and the climate hazard (as defined by specific indicators). If the evaluated element "sees it", or has exposure to a particular climate hazard, the exposure output is evaluated as a "1". If the element is determined not to have exposure to a specific climate hazard, a score of "0" is applied, and the element fails to continue through the risk assessment process. Determination of asset element exposure to the determined climate hazards was completed in the Risk Assessment Workshop.

6.1.1.2 Likelihood

For this high-level screening, a "middle baseline" approach was used to determine climate hazard likelihood as presented in **Table 15**. This approach determines the current climate baseline per climate hazard indicator and assigns a likelihood ranking of 3 for the baseline conditions. Future climate scenarios are then assigned a likelihood score based on the event/condition occurring more or less frequently than current climate conditions, as described in **Table 15.** Deviations from the "middle baseline" likelihood scoring approach, were based on professional judgment and associated with very low likelihood events that may be overstated with the middle-baseline approach.

Table 15: Climate Likelihood Scoring Matrix

Likelihood Score	PIEVC HLSG Method	Rationale
1 – VERY LOW	Unlikely	50-100% reduction in frequency or intensity when compared to baseline mean.
		Not likely to occur during the period.
2 – LOW	Likely to occur less frequently than current climate	10-50% reduction in frequency or intensity when compared to baseline mean.
		Likely to occur once between 30 and 50 years.
3 - MODERATE	Likely to occur as frequently as current climate	Baseline mean conditions or a change in frequency and intensity of ± 10% when compared to the baseline mean
		Likely to occur once between 10 and 30 years.
4 - HIGH	Likely to occur more frequently than current climate	10-50% increase in frequency or intensity when compared to baseline mean.
		Likely to occur at least once per decade.
5 – VERY HIGH	Almost Certain to Occur	50-100% increase in frequency or intensity when compared to baseline mean.
		Likely to occur once or more annually.

Overall likelihood scoring was completed in advance of the Risk Assessment Workshop, though all likelihoods were presented, discussed, and adjusted as needed, based on consensus and professional judgment of the project team before proceeding to discussions of asset exposure and potential consequence.

6.1.1.3 Consequence

The consequence, or severity, of each potential interaction between the climate hazard and specific element, was assigned a numeric score using the criteria outlined in **Table 16**. The score assigned for each potential impact was informed by professional judgment at the risk assessment workshop. Consequence scores are based on community response considerations.

Table 16: Consequence Scoring Matrix

Consequence Score		
1	Very Low	Insignificant
		Little to no financial loss or increase in operational plan/ operational expenses.
2	Low	Minor
		Additional operating costs or small financial loss. Small changes in site operations and maintenance.
3	Moderate	Moderate
		Moderate financial loss. Significant changes in operations and maintenance / operating expenses/repairs.
4	High	Major to Serious
		Impact to load capacity. Major financial loss. Closure for repairs (short-term or extended).
5	Very High	Hazardous to Catastrophic
		Complete loss of function. Extreme financial loss. Partial or full rebuild required.

6.1.1.4 Risk Rating and Classification

A numeric risk rating was determined for each impact based on the product of the exposure, likelihood, and consequence scores. The risk assessment matrix illustrated in **Figure 7** was used to derive a semi-quantitative measure of risk. Based on this methodology, risk ratings were determined as follows:

- **Negligible Risk** (risk scores between 1 and 2): Risk events do not require further consideration.
- **Low risk** (risk scores between 3 and 4) – risk requiring minimal action. Controls are not likely required.
- **Moderate risk** (risk scores between 6 and 9) – risk that may require further action. Some controls may be required to reduce risks to lower levels.
- **High risk** (risk scores between 10 and 19) – risks that require action. High-priority control measures may be required.
- **Extreme risk** (risk scores between 20 and 25) – risks that require immediate action. Immediate controls may be required.
- **Special Consideration** – describes two unique scenarios. Low likelihood and high consequence interactions would consider events such as tornados, where the likelihood of a direct hit is very low, but the overall consequence could be catastrophic; and high likelihood low consequence events such as ongoing deterioration of elements resulting from continued exposure to various climatic conditions.

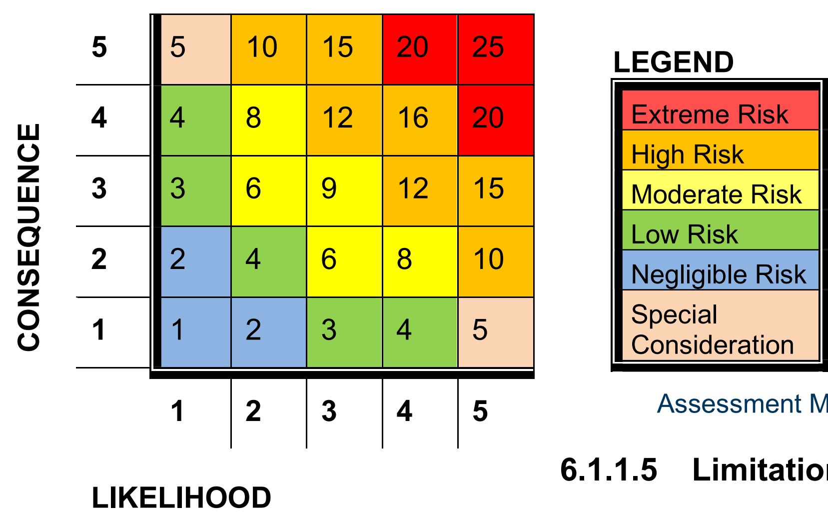

Figure 7: Risk Assessment Matrix

6.1.1.5 Limitations

As our understanding of climate change improves, climate projections may change. This could cause changes to the risk profile. The work should be reviewed from time to time to identify potential changes resulting from newer climate information.

The projections used for this work were based on the business-as-usual (RCP 8.5) climate scenario. While this represents the upper limit of modeled climate results, it also covers extreme values. These outliers are included in the RCP8.5 information used in this analysis, but their impact may be reduced by averaging.

This analysis is based on the combined professional judgment of the team. It reflects the team's best estimate of expected climate risk over the useful service life of the element being assessed. The team used data available at the time of the assessment.

There are uncertainties in every climate risk assessment. The work should be viewed as part of a continuing process. Results from the work reflect the state of climate change and element components at the time of the assessment. As climate science develops, periodic reviews of the risk profile and revisions when necessary are recommended.

The work was done as a high-level screening of elements to inform recommendations to improve resilience and included social, and environmental impacts. More data, analysis, and assessment would be needed to expand the work for wider applications.

6.2 Risk Assessment Workshop Summary

CRA Workshops were held on December 13th, 15th, and 19th 2022. Attendees included MH staff including Climate risk analysts and engineers. A full list of workshop attendees and role can be seen below in

Table 17.

Table 17: Workshop Attendees

Attendee	Role
Andrew Harkness	Consultant Project Manager
Joelle Doubrough	Senior Climate Analyst
Nick Crawford	Team Lead – Environmental Planning
Martin Blouin	Transportation Engineer
Ben MacMaster	Senior Structural Engineer
Ken Luong	Manager – Water Resources
Dan Rozanski	Landscape Architect
Heather Kime	Terrestrial Biologist
Alexander Templeman	Climate Risk Analyst

6.3 Summary of Risk Ranking Results

The Teston Road Extension is generally resilient to the weather under the current baseline climate conditions and into the 2050s and 2080s based on the projections and climate data available at the time of writing. Through the risk assessment process, the team identified several vulnerabilities as documented in the sections below. As illustrated in **Table 18** and

Table 19 baseline conditions did not identify any extreme-risk elements. High and extreme risk elements in the 2050s and 2080s are associated mainly with temperature, precipitation, and flood risk. **Figure 8**, **Figure 9** and **Figure 10** demonstrate the risk distribution by asset component. These summaries include vulnerabilities to natural assets further outlined in Section **7**.

Table 18: Risk Assessment Results Summary by Element

	Baseline Conditions (1976 2005)						Projected 2050s Conditions (2021 2050)						Projected 2080s Conditions (2051 2080)					
	Negligible Risk	Low Risk	Moderate Risk	High Risk	Extreme Risk	Special Consideration	Negligible Risk	Low Risk	Moderate Risk	High Risk	Extreme Risk	Special Consideration	Negligible Risk	Low Risk	Moderate Risk	High Risk	Extreme Risk	Special Consideration
Roadway	0	4	7	1	0	1	1	3	5	3	0	1	1	1	4	4	0	3
Bridge	0	4	7	2	0	0	0	6	2	4	1	0	1	4	1	5	1	1
Bridge Culvert	1	5	5	2	0	0	2	5	3	2	1	0	2	3	2	3	1	2
Culverts (Other)	1	5	5	2	0	0	3	3	4	2	1	0	3	1	3	3	1	2
Stormwater Management Facilities	0	8	3	0	0	0	2	5	3	0	0	1	2	3	2	1	0	3
Retaining Structures	1	7	5	0	0	0	2	6	3	1	0	1	2	3	3	1	0	4
Bus Terminals / Passenger pick up facilities	0	4	7	1	0	1	1	3	5	3	0	1	1	1	4	4	0	3
Pedestrian walking and cycling facilities	0	4	7	1	0	1	1	3	5	3	0	1	1	1	4	4	0	3
Landscaping	0	4	7	1	0	1	1	3	4	3	1	1	1	2	3	3	1	3
Above Ground Utilities	0	5	3	3	0	1	2	3	2	4	0	1	2	1	2	3	1	3
People / Health and Safety general population	0	3	6	0	0	1	0	3	3	3	0	1	0	3	2	4	0	1
People / Health and Safety Vulnerable population	0	0	5	4	0	1	0	0	3	5	1	1	0	0	3	3	3	1
Natural Asset Wetlands	1	4	6	1	0	0	2	3	4	3	0	0	2	3	3	3	0	1
Natural Assets Fish / Fish Habitat	1	5	5	1	0	0	2	5	4	0	1	0	3	3	3	1	1	1
Natural Asset Terrestrial Habitat	0	7	5	1	0	0	2	5	4	2	0	0	2	2	4	2	0	3

Table 19: Risk Assessment Results Summary by Parameter

	Baseline Conditions (1976 2005)						Projected 2050s Conditions (2021 2050)						Projected 2080s Conditions (2051 2080)					
	Negligible Risk	Low Risk	Moderate Risk	High Risk	Extreme Risk	Special Consideration	Negligible Risk	Low Risk	Moderate Risk	High Risk	Extreme Risk	Special Consideration	Negligible Risk	Low Risk	Moderate Risk	High Risk	Extreme Risk	Special Consideration
Average Annual Temp	0	11	4	0	0	0	0	11	2	2	0	0	0	0	0	4	0	11
Extreme Heat	0	2	11	2	0	0	0	0	0	11	2	2	0	0	0	11	2	2
Average Precipitation	0	6	9	0	0	0	0	6	9	0	0	0	0	6	9	0	0	0
Average winter precipitation Freezing Rain	0	5	7	3	0	0	0	5	2	7	1	0	0	0	0	7	3	5
Variability in precipitation Intense Snowfall	0	4	9	2	0	0	0	4	9	2	0	0	0	4	9	2	0	0
Riverine Flooding	0	3	9	3	0	0	0	3	5	4	3	0	0	3	5	4	3	0
Overland Flooding / Rainfall Intensity Duration Frequency	0	1	11	3	0	0	0	1	11	3	0	0	0	1	7	7	0	0
Water Balance Drought / Dry Conditions	0	9	4	0	0	0	9	2	2	0	0	0	11	2	0	0	0	0
Freeze Thaw Cycles	0	7	3	3	0	0	7	3	3	0	0	0	7	3	3	0	0	0
Increase in extreme weather, tornadoes storms, etc.	5	3	0	0	0	7	5	3	0	0	0	7	5	3	0	0	0	7
Wind Events	0	5	8	1	0	0	0	5	5	4	0	0	0	5	5	4	0	0
Air Quality / Indirect Wildfire Impacts	0	9	2	1	0	0	0	9	1	2	0	0	0	0	0	2	1	9
Invasive Species	0	4	6	2	0	0	0	4	5	3	0	0	0	4	5	3	0	0

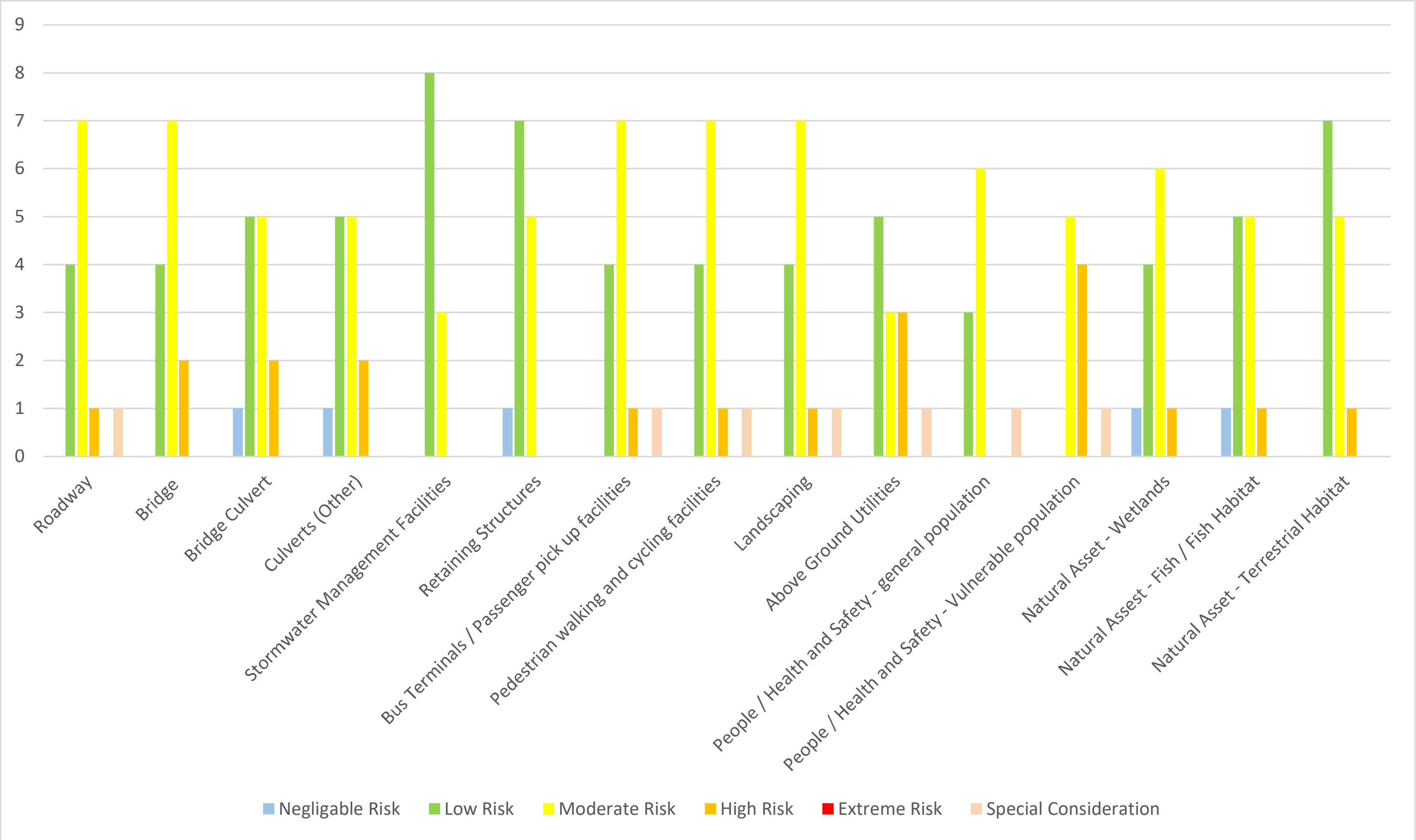

Figure 8: Baseline Conditions Risk Distribution by Asset / Component

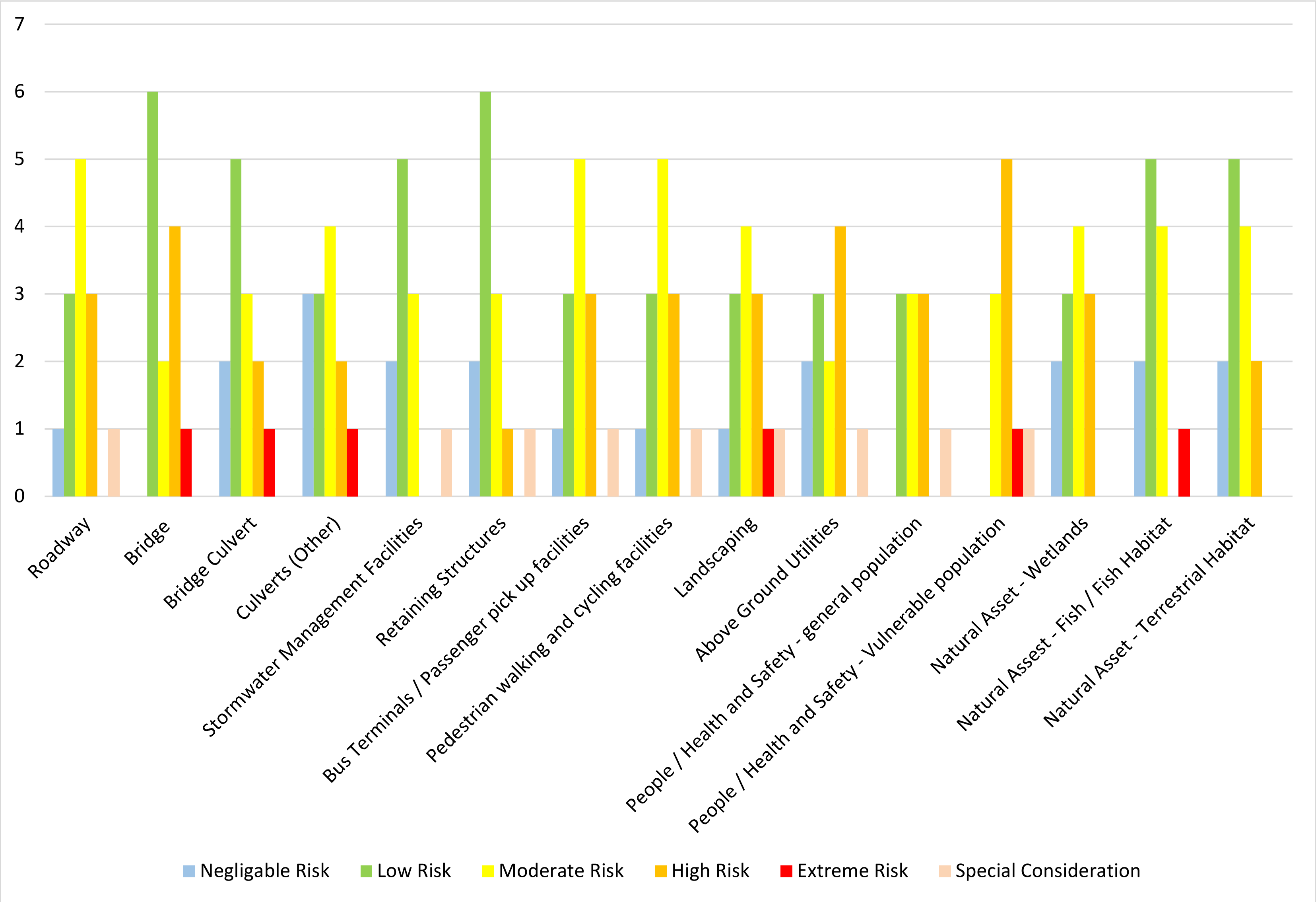

Figure 9: Projected 2050s Conditions Risk Distribution by Asset / Component

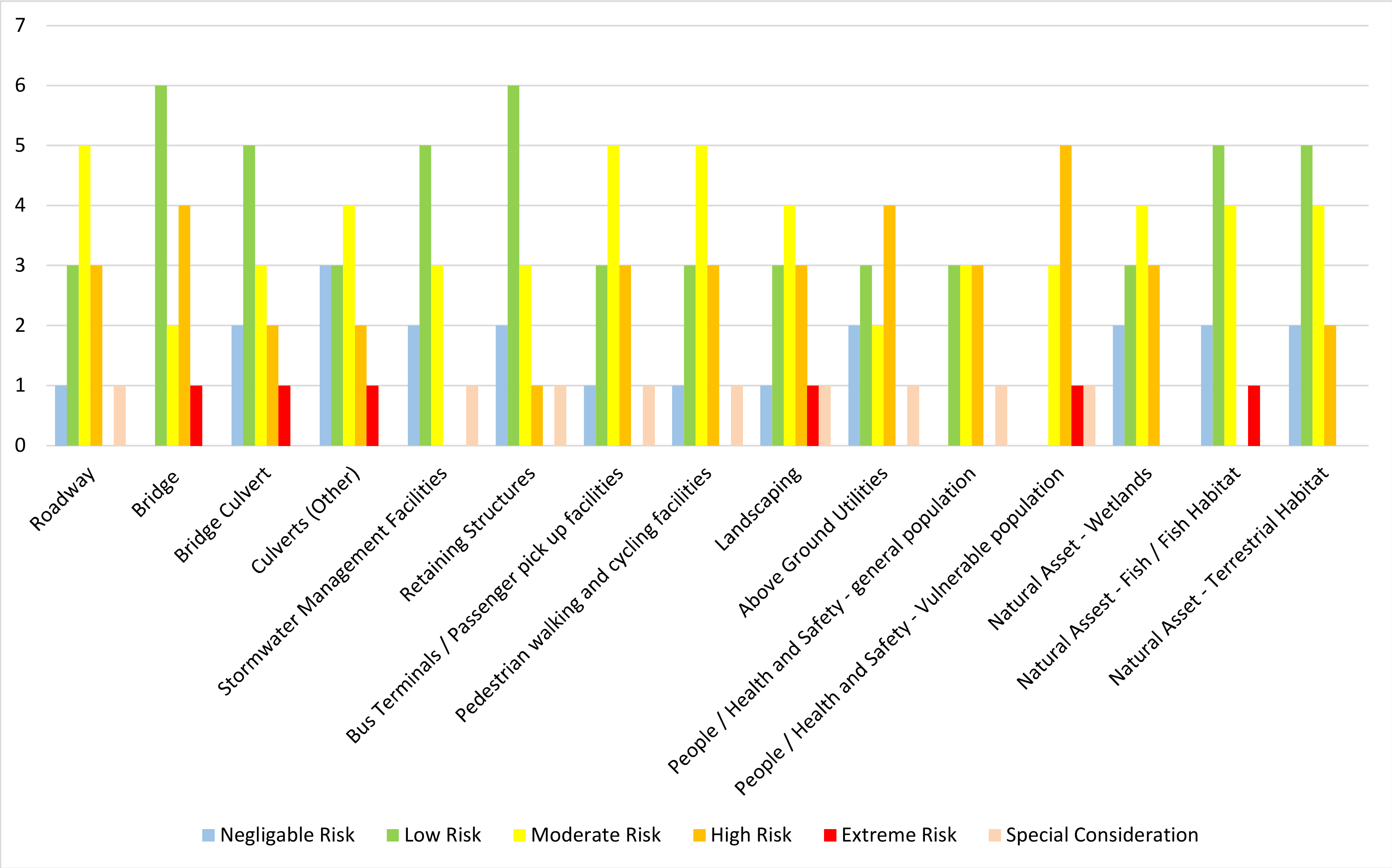

Figure 10: Projected 2080s Conditions Risk Distribution by Asset / Component

6.3.1 High and Extreme Risk

High risk elements are defined as those requiring attention and consideration of high priority controls, with the recommendation that the risk be monitored over time. Extreme risk elements are those requiring significant attention and consideration of immediate control measures. Twenty high risk elements and zero extreme risk interactions have been identified under baseline conditions. By the 2050s this increases to thirty eight high risk and six extreme interactions, and by the 2080s the risk profile changes to include forty four high and nine extreme risk elements. The relevant climate hazards, exposure and consequence of the asset element and the associated risks are presented in the sections below.

6.3.1.1 Average Annual Temperature

No High or extreme risk interactions were found for average annual temperature during baseline conditions. By the 2050s this increases to two high risk and zero extreme interactions, and three high and zero extreme risk interactions by the 2080s as show in **Table 20**.

Table 20: Average Annual Temperature High and Extreme Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
AT-1	**People / Health and Safety - general population:** Increased temperatures could impact health of general population through excessive heat exposure	Moderate			Moderate			High		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	5	2	**10**
AT-2	**People / Health and Safety - Vulnerable population:** Increased temperatures could impact health of vulnerable populations through excessive heat exposure	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	4	3	12	5	3	**15**

6.3.1.2 Extreme Heat

One high and zero extreme risk interactions were found for extreme heat during baseline conditions. By the 2050s this increases to nine high risk and two extreme interactions. No further increase in risk ratings is predicted by the 2080s as show in

Table 21.

Table 21: Extreme Heat High and Extreme Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
EH-1	**Roadway:** Extreme heat events could weaken asphalt resulting in possible reduced lifespan and increased maintenance	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	3	9	5	3	15	5	3	15
EH-2	**Bridge:** Extreme heat events could cause maintenance issues and durability concerns through increased expansion/contraction in elements such as expansion joints, asphalt and waterproofing membranes.	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	2	6	5	2	10	5	2	10
EH-3	**Bridge Culvert:** Extreme heat events could cause maintenance issues and durability concerns through increased expansion/ contraction.	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	2	6	5	2	10	5	2	10
EH-4	**Culverts (Other):** Extreme heat events could cause maintenance issues and durability concerns though increases expansion/ contraction	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	2	6	5	2	10	5	2	10
EH-5	**Bus Terminals / Passenger pick up facilities:** Extreme heat may impact elements of passenger pick up facility infrastructure through increased expansion/contraction.	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	3	9	5	3	15	5	3	15
EH-6	**Pedestrian walking and cycling facilities:** Extreme heat events could weaken asphalt leading to possible reduced lifespan and increased maintenance.	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	3	9	5	3	15	5	3	15
EH-7	**Landscaping:** Extreme heat may impact landscaping elements such as asphalt and planted species	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	3	9	5	3	15	5	3	15
EH-8		Moderate			High			High		

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
	Above Ground Utilities: Extreme heat events may overload capacity of power utility and impact utility service delivery	L	C	R	L	C	R	L	C	R
		3	3	**9**	5	3	15	5	3	**15**
EH-9	**People / Health and Safety - general population:** Extreme heat events could impact health of general population	**Moderate**			**High**			**High**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	5	3	15	5	3	**15**
EH-10	**People / Health and Safety - Vulnerable population:** Extreme heat events could impact health of vulnerable populations.	**High**			**Extreme**			**Extreme**		
		L	C	R	L	C	R	L	C	R
		3	4	**12**	5	4	20	5	4	**20**

6.3.1.3 Freezing Rain

Three high and zero extreme risk interactions were found for freezing rain events during baseline conditions. By the 2050s this increases to seven high risk and one extreme interactions, and seven high and three extreme risk interactions by the 2080s as show in **Table 22**.

Table 22: Freezing Rain Temperature High and Extreme Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
FR-1	**Roadway:** Freezing rain events could lead to higher risks of accidents and property damage.	**Moderate**			**High**			**High**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	4	3	12	5	3	**15**
FR-2	**Bridge:** Freezing rain events could impact bridge elements, particularly in "above deck" designs. Could impact load capacity in extreme cases.	**Moderate**			**High**			**High**		
		L	C	R	L	C	R	C	L	C
		3	3	**9**	4	3	12	5	3	**15**
FR-3	**Bridge Culvert:** Freezing rain events could impact bridge culvert element through increased slip hazards.	**Moderate**			**Moderate**			**High**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	**4**	2	8	5	2	**10**
FR-4		**Moderate**			**Moderate**			**High**		

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
	Culverts (Other): Freezing rain events could impact culvert flow.	L	C	R	L	C	R	L	C	R
		3	2	6	4	2	8	5	2	10
FR-5	**Bus Terminals / Passenger pick up facilities:** Freezing rain may impact elements of passenger pick up facility infrastructure.	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	3	9	4	3	12	5	3	15
FR-6	**Pedestrian walking and cycling facilities:** Freezing rain Cycles may increase slip and fall hazards and rate of accidents.	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	3	9	4	3	12	5	3	15
FR-7	**Landscaping:** Freezing rain events may impact planted species.	High			Extreme			Extreme		
		L	C	R	L	C	R	L	C	R
		3	5	15	4	5	20	5	5	25
FR-8	**Above Ground Utilities:** Freezing rain events could damage power line infrastructure and may impact utility service delivery.	High			High			Extreme		
		L	C	R	L	C	R	L	C	R
		3	4	12	4	4	16	5	4	20
FR-9	**People / Health and Safety - general population:** Freezing rain events could harm general population though increased slip and fall hazards.	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	3	9	4	3	12	5	3	15
FR-10	**People / Health and Safety - Vulnerable population:** Freezing rain events could harm vulnerable populations though increased slip and fall hazards.	High			High			Extreme		
		L	C	R	L	C	R	L	C	R
		3	4	12	4	4	16	5	4	20

6.3.1.4 Snowfall

Two high and zero extreme risk interactions were found for freezing rain events during baseline conditions. No further increases are predicted in future conditions as show in

Table 23.

Table 23: Snowfall Temperature High and Extreme Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
SF-1	**Above Ground Utilities:** Snowfall events may impact powerline infrastructure and load capacity and may impact utility service delivery.	High			High			High		
		L	C	R	L	C	R	L	C	R
		3	4	**12**	3	4	**12**	3	4	**12**
SF-2	**People / Health and Safety - Vulnerable population:** Snowfall events could impact health and safety of vulnerable populations though increased slip and fall hazards and possible inaccessibility.	High			High			High		
		L	C	R	L	C	R	L	C	R
		3	4	**12**	3	4	**12**	3	4	**12**

6.3.1.5 Riverine Flooding

Three high and zero extreme risk interactions were found for riverine flooding during baseline conditions. By the 2050s this increases to four high risk and three extreme interactions, no further increase in risk rating is predicted by the 2080s as show in **Table 24**.

Table 24: Riverine Flooding High and Extreme Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
RF-1	**Roadway:** Flooding events could lead to road washout and road closure.	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	4	3	12	4	3	**12**
RF-2	**Bridge:** Riverine flooding events have the potential to wash out the bridge leading to temporary closures.	High			Extreme			Extreme		
		L	C	R	L	C	R	C	L	C
		3	5	**15**	4	5	20	4	5	**25**
RF-3	**Bridge Culvert:** Riverine flooding events have the potential to wash out the bridge culvert.	High			Extreme			Extreme		
		L	C	R	L	C	R	L	C	R
		3	5	**15**	4	5	20	4	5	**25**
RF-4	**Culverts (Other):** Riverine flooding events could overload culvert capacity.	High			Extreme			Extreme		
		L	C	R	L	C	R	L	C	R

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
		3	5	**15**	4	5	20	4	5	**25**
RF-5	**Retaining Structures:** Riverine flooding events could washout and damage retaining structures.	**Moderate**			**High**			**High**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	4	3	12	4	3	**12**
RF-6	**Bus Stops:** Riverine flooding may washout passenger pick up facilities leading to temporary closure.	**Moderate**			**High**			**High**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	4	3	12	4	3	**12**
RF-7	**Pedestrian walking and cycling facilities:** Riverine flooding events may washout walking and cycling facilities leading to temporary closure.	**Moderate**			**High**			**High**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	4	3	12	4	3	**12**

6.3.1.6 Overland Flooding

Three high and zero extreme risk interactions were found for freezing rain events during baseline conditions. By the 2050s this remains at three high risk and one extreme interaction and increases to seven high and zero extreme risk interactions by the 2080s as show in **Table 25**.

Table 25: Overland flooding High and Extreme Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
OF-1	**Roadway:** Flooding events could lead to road washout and temporary closures.	**Moderate**			**Moderate**			**High**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	3	3	9	4	3	**12**
OF-2	**Bridge:** Overland flooding events have the potential to wash out the bridge, leading to potential closures.	**High**			**High**			**High**		
		L	C	R	L	C	R	L	C	R
		3	4	**12**	3	4	12	4	4	**16**
OF-3	**Bridge Culvert:** Overland flooding events have the potential to wash out the bridge culvert.	**High**			**High**			**High**		
		L	C	R	L	C	R	L	C	R

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
		3	4	**12**	3	4	12	4	4	**16**
OF-4	**Culverts (Other):** Overland flooding events could overload culvert capacity/major system flow routes.	**High**			**High**			**High**		
		L	C	R	L	C	R	L	C	R
		3	4	**12**	3	4	12	4	4	**16**
OF-5	**Stormwater Management Facilities:** Overland flooding has the capacity overload stormwater management facilities.	**Moderate**			**Moderate**			**High**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	3	3	9	4	3	**12**
OF-6	**Bus Terminals / Passenger pick up facilities:** Overland flooding may washout passenger pick up facilities and lead to temporary closure.	**Moderate**			**Moderate**			**High**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	3	3	9	4	3	**12**
OF-7	**Pedestrian walking and cycling facilities:** Overland flooding events may washout walking and cycling facilities and lead to temporary closure.	**Moderate**			**Moderate**			**High**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	3	3	9	4	3	**12**

6.3.1.7 Freeze-Thaw Cycles

Three High and zero extreme risk interactions were found for freeze-thaw cycles during baseline conditions. Future time periods show a reduction in freeze-thaw cycles resulting in zero high and zero extreme risk interactions as shown in **Table 26**.

Table 26: Freeze-thaw cycles High and Extreme Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
FT-1	**Roadway:** Freeze-Thaw Cycles can degrade concrete leading to potential decreased lifespan and increased maintenance.	**High**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	4	**12**	2	4	8	2	4	**8**
FT-2	**Bus Terminals / Passenger pick up facilities:** Freeze Thaw cycles may impact elements of passenger pick up facility infrastructure.	**High**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	4	**12**	2	4	8	2	4	**8**

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
FT-3	**Pedestrian walking and cycling facilities:** Freeze-Thaw Cycles can degrade concrete leading to potential decreased lifespan and increased maintenance.									
		L	C	R	L	C	R	L	C	R
		3	4	**12**	2	4	8	2	4	**8**

6.3.1.8 Wind Gusts

One high and zero extreme risk interactions were found for wind gust events during baseline conditions. By the 2050s this increases to four high risk and zero extreme interactions, no further increase in risk rating is predicted by the 2080s as show in **Table 27**.

Table 27: Wind Gusts High and Extreme Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
W-1	**Bridge:** Wind gust events could impact slender bridge elements such as railings and hangers through direct impact or flying debris.	**Moderate**			**High**			**High**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	4	3	12	4	3	**12**
W-2	**Landscaping:** Wind gusts could harm landscaping through direct impact or flying debris.	**Moderate**			**High**			**High**		
		L	C	L	L	C	R	C	L	C
		3	3	**9**	4	3	12	4	3	**12**
W-3	**Above Ground Utilities:** Wind events may damage utility powerline infrastructure which may impact utility service delivery.	**High**			**High**			**High**		
		L	C	R	L	C	R	L	C	R
		3	4	**12**	4	4	16	4	4	**16**
W-4	**People / Health and Safety - Vulnerable population:** Wind gusts could harm vulnerable populations through direct impact or flying debris.	**Moderate**			**High**			**High**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	4	3	12	4	3	**12**

6.3.1.9 Air Quality / Indirect Wildfire Impacts

One high and zero extreme risk interactions were found for air quality / Indirect wildfire events during baseline conditions. By the 2050s this increases to two high risk and zero extreme interactions, and two high and one extreme risk interactions by the 2080s as show in **Table 28**.

Table 28: Air Quality / Indirect Wildfire Impacts High and Extreme Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
AQ-1	**Bridge:** Indirect wildfire impacts events could impact bridge elements such as elastomers and lower-melting-point metals. However, most bridge elements such as carbon steel and concrete are not easily damaged by fire.	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	5	2	**10**
AQ-2	**People / Health and Safety - general population:** Reductions in air quality could impact health of general population through raspatory issues from contaminated air.	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	4	3	12	5	3	**15**
AQ-3	**People / Health and Safety - Vulnerable population:** Reductions in air quality could impact health of vulnerable populations through raspatory issues from contaminated air.	High			High			Extreme		
		L	C	R	L	C	R	L	C	R
		3	4	**12**	4	4	16	5	4	**20**

6.3.1.10 Invasive Species

Two high and zero extreme risk interactions were found for invasive species during baseline conditions. By the 2050s this increases to three high risk and zero extreme interactions, no further increase in risk rating is predicted by the 2080s as show in **Table 29**.

Table 29: Invasive Species High and Extreme Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
IS-1	**Landscaping:** Invasive species could impact landscaping elements such as planted species.	Moderate			High			High		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	4	3	12	4	3	**12**

6.3.2 Special Consideration – Low Likelihood High Consequence

Extreme and rare combination events were treated as a unique category within this assessment, given the significant stress to the building and potential high consequence for personnel safety when/if the events occur. Risk ratings for these elements were weighed heavily by the low likelihood scores, despite being a high consequence interaction. These events included:

- Increases in extreme weather, tornadoes, storms etc.

While these special consideration events are considered unlikely (low likelihood), it is worthwhile to investigate procedures to ensure that these rare, but significant and high consequence events are contemplated and built into emergency response and continuity planning.

Climate risk professionals are paying close attention to rare and extreme events, and it is noted that the "new normal" climate may include events that were previously thought to be "improbable". Though outcomes of rare, combination, and/or culminating events may be improbable, procedures should be in place to respond if they do occur.

6.3.3 Special Consideration – High Likelihood Low Consequence

High frequency low impact events have been highlighted in the assessment given the consistent exposure of elements to these events over time, potentially resulting in a "slow onset risk". Risk rating scores associated with these events were weighted heavily with low consequence scores despite frequent exposure to the climate hazard. These interactions included:

- Increased Average Temperature
- Extreme Heat
- Freezing Rain
- Air Quality/Indirect Wildfire Impacts

While these special consideration events are considered low impact, continue to investigate internal monitoring procedures to ensure that these special consideration risks do not slowly deteriorate effected elements.

6.3.4 Moderate Risk

Moderate risk elements are defined as those that have exposure/interface with the identified baseline/projected climate hazard and the effects of the hazard on the element are such that further action may be required. Controls could be considered to reduce risks to lower levels.

6.3.4.1 Average Precipitation

Nine moderate risk interactions were found for average precipitation during baseline conditions. No further increases in risk ratings are predicted in future conditions as show in **Table 30**.

Table 30: Average Precipitation Moderate Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
AP-1	**Roadway:** Increases in precipitation could impact lifespan of roadway elements.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	3	2	6	4	2	8
AP-2	**Culverts (Other):** Increases in precipitation could impact culverts and exceed capacity.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	3	2	6	4	2	8
AP-3	**Stormwater Management Facilities:** Increases in precipitation could impact Stormwater Management Facilities and exceed capacity.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	3	2	6	4	2	8
AP-4	**Bus Terminals / Passenger Pick up facilities:** Increases in precipitation could impact elements of Bus Terminals / Passenger pick up facilities.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	3	2	6	4	2	8
AP-5	**Pedestrian walking and cycling facilities:** Increase in precipitation could impact elements of Pedestrian walking and cycling facilities.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	3	2	6	4	2	8
AP-6	**Landscaping:** Increases in precipitation could impact landscaping elements.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	3	2	6	4	2	8
AP-7	**People / Health and Safety - Vulnerable population:** Increases in precipitation could impact health and safety of vulnerable populations.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	3	2	6	4	2	8

6.3.4.2 Snowfall

Nine moderate risk interactions were found for snowfall events during baseline conditions. No further increases in risk ratings are predicted in future conditions as show in **Table 31**.

Table 31: Snowfall Moderate Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
SF-3	**Roadway:** Snowfall events could impact or cause temporary shutdown of roadway.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	3	3	**9**	3	3	**9**
SF-4	**Bridge:** Snowfall events could impact or cause temporary shutdown of bridge.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	3	3	**9**	3	3	**9**
SF-5	**Bridge Culvert:** Snowfall events could impact or cause temporary shutdown of bridge culvert.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	3	2	**6**	3	2	**6**
SF-6	**Culverts (Other):** Snowfall events could impede or block culvert flow.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	3	2	**6**	3	2	**6**
SF-7	**Retaining Structures:** Snowfall events could impact retaining structures.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	3	2	**6**	3	2	**6**
SF-8	**Bus Terminals / Passenger pick up facilities:** Snowfall events could impact elements of Bus Terminals / Passenger pick up facilities.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	3	3	**9**	3	3	**9**
SF-9	**Pedestrian walking and cycling facilities:** Snowfall events could impact elements of Pedestrian walking and cycling facilities.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
		3	3	**9**	3	3	**9**	3	3	**9**
SF-10	**Landscaping:** Snowfall events could impact landscaping elements.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	3	2	**6**	3	2	**6**
SF-11	**People / Health and Safety - general population:** Snowfall events could impact health and safety of general population.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	3	3	**9**	3	3	**9**

6.3.4.3 Riverine Flooding

Five moderate risk interactions were found for riverine flooding events during baseline conditions. No further increases in risk ratings are predicted in future conditions as show in **Table 32**.

Table 32: Riverine Flooding Moderate Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
RF-8	**Above Ground Utilities:** Flooding events may impact utility service delivery.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	4	2	**8**
RF-9	**People / Health and Safety - Vulnerable population:** Flooding events may impact health and safety of vulnerable populations.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	4	2	**8**
RF-10	**Natural Asset – Wetlands:** Flooding events could impact wetlands.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	4	2	**8**
RF-11	**Natural Assets - Fish / Fish Habitat:** Flooding events could impact fish and/or fish habitats.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	4	2	**8**

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
RF-12	**Natural Asset - Terrestrial Habitat:** Flooding events could impact terrestrial habitats.									
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	4	2	**8**

6.3.4.4 Overland Flooding

Seven moderate risk interactions were found for overland flooding events during baseline conditions. No further increases in risk ratings are predicted in future conditions as show in **Table 33**.

Table 33: Overland Flooding Moderate Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
OF-8	**Retaining Structures:** Flooding events could impact retaining structures.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	3	2	6	4	2	**8**
OF-9	**Landscaping:** Flooding events could impact landscaping elements.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	C	L	C
		3	2	**6**	3	2	6	4	2	**8**
OF-10	**Above Ground Utilities:** Flooding events may impact utility service delivery.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	3	2	6	4	2	**8**
OF-11	**People / Health and Safety - Vulnerable population:** Flooding events may impact health and safety of vulnerable populations.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	3	2	6	4	2	**8**
OF-12	**Natural Asset – Wetlands:** Flooding events could impact wetlands.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	3	2	6	4	2	**8**
OF-13		**Moderate**			**Moderate**			**Moderate**		

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
	Natural Assets - Fish / Fish Habitat: Flooding events could impact fish and/or fish habitats.	L	C	R	L	C	R	L	C	R
		3	2	**6**	3	2	6	4	2	**8**
OF-14	**Natural Asset - Terrestrial Habitat:** Flooding events could impact terrestrial habitats.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	3	2	6	4	2	**8**

6.3.4.5 Drought and Dry Conditions

Four moderate risk interactions were found for drought and dry conditions events during baseline conditions. These risk ratings are predicted to decrease in future conditions as show in **Table 34**.

Table 34: Drought and Dry Conditions Moderate Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
DD-1	**Bridge:** Dry and drought conditions could impact elements of bride infrastructure.	**Moderate**			**Low**			**Negligible**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	2	2	4	1	2	**2**
DD-2	**Landscaping:** Dry and drought conditions could impact landscaping elements.	**Moderate**			**Moderate**			**Low**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	2	3	6	1	3	**3**
DD-3	**Natural Asset – Wetlands:** Dry and drought conditions could impact wetlands.	**Moderate**			**Moderate**			**Low**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	2	3	6	1	3	**3**
DD-4	**Natural Assets - Fish / Fish Habitat:** Dry and drought conditions could impact fish and/or fish habitats.	**Moderate**			**Low**			**Negligible**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	2	2	4	1	2	**2**

6.3.4.6 Freeze-thaw cycles

Three moderate risk interactions were found for freeze-thaw cycles during baseline conditions. These risk ratings are predicted to decrease in future conditions as show in **Table 35**.

Table 35: Freeze-Thaw Cycles Moderate Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
FT-4	**Bridge:** Freeze-thaw cycles could impact elements of bridge infrastructure through expansion and contraction cycles.	Moderate			Low			Low		
		L	C	R	L	C	R	L	C	R
		3	2	6	2	2	4	2	2	4
FT-5	**Bridge Culvert:** Freeze-thaw cycles could impact elements of bridge culvert infrastructure through expansion and contraction cycles.	Moderate			Low			Low		
		L	C	R	L	C	R	L	C	R
		3	2	6	2	2	4	2	2	4
FT-6	**Retaining Structures:** Freeze-thaw cycles could impact elements of retaining structure infrastructure through expansion and contraction cycles.	Moderate			Low			Low		
		L	C	R	L	C	R	L	C	R
		3	2	6	2	2	4	2	2	4

6.3.4.7 Wind Gusts

Five moderate risk interactions were found for wind gust events during baseline conditions. No further increases in risk ratings are predicted in future conditions as show in **Table 36**.

Table 36: Wing Gusts Moderate Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
W-5	**Roadway:** Wind gust events could impact roadway elements through direct impacts or flying debris.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	4	2	8	4	2	8
W-6	**Bus Terminals / Passenger pick up facilities:** Wind gust events could impact bus terminals / passenger pick up facilities through direct impacts or flying debris.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	4	2	8	4	2	8

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
W-7	**Pedestrian walking and cycling facilities:** Wind gust events could impact pedestrian walking and cycling facilities through direct impacts or flying debris.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	4	2	**8**
W-8	**People / Health and Safety - general population:** Wind gusts could harm general populations through direct impact or flying debris.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	4	2	**8**
W-9	**Natural Asset - Terrestrial Habitat:** Wind gust events could impact terrestrial habitat through direct impacts or flying debris.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	4	2	**8**

6.3.4.8 Invasive Species

Five moderate risk interactions were found for invasive species during baseline conditions. No further increases in risk ratings are predicted in future conditions as show in **Table 37**.

Table 37: Invasive Species Moderate Risk Summary

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
IS-4	**Bridge Culvert:** Invasive species may impact bridge culvert elements.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	4	2	**8**
IS-5	**Culverts (Other):** Invasive species may impact culvert flow.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	4	2	**8**
IS-6	**Stormwater Management Facilities:** Invasive species may impact stormwater management facilities flow.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	4	2	**8**
IS-7		**Moderate**			**Moderate**			**Moderate**		

Risk ID	Potential Consequence Description	Risk Ranking								
		Present			2050s			2080s		
	Retaining Structures: Invasive Species may impact retaining structure elements.	L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	4	2	**8**
IS-8	**Natural Assets - Fish / Fish Habitat:** Invasive species may impact native fish species.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	4	2	**8**

6.3.2 Negligible and Low Risk

Negligible risk elements have some level of anticipated exposure/interface with the identified climate hazard. The effects of the hazard on the element, however, are negligible/insignificant and thus do not require further action.

Low risk elements were determined for most interactions under baseline climate conditions. Low risk elements identified did not increase in risk level by 2080 under RCP8.5 conditions. Asset components considered to have a low-risk climate impact rating are not likely to be in immediate need of further resilience adaptation considerations, for the climate hazards identified.

6.3.3 No Risk

"No risk elements" are defined as those having no exposure/interface with the identified baseline or projected climate hazard. Where the element and the climate hazard do not interface, climate induced risk to the element is not anticipated. While considered in the overall risk assessment context, these "no risk elements" have been excluded from the detailed summary within this report.

7. VULNERABILITY OF NATURAL SYSTEMS

Natural assets were assessed during the climate risk workshops using the same methodology as built assets as shown in section **5.1**. These systems may be impacted by both the project and by climate change. Within the context of the project specific environmental impact assessment the vulnerability of natural asserts should be considered. A full list on all vulnerabilities identified for natural assets can be seen below in **Table 38**. While these impacts are important and should be considered in the assessment, there are no direct project considerations that will alter the impact to these systems.

Table 38: Vulnerabilities Identified for Natural Assets

Vulnerability ID	Potential Consequence Description	Vulnerability Ranking								
		Present			2050s			2080s		
		L	C	R	L	C	R	L	C	R
NA-1	**Natural Asset – Wetlands (Average Temperatures):** Increased temperatures could impact wetland species.	Moderate			High			High		
		3	3	**9**	4	3	12	5	3	**15**
NA-2	**Natural Assets - Fish / Fish Habitat (Average Temperatures):** Increased temperatures could impact fish species.	Moderate			Moderate			High		
		3	2	**6**	4	2	8	5	2	**10**
NA-3	**Natural Asset – Wetlands (Extreme Heat):** Extreme heat events could impact wetland species.	Moderate			High			High		
		3	3	**9**	5	3	15	5	3	**15**
NA-4	**Natural Asset - Fish / Fish Habitat (Extreme Heat):** Extreme heat events could impact fish species.	Moderate			High			High		
		3	4	**12**	5	4	20	5	4	**20**
NA-5	**Natural Asset - Terrestrial Habitat (Extreme Heat):** Extreme heat events could impact terrestrial species.	Moderate			High			High		
		3	2	**6**	5	2	10	5	2	**10**
NA-6	**Natural Asset – Wetlands (Invasive Species):** Invasive species may impact native wetland species.	High			High			High		
		3	4	**12**	4	4	16	4	4	**16**

Vulnerability ID	Potential Consequence Description	Vulnerability Ranking								
		Present			2050s			2080s		
NA-7	**Natural Asset - Terrestrial Habitat (Invasive Species):** Invasive species may impact native terrestrial species.	High			High			High		
		L	C	R	L	C	R	L	C	R
		3	4	12	4	4	16	4	4	16
NA-8	**Natural Assets - Fish / Fish Habitat (Invasive Species):** Invasive species may impact native fish species.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	4	2	8	4	2	8
NA-9	**Natural Asset – Wetlands (Average Precipitation):** Increases in precipitation could impact wetland areas.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	3	2	6	4	2	8
NA-10	**Natural Asset - Terrestrial Habitat (Average Precipitation):** Increases in precipitation could impact terrestrial habitats.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	3	2	6	4	2	8
NA-11	**Natural Asset – Wetlands (Riverine Flooding):** Flooding events could impact wetlands.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	4	2	8	4	2	8
NA-12	**Natural Assets - Fish / Fish Habitat (Riverine Flooding):** Flooding events could impact fish and/or fish habitats.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	4	2	8	4	2	8
NA-13	**Natural Asset - Terrestrial Habitat (Riverine Flooding):** Flooding events could impact terrestrial habitats.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	4	2	8	4	2	8
NA-14	**Natural Asset – Wetlands (Overland Flooding):** Flooding events could impact wetlands.	Moderate			Moderate			Moderate		
		L	C	R	L	C	R	L	C	R
		3	2	6	3	2	6	4	2	8
NA-15		Moderate			Moderate			Moderate		

Vulnerability ID	Potential Consequence Description	Vulnerability Ranking								
		Present			2050s			2080s		
	Natural Assets - Fish / Fish Habitat (Overland Flooding): Flooding events could impact fish and/or fish habitats.	L	C	R	L	C	R	L	C	R
		3	2	**6**	3	2	6	4	2	**8**
NA-16	**Natural Asset - Terrestrial Habitat (Overland Flooding):** Flooding events could impact terrestrial habitats.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	3	2	6	4	2	**8**
NA-17	**Natural Asset – Wetlands (Drought and Dry Conditions):** Dry and drought conditions could impact wetlands.	**Moderate**			**Moderate**			**Low**		
		L	C	R	L	C	R	L	C	R
		3	3	**9**	2	3	6	1	3	**3**
NA-18	**Natural Assets - Fish / Fish Habitat (Drought and Dry Conditions):** Dry and drought conditions could impact fish and/or fish habitats.	**Moderate**			**Low**			**Negligible**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	2	2	4	1	2	**2**
NA-19	**Natural Asset - Terrestrial Habitat (Wind Gusts):** Wind gust events could impact terrestrial habitat through direct impacts or flying debris.	**Moderate**			**Moderate**			**Moderate**		
		L	C	R	L	C	R	L	C	R
		3	2	**6**	4	2	8	4	2	**8**

8. RECOMMENDATIONS

The Teston Road extension is generally resilient to the weather considered for the current climate and into the 2050s and 2080s. The team, however, has identified several vulnerabilities that should be reviewed for risk treatment and adaptation recommendations.

8.1 Asset Specific Recommendations

8.1.1 Clear Combustible Materials Away from Bridge Structures

This recommendation addresses the following risks: AQ-1

Indirect wildfire impacts events could impact bridge elements such as elastomers and lower-melting-point metals. However, most bridge elements such as carbon steel and concrete are not easily damaged by fire. It is recommended to clear combustible materials away from bridge structures. Avoid use of materials in bridge construction susceptible to fire damage.

8.1.2 Allow clearance for extreme heat movements in expansion joints.

This recommendation addresses the following risks: EH-2, EH-3

Extreme heat events could cause maintenance issues and durability concerns through increased expansion/contraction in elements such as expansion joints, asphalt and waterproofing membranes. Allow clearance for extreme heat movements in expansion joints. Avoid use of waterproofing membranes susceptible to damage from extreme heat.

8.1.3 Avoid structural systems with above-deck elements

This recommendation addresses the following risks: FR-2

Freezing rain events could impact bridge elements, particularly in "above deck" designs. Could cause safety risk due to falling ice and affect load capacity in extreme cases. It is recommended to avoid structural systems with above-deck elements.

8.1.4 Provide enhanced erosion and scour protection measures for bridge foundations.

This recommendation addresses the following risks: OF-2, OF-3, RF-2, RF-3

Flooding events have the potential to cause severe scour or washout events leading to temporary closures. Provide enhanced erosion and scour protection measures for bridge foundations. Position abutments in areas less susceptible to flooding. Consider use of deep foundations rather than shallow.

8.1.5 Avoid use of slender elements susceptible to wind or debris impact.

This recommendation addresses the following risks: W-1

Wind gust events could impact slender bridge elements such as railings and hangers through direct impact or flying debris. It is recommended to avoid use of slender elements susceptible to wind or debris impact. Design superstructures for high wind loads.

8.1.6 Use of High Traction Surfaces

This recommendation addresses the following risks: FR-3

Freezing rain events could impact pedestrian areas through increased slip hazards. The use of high traction surfaces is recommended.

8.1.7 Planted Species Selection

This recommendation addresses the following risks: EH-7, FR-7, W-2

Future climate conditions such as increased temperatures, freezing rain events, and wind gusts events maybe unfavorable for planted landscaping elements.

8.1.8 Additional Storage capacity in Stormwater Management Facilities

This recommendation addresses the following risks: OF-5

Overland flooding has the capacity overload stormwater management facilities. It is therefore recommended to incorporate additional storage capacity in SWM facilities to be resilient to increased runoff volumes and peak flows.

8.1.9 Additional Conveyance Capacity in Culverts

This recommendation addresses the following risks: RF-4

Riverine flooding events have the potential to overload culvert capacity. It is therefore recommended to incorporate additional conveyance capacity in culverts to be resilient to increased peak flows.

8.1.10 Ensure Sufficient Grades are Provided.

This recommendation addresses the following risks: FR-1, FR-5, FR-6

Freezing rain events have the potential to impact project elements and increase the risk of slip and fall hazards and accidents. To mitigate this risk, it is recommended to design components ensuring sufficient grades are provided to ensure sufficient drainage velocity thereby reducing the number of frozen surfaces.

8.2 Policy Related Recommendations

8.2.1 Ongoing Inspection, Maintenance, and Rehabilitation of Roadway and Pedestrian Facilities

This recommendation addresses the following risks: EH-1, EH-5, FT-1, FT-2, FT-3

Climate parameters such as extreme heat and freeze thaw cycles have the potential to impact project elements such as the roadway, walking and cycling areas, and pedestrian pick up facilities. It is recommended to complete ongoing inspection, maintenance, and rehabilitation of the infrastructure throughout the lifecycle of the assets.

8.2.2 Harden Flood Susceptible Roadway Portion and Reduce Velocities Where Possible

This recommendation addresses the following risks: OF-1, OF-6, OF-7, RF-1, RF-6, RF-7

Flooding events could impact or potentially washout project elements such as roadways walking and cycling areas, and pedestrian pick up facilities. To mitigate this risk, it is recommended to harden areas susceptible to flooding to by increasing resistance to erosion and lowering velocities where possible.

8.2.3 Ongoing Inspection, Maintenance, and Rehabilitation of Culverts

This recommendation addresses the following risks: EH-4, FR-4, OF-4

Culvert infrastructure could be impacted by changes in climate parameters such as increased expansion/contraction from extreme heat events, flow impedance from freezing rain events, or system capacity overload from flooding events. It is recommended to complete ongoing inspection, maintenance, and rehabilitation of the culvert infrastructure throughout the lifecycle of the assets.

8.2.4 Invasive Species Monitoring Program

This recommendation addresses the following risks: IS-1

Invasive species could impact landscaping elements such as planted species. To mitigate the impact of invasive species on landscaping elements the creation of an invasive species monitoring plan is recommended. The plan could consider the following operational measures:

- Increased monitoring of landscaping and neighboring areas for signs of new invasive species.
- Planting of landscaping species that are resilient to invasive species.

8.2.5 Health and Safety Management Plan

This recommendation addresses the following risks: AQ-2, AQ-3, AT-1, EH-9, EH-10, FR-9, FR-10, AT-2, SF-2, W-4

Pedestrians travelling in the Teston Road area are vulnerable to climatic impacts that may affect their health and safety. These impacts include reduced air quality from indirect wildfire impacts, increased temperatures, and slip and fall hazards from snowfall and freezing rain events. To mitigate the potential impacts to pedestrians, the creation of a Health and Safety Management Plan is recommended. The plan could consider the following operational measures:

- Increased monitoring of road/sidewalk conditions
- Monitoring of temperatures and air quality in transit facilities.
- Increased snow clearing and road salting (as necessary)

8.2.6 Utility Power (Off-Site Services) Outage Management Plan

This recommendation addresses the following risks: EH-8, FR-8, SF-1, W-3

The Teston Road area is vulnerable to prolonged power outages due to extreme heat, freezing rain, snowfall, or wind events. Extreme temperature escalates power demand that overload utility distribution equipment and cause substations and generation plants to shut down, freezing rain and snowfall causes overhead lines to collapse and wind events could damage or shut down power distribution equipment. To mitigate the impacts of prolonged power outages, the creation of a Utility Power (Off-Site Services) Outage Management Plan is recommended. The plan could consider the following operational measures:

- Monitoring and/or upgrades to current emergency power distribution
- Implementation of additional emergency lighting such as solar powered backup lighting systems.

9. CLOSURE

The Regional Municipality of York retained Morrison Hershfield to conduct the work described in this report, and this report has been prepared solely for this purpose.

This document, the information it contains, the information and basis on which it relies, and factors associated with implementation of suggestions contained in this report are subject to changes that are beyond the control of the authors. The information provided by others is believed to be accurate and may not have been verified.

Morrison Hershfield does not accept responsibility for the use of this report for any purpose other than that stated above and does not accept responsibility to any third party for the use, in whole or in part, of the contents of this document. This report should be understood in its entirety, since sections taken out of context could lead to misinterpretation.

We trust the information presented in this report meets Client's requirements. If you have any questions or need addition details, please do not hesitate to contact one of the undersigned.

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