FINAL

Climate Change Analysis Report

Highway 413 Preliminary Design and Assessment of Environmental Impacts

March 2026

Ontario

wsp

AECOM

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AECOM: 2024-12-21

Authors

Report Prepared By:

Amanda Van Wychen, BSc.
Senior Climate Change Advisor
WSP

Report Reviewed By:

Janya Kelly, PhD
Lead Climate Change Advisor, Climate Science Practice Lead
WSP

Report Approved By:

Janya Kelly, PhD
Lead Climate Change Advisor, Climate Science Practice Lead
WSP

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Acronyms

AR5 .... Fifth Assessment Report

AR6 .... Sixth Assessment Report

ATMS .... Advanced Traffic Management Systems

CCRA .... Climate Change Resilience Assessment

CCTV .... Closed-circuit Television

CH_4.............. Methane

CMIP .... Coupled Model Intercomparison Project

CO_2 .... Carbon Dioxide

CO_2e .... Carbon Dioxide Equivalent

CSA............. Canadian Standards Association

EA .... Environmental Assessment

ECCC .... Environment and Climate Change Canada

EPA .... Environmental Protection Agency

ETR .... Express Toll Route

EV .... Electric Vehicle

FWI.............. Fire Weather Index

GHG .... Greenhouse Gases

GTA............. Greater Toronto Area

GWP............ Global Warming Potential

HFC............. Hydrofluorocarbons

IDF .... Intensity-Duration-Frequency

IPCC............ Intergovernmental Panel on Climate Change

LSA .... Local Study Area

MECP.......... Ministry of Environment, Conservation and Parks

MTO .... Ontario Ministry of Transportation

N_2O .... Nitrous Oxide

NEX-GDDP . NASA Earth Exchange Global Daily Downscaled Projections

PCIC............ Pacific Climate Impacts Consortium

PFC .... Perfluorocarbons

RCP............. Representative Concentration Pathway

ROW .... Right-of-Way

SACC .... Strategic Assessment of Climate Change

SF_6 .... Sulphur Hexafluoride

SSP .... Shared Socio-Economic Pathway

WBCSD .... World Business Council for Sustainable Development

WRI .... World Resources Institute

Executive Summary

The Ontario Ministry of Transportation (MTO) has retained WSP Canada Inc. (WSP) and AECOM Canada ULC (AECOM) in collaboration with various sub-consultant and technical firms to undertake the Highway 413 Preliminary Design and Assessment of Environmental Impacts, hereinafter referred to as “the Project”.

The Project is following the requirements of the *Highway 413 Act*, *2024*.

Although not required under the *Highway 413 Act, 2024*, a climate change assessment was conducted in alignment with the federal Strategic Assessment of Climate Change (SACC) and Ontario’s environmental assessment guidance. This aligns with the MTO Guide for Assessing and Mitigating the Air Quality Impacts and Greenhouse Gas Emissions of Provincial Transportation Projects and is consistent with the Air Quality Assessment completed for the Project. The assessment comprises two key components:

1. **Greenhouse Gas (GHG) Assessment**
   This section quantifies the net GHG emissions as defined in the SACC (i.e., the emissions from the Project less any avoided emissions or offset measures) associated with the construction and operation of the project. It includes emissions from construction equipment, land-use change, and traffic operations. The assessment compares project emissions to provincial and federal GHG inventories and targets. It should be noted that all results of the GHG Assessment are presented in this report; a separate Air Quality Impact Assessment has been completed that assesses impacts to air quality contaminants, excluding GHGs.

   Key findings of the GHG assessment include:

   - Within the air quality local study area (defined as all major highway and arterial roads within 500 metres of the alignment of the proposed mainline Highway 413 and any ramps intended to support traffic flow to and from Highway 413), GHG emissions are anticipated to increase by 157% in 2041 with the Project compared to a scenario without the presence of the Project. While GHG emissions are anticipated to increase by 153% in 2051 with the Project compared to a scenario without the presence of the Project. This indicates that the difference in emissions between a scenario with the Project versus without the Project is generally the same for both 2041 and 2051 (i.e., the difference between 2041 and 2051 is nominal and within the uncertainty associated with the estimates).

- The maximum annual emissions for operations phase of the project are 692 kilotonnes CO_2e/year, which is 0.44% of the 2023 Ontario-wide annual emissions, and 0.10% of the 2023 Canada-wide emissions.
- The maximum annual emissions make up approximately 0.48% of Ontario's 2030 targeted emissions, and 0.17% of Canada's 2030 targeted emissions.

Various mitigation measures can be implemented during construction to reduce net GHG emissions, including use of appropriately sized construction equipment, idle reduction and use of electric vehicles where possible. During operations, this includes the consideration for features such as electric charging stations along the highway. The Government of Ontario is supporting the switch to low or zero-carbon vehicles across the province by making significant investments in public electric vehicle (EV) charging infrastructure.

2. **Climate Change Resilience Assessment (CCRA)**
   The CCRA evaluates how future climate conditions may affect the project's infrastructure and operations. Using various climate change scenarios from the Intergovernmental Panel on Climate Change's (IPCC's) Sixth Assessment Report, the assessment identifies climate hazards such as extreme heat, rainfall, wind, and wildfire, and evaluates their potential impacts on 17 infrastructure components. Risk ratings were assigned to each potential interaction based on likelihood and consequence to estimate the level of risk. Mitigation incorporated into the design was considered in the risk ranking.

Key findings of the CCRA include:

- Most climate-infrastructure interactions were rated as low or negligible risk under mid-century scenarios.
- Under high-emissions scenarios for the 2080s, several medium and high-risk interactions were identified, particularly related to extreme heat, wildfire, and lightning.
- Mitigation measures such as climate-resilient design standards, stormwater management systems, and emergency response planning are expected to reduce risks.
- A continual improvement process is recommended to adapt to evolving climate data and maintain resilience over the project's lifespan.

The report concludes that with the integration of mitigation strategies and adaptive design, the Highway 413 Project is expected to be resilient to future climate conditions. With respect to GHGs, mitigation measures identified in Section 3.3 will aid in minimizing the Project's contribution to climate change.

1. Introduction

The Ontario Ministry of Transportation has retained WSP Canada Inc. and AECOM Canada ULC in collaboration with various sub-consultant and technical firms to undertake the Highway 413 Preliminary Design and Assessment of Environmental Impacts, hereinafter referred to as “the Project”.

The Project is following the requirements of the *Highway 413 Act, 2024*.

The Project includes the 52-kilometre Highway 413 corridor, a 4 kilometre extension to Highway 410, and a 3 kilometre extension to Highway 427 (both facilitating connection to the proposed Highway 413 corridor), for a total of 59 kilometres of new infrastructure (Figure 1). The highway will have 11 interchanges at municipal roads. Features such as stormwater management ponds, carpool lots, Commercial Vehicle Inspection Facilities, maintenance facilities, and the potential for electric vehicle charging stations, have been explored as part of Preliminary Design.

Highway 413 will connect Highway 401 and Highway 407 Express Toll Route in the Regional Municipality of Halton and the Regional Municipality of Peel with Highway 400 in the Regional Municipality of York.

The typical Right-of-Way will be 170 metres which includes 110 metres for the typical mainline highway and 60 metres for a proposed transitway. A multi-use trail parallel to Highway 413 may be accommodated within the proposed transitway Right-of-Way. The right-of-way is expanded at interchanges and high fills areas to accommodate ramps to and from the crossing, as well as in locations with ancillary highway facilities as mentioned above. The Preliminary Design consists of a typical six-lane cross section (three lanes in each direction) with a grassed median. The right-of-way has been designed to accommodate up to ten-lanes (five lanes in each direction) should future traffic conditions warrant additional capacity. These additional lanes would be provided by widening the highway towards the median.

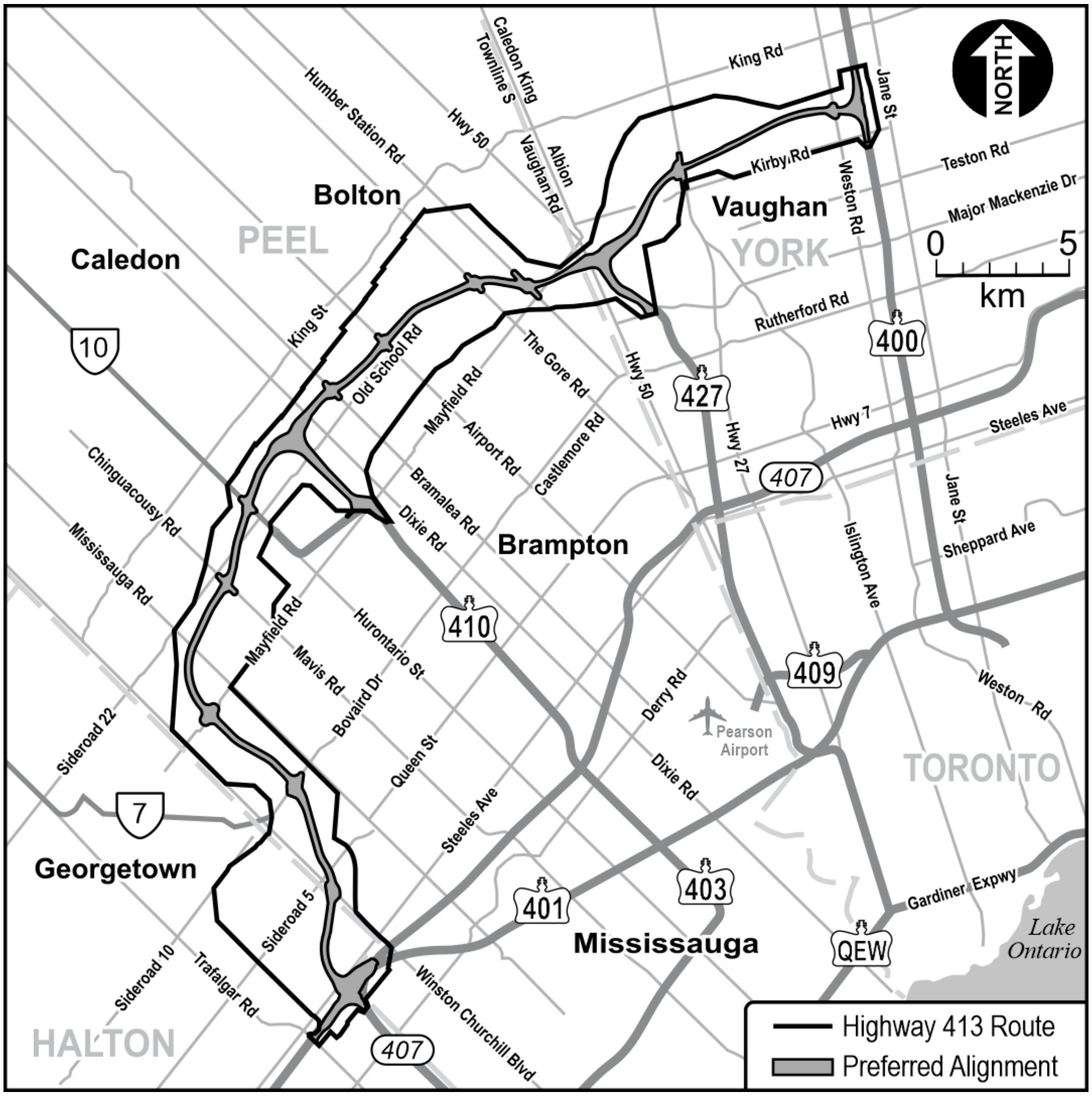
The proposed transitway will be a separate corridor running alongside the highway, dedicated for public transit, including stations to facilitate passenger access at key locations. The proposed transitway and stations will be subject to a separate future assessment of environmental impacts.

Highway 413 is a 400-series highway, which is a network of controlled-access highways throughout the Province of Ontario. Their primary function is to accommodate through traffic and provide links between urban centres. 400-series highways feature full grade separations (such as bridges) at most intersecting roads and railway lines. Interchanges are provided along the 400-series highways to connect to other highways and municipal roads. These highways have design standards to accommodate high speeds and various collision avoidance and traffic management systems. Highway 413 is proposed to have a posted speed limit of 110 kilometres per hour.

The future Highway 413 is expected to:

- Relieve traffic on local roads and parallel highways,
- Help accommodate travel demand,
- Reduce travel times for commuters and goods movement,
- Reduce the social, environmental, and economic costs of congestion,
- Provide greater connectivity between urban growth centres,
- Provide better connections to residential and employment lands, and,
- Provide an alternate route in the event of an incident or road closure on local and regional roads.

Figure 1-1: Highway 413 Route



2. Purpose of Report

Climate change is defined as a change in global or regional climate patterns, primarily attributed to increased atmospheric concentrations of Greenhouse Gases (GHGs) (Government of Canada 2021). GHGs have the potential to affect future climate as they contribute to the greenhouse effect by absorbing infrared radiation in the atmosphere, increasing temperature, and changing weather patterns (Bush and Lemmen 2019).

Although not required under the *Highway 413 Act, 2024*, a Climate Change Assessment was completed in alignment with the Strategic Assessment of Climate Change (SACC) (Government of Canada 2020), and Ontario's guide for Considering Climate Change in the Environmental Assessment Process (Government of Ontario 2017). This aligns with the MTO Guide for Assessing and Mitigating the Air Quality Impacts and Greenhouse Gas Emissions of Provincial Transportation Projects (MTO 2020) and is consistent with the Air Quality Impact Assessment completed for the Project. This includes evaluating:

- How operation of the proposed Project may affect climate change (i.e., the Project's contribution to climate through the emission of GHGs); and
- How potential changes in climate may affect the proposed Project, including supporting facilities and infrastructure (i.e., the resilience of the Project to climate change).

A GHG Assessment, as well as a Climate Change Resilience Assessment (CCRA) were conducted for the Project. The GHG Assessment includes an estimate of the net GHG emissions associated with the Project. To assess the potential impact, the estimated net GHG emissions are compared to the provincial and federal GHG inventories and targets. The GHG Assessment is summarized in Section 3 which includes a description of the methodology, data and assumptions, and emission factors used for GHG estimation. It should be noted that all results of the GHG Assessment are presented in this report; a separate Air Quality Impact Assessment has been completed that assesses impacts to air quality contaminants, excluding GHGs.

The CCRA employs a risk management approach based on the Project design. The assessment anticipates future climatic conditions for the Project region, and how climate change related disruptions or impacts may affect the Project. Given that the Project is at the Preliminary Design stage, a qualitative screening level risk assessment approach was conducted based on the Preliminary Design information. The CCRA is summarized in Section 4.

2.1 Study Area

The GHG Assessment and CCRA do not have associated study areas as GHGs result in impacts that are global in nature (e.g. difficult to attribute to a single project) and physical climate risks are driven by changes at a global scale.

For the purpose of quantifying GHG emissions associated with operations (i.e., traffic), the Air Quality local study area (LSA) was used as the boundary for identifying and quantifying emissions sources (e.g., traffic emissions). The Air Quality LSA is defined as all major highway and arterial roads within 500 metres of the alignment of the proposed mainline Highway 413 and any ramps intended to support traffic flow to and from Highway 413. The results of this local GHG assessment were then compared to a Regional Air Pollutant Burden Analysis completed in 2024 (RWDI 2024) that included estimates of GHGs in 2041 at a regional level both with and without the presence of the Project. The regional study area includes sections of 400 series highways such as Highway 401, 400, 427, 403 and 407ETR, as well as highways such as Highways 7 and 10 and major roads within urban areas. The study area includes city centres such as Milton, Mississauga, Brampton, Vaughan and Bolton, and extends to the southern limits of Orangeville. The methodology for this assessment is detailed in Section 3.1.4.

For the climate change resilience assessment, the project boundary was used as the boundary for identifying infrastructure components. All infrastructure components of the Project as defined in the Project description and outlined in Section 4.3 of this report were considered.

3. Greenhouse Gas Assessment

This section provides information relevant to the scope of the assessment, including GHG emission sources considered, methods for the assessment, results, and identified mitigation for reducing GHGs associated with the Project. The GHGs considered in this assessment are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

The Project activities are not expected to emit material sulphur hexafluoride (SF_6), perfluorocarbons (PFCs) or hydrofluorocarbons (HFCs); as these sources are not commonly present in the highway construction process (Feng Ma et al., 2016) or from typical vehicle exhaust (EPA 2022). Therefore, these compounds are not considered in the assessment.

GHG emissions are expressed in terms of tonnes of carbon dioxide equivalent (CO_2e), calculated by multiplying the annual emissions of each GHG by its 100-year global warming potential (GWP). The GWP for respective GHGs has been obtained from the Intergovernmental Panel on Climate Change's (IPCC's) Fifth Assessment Report (AR5; IPCC 2013), in line with the values provided in the *Greenhouse Gas Pollution Pricing Act* (Government of Canada 2018) as required by the SACC (Government of Canada 2020). The GHG 100-year GWPs used in the assessment are presented in **Table 3-1**.

Table 3-1: Global Warming Potentials for the Greenhouse Gases in the Assessment

Greenhouse Gas	100-Year GWPs	Reference
Carbon dioxide (CO_2)	1	IPCC AR5 (IPCC 2013)
Methane (CH_4)	28	IPCC AR5 (IPCC 2013)
Nitrous oxide (N_2O)	265	IPCC AR5 (IPCC 2013)

GWPs = global warming potentials

The GHG Assessment considered the following activities:

- **Site Preparation and Construction**: This phase includes site preparation and activities associated with the construction of the Project. This includes activities such as road construction, bridge construction, and changes to the land use (resulting in the removal of a carbon sink which removes future carbon uptake potential), as well as the one-time GHG emissions from the removal of the vegetation (as carbon stored in the vegetation may be released with removal). Site preparation and construction activities are estimated to take place over ten years, though specific construction timelines and phasing delivery of the project have not yet been determined.
- **Operation**: This phase includes activities associated with operation and maintenance activities. Emissions from the operation of the Project include vehicle exhaust, brake and tire wear. This phase also includes emissions associated with land clearing activities (i.e., land-use change), resulting in the removal of a carbon sink. Notably, this phase does not include the one-time emissions occurring at the time of the vegetation removal, and does not include the proposed transitway which will be subject to a separate environmental assessment.
- **Decommissioning**: A decommissioning phase is not included in the assessment as these are rare occurrences for linear infrastructure and is not anticipated.

3.1 Methods

Although the SACC (Government of Canada, 2020) is not a regulatory requirement for this Project, its framework was applied where appropriate aligning with the MTO Environmental Guide for Assessing and Mitigating the Air Quality Impacts of Transportation Projects (MTO 2020). This approach supports an assessment of GHG emissions in alignment with both federal and provincial expectations.

The SACC (Government of Canada 2020) requires proponents to calculate net GHG emissions based on the following equation and definitions:

Net GHG Emissions = Direct GHG Emissions + Acquired Energy GHG Emissions – Avoided Domestic GHG Emissions – Offset Measures

Where:

- The **Direct GHG Emissions** = emissions generated by sources that are within the defined scope of the Project (e.g., generators, vehicles, and fugitive emissions) (Government of Canada 2020). This definition is consistent with the definition provided in the World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD), GHG reporting guidance (WRI and WBCSD 2013).
- The **Acquired Energy GHG Emissions** = emissions from the generation of purchased electricity, heating, and cooling consumed by the proponent from a third-party for the Project (Government of Canada 2020). This definition is consistent with the definition provided in WRI and WBCSD 2013.
- **Avoided Domestic GHG Emissions** = emissions that are reduced or eliminated in Canada as a result of the Project.
- **Offset Measures** = emission reductions or removals in Canada generated from activities that are additional to what would have occurred in the absence of the offset Project.

Consistent with the SACC guidance, the net GHG emissions for the Project were calculated based on the sum of Direct GHG emissions as well as the Indirect Acquired Energy GHG emissions. As a measure of conservatism, the GHG assessment does not consider offset credits, and therefore is set to zero tonnes of carbon dioxide equivalent (0 t CO_2e). Additionally, avoided emissions were not identified for the Project. The following sections describe the methods used to quantify emissions associated with the identified GHG sources for the Project:

- Construction Emissions
  - Construction equipment (direct emissions)
  - Land clearing / land-use change (direct emissions)
  - Electricity consumption during construction (acquired energy)

- Operational Emissions
    - Traffic emissions during operations (direct emissions)
    - Impacts to carbon sinks (direct emissions)

3.1.1 Construction Equipment

The GHG emissions associated with construction equipment were obtained from the Highway 413 Greater Toronto Area Preliminary Construction GHG Assessment (RWDI 2022). These emissions were calculated using an emission factor methodology using emission factors from ECCC's GHG Quantification Requirements (RWDI 2022; ECCC 2020).

3.1.2 Land Clearing

The following sections outline the methods used to assess emissions associated with land clearing, including the one-time GHG emissions associated with the removal of the carbon stock that has the potential for conversion to GHGs, as well as the effect of the removal of the carbon sink on net GHG emissions each year. The emissions have been calculated using methods described in 2006 IPCC Volume 4, Chapter 2 (IPCC 2006) and the 2019 Refinement to the 2006 IPCC Guidelines for National GHG Inventories (IPCC 2019). The various land-use categories to be cleared as part of the Project are being defined as per the 2006 IPCC guidelines Volume 4, Chapter 3 (IPCC 2006). The amount of, and types of, vegetation removals were obtained from the Project's Terrestrial Ecosystems Impact Assessment Report (MTO 2025)

3.1.2.1 Land-Use Change

For this assessment, land-use change emissions were estimated based on the area of vegetation clearing within the final ROW footprint, classified according to IPCC land-use categories. Emissions were calculated assuming that all vegetation within the ROW will be cleared and the carbon will be converted to CO_2 in the first year, representing a conservative scenario. No credit was applied for potential revegetation, as future restoration areas remain unknown. Indirect vegetation impacts (e.g., from salting or construction-related damage outside the ROW) were excluded due to spatial uncertainty, and their contribution to carbon loss is expected to be negligible relative to direct ROW clearing.

A combination of Tier 1 and Tier 2 methodologies was applied, using default IPCC emission factors and peer-reviewed, region-specific carbon stock data where available.

Carbon losses from aboveground biomass and soils were calculated by multiplying carbon density factors by the affected area, with results converted to CO_2e using molecular weight ratios and global warming potentials. Further details on emission factors and data sources are provided in Appendix A.

3.1.2.2 Impact to Carbon Sinks

The loss of carbon sink capacity due to land clearing was estimated based on the annual biomass accumulation that would have occurred in the absence of the Project. Only areas identified as high carbon sink capacity, specifically forested land and wetlands, were included in accordance with the SACC guidance. For each ecozone, the impacted area (in hectares) was multiplied by the average annual aboveground biomass growth rate, and adjusted using IPCC Tier 1 ratios for belowground biomass, carbon fraction of dry matter, and molecular conversion to CO_2.

Growth rates were sourced from peer-reviewed literature specific to Southern Ontario (Tier 2), while ratios and conversion factors were based on IPCC defaults. The resulting CO_2e values represent the annual loss of carbon sequestration potential from disturbed areas. Further details, including emission factors, assumptions, and sources, are provided in Appendix A.

3.1.3 Construction Electricity Consumption

Based on current projections, grid-connected electricity is not expected during the construction phase; instead, on-site power demand is predicted to be supplied by fossil fuel-fired generators, with their associated emissions accounted for with the construction equipment sources in Section 3.1.1.

3.1.4 Traffic Emissions During Operations

Based on traffic modelling results, an estimate of vehicle GHG emissions with and without the Project was developed for traffic on roadways within the Air Quality LSA 2041 and 2051.

The No-Build scenario (for both 2041 and 2051) considered no construction of Highway 413 and was used as the baseline for this analysis. The Build scenario (for both 2041 and 2051) considered potential incremental GHG emission impacts from the implementation and operation of Highway 413.

Road traffic data based on AM peak, PM peak, and Annual Average Daily Traffic (AADT) volumes for all roadways in the Air Quality LSA for the No-Build and Build scenarios in 2041 and 2051 was used. The traffic data detailed the percentages of medium trucks and heavy trucks for each roadway within each dataset. The remaining vehicles were assumed to be passenger vehicles.

The standard approach for estimating vehicular emissions is to use computer simulation techniques that are based on extensive previous testing of a wide range of vehicles. Motor Vehicle Emission Simulator (MOVES4) is such a model that has been developed for this purpose by the U.S. Environmental Protection Agency (EPA). MOVES4 was used to generate vehicle emission factors for all scenarios.

Exhaust emissions vary widely by vehicle type and speed, and MOVES4 was configured to generate emission factors based on the vehicle type and posted travel speed. These individual emission factors were aggregated to produce a composite emission factor for each key air contaminant, representing the average vehicle for each road segment assessed.

The split of passenger vehicles as Passenger Car (MOVES Source Type 21) and Passenger Truck (MOVES Source Type 31) was based on 2023 vehicle registration for Ontario (Statistics Canada 2024b), with this spilt assumed for both 2041 and 2051. The split of Single-Unit and Combination trucks into Short-Haul and Long-Haul was based on MOVES technical guidance (US EPA, 2024).

Hourly profiles were developed for each roadway, adapted from MOVES technical guidance (US EPA, 2021), to determine diurnal variation of traffic volumes expressed as a percentage of peak hour. The AM peak and PM peak emission rates were calculated for each roadway based on traffic data, and these were assigned to each hour in the periods 6 a.m. to 9 a.m. and 4 p.m. to 7 p.m. respectively. The maximum of these two emission rates was used as the peak hour for the hourly profile. These per second emission rates were assumed to be constant for each hour, from which hourly emission rates were calculated. The daily emissions were calculated as a sum of each hour in the day.

MOVES4 default data were used to represent the percentages of electric vehicles in the future Ontario fleet. Based on combined MOVES4 vehicle age distribution by vehicle type and fuel type distribution by vehicle type, the estimated percentage of electric vehicles in modelling year 2041 is 30% for Passenger Car, 24% for Passenger Truck, and 9% for Single Unit Short Haul Truck. For 2051, the estimated percentage of electric vehicles used in the modelling is 33% for Passenger Car, 31% for Passenger Truck, and 13% for Single Unit Short Haul Truck.

Details regarding the calculations, assumptions, and sources for the operational emissions can be found in the Air Quality Impact Assessment Report (MTO, 2025).

As mentioned in Section 2.1, the results of GHG assessment have been compared to the Regional Air Pollutant Burden Analysis (RWDI, 2024) to identify how the Project will affect GHG emissions at a regional level compared to locally. This regional analysis was completed based on regional ("macro") traffic modelling results.

3.2 Project GHG Emissions

3.2.1 Construction

This subsection outlines the expected direct GHG emissions from the construction of the Project (RWDI 2022). For each emission source, the total annual emissions have been expressed as CO_2e. The direct emissions represent:

- **Road Construction:** This includes emissions from construction activities such as road preparation, utility relocation, earthworks, sewer/drainage installation, base preparation, barrier walls/fencing, and paving.
- **Bridge Construction:** This includes emissions from construction activities such as piles/footings, pier columns/wingwalls, girders, deck, barrier walls, sidewalks approaches, and paving.
- **Major Bridge Construction:** This includes emissions from construction activities such as coffer dam/dewatering, caissons, foundations, columns/abutments, girders, post tensioning, deck, barriers, expansion joints, and paving.
- **Electricity Consumption:** Construction phase is not expected to require electrical services. Any energy required will be provided via fuel-fired generators whose emissions have been considered within the Construction Equipment Source.
- **Land-Use Change Emissions:** This includes the carbon losses in biomass due to disturbances (e.g., removal of vegetation), defined in the SACC as carbon stock change resulting in direct GHG emissions or removals from land use conversions. There are no N_2O emissions associated with land use change.

- **Impact to Carbon Sinks:** The annual emissions associated with lost carbon sinks due to the removed vegetation (i.e., lost ability to store additional carbon on an annual basis because the vegetation has been removed) is included in both the construction and the operational emissions. The SACC defines this as the post-disturbance GHG emissions included in direct GHG emissions resulting from land use change.

The results of the GHG assessment for the construction phase are provided in **Table 3-2**.

Table 3-2: Greenhouse Gas Emissions (Construction Phase)

Activity	Highest-year Emissions (tonnes CO_2e/year)	Number of years	Total Emissions for Construction Phase (tonnes CO_2e)
Road Construction[(a)]	15,274	10	152,740
Bridge Construction[(a)]	2,312	10	23,120
Major Bridge Construction[(a)]	1,972	10	19,720
Acquired energy [(b)]	n/a	10	n/a
Land-Use Change[(c)]	87,076	1	87,076
Impact to Carbon Sinks[(d)]	519	10	5,188
Total	**107,153**	**n/a**	**287,844**

(a) Road construction, bridge construction, and major bridge construction emissions are from the Highway 413 Greater Toronto Area Preliminary Construction GHG Assessment (RWDI 2022).

(b) Electrical services are not expected to be required during the construction phase; all power will be supplied by fuel-fired generators, whose emissions are included under the Construction Equipment Source (RWDI 2022).

(c) Land-Use Change from loss of carbon from carbon stock change (e.g., removal of vegetation/disturbances) is included in construction phase emissions. This does not have an associated no. of years, because this value is only emitted one time, when the disturbance occurs. For conservatism, it is assumed that the emissions associated with land-use change will all occur in a single year, and all vegetation removed will be burned, representing the worst-case scenario.

(d) Impact to Carbon Sinks – post disturbance is the annual lost ability to store additional carbon on an annual basis because the vegetation has been removed. For the construction phase, this annual loss occurs for 10 years, as this is the duration of the construction phase. This annual loss will continue into the operations phase.

3.2.2 Operations

Estimated annual GHG emission estimates from within the Air Quality LSA for the No-Build and Build scenarios are presented in **Table 3-3**, along with the percent change in emissions between the No-Build and Build conditions. This is presented for both the 2041- and 2051-time horizons based on traffic modelling for these horizons. The total emissions from each scenario were compared to assess the incremental impact from the Project.

In addition to these local GHG emission estimates, Table 3-4 presents the regional impacts to GHG emissions for the 2041 No-Build and Build scenarios, along with the percent change in emissions between the No-Build and Build conditions.

Within the LSA, GHG emissions are anticipated to increase by 157% in the Build Scenario compared to the No Build Scenario in the 2041 scenario and by 153% in the 2051 scenario (RWDI 2025). Regionally, GHG emissions are anticipated to increase by 0.3% as a result of the Project (RWDI 2024).

Based on these results, GHG emissions associated with traffic are expected to more than double locally, however when you consider the larger region and the related changes in traffic (including diversion from other routes), GHG emissions are expected to increase only marginally.

Table 3-3: Maximum LSA Annual Tailpipe Emissions Between No-Build and Build Scenarios

Roadway Type	Maximum Annual Tailpipe Emissions (Tonnes CO_2e) No-Build Scenario 2041 Time Horizon	Maximum Annual Tailpipe Emissions (Tonnes CO_2e) Build Scenario 2041 Time Horizon	Change in Maximum Annual Tailpipe Emissions (%) 2041 Time Horizon	Maximum Annual Tailpipe Emissions (Tonnes CO_2e) No-Build Scenario 2051 Time Horizon	Maximum Annual Tailpipe Emissions (Tonnes CO_2e) Build Scenario 2051 Time Horizon	Change in Maximum Annual Tailpipe Emissions (%) 2051 Time Horizon
Highway 413 and Associated Ramps	0	657,598	—	0	572,569	—
Other Highways	230,630	272,889	18%	210,726	244,891	16%
Arterial	209,094	200,891	-4%	183,730	178,602	-3%
Total	**439,724**	**1,131,378**	**157%**	**394,456**	**996,062**	**153%**

Source: RWDI 2025

Table 3-4: Maximum Regional Annual Tailpipe Emissions Between No-Build and 2041 Build Scenarios

Roadway Type	Maximum Annual Tailpipe Emissions (Tonnes) No-Build Scenario CO_2e	Maximum Annual Tailpipe Emissions (Tonnes) 2041 Build Scenario CO_2e	Change in Maximum Annual Tailpipe Emissions (%) CO_2e
Freeway	2,890,987	3,147,467	8.9%
Highway	1,165,218	1,070,530	-8.1%
Arterial	2,489,218	2,349,432	-5.6%
Total	**6,545,423**	**6,567,428**	**0.3%**

Source: RWDI 2024

Table 3-5 summarizes the local GHG emissions in the Build scenario from the impacts to carbon sinks (i.e., the annual loss of carbon uptake) during the operational phase and from changes in local traffic in both the 2041- and 2051-time horizons. The comparison tables that follow only consider the change in local GHG emissions from traffic rather than that from the regionally estimated emissions to represent the emissions attributed to the Project. This is for conservatism since the change in emissions locally is larger than that estimated for the region.

Table 3-5: Total Annual GHG Emissions during the Operational Phase Attributed to the Project

Source	Emissions in 2041 (CO_2e tonnes/year)	Emissions in 2051 (CO_2e tonnes/year)
Traffic GHGs[a]	691,654	601,597
Impact to Carbon Sinks (Annual Losses)[b]	519	519
Total	**692,173**	**602,116**

(a) The traffic GHG emissions listed here are based on the difference in local emissions between the no-build and build scenarios.
(b) This represents the impacts to carbon sinks from the Project only.

A comparison of the estimated annual GHG emissions from the Project for the modelled year with the highest emissions of the operations phase (in this case the 2041-time horizon) to the federal and provincial totals are provided in **Table 3-6**.

A comparison of the Project GHG emissions to Canada's and Ontario's 2030 targets is also presented in **Table 3-6** to identify the impact of the Project on Canada's GHG reduction target. Canada continues to aim to reduce it's GHG emissions by approximately 40-45% compared to the 2005 levels (ECCC 2023) by 2030. Ontario aims to reduce it's GHG emissions by approximately 30% by 2030 compared to the 2005 levels (Sussex 2022). The total estimated GHG emissions from the project represent less than 0.2% of Canada's 2030 GHG emissions target.

Table 3-6: Comparison to Provincial and Federal Totals

Source	GHG Emissions (CO_2e kilotonnes/year)
Project GHG Emissions (Maximum Annual Emissions)	692[a]
Ontario-wide GHG Emissions[b] (2023)	158,728
Canada-wide GHG Emissions[b] (2023)	693,912
Ontario 2030 Target Emissions[c]	144,000
Canada 2030 Target Emissions[d]	408,000
Comparison to Ontario 2023 Total	0.44%
Comparison to Canada-wide 2023 Total	0.10%
Comparison to Ontario's 2030 Targets	0.48%
Comparison to Canada's 2030 Targets	0.17%

(a) This represents the total annual GHG emissions for the 2041 Build scenario within the LSA, as well land use change associated with the Project.

(b) Federal and Provincial total emissions taken for the year 2023 from NIR 1990-2023, Part 1, Table 2-2 (ECCC 2025). Federal and Provincial GHG Emissions have been converted from mega tonne to kilo tonnes.

(c) Ontario 2030 targets taken from Sussex 2022.

(d) For conservatism, these emissions were calculated based on a 45% reduction compared to 2005 levels (rather than 40%). Canada 2030 targets taken from NIR 1990-2023, Part 1 (ECCC 2025).

The maximum annual emissions for operations phase of the project are 692 kilotonnes CO_2e/year, which is 0.44% of the 2023 Ontario-wide annual emissions, and 0.10% of the 2023 Canada-wide emissions. The maximum annual emissions make up approximately 0.48% of Ontario's 2030 targeted emissions, and 0.17% of Canada's 2030 targeted emissions.

3.3 Mitigation Measures

Various mitigation measures will be included throughout the Project to minimize GHG emissions. During operations, this includes the consideration for features such as electric charging stations along the highway, as outlined in Section 1.0. Additionally, construction phase mitigation measures that could be implemented include:

- Reduction of unnecessary traffic and implementation of speed limits during construction (e.g., encouraging carpooling when moving between locations within the construction site);
- Use of construction and maintenance vehicles, machinery, and equipment that are equipped with the current emission controls, and in a good state of repair;
- Use of appropriately sized construction equipment;
- Use of idle reduction for construction and maintenance vehicles;
- Increase the biodiesel or renewable diesel (RD) content of fuels for construction equipment where feasible, as a drop-in fuel to help reduce fossil diesel consumption;
- Use of electric construction and maintenance vehicles such as electric pick-up trucks, wherever possible;
- Using approaches to construction that improve efficiency of vehicles travelling through construction zones;
- Use renewable energy sources to replace fossil fuels, where possible;
- As further detailed in the Terrestrial Ecosystems Impact Assessment Report (MTO 2025), minimize the area of vegetation cleared, and implement progressive revegetation as construction progresses; and
- Using cleared wood as merchantable timber where possible.

In addition to the measures identified above relating to direct emissions, consideration of making adjustments to materials used for the construction of highway infrastructure can also reduce GHG emissions. This includes using sustainable, renewable, and recycled materials and exploring ways to minimize waste.

The “Made in Ontario Environmental Plan” aligns Ontario with Canada’s 2030 targets under the Paris Agreement (Government of Ontario, 2018). This includes the Cleaner Transportation Fuels regulation that increases requirements for renewable content in gasoline, supporting low – or zero carbon technology through funding opportunities and continue to look at supporting the clean technology sector as part of broader economic growth and recovery efforts.

The Government of Ontario is supporting the switch to low or zero-carbon vehicles across the province by making significant investments in public electric vehicle (EV) charging infrastructure and supporting the installation of public EV chargers outside of Ontario’s large urban centres (including at community hubs, Ontario’s highway rest areas, carpool parking lots, and Ontario Parks), as low-carbon emission vehicles have a significant role to play in transitioning to a sustainable low-carbon transportation system and a clean-growth economy.

As new and emerging low and zero-carbon technology evolves, including for heavy duty vehicles, MTO will continue to assess the suitability for use in the maintenance of our transportation network.

4. Climate Change Resilience Assessment

The CCRA employs a risk management approach that aligns with the SACC guidance (Government of Canada 2020) and the draft technical guidance on Assessing Climate Change Resilience (Government of Canada 2022) as well as Ontario's guide for Considering Climate Change in the Environmental Assessment Process (Government of Ontario 2017). The assessment anticipates future climatic conditions for the Project region, and how climate change related disruptions or impacts may affect the Project design. The assessment focuses on key impacts to the Project (i.e., interactions with climate that have the potential to present the highest risks).

The following elements are considered in this CCRA:

- **Introduction to Climate Change:** An introduction to climate change projections to help understand context for the assessment.
- **Approach and Methods:** An outline of the methods used to undertake the CCRA, specifically identifying how the risks associated with climate change will be assessed.
- **Project Stages, Infrastructure and Activities:** A summary of the stages of the Project (e.g., construction, operation, and decommissioning), as well as a list and description of the infrastructure and activities associated with the Project based on the Project description.
- **Future Climate Projections:** A summary of the future climate projections for the Project location based on information available from readily accessible climate data portals and literature.
- **Climate Interactions:** Identification of potential climate-infrastructure interactions.
- **In-Design Mitigation Measures:** Identification of existing in-design mitigation measures based on the available design parameters.

- **Risk Ranking:** Qualitative risk ratings of either negligible, low, medium, high, or extreme, based on the likelihood of an interaction occurring and the consequence if the interaction takes place. These were assigned to each potential climate interaction for the Project, considering the in-design mitigation measures.
- **Continual Improvement Processes:** Identification of continuous improvement techniques that could be applied to the Project to further reduce climate related risk and allow the Project to operate with flexibility as the climate continues to change and as new information becomes available.
- **Summary and Conclusions:** Summary of how the available information could be used to support the continual improvement processes and risk management strategies at the site.

4.1 Introduction to Climate Change and Projections

The Intergovernmental Panel on Climate Change (IPCC) is generally considered to be the definitive source of information related to past and future climate change as well as climate science. The IPCC is a United Nations body dedicated to providing an objective, scientific assessment of climate change information, and the potential natural, political, economic, and human impacts of climate change. The IPCC periodically releases Assessment Reports, each of which provides the current state of climate change science, where there is agreement within the scientific community. The IPCC released the Fifth Assessment Report (AR5) in 2013 followed by the Sixth Assessment Report (AR6) in 2021 (IPCC 2013; IPCC 2021). The AR6 is the most current complete synthesis of information regarding climate change that include general global and regional trends. Where available, AR6 was used, however, downscaled projections for wind are based on AR5 as they were not available from AR6 at the time of this assessment. The projections for wind are in alignment with the projections from AR6 and are considered suitable for the approach taken in this assessment.

When projecting future climate conditions, there needs to be consideration of future climate scenarios which are based on assumptions about future GHG emissions and atmospheric concentrations. In AR6, these scenarios, are called Shared Socioeconomic Pathways (SSPs), and are summarized in **Table 4-1**. These scenarios represent the uncertainty in human contribution to climate change from now to the end of century.

Table 4-1: Characterization of Shared Socioeconomic Pathways in IPCC Sixth Assessment Report (O'Neil et al. 2014)

SSP	Radiative Forcing in 2100	Challenges	Global Temperature Change	Characterization
SSP1	1.9 W/m^2 2.6 W/m^2	Sustainability – Low for mitigation and adaptation	1.0°C to 2.4°C	Sustainable development proceeds at a reasonably high pace.
SSP2	4.5 W/m^2	Middle of the Road – Medium for mitigation and adaptation	2.1°C to 3.5°C	An intermediate case between SSP1 and SSP3. Analogous to RCP 4.5 scenario.
SSP3	7.0 W/m^2	Regional Rivalry – High for mitigation and adaptation	2.8°C to 4.6°C	Unmitigated emissions are high due to moderate economic growth.
SSP4	3.4 W/m^2 6.0 W/m^2	Inequality – High for adaptation, low for mitigation	—[a]	A mixed world, with relatively rapid technological development in low carbon energy sources in key emitting regions, leading to relatively large mitigative capacity in places where it mattered most to global emissions.
SSP5	8.5 W/m^2	Fossil-fuelled Development – Low for mitigation, high for adaptation	3.3 to 5.7°C	In the absence of climate policies, energy demand is high and most of this demand is met with carbon-based fuels. Analogous to RCP 8.5 scenario.

[a] Although the IPCC references SSP4, it is not evaluated throughout and therefore an associated global temperature change is not provided in the IPCC.

The Coupled Model Intercomparison Project (CMIP) is an international effort to develop global climate models for the purpose of better understanding past, present, and future climate change. One of the outputs of CMIP are sets of climate models used by practitioners in many fields for projections of climate variables and derived climate indicators.

The current generation of these models, referred to as CMIP6 (associated with AR6), uses combinations of SSPs with targeted radiative forcing scenarios to provide a set of models that describe possible ways that the global climate system is affected by development and climate mitigation and adaption policies.

4.2 Approach and Methods

Given the Project is at the Preliminary Design stage, this CCRA was completed by conducting a screening-level risk assessment to assess how project infrastructure and activities interact with climate change and bring awareness of potential impacts to the Project. This involved assigning a qualitative risk rating based on the likelihood of occurrence of a climate hazard and the consequence of the unwanted events caused by the climate hazard. Section 4.2.2 and Section 4.2.3 provide the criteria for the likelihood and consequence ratings that have been used to assign the risk ratings to each climate interaction.

4.2.1 Climate Analysis and Projections

Climate hazards that could impact the site were selected based on a preliminary review of regional climate trends, previous risk assessments, and professional judgement. Climate hazards are environmental conditions driven by climate change, such as extreme rainfall or high winds, that could affect infrastructure performance.

Climate hazards are evaluated using climate indicators, which are quantifiable metrics representing the intensity or frequency of a given hazard to assess potential impacts on Project infrastructure and activities. For example, the hazard “extreme rainfall” is represented by the indicator “maximum 1-day precipitation,” which is relevant for assessing whether projected rainfall in a given day may exceed the design capacity of drainage infrastructure. This indicator-based approach supports the identification of potential interactions between climate hazards and infrastructure components, enabling a structured assessment of risk under future climate scenarios.

The indicators were computed using WSP’s in-house software and climate data warehouse. This software uses an industry standard library (Bourgault et al., 2023) for indicators that is consistent with those used in other infrastructure climate risk assessments and are detailed in Section 4.4.

The following time horizons are used in this assessment to assess how climate conditions, and associated risks to the Project, may change over time:

- Historical (1981-2010) – representing baseline climate conditions
- Near-future (2036-2065) – representing construction and mid-century operations
- Far-future (2066-2095) – representing late century operations

Each indicator was averaged over a 30-year period to reflect climate trends rather than short-term variability. This approach allows for the assessment to capture long-term shifts in climate that may influence the performance, durability, and safety of the Project infrastructure.

4.2.2 Likelihood

Each climate hazard was given a likelihood score based on a 5-point scale from Very Low to Very High. Each climate hazard was evaluated using a representative climate indicator, with a likelihood score assigned to each indicator. The likelihood score reflects the probability that the projected value of a climate indicator will exceed a defined threshold during a given future time horizon (see Section 4.4).

In this assessment, design-specific thresholds were not available. Therefore, the 90th percentile of the indicator's modeled values from the historical baseline period (1981–2010) was used as the threshold. This approach provides a conservative basis for identifying potential exceedances.

The likelihood of exceedance was calculated by evaluating how often the modeled climate data for each future time horizon surpassed the historical baseline value. These frequencies were then converted into likelihood scores using the scale in **Table 4-2**. Where likelihood scores varied across the length of the Project infrastructure, the most conservative value was selected.

Table 4-2: Likelihood Scale

Qualitative Likelihood Description	Likelihood Score	Probability of Exceeding Baseline Value	Qualitative Description
Very Low	**1**	0% ≤ p < 1%	Not likely to occur during the entire Project's operational life.
Low	**2**	1% ≤ p < 10%	Not likely to increase in intensity or duration during the Project life.
Moderate	**3**	10% ≤ p < 50%	Likely to occur during the Project's life and/or likely to increase in intensity or duration.
High	**4**	50% ≤ p < 90%	Very likely to occur during the Project's life and very likely to increase in intensity or duration.
Very High	**5**	90% ≤ p ≤ 100%	Very likely to occur many times throughout the Project life, and likely to increase in intensity or duration in the near term (e.g., the next 10 to 20 years).

For climate hazards where quantitative data was insufficient, likelihoods scores were assigned qualitatively based on climate trends identified in peer-reviewed literature.

4.2.3 Consequence

Each climate-infrastructure interaction was given a consequence score based on a 5-point scale from Insignificant to Catastrophic. The consequence scale considers damage to infrastructure, level of repairs required, health and safety of users, and environmental impact that could occur from an interaction. Existing in-design mitigation measures are considered in the consequence scoring. If a mitigation measure could reduce the impact of an interaction, this is accounted for in the consequence scoring. **Table 4-3** provides the consequence scale being used in this assessment.

Table 4-3: Criteria Defining Consequence of Unwanted Events caused by the Climate Hazard

Qualitative Descriptor	Consequence Score	Description
Insignificant	1	Not likely to cause infrastructure damage, service disruption, or impact the safety of the users. Any required repairs would be undertaken during regular maintenance. Not likely to result in any environmental impacts.
Minor	2	Could cause localized infrastructure disruption with no permanent damage. Some minor restoration work could be required but could be undertaken within the planned operations and maintenance budget. Not likely to result in a safety risk to users. Could result in minor, localized environmental impacts not requiring any remediation efforts.
Moderate	3	Likely to cause limited infrastructure damage and loss of service. Damage would be recoverable through minor repair and maintenance, may be beyond the planned operations and maintenance budget. Could result in a minor safety risk to users. Could result in moderate environmental impacts requiring basic remediation efforts.
Major	4	Likely to cause extensive infrastructure damage and major loss of infrastructure service that might require major repair and is likely beyond the planned operations and maintenance budget. Could result in a moderate safety risk to users. Could result in serious environmental impacts requiring extensive remediation efforts.
Catastrophic	5	Likely to cause permanent damage and/or complete loss of the infrastructure and the infrastructure service. All costs beyond planned operations and maintenance budget. Could result in a major safety risk to users. Could result in detrimental environmental impacts extending significantly beyond project area, requiring extensive remediation efforts.

4.2.4 Risk Rating

Risk ratings were assigned to all identified climate interactions using a 5-point scale ranging from Negligible to Extreme, as shown in **Table 4-4**. These ratings were determined by combining the likelihood score (i.e., the probability that a climate indicator will exceed a defined threshold) with the consequence score (i.e., the severity of the impact if the threshold is exceeded) as described in Sections 4.2.2 and 4.2.3. The following equation was used to calculate risk:

$$Risk = Consequence * Likelihood$$

A low or negligible risk rating indicates that the probability of the hazard occurring is low and/or the resulting impact is minor. Conversely, a medium, high, or extreme risk rating reflects either a higher probability of occurrence, more severe impacts, or both. For example, while extreme events such as severe storms may have a lower probability of occurrence, their potential to cause significant infrastructure damage or service disruption results in a higher overall risk rating.

Where no interaction was identified, or data was unavailable, interactions were noted as not applicable.

Table 4-4: Risk Rating Matrix

Consequence					
Catastrophic	**Medium**	**High**	**High**	**Extreme**	**Extreme**
Major	**Low**	**Medium**	**High**	**High**	**Extreme**
Moderate	**Low**	**Low**	**Medium**	**High**	**High**
Minor	**Negligible**	**Low**	**Low**	**Medium**	**Medium**
Insignificant	**Negligible**	**Negligible**	**Low**	**Low**	**Low**
Likelihood	**Very Low**	**Low**	**Moderate**	**High**	**Very High**

4.3 Project Stages, Infrastructure and Activities

There are typically three stages of a Project to consider: construction, operation, decommissioning. For this Project, the construction timeline has not yet been determined. It is anticipated that construction could span a number of years; however, the duration is not expected to be long enough to result in notable climate change impacts beyond seasonal variation. These seasonal variations would be addressed through planning and operational policies, such as Health and Safety procedures and Emergency Response procedures. As a result, and in line with standard practice, construction has not been considered in the CCRA. Additionally, a decommissioning and abandonment phase is not included in the assessment as these are rare occurrences for linear infrastructure and is not anticipated.

The greatest possibility of meaningful interactions with the long-term climate is the operational phase of the Project and thus that is the focus of the CCRA. Climate change not only has the potential to impact Project infrastructure which presents a risk to the health and safety of maintenance staff and road users through damage to infrastructure. Climate change can also result in direct risks to health and safety through such as potential for heat stress to staff during extreme heat events. These are described in detail in the following sections and Appendix C.

Climate change could also result in secondary impacts to the surrounding environment. For example, increased precipitation can result in increased runoff that may cause erosion and sedimentation into nearby watercourses. These potential impacts to the environment are described in Section 4.9.

Table 4-5 provides a list of the infrastructure and activities that have been considered for the CCRA and provided descriptions for each.

Table 4-5: Infrastructure and Activities Considered

Infrastructure/Activity Considered	Description
Highway 413 and Extensions to Highways 410 and 427, Interchanges and Freeway-to-Freeway Connections	Approximately 59 kms of 4- to 6-lane 400-series highway (90% 6-lane) Freeway-to-freeway connections at Highway 401/407 ETR, Highway 410, Highway 427, and Highway 400. Including a 4 km extension to Highway 410, and a 3 km extension to Highway 427. The infrastructure includes ramps and bridges that connect the freeways. 11 new interchanges and modifications to 2 existing interchanges at municipal arterial roads.
Municipal Road Realignments	Minor municipal road realignments as required throughout Halton, Peel, and York Regions.
Maintenance Yard Facilities and Carpool Lots	Maintenance yards including office space (office space assessed separately, with staff buildings), salt storage, maintenance vehicle depot, among other related infrastructure. Commuter carpool lots at interchanges within lands designated for transitway stations, with ~100 spots each and provisions for future transit connections.
Commercial Vehicle Inspection Facilities	Inspection lanes, weigh scales, parking areas, staff building (staff building assessed separately, with office buildings).
Offices/Staff Buildings	There will be office space in maintenance yards and staff buildings at commercial vehicle inspection facilities.
Major Water Crossings and Other Bridges	This includes a Credit River, East Humber, Main Humber and West Humber crossing. Other bridges include highway over road (overpass), road over highway (underpass), highway over rail, highway over watercourse, and ramp over highway.
Structural Culverts and Non-Structural Culverts, Storm Sewers	Over 200 culverts conveying watercourses across the highway and through interchanges. Storm sewers include catch basins, maintenance holes, pipes, and subdrains.

Infrastructure/Activity Considered	Description
Stormwater Management Infrastructure	Grassed embankments, enhanced grassed swales, infiltration facilities, vegetated filter strips, dry ponds, and wet ponds
Static Overhead and Roadside Signage	Typical freeway overhead and ground mounted signage.
Illumination and Traffic Signal Infrastructure	Either fully or partially illuminated (warrant outstanding). Traffic signalization at all interchange ramp terminals. Modifications to municipal intersections as required.
Advanced Traffic Management Systems (ATMS) Infrastructure	Overhead variable message signs, shoulder travel time signs, CCTV cameras for traffic/incident monitoring.
Road Maintenance Activities	Includes winter maintenance (e.g., snow removal, de-icing), pavement resurfacing or replacement of full pavement structure, cleaning and repairs of drainage system. Rehabilitation of structure, retaining walls, noise walls, and other related infrastructure. Maintenance of traffic signs and lighting, road monitoring and routine maintenance, maintenance of environmental mitigation and compensation features.
Environmental mitigations and compensation features	To consider the following but not limited to wetland compensation, fisheries mitigation/compensation, bank stabilization along watercourses, habitat compensation/offsetting for SAR, grading & seeding & planting for approached to culverts and bridges (using native species where possible), install wildlife passage, plantings within stormwater management facilities.
Electric charging stations	Charging stations anticipated at commuter parking lots and rest areas.
Roadside safety infrastructure	Typical freeway steel beam guiderails and concrete barriers, including end treatments/energy attenuators.
Overhead and underground utilities	Relocations of many utilities, including high voltage electricity, underground gas pipelines, telecommunications, watermains, sanitary sewers, and other related infrastructure.
Landscaping	Compensation planting, trees, shrubs, seeding/sodding, gateway features, wildlife fence.

4.4 Climate Analysis and Projections

The climate hazards used in this assessment are described in **Table 4-6**. As described in Section 4.2.1, climate indicators are quantifiable metrics used to measure the intensity or frequency of climate hazards. The indicator used for each climate hazard was based on the most relevant indicator for each climate-infrastructure interaction.

Table 4-6: Climate Hazards and Indicators

Climate Hazard	Climate Indicator	Description
Extreme Heat	Days above 39˚C	Annual number of days that exceed 39˚C
Extreme Heat	Heat wave duration (above 35˚C)	Number of periods with consecutive above 35˚C.
Extreme Cold	Cold spell duration indicator (-15˚C)	Number of periods with consecutive below -15˚C.
Freeze-Thaw Cycles	Daily freeze-thaw cycles	Annual number of days when the minimum temperature is below -2°C and the maximum temperature is above 2°C
Extreme Rainfall	Max 1-day precipitation event	Annual maximum precipitation totaled over the course of 1 day
Snowfall	Total Snowfall	Annual total snowfall
Snowfall	Max 1-day snowfall	Annual maximum snowfall totaled over the course of 1 day
Freezing Rain	*Assessed qualitatively*	Assessed qualitatively through projected changes in freezing rain events during winter months.
Extreme Wind	Max daily wind speed	Annual maximum daily wind speed
Lightning	*Assessed qualitatively*	Assessed qualitatively through the projected increase in lightning activity with increases in global temperature.
Overland Flooding	Days above 20 mm rain	Number of days where the rainfall exceeds 20 mm in a 1-day period.
Overland Flooding	Max 5-day rain	Annual maximum rainfall totaled over the course of a 5-day period.
Wildfires	Fire weather index (FWI) above 10	Number of days where FWI is above 10, representing moderate or higher conditions for a potential fire.
Wildfires	Max fire weather index	Maximum FWI that occurs within 1 year.

Freezing rain and lighting were assessed semi-qualitatively using peer-reviewed literature.

For freezing rain, Jeong et al. (2019) projected freezing precipitation and ice accretion on surfaces. Compared to a baseline period of 1986-2016, by both the 2013-2043 and 2034-2064 periods, there is no projected change in the 50-year return level of maximum ice thickness on a radial surface, and a possible decrease for the 2053-2083 period. These projections are based on a high emission scenario (RCP 8.5). However, there is high uncertainty in these projections.

For lightning, literature suggests that there is a projected increase in lightning strikes by 12% per 1˚C increase in annual average temperature (Romps et al. 2014). Therefore, given the projected increase in average temperature identified in the assessment, (lightning is projected to increase).

For all climate hazards assessed quantitatively, **Table 4-7**, provides a summary of future projections. The table shows a range of projections for each climate indicator. The SSP2-4.5 scenario was chosen to align with the Ontario Provincial Climate Change Impact Assessment (Climate Risk Institute 2023) and represent a 'middle of the road' scenario, while SSP5-8.5 was chosen to represent a worst-case scenario. Multiple grid cells were used to reflect the long linear nature of the infrastructure, and therefore the table presents the range of projections across the grid cells used in the study. A complete list of datasets and grid cells used for the study are included in Appendix B.

Table 4-7: Climate Projections

				Projections			
Climate Hazard	Climate Indicator	Unit	Historical (median)	SSP2-4.5 2050s	SSP2-4.5 2080s	SSP5-8.5 2050s	SSP5-8.5 2080s
Extreme Heat	Days above 39˚C	Days	0	1	2 – 5	2 – 4	10 – 22
Extreme Heat	Heat wave duration (above 35˚C)	Count	0	5 – 6	6 – 7	7	18 – 20
Extreme Cold	Cold spell duration indicator (-15˚C)	Count	4 – 6	5 – 7	3 – 4	4 – 6	1 – 3
Freeze-Thaw Cycles	Daily freeze-thaw cycles	Cycles	33 – 38	41 – 47	39 – 47	39 – 47	33 – 42
Extreme Rainfall	Max 1-day precipitation event	mm	36 – 40	66 – 81	64 – 92	68 – 88	72 – 86
Snowfall	Total Snowfall	cm	123 – 151	159 – 196	147 – 181	148 – 186	107 – 143
Snowfall	Max 1-day snowfall	cm	18 – 19	29 – 31	29 – 32	28 – 31	28 – 30
Extreme Wind	Max daily wind speed	m/s	57– 60	No data	No data	84 – 93	81 – 87
Overland Flooding	Days above 20 mm rain	Days	5 – 6	10 – 11	11 – 12	11 – 12	13 – 14
Overland Flooding	Max 5-day rain	mm	61 – 64	102 – 116	105 – 125	104 – 123	116 – 129
Wildfires	Fire weather index (FWI) above 10	Days	0	14 - 15	17 – 19	17 – 19	33 – 35
Wildfires	Max fire weather index	FWI	9.5 – 9.6	18.1 – 18.3	19.1 – 19.8	19.0 – 19.9	24.9 – 25.5

4.5 Climate-Infrastructure Interactions

Future climate projections indicate changes in temperature, precipitation, and extreme events, which could potentially interact with different components of the Project during the operations phase. **Table 4-8** outlines the climate-infrastructure interactions by identifying which climate hazards interact with each infrastructure component of the Project during operations. Both the impact of climate change on Project infrastructure (i.e., how climate change may result in damage to the infrastructure) and impact on activities associated with the Project (i.e., how climate change may impact the ability to carry out maintenance activities) have been considered. Along with project-specific information, the Ontario Provincial Climate Change Impact Assessment was consulted to inform potential risks to the Project associated with climate change (Climate Risk Institute 2023).

Table 4-8: Climate Interactions

Infrastructure	Extreme Heat	Extreme Cold	Freeze-Thaw Cycles	Extreme Rainfall	Changes in Snowfall	Freezing Rain	Extreme Wind	Lightning	Overland Flooding	Wildfires
Highway 413 and Extensions to Highways 410 and 427, Interchanges and Freeway-to-Freeway Connections	✓	✓	✓	✓	✓	✓	✓	n/a	✓	✓
Municipal Road Realignments	✓	✓	✓	✓	✓	✓	✓	n/a	✓	✓
Maintenance Yard Facilities & Carpool Lots	✓	✓	✓	✓	✓	✓	✓	n/a	✓	✓
Commercial Vehicle Inspection Facilities	✓	✓	✓	✓	✓	✓	✓	n/a	✓	✓
Offices/Staff Buildings	✓	✓	n/a	✓	✓	✓	✓	✓	✓	✓
Major Water Crossings and Other Bridges	✓	✓	✓	✓	✓	✓	✓	n/a	✓	✓

Infrastructure	Extreme Heat	Extreme Cold	Freeze-Thaw Cycles	Extreme Rainfall	Changes in Snowfall	Freezing Rain	Extreme Wind	Lightning	Overland Flooding	Wildfires
Structural Culverts and Non-Structural Culverts, Storm Sewers	✓	✓	✓	✓	✓	n/a	✓	n/a	✓	n/a
Stormwater Management Infrastructure	✓	✓	✓	✓	✓	n/a	n/a	n/a	✓	n/a
Static Overhead and Roadside Signage	n/a	✓	✓	✓	n/a	✓	✓	✓	✓	✓
Illumination and Traffic Signal Infrastructure	✓	✓	✓	✓	n/a	✓	✓	✓	✓	✓
Advanced Traffic Management Systems (ATMS) Infrastructure	✓	✓	✓	✓	n/a	✓	n/a	✓	✓	✓
Road Maintenance Activities	✓	n/a	✓	✓	✓	✓	n/a	n/a	✓	✓
Environmental Mitigations and Compensation Features	✓	n/a	n/a	✓	n/a	n/a	n/a	n/a	✓	✓

Infrastructure	Extreme Heat	Extreme Cold	Freeze-Thaw Cycles	Extreme Rainfall	Changes in Snowfall	Freezing Rain	Extreme Wind	Lightning	Overland Flooding	Wildfires
Electric Charging Stations	✓	✓	✓	✓	n/a	✓	n/a	✓	✓	✓
Roadside Safety Infrastructure	✓	✓	✓	✓	✓	n/a	n/a	n/a	✓	n/a
Overhead and Underground Utilities	n/a	✓	✓	✓	n/a	✓	n/a	✓	✓	✓
Landscaping	✓	n/a	n/a	✓	n/a	n/a	n/a	n/a	✓	✓

4.6 Mitigation Measures

The risk rankings presented in Section 4.7, below, consider in-design and operational adaptation measures that would be in place. For this assessment, the following mitigation measures were assumed:

- The Project drainage systems and stormwater management systems and infrastructure will be designed in accordance with the MTO Highway Drainage Design Standards, which require designs to be based on future flooding potential under a changing climate. Design measures can include adjusting the size of a culvert to accommodate future precipitation events. MTO Memo DCSO-2016-14 requires the use of Intensity-Duration-Frequency (IDF) curves during the design process to anticipate future rainfall scenarios and flooding capacity needs.
- Pavement design, and asphalt cement grade will include deterioration thresholds from -40°C to 40°C.
- The Canadian Standards Association (CSA) S6 Canadian Highway Bridge Design code requires bridges to be designed with climate change in consideration.
- Vegetation or best management practices will be used to mitigate soil erosion within the highway right of way.
- Maintenance and operational policies and procedures that will consider climate change impacts (e.g. snow clearing practices, rutting, potholes), will be implemented.
- An emergency response plan will be in place to address the impacts associated with extreme weather events.
- Strategies to increase traction on highways.

4.7 Risk Ranking Results

The results of the climate change risk assessment are summarized below to describe the potential impacts of climate change on the Project infrastructure, as well as the change in risk from current conditions to future climate conditions. The complete Risk Assessment is provided in Appendix C. The risk ranking presented in this section consider the mitigation measures identified in Section 4.6 above. Understanding these risks informs treatment and adaptation measure identification. Where no interaction was identified, or data was unavailable, interactions were noted as not applicable.

In both the 2050s and 2080s, interactions between each of the 17 infrastructure components (Section 4.3) and each of the 10 climate hazards (Section 4.4) were assessed, resulting in a total of 170 potential interactions evaluated under each scenario (SSP2-4.5 and SSP5-8.5). The risk rankings are summarized across the 170 interactions in **Table 4-9** and a count of interactions by risk level for each scenario are shown in **Figures 2 to 5**.

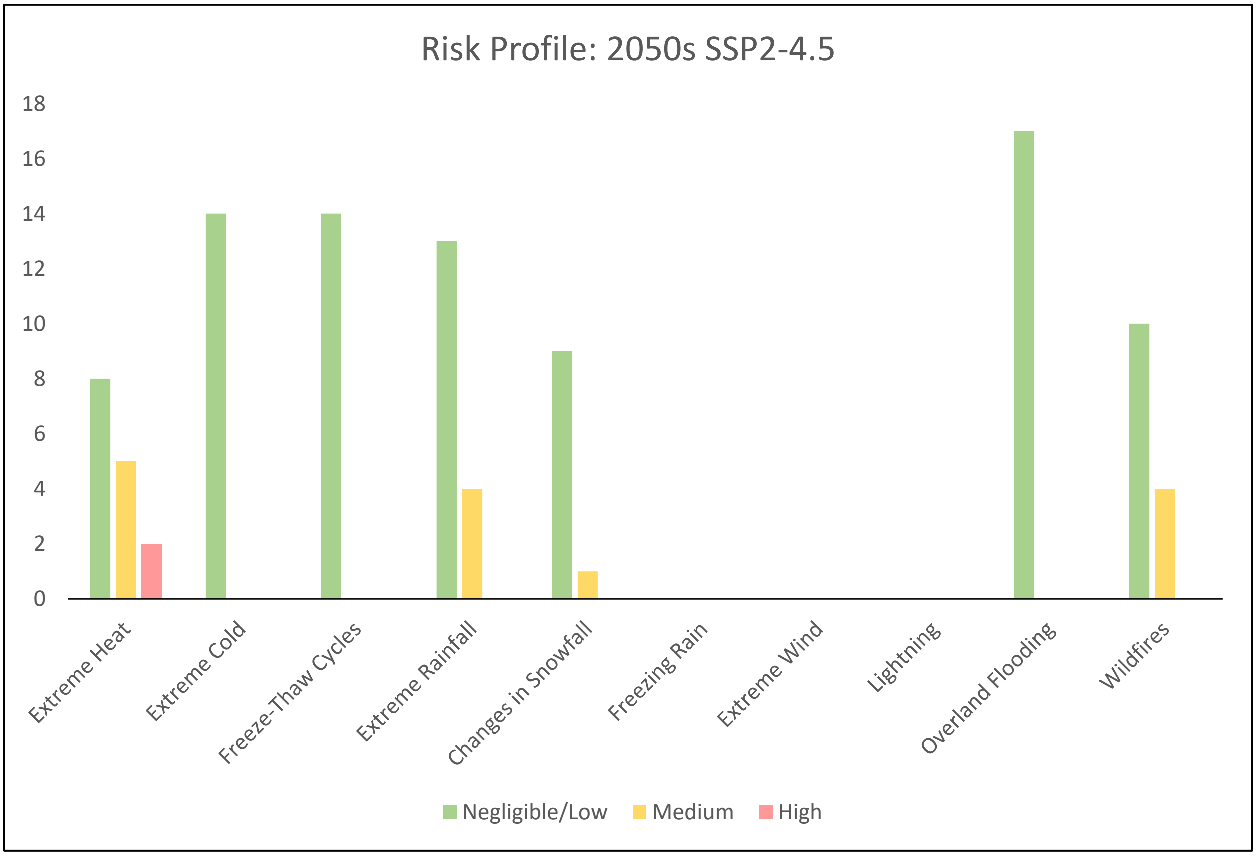
Table 4-9: Number of Interactions by Risk Level, Scenario, and Time Horizon.

Scenario	Not Applicable	Negligible/Low	Medium	High
2050s SSP2-4.5	69 (41%)	85 (50%)	14 (8%)	2 (1%)
2050s SSP5-8.5	41 (24%)	107 (63%)	20 (12%)	2 (1%)
2080s SSP2-4.5	69 (41%)	85 (50%)	14 (8%)	2 (1%)
2080s SSP5-8.5	41 (24%)	55 (32%)	66 (39%)	8 (5%)

The number of interactions labeled as not applicable or with no data between the SSP2-4.5 scenarios and the SSP5-8.5 scenarios changed from 69 to 41, regardless of the time horizon. This change was due to the unavailability of data for SSP2-4.5 in relation to Freezing Rain, Extreme Wind, or Lightning hazards. Projection data for these hazards was available and assessed for SSP5-8.5 in both time horizons. The 41 interactions identified as not applicable across all scenarios had no interaction.

The following sections summarize the identified risks by risk level and describe the changes in the risk profile between each time period and scenario.

Figure 4-1: Risk Profile for 2050 SSP2-4.5. Count of climate-infrastructure interactions by climate hazard and risk level.



Note: Climate projection data was unavailable for data available for SSP2-4.5 for freezing rain, extreme wind, and lightning.

Figure 4-2: Risk Profile for 2050 SSP5-8.5. Count of climate-infrastructure interactions by climate hazard and risk level.

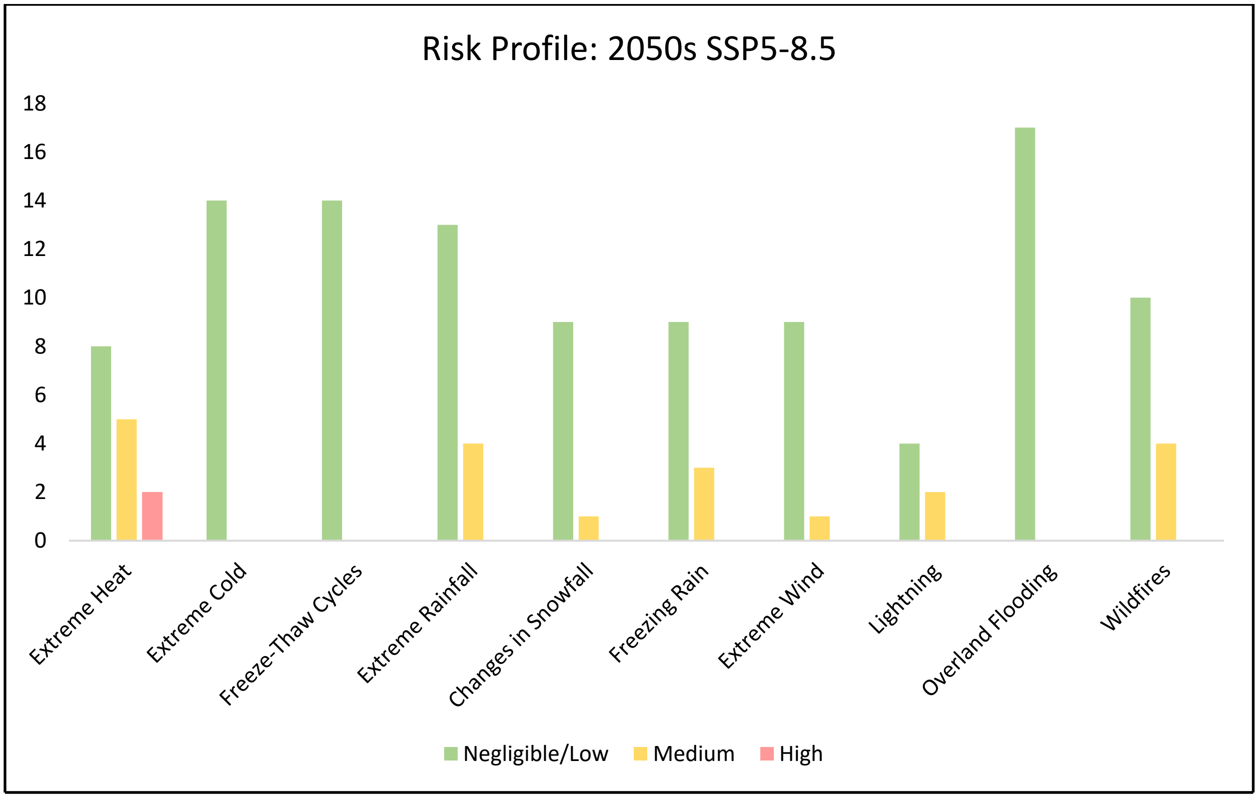
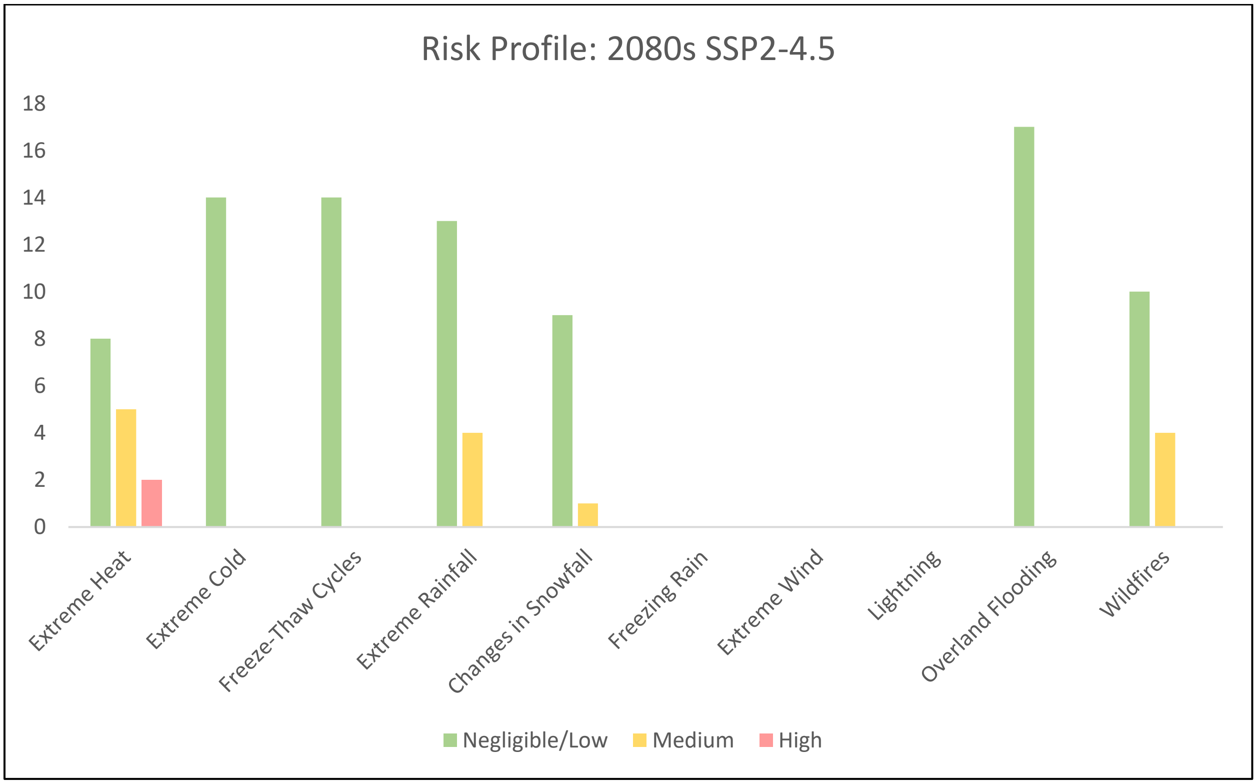
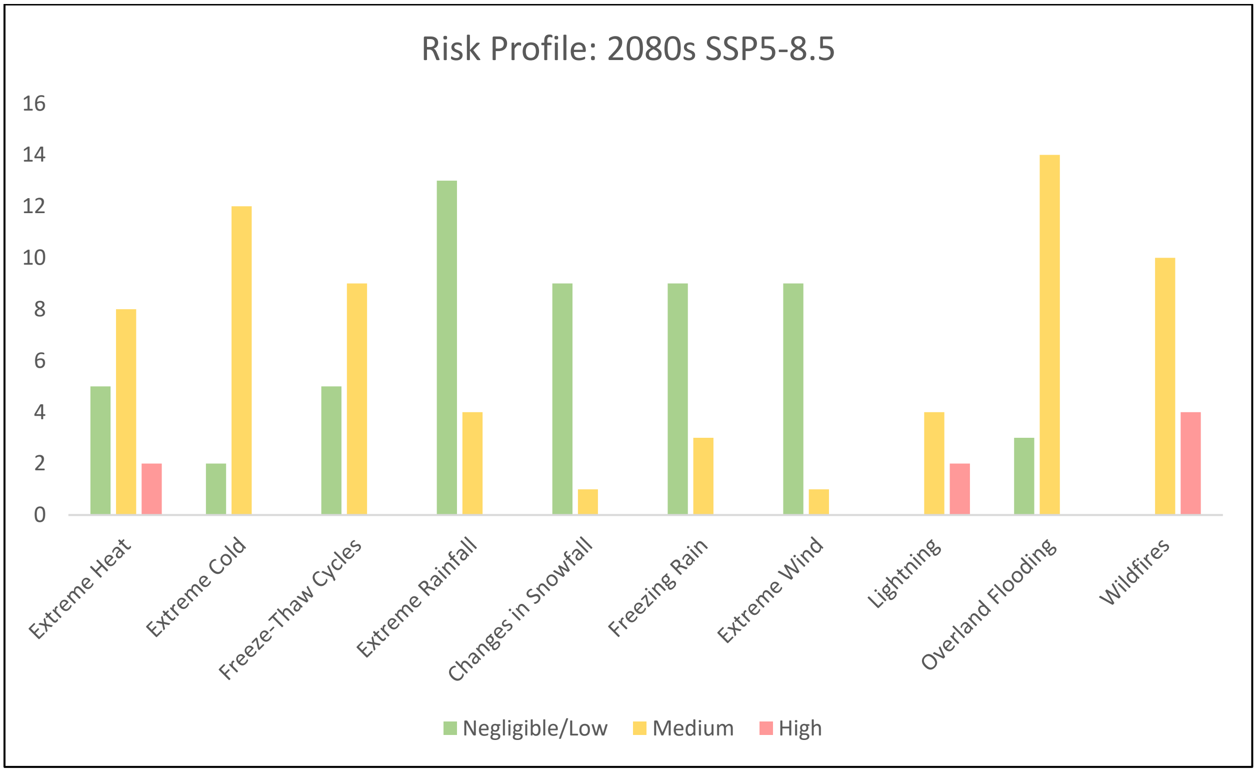


Figure 4-3: Risk Profile for 2080 SSP2-4.5. Count of climate-infrastructure interactions by climate hazard and risk level.



Note: Climate projection data was unavailable for data available for SSP2-4.5 for freezing rain, extreme wind, and lightning.

Figure 4-4: Risk Profile for 2080 SSP5-8.5. Count of climate-infrastructure interactions by climate hazard and risk level.



4.7.1 High Risks

The following summarizes climate hazard-infrastructure interactions that were identified as having a high risk under future climate scenarios. Summaries are provided for the four scenarios (2050s SSP2, 2050s SSP5, 2080s SSP2 and 2080s SSP5).

2050 SSP2-4.5

Two (2) high risks were identified in 2050 SSP5-4.5, both of which were associated with the Commercial Vehicle Inspection Facilities and Road Maintenance Activities, both due to extreme heat. In both instances, the risk was related to potential for health and safety impacts on workers, as well as potential loss of working time due to unsafe working conditions, resulting in some loss of service.

2050 SSP5-8.5

The high-risk interactions identified in 2050 SSP2-4.5 remain the same for the 2050 SSP5-8.5

2080 SSP2-4.5

The high-risk interactions identified in 2050 SSP2-4.5 remain the same for 2080 SSP2-4.5.

2080 SSP5-8.5

In addition to the high risks identified in the previous three (3) scenarios, six (6) additional high-risk interactions were identified in 2080 SSP5-8.5. Two (2) of the interactions were due to lightning and its impacts on offices/staff buildings, and static overhead and roadside signage. These interactions could result in loss of electricity leading to the need for maintenance.

Four (4) additional high-risk interactions were from wildfire interacting with highway components, road realignments, maintenance yard facilities and carpool lots, and commercial vehicle inspection facilities. Concerns related to potential for direct damage to facilities from exposure to fire, as well as health and safety impacts from smoke.

4.7.2 Medium Risks

The following summarizes interactions identified has potentially having a medium risk associated with climate change. Summaries are provided for the four scenarios (2050s SSP2, 2050s SSP5, 2080s SSP2 and 2080s SSP5).

2050 SSP2-4.5

The 14 medium risks for this scenario were related to extreme heat, extreme rainfall, changes in snowfall, and wildfire. Extreme heat was found to have a medium risk interaction with office / staff buildings and major water crossings and other bridges. For the former, the risk level resulted from the potential for impacts on human health and safety. For the latter, it resulted from potential local damage due to thermal expansion of bridge joins.

There were medium risk interactions between extreme rainfall and highways, roads, interchanges and bridge components identified due to potential for flooding, washout, increased debris on highways, and visibility concerns that could cause minor safety risk for users or could result in the need for minor repairs. Assumed mitigation measures, including having a robust emergency response plan in place, reduces the potential consequence for these interactions.

Highways, roads, interchanges and bridge components, and office / staff buildings were found to have a medium risk interaction with wildfire. The risks are due to impacts from wildfire smoke on visibility on the highway, and on health for highway users, workers, and staff in buildings.

Extreme heat was found to have a medium risk interaction with office / staff buildings and major water crossings and other bridges. For the former, the risk level resulted from the potential for impacts on human health and safety. For the latter, it resulted from potential local damage due to thermal expansion of bridge joins.

Medium risk interactions were found between each illumination and traffic signal infrastructure, ATMS Infrastructure, and electric charging stations with extreme heat due to the potential for power outages impacting service.

Finally, a medium risk interaction between structural culverts and non-structural culverts, storm sewers and changes in snowfall was identified due to the potential for damage that could require minor restoration work.

2050 SSP5-8.5

For the 2050 SSP5-8.5 scenario, there were 20 medium-risk interactions identified, including the 14 interactions noted for 2050 SSP2-4.5, as well as 6 additional medium-risk interactions related to extreme wind, freezing rain, and lightning.

Extreme wind was found to results in a medium risk with highways, roads, interchanges and bridge components due to the potential for minor safety concerns.

There were three (3) medium-risk interaction identified between freezing rain and highways, roads, interchanges and bridge components identified due to due to potential health and safety impacts for road users.

Medium risk interactions were found between each illumination and traffic signal infrastructure, ATMS Infrastructure, and electric charging stations with lightning due to the potential for power outages impacting service.

2080 SSP2-4.5

The medium-risk interactions identified in 2050 SSP2-4.5 remain the same for 2080 SSP2-4.5.

2080 SSP5-8.5

There were 66 medium risk interactions identified for this scenario. This included the medium risk interactions described for 2050 SSP5-8.5, as well as additional risks related to extreme heat, lightning, overland flooding, and wildfire.

For extreme heat, the additional medium risks were for maintenance yard facilities and carpool lots, major water crossings and other bridges, and structural culverts and non-structural culverts, storm sewers, due to the potential for minor, localized damage.

For lightning, medium risk interactions were identified with illumination and traffic signal infrastructure, ATMS infrastructure, electric charging stations, and overhead and underground utilities, with potential disruptions to power.

There were 14 medium risk interactions identified with overland flooding. Infrastructure components included highway and road infrastructure, office and inspection facilities, major water crossings and other bridges, structural culverts and non-structural culverts, storm sewers, and electrical/signal infrastructure. Impacts noted included potential for direct damage and washouts leading to increased need for maintenance and repairs, and disruption to electricity,

4.7.3 Low Risks

The remaining interactions identified for each scenario were assessed as low risk. This is largely as result of the in-design adaptation measures identified in Section 4.6, as well as assumed maintenance and operational procedures.

4.8 Continual Improvement Process

In addition to the mitigation measures identified in Section 4.6, continuous improvement techniques can be applied to further reduce climate related risk. This continual improvement allows the Project to operate with flexibility as the climate continues to change and as information on climate projections are updated. This can include monitoring of climate change impacts on a regular basis and updating road maintenance plans, procedures, and contingency plans accordingly. It can also include monitoring the impact of extreme weather events on the static overhead and roadside signage and implementing design changes as needed. Additional adaptation measures that could be considered during the Detail Design process include:

- Implementation of an automated system for detecting traffic signals affected by power outages.
- Installing battery back-ups at all intersections that would require a traffic officer if there was an outage.
- Increase thickness of different pavement layers and use stiffer binders in pavement.

These measures are suggestions that would be in addition to the adaptation measures that are already included within the design of the Project.

The continual improvement process can also be used to support decision-making processes, providing additional information to identify when action may need to be taken. By adding a climate lens to existing risk management and operational practices, climate risks can be reviewed on a regular basis and actions taken when a risk threshold is reached. Prioritizing the climate related risks supports decisions around capital expenditure by planning out which risks need to be addressed first and the timing of the potential expenses. For long-lived projects, the continual improvement processes allow for climate-informed planning, operation and decision-making.

4.9 Climate Change Interactions with the Environment

This CCRA examines how climate-related disruptions may affect the Project's design and its environmental interactions. This section focuses on indirect environmental impacts influenced by the Project's resilience to climate change. The Project's ability to withstand climate hazards (namely, including extreme heat and cold, freeze-thaw cycles, rainfall, snowfall, freezing rain, wind, lightning, flooding, and wildfires) is essential to minimizing environmental impacts. Key considerations include:

- Ecosystems: Infrastructure and activities may affect ecosystem resilience. While mitigation features like offsetting / compensation for vegetation removals and habitat enhance ecological stability, unmanaged infrastructure could increase vulnerability to hazards like wildfire and flooding.
- Water Resources: Stormwater systems are designed to manage runoff and reduce flood risk. Ongoing maintenance is important to protect water quality and aquatic habitats.
- Soil and Vegetation: Climate change may affect soil stability and vegetation. Erosion control and planting measures help maintain soil integrity and support wildlife habitat.
- Wildlife and Habitat: Infrastructure may reduce and fragment available habitat leading to stress on wildlife, with climate change intensifying these effects by increasing species stress from extreme weather, shifting habitat ranges, and altered ecological conditions.

- Human Health and Safety: Extreme weather poses risks to workers and the public. Emergency response plans and safety protocols will help to mitigate these risks.

In summary, by integrating robust mitigation and adaptive strategies, the Project can enhance its climate resilience and reduce potential environmental impacts.

5. Summary and Conclusions

Based on the assessment, the vulnerability of the project to a changing climate is primarily concentrated in its operational phase. The construction phase is not expected to experience notable climate-related impacts beyond seasonal variability, which will be managed through standard planning and operational procedures. Similarly, decommissioning and post-closure phases are not anticipated due to the nature of linear infrastructure. The operational phase, however, is subject to a range of climate hazards such as extreme heat, rainfall, wind, and wildfire, with several medium to high-risk interactions identified, particularly under the SSP5-8.5 scenario for the 2080s.

The project may indirectly influence the resilience of surrounding ecosystems to climate change through its environmental mitigation and compensation features, which will be developed during detail design. These include wetland and fisheries compensation, as well as vegetation and habitat offsetting, which are designed to enhance ecological resilience. However, the project's footprint and associated infrastructure could also contribute to ecosystem vulnerability if not properly managed, especially in the face of increasing climate stressors such as wildfire and flooding.

Climate change poses several risks to the project, particularly through interactions that could lead to infrastructure damage, service disruption, and safety hazards.

Alternative methods to reduce climate-related risks include enhancing the robustness of design standards, such as increasing culvert capacity, using climate-resilient materials, and integrating adaptive management strategies. The project already incorporates several in-design mitigation measures aligned with MTO and CSA standards. Further refinements, such as incorporating nature-based solutions, could further reduce environmental risks.

Finally, while the assessment does not explicitly address Indigenous cultural resources, the potential for climate change to disrupt lands and waters associated with such resources exists, particularly through increased flooding, wildfire, and extreme weather events. These disruptions have the potential to affect access, integrity, and use of culturally significant areas and resources.

With the mitigation measures identified in this assessment, as well as the continual improvement process, the Project is anticipated to be resilient to climate change which will reduce potential impacts to the surrounding environment and resources.

6. References

Bush, E. and Lemmen, D.S. (2019). Canada's Changing Climate Report; Government of Canada, Ottawa, ON. 444 p.

Climate Risk Institute (2023) Ontario Provincial Climate Change Impact Assessment Technical Report. Report prepared by the Climate Risk Institute, Dillon Consulting, ESSA Technologies Ltd., Kennedy Consulting and Seton Stiebert for the Ontario Ministry of Environment, Conservation and Parks. Available at: https://www.ontario.ca/page/ontario-provincial-climate-change-impact-assessment

ECCC (Environment and Climate Change Canada). 2020. Canada's Greenhouse Gas Quantification Requirements, Ver. 4.0. Greenhouse Gas Reporting Program. Available at: https://publications.gc.ca/collections/collection_2021/eccc/En81-28-2020-eng.pdf

ECCC. 2024. 2023. Progress Report on the 2030 Emissions Reduction Plan. Available at: https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/emissions-reduction-2030/2023-progress-report/table-contents.html

ECCC. 2025. National Inventory Report 1990 –2023: Greenhouse Gas Sources and Sinks in Canada. Available at: https://publications.gc.ca/collections/collection_2025/eccc/En81-4-2023-1-eng.pdf

Environmental Protection Agency (EPA). 2022. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020. Available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020

Government of Canada. 2020. Strategic Assessment of Climate Change: A New Impact Assessment System. Available at https://www.mGovernment of Canada. 2021. Draft Technical Guide Related to the Strategic Assessment of Climate Change. Available at: https://www.canada.ca/en/environment-climate-change/corporate/transparency/consultations/draft-technical-guide-strategic-assessment-climate-change.html

Government of Canada. 2022. Technical Guide Related to the Strategic Assessment of Climate Change: Assessing Climate Change Resilience, March 2022. Accessed from:https://www.canada.ca/en/services/environment/conservation/assessments/strategic-assessments/draft-second-technical-guide-strategic-assessment-climate-change.html

Government of Ontario. 2018. Preserving and Protecting our Environment for Future Generations: A Made-in-Ontario Environment Plan. Available at: https://prod-environmental-registry.s3.amazonaws.com/2018-11/EnvironmentPlan_1.pdf

Government of Ontario. 2017. Considering Climate Change in the Environmental Assessment Process, Revision 0. Available at: https://www.ontario.ca/page/considering-climate-change-environmental-assessment-process

Intergovernmental Panel on Climate Change (IPCC). 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the IPCC. Available at https://www.ipcc.ch/report/ar5/wg1/

IPCC. 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the IPCC. Available at https://www.ipcc.ch/report/ar6/wg1/

IPCC. 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Available at https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

IPCC. 2006. IPCC Guidelines for National Greenhouse Gas Inventories. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K, editors. Hayama: Institute for Global Environmental Strategies. Available at https://www.ipcc-nggip.iges.or.jp/public/2006gl/

Jeong, D.I, Cannon, A.J., and Zhang, X. 2019. Projected Changes to extreme freezing precipitation and design ice loads over North America based on a large ensemble of Canadian regional climate model simulations. Nat Hazards Earth Syst. Sci. 19, 857-872.

O'Neil BC, Kriegler E, Riahi K, Ebi KL, Hallegatte S et al. 2014. A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Climatic Change, 122: 387-400. doi: 10.1007/s10584-013-0905-2.

Romps, D.M., Seeley, J.T., Vollaro, D., and Molinari, J. 2014. Projected increase in lightning strikes in the United States due to global warming. Science Magazine, 346, 6211.

RWDI, 2024. Highway 413, Ontario: Regional Air Pollutant Burden Analysis. October 2, 2024.

RWDI, 2022. Preliminary Construction GHG Assessment: Highway 413. March 25, 2022.

Ma, F., Aimin, S., Ruiyu, L., Yue, H., Chao, W. 2016. Greenhouse gas emissions from asphalt pavement construction: A case study in China. International journal of environmental research and public health 13, no. 3 (2016): 351.

National Aeronautics and Space Administration (NASA). 2021. NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP). Available at: https://www.nccs.nasa.gov/services/data-collections/land-based-products/nex-gddp.

Ontario Ministry of Transportation (MTO). 2020. Ministry of Transportation Environmental Guide for Assessing and Mitigating the Air Quality Impacts and Greenhouse Gas Emissions of Provincial Transportation Projects. May 2020. Available at: https://test.ero.ontario.ca/public/2020-07/AQGHG%20Guide%20%28May%202020%29.pdf

Ontario Ministry of Transportation (MTO). 2025. Highway 413 Preliminary Design and Assessment of Environmental Impacts: Terrestrial Ecosystems Impact Assessment Report. May 2025.

Ontario Ministry of Transportation (MTO). 2025. Highway 413 Preliminary Design and Assessment of Environmental Impacts: Air Quality Impact Assessment Report. DATE 2025.

PCIC. (2021). Bias correction/constructed analogues with quantile mapping reordering (BCCAQv2) [Dataset]. Pacific Climate Impacts Consortium. Available at https://pacificclimate.org/data/statistically-downscaled-climate-scenarios

Scinocca, J. F., Kharin, V. V., Jiao, Y., Qian, M. W., Lazare, M., Solheim, L., Flato, G.M., Biner, S., Desgagne, M. & Dugas, B. (2016). Coordinated global and regional climate modeling. Journal of Climate, 29(1), 17-35.

Sussex. 2022. Ontario Releases Modelling for its 2030 Emissions Reduction Target and Principles to Align the EPS with the Federal Benchmark for 2023-2030, Published on April 11, 2022. Available at: https://www.sussex-strategy.com/posts/ontario-releases-modelling-for-its-2030-emissions-reduction-target-and-principles-to-align-the-eps-with-the-federal-benchmark-for-2023-2030

WRI and WBCSD (World Resources Institute and World Business Council for Sustainable Development). 2013. The Greenhouse Gas Reporting Protocol: A Corporate Accounting and Reporting Standard.

A

Emissions Estimates

Appendix A.1

Vegetation Community Impacts

Ecological land Classification Community	Total Area within the Assessment Area (hectares)	Total Area within the Right-of-Way (hectares)
Mineral Cultural Meadow Ecosite (C U M 1)	**311.27**	160.68
Cultural Meadow (C U M) Subtotal	**311.27**	160.68
Cultural Plantation (C U P)	**0.48**	< 0.01
Deciduous Plantation Ecosite (C U P 1)	**1.44**	0.03
Sugar Maple Deciduous Plantation Type (C U P 1 – 1)	**0.27**	< 0.01
Coniferous Plantation Ecosite (C U P 3)	**5.52**	2.28
Red Pine Coniferous Plantation Type (C U P 3 – 1)	**15.04**	7.72
White Pine Coniferous Plantation Type (C U P 3 – 2)	**2.17**	0.53
Scotch Pine Coniferous Plantation Type (C U P 3 – 3)	**0.92**	0.74
European Larch Coniferous Plantation Type (C U P 3 – 6)	**0.27**	< 0.01
White Spruce – European Larch Coniferous Plantation Type (C U P 3 – 8)	**3.01**	0.96
Norway Spruce – European Larch Coniferous Plantation Type (C U P 3 – 9)	**0.35**	0.05
Cultural Plantation (C U P) Subtotal	**29.47**	12.31
Mineral Cultural Savannah Ecosite (C U S 1)	**9.47**	5.81
Cultural Savannah (C U S) Subtotal	**9.47**	5.81
Cultural Thicket (C U T)	**1.18**	0.88
Mineral Cultural Thicket Ecosite (C U T 1)	**24.87**	5.88
Cultural Thicket (C U T) Subtotal	**26.05**	6.76
Mineral Cultural Woodland Ecosite (C U W 1)	**24.81**	6.81
Cultural Woodland (C U W) Subtotal	**24.81**	6.81
Coniferous Forest (F O C)	**0.18**	< 0.01
Dry – Fresh White Cedar Coniferous Forest Type (F O C 2 – 2)	**0.66**	< 0.01
Fresh Hemlock Coniferous Forest Type (F O C 3 – 1)	**1.9**	0.41
Moist – Fresh White Cedar – Hemlock Coniferous Forest Type (F O C 4 – 2)	**2.67**	< 0.01
Naturalized Coniferous Plantation (F O C M 6)	**0.86**	0.3
Dry – Fresh White Pine Naturalized Coniferous Plantation Type (F O C M 6 –	**3.73**	2.81
Coniferous Forest (F O C) Subtotal	**10**	3.52
Deciduous Forest (F O D)	**7.27**	1.36
Dry Oak – Hickory Deciduous Forest Type (F O D 2 – 2)	**0.52**	< 0.01
Dry – Fresh Oak – Sugar Maple Deciduous Forest Type (F O D 2 – 4)	**0.83**	0.16
Dry – Fresh Aspen – Poplar Deciduous Forest Type (F O D 3 – 1)	**3.61**	1.8
Dry – Fresh White Birch Deciduous Forest Type (F O D 3 – 2)	**0.31**	< 0.01
Dry – Fresh Upland Deciduous Forest Ecosite (F O D 4)	**2.53**	0.46
Dry – Fresh White Ash Deciduous Forest Type (F O D 4 – 2)	**3.33**	0.95
Dry – Fresh Sugar Maple – Hardwood Calcareous Shallow Deciduous Forest	**0.02**	< 0.01
Fresh Sugar Maple Deciduous Forest Type (F O D 5 – 1)	**19.89**	4.69
Fresh Sugar Maple – White Birch – Aspen Deciduous Forest Type (F O D 5 –	**1.24**	1.1
Fresh Sugar Maple – Beech Deciduous Forest Type (F O D 5 – 2)	**2.07**	1.15
Dry – Fresh Sugar Maple – Oak Deciduous Forest Type (F O D 5 – 3)	**9.85**	3.41
Dry – Fresh Sugar Maple – Ironwood Deciduous Forest Type (F O D 5 – 4)	**4.82**	1.13
Dry – Fresh Sugar Maple – Hickory Deciduous Forest Type (F O D 5 – 5)	**2.21**	1.58
Dry – Fresh Sugar Maple – Basswood Deciduous Forest Type (F O D 5 – 6)	**2**	0.54
Dry – Fresh Sugar Maple – Black Cherry Deciduous Forest Type (F O D 5 – 7	**0.54**	0.36
Fresh Sugar Maple – White Ash Deciduous Forest Type (F O D 5 – 8)	**0.22**	< 0.01
Fresh Sugar Maple – Red Maple Deciduous Forest Type (F O D 5 – 9)	**0.7**	< 0.01
Moist – Fresh Sugar Maple – Black Maple Deciduous Forest Type (F O D 6 –	**0.38**	< 0.01
Fresh – Moist Sugar Maple – Hardwood Deciduous Forest Type (F O D 6 – 5	**4.19**	1.67
Fresh – Moist Lowland Deciduous Forest Ecosite (F O D 7)	**0.05**	< 0.01
Fresh – Moist Ash Lowland Deciduous Forest Type (F O D 7 – 2)	**1.1**	0.5
Fresh – Moist Willow Lowland Deciduous Forest Type (F O D 7 – 3)	**5.87**	1.9
Moist – Fresh Black Walnut Deciduous Forest Type (F O D 7 – 4)	**11.08**	7.43
Moist – Fresh Aspen – Poplar Deciduous Forest Type (F O D 8 – 1)	**1.68**	0.09
Fresh – Moist Oak – Sugar Maple Deciduous Forest Type (F O D 9 – 1)	**1.64**	1.12
Fresh – Moist Bur Oak Deciduous Forest Type (F O D 9 – 3)	**0.63**	0.27
Dry – Fresh Black Locust Deciduous Forest Type (F O D M 4 – 11)	**4.83**	2.03
Dry – Fresh Basswood Deciduous Forest Type (F O D M 4 – 9)	**0.75**	0.21
Dry – Fresh Sugar Maple – Hardwood Deciduous Forest Type (F O D M 5 – 1	**4.64**	2.29
Fresh – Moist Manitoba Maple Lowland Deciduous Forest Type (F O D M 7 –	**4.65**	1.32
Deciduous Forest (F O D) Subtotal	**103.45**	37.52
Mixed Forest (F O M)	**< 0.01**	< 0.01
Dry – Fresh White Pine – Sugar Maple Mixed Forest Type (F O M 2 – 2)	**5.49**	0.48
Moist – Fresh Hemlock – Sugar Maple Mixed Forest Type (F O M 3 – 2)	**5.03**	2.48
Fresh – Moist Sugar Maple – Hemlock Mixed Forest Type (F O M 6 – 1)	**8.64**	2.61
Mixed Forest (F O M) Subtotal	**19.16**	5.57
Meadow Marsh (M A M)	**3.32**	0.51
Graminoid Mineral Meadow Marsh Ecosite (M A M 2)	**5.37**	1.88
Forb Mineral Meadow Marsh Type (M A M 2 – 10)	**12.05**	3.9
Reed-canary Grass Mineral Meadow Marsh Type (M A M 2 – 2)	**39.32**	14.5
Red – top Mineral Meadow Marsh Type (M A M 2 – 3)	**0.53**	< 0.01
Broad – leaved Sedge Mineral Meadow Marsh Type (M A M 2 – 6)	**0.18**	< 0.01
Common Reed Graminoid Mineral Meadow Marsh Type (M A M M 1 – 12)	**3.2**	1.31
Cattail Graminoid Mineral Meadow Marsh Type (M A M M 1 – 2)	**3.25**	1.57
Mixed Mineral Meadow Marsh Type (M A M M 3 – 1)	**5.09**	2.93
Meadow Marsh (M A M) Subtotal	**72.31**	26.6
Shallow Marsh (M A S)	**0.39**	0.32
Graminoid Mineral Shallow Marsh Ecosite (M A S 2)	**0.22**	< 0.01
Cattail Mineral Shallow Marsh Type (M A S 2 – 1)	**10.62**	3.93
Bur – reed Mineral Shallow Marsh Type (M A S 2 – 7)	**0.1**	0.04
Rice Cut – grass Mineral Shallow Marsh Type (M A S 2 – 8)	**0.2**	< 0.01
Forb Mineral Shallow Marsh Type (M A S 2 – 9)	**0.12**	< 0.01
Cattail Organic Shallow Marsh Type (M A S 3 – 1)	**1.8**	0.54
Common Reed Mineral Shallow Marsh Type (M A S M 1 – 12)	**0.28**	0.26
Reed-canary Grass Mineral Shallow Marsh Type (M A S M 1 – 14)	**2.13**	0.93
Shallow Marsh (M A S) Subtotal	**15.86**	6.02
Annual Row Crops – Wheat (O A G M 1)	**35.75**	11.51
Open Pasture (O A G M 4)	**63.59**	25.33
Open Agriculture (O A G) Subtotal	**99.34**	36.84
Open Aquatic (O A O)	**10**	5.55
Open Aquatic (O A O) Subtotal	**10**	5.55
Duckweed Floating – leaved Shallow Aquatic Type (S A F 1 – 3)	**0.36**	0.03
Floating – leaved Shallow Aquatic (S A F) Subtotal	**0.36**	0.03
Submerged Shallow Aquatic Ecosite (S A S 1)	**0.38**	< 0.01
Pondweed Submerged Shallow Aquatic Type (S A S 1 – 1)	**0.36**	0.09
Stonewort Submerged Shallow Aquatic Type (S A S 1 – 3)	**0.38**	0.3
Submerged Shallow Aquatic (S A S) Subtotal	**1.12**	0.39
White Cedar Mineral Coniferous Swamp Type (S W C 1 – 1)	**1.77**	< 0.01
Coniferous Swamp (S W C) Subtotal	**1.77**	< 0.01
Deciduous Swamp (S W D)	**3.94**	1.03
Red / Green Ash Mineral Deciduous Swamp Type (S W D 2 – 2)	**0.18**	0.08
Silver / Red Maple Mineral Deciduous Swamp Type (S W D 3 – 1)	**1.17**	< 0.01
Silver Maple Mineral Deciduous Swamp Type (S W D 3 – 2)	**0.77**	0.01
Swamp Maple Mineral Deciduous Swamp Type (S W D 3 – 3)	**10.69**	4.72
Manitoba Maple – Willow Mineral Deciduous Swamp Type (S W D 3 – 4)	**2.01**	1.36
Mineral Deciduous Swamp Ecosite (S W D 4)	**0.47**	0.47
Willow Mineral Deciduous Swamp Type (S W D 4 – 1)	**3.79**	1.45
Aspen – White Birch – Poplar Mineral Deciduous Swamp Type (S W D 4 – 3)	**0.08**	< 0.01
Silver Maple Organic Deciduous Swamp Type (S W D 6 – 2)	**0.46**	< 0.01
Swamp Maple Organic Deciduous Swamp Type (S W D 6 – 3)	**0.58**	0.57
Aspen – White Birch – Poplar Deciduous Organic Swamp Type (S W D 7 – 1	**0.4**	0.38
Deciduous Swamp (S W D) Subtotal	**24.54**	10.07
Mixed Swamp (S W M)	**1.06**	0.01
White Cedar – Mixed Mineral Swamp Type (S W M 1 – 1)	**< 0.01**	< 0.01
White Cedar Mixed Organic Swamp Type (S W M 4 – 1)	**0.29**	0.11
Mixed Swamp (S W M) Subtotal	**1.35**	0.12
Thicket Swamp (S W T)	**0.2**	0.14
Alder Mineral Thicket Swamp Type (S W T 2 – 1)	**0.2**	< 0.01
Willow Mineral Thicket Swamp Type (S W T 2 – 2)	**1.19**	0.06
Redosier Mineral Thicket Swamp Type (S W T 2 – 5)	**0.27**	0.14
Mixed Willow Mineral Deciduous Thicket Swamp Type (S W T M 3 – 6)	**0.29**	< 0.01
Thicket Swamp (S W T) Subtotal	**2.15**	0.34
Buckthorn Deciduous Shrub Thicket Type (T H D M 2 – 6)	**11.8**	7.62
Buckthorn Deciduous Hedgerow Thicket Type (T H D M 3 – 1)	**0.21**	< 0.01
Deciduous Thicket (T H D) Subtotal	**12.01**	7.62
Grand Total	**774.49**	332.56

Note: Updated March 6, 2025 - Based on Draft Terrestrial Report (Jan 24, 2025)

Summary of Vegetation Community Impacts

Ecological land Classification Community	IPCC Land-use Category [1]	Total Area within the Assessment Area (hectares)	Total Area within the Right-of-Way (hectares)
Open Agriculture (O A G) Subtotal	Cropland	99.3	36.8
Cultural Plantation (C U P) Subtotal	Forest Land	29.5	12.3
Cultural Woodland (C U W) Subtotal	Forest Land	24.8	6.8
Coniferous Forest (F O C) Subtotal	Forest Land	10.0	3.5
Deciduous Forest (F O D) Subtotal	Forest Land	103.5	37.5
Mixed Forest (F O M) Subtotal	Forest Land	19.2	5.6
Cultural Meadow (C U M) Subtotal	Grassland	311.3	160.7
Open Aquatic (O A O) Subtotal [2]	Wetlands	10.0	5.6
Cultural Savannah (C U S) Subtotal	Grassland	9.5	5.8
Cultural Thicket (C U T) Subtotal	Grassland	26.1	6.8
Deciduous Thicket (T H D) Subtotal	Grassland	12.0	7.6
Meadow Marsh (M A M) Subtotal	Wetlands	72.3	26.6
Shallow Marsh (M A S) Subtotal	Wetlands	15.9	6.0
Floating – leaved Shallow Aquatic (S A F) Subtotal	Wetlands	0.4	0.0
Submerged Shallow Aquatic (S A S) Subtotal	Wetlands	1.1	0.4
Coniferous Swamp (S W C) Subtotal	Wetlands	1.8	< 0.01
Deciduous Swamp (S W D) Subtotal	Wetlands	24.5	10.1
Mixed Swamp (S W M) Subtotal	Wetlands	1.4	0.1
Thicket Swamp (S W T) Subtotal	Wetlands	2.2	0.3
Grand Total		**774.5**	**332.6**

Notes: [1] 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4

[2] Open Aquatic is conservatively categorized as a wetland in this assessment.

IPCC Land use Categories & ROW Areas

Land Use Category	ROW Area
Forest Land	65.7
Cropland	36.8
Grassland	180.9
Wetlands	49.1
Settlements	0.0
Other Land	0.0
Grand Total	332.6

Appendix A.2

Areas directly Impacted by the highway

Land Use Category	Area (ha)	Source
Forest Land	65.7	Draft Terrestrial Report (Jan 24, 2025)
Cropland	36.8	
Grassland	180.9	
Wetlands	49.1	
Thicket Swamp	0.3	
Settlements [1]	n/a	
Other Land [1]	n/a	

Note [1]: Settlements and other land categories were omitted from the greenhouse gas assessment, as their area is negligible and they do not constitute significant sources or sinks of GHG emissions.

Global Warming Potentials

GHG	GWP	Source
CO2	1	Government of Canada (2025) https://laws-lois.justice.gc.ca/eng/acts/G-11.55/page-28.html
CH4	28	Government of Canada (2025) https://laws-lois.justice.gc.ca/eng/acts/G-11.55/page-28.html
N2O	265	Government of Canada (2025) https://laws-lois.justice.gc.ca/eng/acts/G-11.55/page-28.html

Conversion Factors

Conversion Factor	Value	Source
C stock changes to CO2	3.67	Section 2.2.3 of IPCC 2006 Vol 4, Chapter 2.

Appendix A.3

Land Use Change

This tab calculates the emissions from the land use change for living biomass, dead organic matter, and soil organic matter.

Assumptions:

Conservatively, vegetation clearing is assumed to be undertaken for the entire footprint of the ROW; and it is assumed that all cleared vegetation will be burned in the first year.
Conservatively, any revegetation efforts are not included in the estimates as area of vegetation to be restored is currently unknown.
Indirect impacts to vegetation (e.g., incidental vegetation damage, damage from highway salting) during construction and operation are not included in the estimates as the exact area is unknown. The loss of a carbon sink from these impacts are expected to be minimal / insignificant in comparison to the impacts from direct clearing from the ROW.
It is assumed the wetland area are unmanaged and not high capacity carbon sinks, and therefore do not require the use of specialized methodology.
For the purposes of this assessment, it is assumed that the wetlands are not bogs, and instead are forested wetland.
For the purposes of this assessment, Thicket is assumed to be forested land use.

DIRECT EMISSIONS FROM LAND USE CHANGE - LIVING BIOMASS

Section 2.3.1.1.A.2 of the 2006 IPCC Volume 4, Chapter 2 outlines the calculation for total carbon losses in biomass due to d isturbances as follows:

1 - Direct emissions from land use change - living biomass

Ecozone	Parameters	Value	Unit	Source
Forest Land	Area (A)	65.73	ha	Draft Terrestrial Report (Jan 24, 2025)
	Average above-ground biomass affected by disturbance (B_W)	128.90	tonne dm ha^{-1}	Table 4.7 of IPCC 2006 Vol 4, Chapter 4. Temperate Continental Forest, North and South America. Conservatively assumed >20 years.
	Ratio of below-ground to above-ground biomass (R)	0.48	—	Table 4.4 of IPCC 2019 Refinement to the 2006 IPCC Guidelines for National GHG Inventories Vol 4, Chapter 4. Temperate - Continental - North and South America - Natural (other broadleaf), with biomass density≤ 125, for reasonable assumption.
	Carbon fraction of dry matter (CF)	0.47	tonne C	IPCC 2006 Vol 4, Chapter 4. Table 4.3, Temperate and Boreal value.
	Fraction of biomass lost (fd)	1.00	—	Assume all biomass is lost.
Wetlands	Area (A)	49.12	ha	Draft Terrestrial Report (Jan 24, 2025)
	Average above-ground biomass affected by disturbance (B_W)	128.90	tonne dm ha^{-1}	Table 4.12 of IPCC 2019 Refinement to the 2006 IPCC Guidelines for National GHG Inventories Vol 4, Chapter 4. Default value from forest-type closest to non-forest vegetation is used - Steppe, Secondary >20 years used (as per directions in Chapter 2). This is under the assumption that this is a forested wetland - left separate from forest for the purposed of clarity in future assessments.
	Ratio of below-ground to above-ground biomass (R)	0.48	—	Table 4.4 of IPCC 2019 Refinement to the 2006 IPCC Guidelines for National GHG Inventories Vol 4, Chapter 4. Temperate - Continental - North and South America - Natural (other broadleaf), with biomass density≤ 125, for reasonable assumption. This is under the assumption that this is a forested wetland - left separate from forest for the purposed of clarity in future assessments.
	Carbon fraction of dry matter (CF)	0.47	tonne C	Section 6.3.1 of IPCC 2006 Vol 4, Chapter 6. Default value for herbaceous biomass.
	Fraction of biomass lost (fd)	1.00	—	Assume all biomass is lost.
Grassland	Area (A)	180.87	ha	Draft Terrestrial Report (Jan 24, 2025)
	Average above-ground biomass affected by disturbance (B_W)	30.00	tonne C ha^{-1}	Table 20 of SACC Technical Guide. Annex B. Ontario Mixedwood Plains - trees. Selected for reasonable conservativism.
	Ratio of below-ground to above-ground biomass (R)	4.00	—	Table 6.1, Section 6.2.1.2 of IPCC 2006 Vol 4, Chapter 6. Grassland - Steppe/tundra/prairie grassland
	Carbon fraction of dry matter (CF)	1.00	tonne C	Since most representative value from SACC is used, this value must be 1.
	Fraction of biomass lost (fd)	1.00	—	Assume all biomass is lost.
Cropland	Area (A)	36.84	ha	Draft Terrestrial Report (Jan 24, 2025)
	Average above-ground biomass affected by disturbance (B_W)	30.00	tonne C ha^{-1}	Table 20 of SACC Technical Guide. Annex B. Ontario Mixedwood Plains - trees. Selected for reasonable conservativism.
	Ratio of below-ground to above-ground biomass (R)	4.00	—	Table 6.1, Section 6.2.1.2 of IPCC 2006 Vol 4, Chapter 6. Grassland - Steppe/tundra/prairie grassland
	Carbon fraction of dry matter (CF)	1.00	tonne C	Since most representative value from SACC is used, this value must be 1.
	Fraction of biomass lost (fd)	1.00	—	Assume all biomass is lost.
Thicket	Area (A)	0.34	ha	Draft Terrestrial Report (Jan 24, 2025)
	Average above-ground biomass affected by disturbance (B_W)	128.90	tonne dm ha^{-1}	Table 4.7 of IPCC 2006 Vol 4, Chapter 4. Temperate Continental Forest, North and South America. Considered similar enough to forest to include forest value here.
	Ratio of below-ground to above-ground biomass (R)	2.80	—	Table 6.1, Section 6.2.1.2 of IPCC 2006 Vol 4, Chapter 6. Shrubland value used.
	Carbon fraction of dry matter (CF)	0.47	tonne C	Section 6.3.1 of IPCC 2006 Vol 4, Chapter 6. Default value for herbaceous biomass.
	Fraction of biomass lost (fd)	1.00	—	Assume all biomass is lost.
None - constant value	Conversion factor C to CO_2	3.67	—	Molecular weight

Note: the values for forest and wetland are consistent, under the assumption that the wetland is a forested wetland. These are kept separate for the purposed of clarity when future, more detailed assessments are undertaken in the Preliminary EA phase of the project.

Ecozone	Total CO_2 Emissions (tonne)[(a)]
Forest Land	21,624
Wetlands	16,160
Grassland	19,896
Cropland	4,052
Thicket	287
Total	**62,019**

(a) Total CO_2 emissions representative of the one-time emissions from removal of the forest.

Note: Due to biomass values used for meadow and cropland, the calculation slightly changes to exclude CF and R, as this is already included in these values.

Sample Calculation (Direct emissions from land use change - living biomass: forest land)

$$\Delta C = A \times B_w \times (1 + R) \times CF \times fd$$

$$CO_2 = \Delta C \times 44/12$$

ΔC = loss of carbon, measured in tonnes of carbon (tonnes C)
A = total area being disturbed, measured in hectares (ha)
B_W = Average above-ground biomass affected by disturbance, measured in tonnes of carbon per hectare (tonne dm ha^{-1})
R = Ratio of below-ground to above-ground biomass, no units
CF = Carbon fraction of dry matter, measured in tonnes of carbon (tonne C)
fd = Fraction of biomass lost, set to 1 by assuming all biomass is lost
CO_2 = carbon dioxide emissions, measured in tonnes of carbon dioxide (tonnes CO_2)

ΔC = 65.73 ha X 128.9 tonne dm ha^{-1} X (1 + 0.481) x 0.47 tonne C X 1
ΔC = 5,897.52 tonnes C

CO_2 = 5,897.52 tonnes C X 44/12
CO_2 = 21,624.24 tonnes CO_2

DIRECT EMISSIONS FROM LAND USE CHANGE - DEAD ORGANIC MATTER (DOM)

2 - Direct emissions from land use change - dead organic matter

Ecozone	Parameters	Value	Unit	Source
Forest Land	Dead Wood/littler stock, under the old land use category (C_0)	23.90	tonne C ha^{-1}	Volume 4, Chapter 2, Table 2.2 (IPCC 2019). Dead wood carbon stocks - temperate continental forest - broadleaf deciduous selected for reasonable conservativism.
	Dead wood/litter stock, under the new land-use category (Cn)	0.00	tonne C ha^{-1}	It is assumed that all dead organic matter will be cleared for the Highway.
	Area (Aon) undergoing conversion from old to new land use category	65.73	ha	Draft Terrestrial Report (Jan 24, 2025)
	Time period transition from old to ne land-use category (Ton)	1.00	yr	See Note 2

Note 1: As per IPCC 2019 guidance document based on Teir 1 methodology, the Tier 1 method assumes that all carbon contained in biomass is killed during land-use conversion event and emitted directly into the atmosphere.

Note 2: As per IPCC 2019 guidance document based on Teir 1 methodology, the Tier 1 method assumes that all dead wood and litter pool carbon losses occur the year of the transition (page 2.8 or 6 of 69 of PDF Vol 2).

Note 3: As per IPCC 2019 guidance document Teir 1 methods assume litter and dead wood pools are zero in all non-forest land categories and therefore, there is no change in carbon stock changes in these pools (page 2.8 or 6 of 69 of PDF Vol 2).

Ecozone	Total CO_2 Emissions (tonne)[a]
Forest Land	5,760
Total	**5,760**

DIRECT EMISSIONS FROM LAND USE CHANGE - SOIL ORGANIC MATTER (SOM)

Assumptions:
All soil is mineral soil, therefore L_organic is set to 0.
As per Tier 1 SACC guidance, change in inorganic carbon in equal to 0 (Government of Canada 2021,
It is assumed the soil is disposed of immediately, and carbon in released all at once. Therefore D = 1 in equation 2.25.
It is assumed based on the source https://openpress.usask.ca/soilscience/chapter/soils-of-ontario/ that the soil in this area is clay, gray luvisol.
No land reclamation or remediation will be undertaken thus F_{MG} and F_I are not applicable

Sample Calculation (Direct emissions from land use change - dead organic matter: forest land)

$$\Delta C = \frac{(Cn - Co \times Aon)}{Ton}$$

$$CO_2 = \Delta C \times 44/12$$

ΔC = change in carbon stock in dead organic matter, measured in tonnes of carbon per year (tonnes C)
Co = Dead Wood/littler stock under old land use category, measured in tonnes of carbon per year (tonnes C ha^{-1})
Cn = Dead wood/litter stock, under the new land-use category (Cn), measured in tonnes of carbon per year (tonnes C ha^{-1})
Aon = area undergoing conversion from old to new land use category, measured in hectares (ha)
Ton = Time period transition from old to ne land-use category (Ton), measured in years
CO_2 = carbon dioxide emissions, measured in tonnes of carbon dioxide (tonnes CO_2)

ΔC = (23.9 tonne C ha^{-1} - 0 X 65.73 ha) / 1
ΔC = 1,570.95 tonnes C

CO_2 = 23.9 tonnes C X 44/12
CO_2 = 5,760.14 tonnes CO_2

3 - Direct emissions from land use change - soil organic matter

Ecozone	Parameters	Value	Unit	Source
Forest Land	Area (A)	65.73	ha	Draft Terrestrial Report (Jan 24, 2025)
	Carbon Stock (SOC_ref)	81.00	tonne C ha^{-1}	Volume 4, Chapter 2, IPCC 2019 refinement of 2006 Guidelines. Table 2.3. Cool temperate moist - High Activity Clay Soils (selected this because in this source https://openpress.usask.ca/soilscience/chapter/soils-of-ontario/ it described this areas a clay, Luvisol)
Wetlands	Area (A)	49.12	ha	Draft Terrestrial Report (Jan 24, 2025)
	Carbon Stock (SOC_ref)	128.00	tonne C ha^{-1}	Volume 4, Chapter 2, IPCC 2019 refinement of 2006 Guidelines. Table 2.3. Cool temperate moist - wetland soils
Grassland	Area (A)	180.87	ha	Draft Terrestrial Report (Jan 24, 2025)
	Carbon Stock (SOC_ref)	81.00	tonne C ha^{-1}	Volume 4, Chapter 2, IPCC 2019 refinement of 2006 Guidelines. Table 2.3. Cool temperate moist - High Activity Clay Soils (selected this because in this source https://openpress.usask.ca/soilscience/chapter/soils-of-ontario/ it described this areas a clay, Luvisol)
Thicket	Area (A)	0.34	ha	Draft Terrestrial Report (Jan 24, 2025)
	Carbon Stock (SOC_ref)	81.00	tonne C ha^{-1}	Volume 4, Chapter 2, IPCC 2019 refinement of 2006 Guidelines. Table 2.3. Cool temperate moist - High Activity Clay Soils (selected this because in this source https://openpress.usask.ca/soilscience/chapter/soils-of-ontario/ it described this areas a clay, Luvisol)
None - constant value	Stock change factor for mineral soil organic C (F_lu)	0.80	n/a	SACC - Annex B - default value for paving section 8.3.3.2, IPCC 2006)

Equation 2.25 results

Ecozone	SOC_0 (carbon after land use change); (tonne C)
Forest Land	4,259.30
Wetlands	5,029.89
Grassland	11,720.38
Thicket	22.03
Total	**21,031.60**

Ecozone	SOC_0 (carbon before land use change); (tonne C)
Forest Land	5,324.13
Wetlands	6,287.36
Grassland	14,650.47
Thicket	27.54
Total	**26,289.50**

Ecozone	ΔC_mineral; (tonne C)	ΔC_mineral; (tonne CO_2)
Forest Land	1,064.83	3,907.91
Wetlands	1,257.47	4,614.92
Grassland	2,930.09	10,753.44
Thicket	5.51	20.21
Total	**5,257.90**	**19,296.49**

Sample Calculation (Direct emissions from land use change - soil organic matter: forest land)

$$\Delta C = (SOC\_ref \times A \times F\_lu) - (SOC_{ref} \times A)$$

$$CO_2 = \Delta C \times 44/12$$

ΔC = change in carbon stock in soils, measured in tonnes of carbon per year (tonnes C)
SOC ref = carbon stock prior to land use change, measured in tonnes of carbon per year (tonnes C ha^{-1})
A = area undergoing conversion from old to new land use category, measured in hectares (ha)
F_lu = stock change factor for mineral soil, no units
CO_2 = carbon dioxide emissions, measured in tonnes of carbon dioxide (tonnes CO_2)

ΔC = (81 tonne C ha^{-1} X 65.73 ha X 0.8) - (81 tonne C ha-1 X 65.73 ha)
ΔC = 1,064.83 tonnes C

CO_2 = 1,064.83 X 44/12
CO_2 = 3,907.91 tonnes CO_2

TOTAL EMISSIONS FROM LAND USE CHANGE

Land Use Change Emission Type	Emissions (tonnes CO_2 emissions)
Living biomass	62,019
Dead Organic Matter	5,760
Soil Organic Matter	19,296
Total	**87,076**

Appendix A.4
Impact to Carbon Sinks

This tab calculates the lost potential of carbon sinks due to land use change.

Annual losses from disturbance of carbon sinks

Ecozone	Parameter	Value	Unit	Source
Forest Land	Area (A)	65.73	ha	Highway 413 Draft IPD, Section 19.5.1
	Average annual above-ground biomass growth (G_W)	1.77	tonne dm ha-1 yr-1	Froelich, Norma, et al. "Trends of carbon fluxes and climate over a mixed temperate–boreal transition forest in southern Ontario, Canada." Agricultural and Forest Meteorology 211 (2015): 72-84.
	Ratio of below-ground to above-ground biomass (R)	0.48	—	Table 4.4 of IPCC 2019 Refinement to the 2006 IPCC Guidelines for National GHG Inventories Vol 4, Chapter 4. Temperate - Continental - North and South America - Natural (other broadleaf), with biomass density≤ 125, for conservativism
	Carbon fraction of dry matter (CF)	0.47	tonne C	Table 4.3 of IPCC 2006 Vol 4, Chapter 4. Temperature and Boreal forest with all parts (broad-leaves and conifers) (No Refinement in IPCC 2019)
Wetlands	Area (A)	49.12	ha	Highway 413 Draft IPD, Section 19.5.1
	Average annual above-ground biomass growth (G_W)	1.77	tonne dm ha-1 yr-1	Froelich, Norma, et al. "Trends of carbon fluxes and climate over a mixed temperate–boreal transition forest in southern Ontario, Canada." Agricultural and Forest Meteorology 211 (2015): 72-84.
	Ratio of below-ground to above-ground biomass (R)	0.48	—	Table 4.4 of IPCC 2019 Refinement to the 2006 IPCC Guidelines for National GHG Inventories Vol 4, Chapter 4. Temperate - Continental - North and South America - Natural (other broadleaf), with biomass density≤ 125, for conservativism
	Carbon fraction of dry matter (CF)	0.47	tonne C	Table 4.3 of IPCC 2006 Vol 4, Chapter 4. Temperature and Boreal forest with all parts (broad-leaves and conifers)
None - constant value	Conversion factor C to CO_2	3.67	—	Molecular weight

Note: According to the SACC, impact to carbon sinks are only calculated for areas with high carbon sink capacity, which included forests and wetlands (Government of Canada 2021).

Ecozone	Total CO_2 Emissions (tonne/year)
Forest Land	297
Wetlands	222
Total	**519**

Sample Calculation (Annual losses from disturbance of carbon sinks: forest land)

$$\Delta C = A \times G_W \times (1 + R) \times CF$$

$$CO_2 = \Delta C \times 44/12$$

ΔC =annual loss of carbon sequestration, measured in tonnes of carbon per year (tonnes C yr^{-1})
A = total area being disturbed, measured in hectares (ha)
G_W = Average annual above-ground biomass growth, measured in tonnes of carbon per hectare (tonne dm ha^{-1} yr^{-1})
R = Ratio of below-ground to above-ground biomass, no units
CF = Carbon fraction of dry matter, measured in tonnes of carbon (tonne C)
CO_2 = annual loss of carbon dioxide sequestration, measured in tonnes of carbon dioxide (tonnes CO_2)

ΔC = 65.73 ha X 1.77 tonne dm $ha^{-1\ yr-1}$ X (1 + 0.481) x 0.47 tonne C
ΔC = 80.93 tonnes C yr^{-1}

CO_2 = 297 tonnes C yr^{-1} X 44/12
CO_2 = 297 tonnes CO_2 yr^{-1}

Appendix A.5
Summary Land Use Change and Impact to Carbon Sink Emissions

Direct emissions from land use change

Land Use Change Emission Type	Emissions (tonnes CO_2 emissions)
Living Biomass	62,019
Dead Organic Matter	5,760
Soil Organic Matter	19296
Total	**87,076**

Total
87,595

Annual impact on carbon sinks

Ecozone	Total CO_2 Emissions (tonne/year)
Forest- Temperate Continental	297
Wetland	222
Total	**519**

Phase	Activity	Average Annual Emissions (tonnes CO_2e/year)	No. of years	Average Emissions for Total Construction Phase (tonnes CO_2e)
Construction	Road Construction[(a)]	15,300	10	153,000
	Bridge Construction[(a)]	2,320	10	23,200
	Major Bridge Construction[(a)]	1,980	10	19,800
	Acquired energy [(b)]			
	Land Use Change [(c)]	87,076	n/a	87,076
	Impcat to Carbon Sinks [(d)]	519	10	5,188
	Total	**107,195**	**n/a**	**288,264**

(a) Road construction, bridge construction, and major bridge construction emissions are from the Highway 413 Greater Toronto Area Preliminary Construction GHG Assessment – Draft Report (RWDI 2022).

(b) Electrical services are not expected to be required during the construction phase; all power will be supplied by fuel-fired generators, whose emissions are included under the Construction Equipment Source (RWDI 2022).

(c) Land-Use Change from loss of carbon from carbon stock change (e.g., removal of vegetation/disturbances) is included in construction phase emissions. This does not have an associated no. of years, because this value is only emitted one time, when the disturbance occurs. For conservatism, it is assumed that the emissions associated with land-use change will all occur in a single year, and all vegetation removed will be burned, representing the worst-case scenario.

(d) Impact to Carbon Sinks – post disturbance is the annual lost ability to store additional carbon on an annual basis because the vegetation has been removed. For the construction phase, this annual loss occurs for 10 years, as this is the duration of the construction phase. This annual loss will continue into the operations phase.

B

Climate Data Sources

Appendix B: Climate Data Sources

The table below lists the datasets and grid cell sizes used for this study. The climate projections were derived from Coupled Model Intercomparison Project Phase 6 (CMIP6), which underpins the IPCC Sixth Assessment Report (AR6). Specifically, the Pacific Climate Impacts Consortium (PCIC) CMIP6 SSP5-8.5 and SSP2-4.5 datasets were used for the majority of climate indicators. For extreme wind, projections were based on the CanRCM4 model under RCP8.5 and RCP4.5 scenarios, as wind data was not available in the PCIC CMIP6 dataset. Additionally, the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) dataset was used to assess wildfire-related climate hazards.

Table A1. Datasets used in this study

Dataset	Grid Cell Centre	Grid Cell Size (degrees)
PCIC	43.54°N, 79.88°W 43.62°N, 79.88°W 43.79°N, 79.71°W 43.87°N, 79.71°W 43.79°N, 79.63°W 43.87°N, 79.63°W 43.71°N, 79.88°W 43.87°N, 79.54°W 43.79°N, 79.88°W 43.54°N, 79.79°W 43.62°N, 79.79°W 43.71°N, 79.79°W 43.79°N, 79.79°W 43.87°N, 79.79°W	0.08
CanRCM4	43.64°N, 80.03°W 43.85°N, 79.96°W 43.59°N, 79.73°W 43.8°N, 79.66°W 44.02°N, 79.6°W	0.22
NEX-GDDP	43.63°N, 79.88°W 43.88°N, 79.88°W 43.88°N, 79.63°W	0.25

Sources: PCIC 2021; Scinocca et al. 2016; NASA 2021

C

Risk Assessment

Appendix C

Infrastructure	Climate Variable	Climate Indicator	Focus Risk	Consequence	Consequence Score Rationale	Likelihood Score				Risk Score							
						2050s		2080s		2050s				2080s			
						SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5		SSP5-8.5		SSP2-4.5		SSP5-8.5	
Highway 413 and extensions to Highways 410 and 427, Interchanges and Freeway-to-Freeway Connections	Extreme Heat	Days above 39 degC	Extreme heat could cause pavement softening, rutting, bleeding, damaging the roads causing increased need for repair, or need different asphalt cement grades.	2	Extreme heat causing rutting, bleeding, damage in highway could cause minor damage causing need for repair with localized disruption, however there are assumed robust monitoring and maintenance for damage inclusive of climate change considerations. Minor damage within planned operations.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Highway 413 and extensions to Highways 410 and 427, Interchanges and Freeway-to-Freeway Connections	Extreme Cold	Cold spell duration indicator (-15 deg C)	Extended cold spells could cause increased frost penetration, causing increased need for repair. Extended cold spells could cause reduced traction which is a safety concern for traffic.	2	Frost penetration increasing rutting could cause minor damage and need for repair with localized disruption, however there are assumed robust monitoring and maintenance for damage inclusive of climate change considerations. Repairs could be within planned operations. Decreased traction from extreme cold not likely to cause safety risk due to mitigative measures in place to increase traction on highways.	2	2	1	1	4	Low Risk	4	Low Risk	2	Negligible Risk	2	Negligible Risk
Highway 413 and extensions to Highways 410 and 427, Interchanges and Freeway-to-Freeway Connections	Freeze-Thaw Cycles	Daily freeze-thaw cycles	Freeze-thaw cycles could cause increased potholes and rutting, which would increase the need for repair. Could cause accelerated deterioration of roads, causing more frequent maintenance.	2	Freeze-thaw damage increasing potholes and rutting could cause minor damage and need for repair with localized disruption, however there are assumed robust monitoring and maintenance for damage inclusive of climate change considerations. Repairs could be within planned operations.	2	2	2	2	4	Low Risk	4	Low Risk	4	Low Risk	4	Low Risk
Highway 413 and extensions to Highways 410 and 427, Interchanges and Freeway-to-Freeway Connections	Extreme Rainfall	Max 1-day precipitation event	Heavy precipitation events could cause flooding resulting in washout, increased debris on highways, and deterioration of the edges of the pavement. This could cause increased need for repair. Heavy rainfall could cause increased effort to keep arterial roads accessible and safe to travel. Decreased visibility due to extreme rainfall is a safety concern to travelers.	3	Flooding, washout, increased debris on highways, and visibility concerns could cause minor safety risk for users. Assumed to have a robust emergency response plan in place to address impacts from extreme events, which reduces the consequence from major safety risk to moderate safety risk.	3	3	3	3	9	Medium Risk	9	Medium Risk	9	Medium Risk	9	Medium Risk
Highway 413 and extensions to Highways 410 and 427, Interchanges and Freeway-to-Freeway Connections	Changes in snowfall	Total snowfall	Changes in snowfall events may change salting needs, potentially impacting the vegetation around the highway. Changes in snowfall could change snow clearing efforts on the highway, with potential changes in damage to pavement surface and need for repair. Snowfall can result in reduced usability and safety concerns to highway users.	3	Changes in snowfall causing reduced usability of highways could cause a minor safety risk for users, assuming there are robust snow clearing practices in place. Changes in snow clearing effort, however within planned maintenance and operation budget. Increased salting causing minor damage to localized vegetation, no remediation required.	2	2	2	2	6	Low Risk	6	Low Risk	6	Low Risk	6	Low Risk
Highway 413 and extensions to Highways 410 and 427, Interchanges and Freeway-to-Freeway Connections	Freezing Rain	Assessed Semi-Qualitatively	Freezing rain storms could also result in increased effort to keep highway clear and accessible, more clearing can damage highway causing increased need for repair. Freezing rain could reduce usability and cause a safety concern due to issues like ice cover, debris on roads. Freezing rain could cause increased use of the shoulder in low visibility scenarios. This could be a safety issue for the usability of the highway.	3	Increased freezing-rain could reduce usability of the highway causing a minor safety concern, assuming robust clearing practices are in place. Increased clearing could result in damage recoverable through minor repair and maintenance, but would be within maintenance budget due to robust monitoring and maintenance practices inclusive of considering climate change.	Not Available	3	Not Available	3	Not Available	Not Available	9	Medium Risk	Not Applicable	Not Available	9	Medium Risk
Highway 413 and extensions to Highways 410 and 427, Interchanges and Freeway-to-Freeway Connections	Extreme Wind	Max daily wind speed	Extreme wind could cause increased effort to keep highway clear and accessible due to increased debris on highway. Could cause accessibility issues in severe cases.	2	Extreme wind causing debris on highway would not likely cause a health and safety issue to users as debris is unlikely to occur on all 6 lanes. Assumed robust emergency response plans and monitoring and maintenance plans inclusive of climate change further reduced the consequence. Only localized disruptions would occur.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	6	Low Risk

Infrastructure	Climate Variable	Climate Indicator	Focus Risk	Consequence	Consequence Score Rationale	Likelihood Score				Risk Score							
						2050s		2080s		2050s				2080s			
						SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5		SSP5-8.5		SSP2-4.5		SSP5-8.5	
Highway 413 and extensions to Highways 410 and 427, Interchanges and Freeway-to-Freeway Connections	Overland flooding	Days above 20 mm rain	Overland flooding could cause washout, and deterioration of pavement due to erosion, causing increased need for repair. This could cause a safety concern for users. Overland flooding could cause increased debris on highways and cause unsafe driving conditions for users.	2	Due to existing mitigation measures including robust monitoring and maintenance plan, emergency response plan, and drainage systems designs in accordance with MTO Highway Drainage Design Standards, there could be localized disruption with no permanent damage. Repairs would be within maintenance budget. Not likely to cause a safety risk to users due to mitigations.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Highway 413 and extensions to Highways 410 and 427, Interchanges and Freeway-to-Freeway Connections	Wildfires	Fire Weather Index above 10	Wildfire smoke could cause visibility issues for highway users, causing a health and safety concern.	3	Wildfire smoke causing visibility concerns for highway users would cause a minor health and safety impact to users, considering robust monitoring and maintenance plan in place and emergency response plans. Could cause limited loss of service of highway.	3	3	3	4	9	Medium Risk	9	Medium Risk	9	Medium Risk	12	High Risk
Municipal Road Realignments	Extreme Heat	Days above 39 degC	Extreme heat could cause pavement softening, rutting, bleeding, damaging the roads and caused increased need for repair, or need different asphalt cement grades.	1	Any damage from extreme heat on municipal roads likely to within regular maintenance, due to assumed robust monitoring and maintenance for damage inclusive of climate change considerations. Note - a lower impact than highways due to lower speeds usage.	3	3	3	4	3	Low Risk	3	Low Risk	3	Low Risk	4	Low Risk
Municipal Road Realignments	Extreme Cold	Cold spell duration indicator (-15 deg C)	Extended cold spells could cause increased frost penetration, causing increased need for repair. Extended cold spells could cause reduced traction which is a safety concern for traffic.	1	Any damage from extreme cold on municipal roads likely to within regular maintenance, due to assumed robust monitoring and maintenance for damage inclusive of climate change considerations. Note - a lower impact than highways due to lower speeds usage.	2	2	1	1	2	Negligible Risk	2	Negligible Risk	1	Negligible Risk	1	Negligible Risk
Municipal Road Realignments	Freeze-Thaw Cycles	Daily freeze-thaw cycles	Freeze-thaw cycles could cause increased potholes and rutting, which would increase the need for repair. Could cause accelerated deterioration of roads, causing more frequent maintenance.	1	Any damage from freeze-thaw on municipal roads likely to within regular maintenance, due to assumed robust monitoring and maintenance for damage inclusive of climate change considerations. Note - a lower impact than highways due to lower speeds usage.	2	2	2	2	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk
Municipal Road Realignments	Extreme Rainfall	Max 1-day precipitation event	Heavy precipitation events could cause flooding resulting in washout, increased debris on highways, and deterioration of the edges of the pavement. This could cause increased need for repair. Heavy rainfall could cause increased effort to keep arterial roads accessible and safe to travel. Decreased visibility due to extreme rainfall is a safety concern to travelers.	3	Flooding, washout, increased debris on municipal roads, and visibility concerns could cause minor safety risk for users. Assumed to have a robust emergency response plan in place to address impacts from extreme events, which reduces the consequence from major safety risk to moderate safety risk.	3	3	3	3	9	Medium Risk	9	Medium Risk	9	Medium Risk	9	Medium Risk
Municipal Road Realignments	Changes in snowfall	Total snowfall	Changes in snowfall events may change salting needs, potentially impacting the vegetation around the highway. Changes in snowfall could change snow clearing efforts on municipal roads, with potential changes in damage to pavement surface and need for repair. Snowfall can result in reduced usability and safety concerns to road users.	3	Changes in snowfall causing reduced usability of municipal roads could cause a minor safety risk for users, assuming there are robust snow clearing practices in place. Changes in snow clearing effort, however within planned maintenance and operation budget. Increased salting causing minor damage to localized vegetation, no remediation required.	2	2	2	2	6	Low Risk	6	Low Risk	6	Low Risk	6	Low Risk
Municipal Road Realignments	Freezing Rain	Assessed Semi-Qualitatively	Freezing rain storms could also result in increased effort to keep highway clear and accessible, more clearing can damage highway causing increased need for repair. Freezing rain could reduce usability and cause a safety concern due to issues like ice cover, debris on roads. Freezing rain could cause increased use of the shoulder in low visibility scenarios. This could be a safety issue for the usability of the highway.	3	Increased freezing-rain could reduce usability of the municipal roads causing a minor safety concern, assuming robust clearing practices are in place. Increased clearing could result in damage recoverable through minor repair and maintenance, but would be within maintenance budget due to robust monitoring and maintenance practices inclusive of considering climate change.	Not Available	3	Not Available	3	Not Available	Not Available	9	Medium Risk	Not Applicable	Not Available	9	Medium Risk

Infrastructure	Climate Variable	Climate Indicator	Focus Risk	Consequence	Consequence Score Rationale	Likelihood Score				Risk Score							
						2050s		2080s		2050s				2080s			
						SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5		SSP5-8.5		SSP2-4.5		SSP5-8.5	
Municipal Road Realignments	Extreme Wind	Max daily wind speed	Extreme wind could cause increased effort to keep roads clear and accessible due to increased debris on roads. Could cause accessibility issues in severe cases.	2	Extreme wind causing debris on municipal roads would not likely cause a health and safety issue to users considering if debris occurred on highway, it would be unlikely to occur on all 6 lanes. Assumed robust emergency response plans and monitoring and maintenance plans inclusive of climate change further reduced the consequence. Only localized disruptions would occur.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	6	Low Risk
Municipal Road Realignments	Overland flooding	Days above 20 mm rain	Overland flooding could cause washout, and deterioration of pavement due to erosion, causing increased need for repair. This could cause a safety concern for users. Overland flooding could cause increased debris on highways and cause unsafe driving conditions for users.	2	Due to existing mitigation measures including robust monitoring and maintenance plan, emergency response plan, and drainage systems designs in accordance with MTO Highway Drainage Design Standards, there could be localized disruption with no permanent damage. Repairs would be within maintenance budget. Not likely to cause a safety risk to users due to mitigations.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Municipal Road Realignments	Wildfires	Fire Weather Index above 10	Wildfire smoke could cause visibility issues for highway users, causing a health and safety concern.	3	Wildfire smoke causing visibility concerns for highway users would cause a minor health and safety impact to users, considering robust monitoring and maintenance plan in place and emergency response plans. Could cause limited loss of service of municipal roads.	3	3	3	4	9	Medium Risk	9	Medium Risk	9	Medium Risk	12	High Risk
Maintenance Yard Facilities & Carpool Lots	Extreme Heat	Days above 39 degC	Increased extreme heat could cause increased pavement softening, rutting, bleeding, damaging the maintenance yards and lots. Extreme heat could cause fading and deterioration of hard surfaces.	1	Pavement damage from extreme heat would likely be undertaken within regular maintenance.	3	3	3	4	3	Low Risk	3	Low Risk	3	Low Risk	4	Low Risk
Maintenance Yard Facilities & Carpool Lots	Extreme Cold	Cold spell duration indicator (-15 deg C)	Increased extended cold spells could cause reduced traction on surfaces, causing a safety concern for drivers in yards and lots. Extended cold spells could cause increased frost penetration meaning there is higher risk of potholes and rutting.	1	Reduced traction in maintenance yards would not cause significant safety impact due to slow moving vehicles. Pavement damage from extreme cold would likely be undertaken within regular maintenance.	2	2	1	1	2	Negligible Risk	2	Negligible Risk	1	Negligible Risk	1	Negligible Risk
Maintenance Yard Facilities & Carpool Lots	Freeze-Thaw Cycles	Daily freeze-thaw cycles	Freeze-thaw cycles could cause increase in potholes and rutting causing increased need for repair.	1	Pavement damage from freeze-thaw would likely be undertaken within regular maintenance.	2	2	2	2	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk
Maintenance Yard Facilities & Carpool Lots	Extreme Rainfall	Max 1-day precipitation event	Heavy precipitation events including high intensity rainfalls and storms can cause flooding in the maintenance yard facilities lot, causing damage to the equipment and limiting access.	2	Extreme rainfall causing flooding would not likely result in health and safety impact assuming a robust emergency response plan. Damage from flooding may be within planned maintenance budget, assuming robust monitoring and maintenance budget considering climate change.	3	3	3	3	6	Low Risk	6	Low Risk	6	Low Risk	6	Low Risk
Maintenance Yard Facilities & Carpool Lots	Changes in snowfall	Total snowfall	Changes in snowfall could change snow clearing efforts on maintenance yards and parking lots, with potential changes in damage to pavement surface and need for repair. Snowfall can result in reduced usability and safety concerns to users.	2	Safety risk for users is not likely to be significant due to slow moving vehicles in maintenance yards. Damage to pavement from increased clearing efforts is likely to be within planned maintenance budget due to assumed robust monitoring and maintenance in place for damage which will consider climate change.	2	2	2	2	4	Low Risk	4	Low Risk	4	Low Risk	4	Low Risk
Maintenance Yard Facilities & Carpool Lots	Freezing Rain	Assessed Semi-Qualitatively	Freezing rain could cause ice accumulation in maintenance yards and carpool lots, causing increased effort for clearing, and unsafe driving conditions.	2	Icy conditions could be cause would not likely cause safety risk for cars in carpool lots and maintenance yards due to robust maintenance practices.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	6	Low Risk
Maintenance Yard Facilities & Carpool Lots	Extreme Wind	Max daily wind speed	Extreme weather events such as high winds could cause accumulation of debris on the maintenance yard facilities.	2	Extreme wind causing debris on maintenance yards and carpool lots could cause increased maintenance for clearing, but within planned maintenance budget due to assumed robust monitoring and maintenance in place.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	6	Low Risk
Maintenance Yard Facilities & Carpool Lots	Overland flooding	Days above 20 mm rain	Overland flooding could cause accumulation of debris on the maintenance yard facilities. Overland flooding could cause washout and deterioration of pavement edges, causing increased need for repair. This would cause a safety risk for users.	2	Due to existing mitigation measures including robust monitoring and maintenance plan, emergency response plan, and drainage systems designs in accordance with MTO Highway Drainage Design Standards, there could be localized disruption with no permanent damage. Repairs would be within maintenance budget. Not likely to cause a safety risk to users due to mitigations.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk

Infrastructure	Climate Variable	Climate Indicator	Focus Risk	Consequence	Consequence Score Rationale	Likelihood Score				Risk Score							
						2050s		2080s		2050s				2080s			
						SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5		SSP5-8.5		SSP2-4.5		SSP5-8.5	
Maintenance Yard Facilities & Carpool Lots	Wildfires	Fire Weather Index above 10	Wildfire events could cause physical damage to the maintenance yard facilities.	2	Wildfire damaging maintenance yard facilities would likely cause localized loss of service which would be recoverable through maintenance within planned maintenance budget. This is due to the robust monitoring and maintenance plan that is inclusive of climate change considerations.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Commercial Vehicle Inspection Facilities	Extreme Heat	Heat wave duration (above 35 deg C)	Increase in extreme heat events could limit the number of hours road crew can work due to health and safety concerns for the workers, impacting commercial vehicle inspection.	3	Extreme heat could impact worker health and safety, causing minor safety risk. Could also cause limited loss of service for commercial vehicle inspection.	4	4	4	5	12	High Risk	12	High Risk	12	High Risk	15	High Risk
Commercial Vehicle Inspection Facilities	Extreme Cold	Cold spell duration indicator (-15 deg C)	Extended cold spells could cause increased frost penetration, causing increased need for repair. Extended cold spells could cause reduced traction which is a safety concern for traffic.	1	Reduced traction in commercial inspection facilities would not cause significant safety impact due to slow moving vehicles. Pavement damage from extreme cold would likely be undertaken within regular maintenance.	2	2	1	1	2	Negligible Risk	2	Negligible Risk	1	Negligible Risk	1	Negligible Risk
Commercial Vehicle Inspection Facilities	Freeze-Thaw Cycles	Daily freeze-thaw cycles	Freeze-thaw cycles could cause increased potholes and rutting, which would increase the need for repair.	1	Pavement damage from freeze-thaw would likely be undertaken within regular maintenance.	2	2	2	2	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk
Commercial Vehicle Inspection Facilities	Extreme Rainfall	Max 1-day precipitation event	Extreme precipitation events can impact access of commercial vehicles to access the inspection facilities due to fooding or visibility issues. Extreme rainfall could also cause floodings of inspection facilities, damaging equipment.	2	Extreme rainfall causing flooding would not likely result in health and safety impact assuming a robust emergency response plan. Damage from flooding may be within planned maintenance budget, assuming robust monitoring and maintenance budget considering climate change.	3	3	3	3	6	Low Risk	6	Low Risk	6	Low Risk	6	Low Risk
Commercial Vehicle Inspection Facilities	Changes in snowfall	Max 1-day snowfall	Changes in snowfall events can impact access of commercial vehicles to access the inspection facilities.	2	Assuming robust snow clearing practices, not likely a safety risk with non-significant impact to services.	3	3	3	2	6	Low Risk	6	Low Risk	6	Low Risk	4	Low Risk
Commercial Vehicle Inspection Facilities	Freezing Rain	Assessed Semi-Qualitatively	Freezing rain could cause damage to equipment in commercial vehicle inspection facilities.	2	Freezing rain damaging equipment in commercial inspection facilities could cause localized infrastructure disruption, some minor restoration work within planned budget, assuming robust monitoring and maintenance plans including considering climate change.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	6	Low Risk
Commercial Vehicle Inspection Facilities	Extreme Wind	Max daily wind speed	Extreme weather events such as high winds, can impact access of commercial vehicles to access the inspection facilities.	2	Extreme wind impacting ability to access commercial vehicle inspection facilities could cause localized disruption, with no significant safety risk, assuming robust emergency response plan is in place.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	6	Low Risk
Commercial Vehicle Inspection Facilities	Overland flooding	Days above 20 mm rain	Overland flooding events can impact access of commercial vehicles to access the inspection facilities.	2	Due to existing mitigation measures including robust monitoring and maintenance plan, emergency response plan, and drainage systems designs in accordance with MTO Highway Drainage Design Standards, there could be localized disruption with no permanent damage. Repairs would be within maintenance budget. Not likely to cause a safety risk to users due to mitigations.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Commercial Vehicle Inspection Facilities	Wildfires	Fire Weather Index above 10	Wildfire could impact access of commercial vehicles to access the inspection facilities.	2	Wildfire damaging maintenance yard facilities would likely cause localized loss of service which would be recoverable through maintenance within planned maintenance budget. This is due to the robust monitoring and maintenance plan that is inclusive of climate change considerations.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Offices/Staff Buildings	Extreme Heat	Heat wave duration (above 35 deg C)	Extreme heat could cause worker discomfort in office/staff buildings and could cause increased use of HVAC systems.	2	Extreme heat would not likely cause worker health and safety concerns due to robust emergency response plans and assumed HVAC in office buildings. Could cause limited localized damage repairable through planned operations and maintenance budget assuming robust maintenance and monitoring in place which will consider climate change.	4	4	4	5	8	Medium Risk	8	Medium Risk	8	Medium Risk	10	Medium Risk

Infrastructure	Climate Variable	Climate Indicator	Focus Risk	Consequence	Consequence Score Rationale	Likelihood Score				Risk Score							
						2050s		2080s		2050s				2080s			
						SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5		SSP5-8.5		SSP2-4.5		SSP5-8.5	
Offices/Staff Buildings	Extreme Cold	Cold spell duration indicator (-15 deg C)	Extreme cold could cause worker discomfort in office/staff buildings and could cause increased use of HVAC systems.	2	Extreme cold could impact worker health and safety, causing minor safety risk. Could cause limited loss of service, with minor damage repairable through planned operations and maintenance budget assuming robust maintenance and monitoring in place which will consider climate change.	2	2	1	1	4	Low Risk	4	Low Risk	2	Negligible Risk	2	Negligible Risk
Offices/Staff Buildings	Extreme Rainfall	Max 1-day precipitation event	Extreme rainfall could cause damage to the exterior components of buildings, causing need for repairs. Could also cause flood/leak damage causing need for maintenance and repairs.	2	Extreme rainfall causing damage to exterior parts of building/leakage/flooding could cause minor damage and loss of service with minor damage repairable through planned operations and maintenance budget assuming robust maintenance and monitoring in place which will consider climate change.	3	3	3	3	6	Low Risk	6	Low Risk	6	Low Risk	6	Low Risk
Offices/Staff Buildings	Changes in snowfall	Max 1-day snowfall	Snowfall or rain on snow events could cause damage to the exterior components of buildings due to changes in load, causing need for maintenance and repairs.	2	Changes in snowfall causing damage to exterior parts of building could cause minor damage and loss of service with minor damage repairable through planned operations and maintenance budget assuming robust maintenance and monitoring in place which will consider climate change.	3	3	3	2	6	Low Risk	6	Low Risk	6	Low Risk	4	Low Risk
Offices/Staff Buildings	Freezing Rain	Assessed Semi-Qualitatively	Freezing rain could cause damage to the exterior components of buildings, causing need for maintenance and repairs.	2	Freezing causing damage to exterior parts of building could cause minor damage and loss of service with minor damage repairable through planned operations and maintenance budget assuming robust maintenance and monitoring in place which will consider climate change.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	6	Low Risk
Offices/Staff Buildings	Extreme Wind	Max daily wind speed	Extreme wind could cause damage to the exterior components of buildings, causing need for maintenance and repairs.	2	Extreme wind damage to exterior parts of building could cause minor damage and loss of service with minor damage repairable through planned operations and maintenance budget assuming robust maintenance and monitoring in place which will consider climate change.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	6	Low Risk
Offices/Staff Buildings	Lightning	Assessed Semi-Qualitatively	Lightning could cause power outage in buildings.	2	Lightning causing power outages in building could cause localized infrastructure disruptions, with no permanent damage. Minor restoration work to get power working.	Not Available	3	Not Available	4	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	8	Medium Risk
Offices/Staff Buildings	Overland flooding	Days above 20 mm rain	Overland flooding could cause damage to offices/staff buildings causing increased need for repair and maintenance.	2	Overland flooding causing damage to exterior parts of building. Could cause localized infrastructure damage with restoration. Within planned maintenance budget due to assumed robust monitoring and maintenance plan which will consider climate change.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Offices/Staff Buildings	Wildfires	Fire Weather Index above 10	Wildfire could damage offices/staff buildings and cause need for maintenance and repairs. Wildfire smoke could also cause air quality issues which could impact workers.	3	Wildfire smoke could cause minor safety risk for staff in buildings. Wildfire could cause extensive damage to office buildings, requiring repair beyond planned maintenance budget.	3	3	3	4	9	Medium Risk	9	Medium Risk	9	Medium Risk	12	High Risk
Major Water Crossings and Other Bridges	Extreme Heat	Heat wave duration (above 35 deg C)	Extreme heat could cause pavement softening, rutting, bleeding and cause increased need for repair, or need to different asphalt cement oil grade. This damages the material and could also place stress on expansion joints causing a safety risk. Adding additional joint could become requires as part of maintenance activities. Extreme temperatures could cause durability impact on the concrete.	2	Thermal expansion of bridge joints from extreme heat could cause localized damage, repairable within planned maintenance budget, assuming robust monitoring and maintenance in place which will consider climate change.	4	4	4	5	8	Medium Risk	8	Medium Risk	8	Medium Risk	10	Medium Risk
Major Water Crossings and Other Bridges	Extreme Cold	Cold spell duration indicator (-15 deg C)	Extended cold spells could cause increased frost penetration, causing increased need for repair. Extended cold spells could increase the road icing threats, causing accretion. Extreme cold could also place stress on expansion joints causing a safety risk. Adding additional joint could become requires as part of maintenance activities. Extreme temperatures could cause durability impact on the concrete.	3	Extreme cold could cause localized damage, repairable within planned maintenance budget, assuming robust monitoring and maintenance in place which will consider climate change. Increased icing on bridge could cause minor health and safety risk to users assuming robust ice clearing and maintenance and monitoring in place.	2	2	1	1	6	Low Risk	6	Low Risk	3	Low Risk	3	Low Risk

Infrastructure	Climate Variable	Climate Indicator	Focus Risk	Consequence	Consequence Score Rationale	Likelihood Score				Risk Score							
						2050s		2080s		2050s				2080s			
						SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5		SSP5-8.5		SSP2-4.5		SSP5-8.5	
Major Water Crossings and Other Bridges	Freeze-Thaw Cycles	Daily freeze-thaw cycles	Freeze-thaw cycles could cause potholes and rutting causing increased need for repair. Increase in potholes and rutting can also place stress on expansion joints causing a safety risk. Freeze-thaw cycles could cause increase deterioration of concrete and pavement, causing increased need for repair.	2	Freeze-thaw could cause localized damage, repairable within planned maintenance budget, assuming robust monitoring and maintenance in place which will consider climate change.	2	2	2	2	4	Low Risk	4	Low Risk	4	Low Risk	4	Low Risk
Major Water Crossings and Other Bridges	Extreme Rainfall	Max 1-day precipitation event	Heavy precipitation events could cause insufficient hydraulic capacity for new water flows. Extreme rainfall could cause pooling of water resulting in washout and increased debris on bridges. This could cause increased need for repair and increased effort to keep bridges accessible and safe to travel, impacting traffic. This could result in a safety concern.	3	Extreme rainfall causing pooling, washout and increased effort to keep bridges clear could cause a minor safety risk for users assuming robust emergency response plan in place for extreme weather events. Damage from extreme rainfall could be recoverable through minor repair that within maintenance budget assuming robust monitoring and maintenance in place considering climate change.	3	3	3	3	9	Medium Risk	9	Medium Risk	9	Medium Risk	9	Medium Risk
Major Water Crossings and Other Bridges	Changes in snowfall	Total snowfall	Changes in snowfall events may cause physical damage to infrastructure and could cause decreased ease of usability of bridges. Changes in snowfall volumes may change salting requirements and durability of pavements and concrete. Changes in snowfall events may change needs for snow being cleared off overhead structures, and being cleared onto roadways below, which could be a safety concern. Flooding associated with snowmelt events could impact shorelines, that could impact the embankments, if the earth works are at the proximity of the edge of the water. This could result in need for repair and efforts to keep underpass accessible and safe to travel	3	Changes in snowfall and snowmelt causing pooling, washout and increased effort to keep bridges clear could cause a minor safety risk for users assuming robust emergency response plan in place for extreme weather events. Damage from extreme rainfall could be recoverable through minor repair that within maintenance budget assuming robust monitoring and maintenance in place considering climate change.	2	2	2	2	6	Low Risk	6	Low Risk	6	Low Risk	6	Low Risk
Major Water Crossings and Other Bridges	Freezing Rain	Assessed Semi-Qualitatively	Freezing rain events could cause physical damage to the bridges, causing increased need for repair. Ice and hail storms could cause increased ice accretion, which could impact the bridge. This would cause increased salting, and salt speeds up the deterioration of concrete.	3	Freezing rain causing ice accretion on bridges could cause a minor safety risk for bridge users, assuming there are robust monitoring and maintenance in place including consideration of climate change. Limited damage recoverable through planned maintenance and operations.	Not Available	3	Not Available	3	Not Available	Not Available	9	Medium Risk	Not Applicable	Not Available	9	Medium Risk
Major Water Crossings and Other Bridges	Extreme Wind	Max daily wind speed	Extreme wind could have an impact on traffic on bridge causing a safety issue.	3	Extreme wind on bridge could impact traffic causing minor safety risk for users.	Not Available	3	Not Available	3	Not Available	Not Available	9	Medium Risk	Not Applicable	Not Available	9	Medium Risk
Major Water Crossings and Other Bridges	Overland flooding	Days above 20 mm rain	Overland flooding could cause washout, increased debris underpass, and deterioration of pavement, causing increased need for repair. Increased overland flooding events could impact shorelines, that could impact the embankments, if the earth works are at the proximity of the edge of the water.	2	Overland flooding causing washout, deterioration of pavement, increased effort to keep bridges clear would not likely cause a safety risk for users assuming robust emergency response plan in place for extreme weather events. Damage from flooding could be recoverable through minor repair within planned operation and maintenance budget due to assumed robust monitoring and maintenance in place which will consider climate change.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Major Water Crossings and Other Bridges	Wildfires	Fire Weather Index above 10	Wildfire could cause physical damage to bridges, causing need for repair, and inaccessibility for users.	2	Wildfire damaging bridge could cause localized infrastructure disruption with no permanent damage to bridge considering non-combustible bridge materials. Repairs within maintenance budget considering assumed robust monitoring and maintenance in place that will consider climate change.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Structural Culverts and Non-Structural Culverts, Storm Sewers	Extreme Heat	Days above 39 degC	Increased extreme heat could cause deterioration of structural culverts and storm sewers. This would cause increased need for repair.	2	Could cause some damage with minor restoration work within the maintenance and operation budget assuming robust operation and maintenance planning considering climate change.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Structural Culverts and Non-Structural Culverts, Storm Sewers	Extreme Cold	Cold spell duration indicator (-15 deg C)	Extended cold spell could increase frost penetration which could cause shifting and damage to culverts and storm sewers increasing need for repair.	2	Could cause some damage with minor restoration work within the maintenance and operation budget assuming robust operation and maintenance planning considering climate change.	2	2	1	1	4	Low Risk	4	Low Risk	2	Negligible Risk	2	Negligible Risk

Infrastructure	Climate Variable	Climate Indicator	Focus Risk	Consequence	Consequence Score Rationale	Likelihood Score				Risk Score							
						2050s		2080s		2050s				2080s			
						SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5		SSP5-8.5		SSP2-4.5		SSP5-8.5	
Structural Culverts and Non-Structural Culverts, Storm Sewers	Freeze-Thaw Cycles	Daily freeze-thaw cycles	Freeze-thaw could cause icing in culverts, leading to blockage and damage, leading to increased maintenance and need for repair.	2	Could cause some damage with minor restoration work within the maintenance and operation budget assuming robust operation and maintenance planning considering climate change.	2	2	2	2	4	Low Risk	4	Low Risk	4	Low Risk	4	Low Risk
Structural Culverts and Non-Structural Culverts, Storm Sewers	Extreme Rainfall	Max 1-day precipitation event	Heavy rainfall could overwhelm the culverts and storm sewers causing the purpose of the infrastructure to fail, and potentially causing damage to infrastructure.	3	Could cause some damage with minor restoration work that could be outside of the maintenance and operation budget assuming robust operation and maintenance planning considering climate change.	3	3	3	3	9	Medium Risk	9	Medium Risk	9	Medium Risk	9	Medium Risk
Structural Culverts and Non-Structural Culverts, Storm Sewers	Changes in snowfall	Max 1-day snowfall	Changes in snowfall events and associated snowmelt may result in increased flooding events which may lead to debris blocking drainage systems. This could cause flash flooding and slope failures. Snowmelt associated flooding events could wash out soil and culverts that support the roads, tunnels, and bridges.	3	Could cause some damage with minor restoration work that could be outside of the maintenance and operation budget assuming robust operation and maintenance planning considering climate change.	3	3	3	2	9	Medium Risk	9	Medium Risk	9	Medium Risk	6	Low Risk
Structural Culverts and Non-Structural Culverts, Storm Sewers	Extreme Wind	Max daily wind speed	Extreme wind associated with storms could cause excessive debris and blockage in drainage systems, leading to flooding and damage.	2	Could cause some damage with minor restoration work within the maintenance and operation budget assuming robust operation and maintenance planning considering climate change.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	6	Low Risk
Structural Culverts and Non-Structural Culverts, Storm Sewers	Overland flooding	Days above 20 mm rain	Overland flooding events could cause excessive vegetation and debris to block culverts, causing flash flooding and slope failures. Overland flooding events could wash out soil and culverts that support the roads, tunnels, and bridges.	2	Could cause some damage with minor restoration work within the maintenance and operation budget assuming robust operation and maintenance planning considering climate change.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Stormwater Management Infrastructure	Extreme Heat	Days above 39 degC	Increase in extreme heat could impact the populations of flora and fauna which could impact the ability of the SWM system to function properly and/or at maximum efficiency. Increased extreme heat could cause deterioration of SWM infrastructure that contains concrete. This would cause increased need for repair.	2	Assuming robust monitoring and maintenance, could cause minor damage within operations and maintenance budget, localized disruption.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Stormwater Management Infrastructure	Extreme Cold	Cold spell duration indicator (-15 deg C)	Extended cold spell could increase frost penetration which could cause damage to infrastructure such as storm sewers increasing need for repair.	2	Assuming robust monitoring and maintenance, could cause minor damage within operations and maintenance budget, localized disruption.	2	2	1	1	4	Low Risk	4	Low Risk	2	Negligible Risk	2	Negligible Risk
Stormwater Management Infrastructure	Freeze-Thaw Cycles	Daily freeze-thaw cycles	Freeze-thaw cycles could increase frost heave, causing damage to infrastructure such as storm sewers and increasing need for repair.	2	Assuming robust monitoring and maintenance, could cause minor damage within operations and maintenance budget, localized disruption.	2	2	2	2	4	Low Risk	4	Low Risk	4	Low Risk	4	Low Risk
Stormwater Management Infrastructure	Extreme Rainfall	Max 1-day precipitation event	Frequent and severe rainfall events could cause exceedance in the carrying capacity of the existing stormwater management system, causing ponding, flooding, and flash flooding that could damage the assets and close roads.	2	Flooding of stormwater management system would cause limited damage and loss of service assuming drainage system is designed in accordance with MTO Highway Drainage Design Standards, which accommodated future precipitation events. Assumed robust emergency response plan.	3	3	3	3	6	Low Risk	6	Low Risk	6	Low Risk	6	Low Risk
Stormwater Management Infrastructure	Changes in snowfall	Max 1-day snowfall	Changes in snowfall events and associated snowmelt may result in increased flooding events which may lead to debris blocking drainage systems. This could result in flash flooding and slope failures. Snowmelt associated flooding events could wash out soil in stormwater management systems.	2	Flooding of stormwater management system due to flash snowmelt would cause limited damage and loss of service assuming drainage system is designed in accordance with MTO Highway Drainage Design Standards, which accommodated future precipitation events. Assumed robust emergency response plan.	3	3	3	2	6	Low Risk	6	Low Risk	6	Low Risk	4	Low Risk
Stormwater Management Infrastructure	Overland flooding	Days above 20 mm rain	Overland flooding events could cause excessive vegetation and debris to block the drainage systems, causing flash flooding and slope failures. Overland flooding events could wash out soil in stormwater management systems.	2	Flooding of stormwater management system would cause localized damage and loss of service assuming drainage system is designed in accordance with MTO Highway Drainage Design Standards, which accommodated future precipitation events. Assumed robust emergency response plan.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Static Overhead and Roadside Signage	Extreme Cold	Cold spell duration indicator (-15 deg C)	Extended cold spells could cause an increase in frost heave, which could disrupt the signage footings, causing increased need for maintenance and repair.	1	Not likely to cause damage or service disruption assuming robust monitoring and maintenance in place.	2	2	1	1	2	Negligible Risk	2	Negligible Risk	1	Negligible Risk	1	Negligible Risk

Infrastructure	Climate Variable	Climate Indicator	Focus Risk	Consequence	Consequence Score Rationale	Likelihood Score				Risk Score							
						2050s		2080s		2050s				2080s			
						SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5		SSP5-8.5		SSP2-4.5		SSP5-8.5	
Static Overhead and Roadside Signage	Freeze-Thaw Cycles	Daily freeze-thaw cycles	Freeze-thaw could impact the concrete foundation for the sign causing it to potentially subside.	1	Not likely to cause damage or service disruption assuming robust monitoring and maintenance in place.	2	2	2	2	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk
Static Overhead and Roadside Signage	Extreme Rainfall	Max 1-day precipitation event	Heavy rainfall could cause physical damage to signage, causing increased need for repair and replacement.	1	Not likely to cause damage or service disruption assuming robust monitoring and maintenance in place.	3	3	3	3	3	Low Risk	3	Low Risk	3	Low Risk	3	Low Risk
Static Overhead and Roadside Signage	Freezing Rain	Assessed Semi-Qualitatively	Freezing rain could cause physical damage to signage, causing increased need for repair or replacement.	1	Not likely to cause damage or service disruption assuming robust monitoring and maintenance in place.	Not Available	3	Not Available	3	Not Available	Not Available	3	Low Risk	Not Applicable	Not Available	3	Low Risk
Static Overhead and Roadside Signage	Extreme Wind	Max daily wind speed	Extreme wind could cause physical damage to signage, causing increased need for repair or replacement.	2	Could cause localized damage and loss of service, repairable within maintenance budget assuming robust monitoring and maintenance in place.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	6	Low Risk
Static Overhead and Roadside Signage	Lightning	Assessed Semi-Qualitatively	Lightning could cause power outages, causing signage to be down.	2	Lightning causing power outages could cause localized disruption with need for maintenance.	Not Available	3	Not Available	4	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	8	Medium Risk
Static Overhead and Roadside Signage	Overland flooding	Days above 20 mm rain	Overland flooding could cause physical damage to signage, causing increased need for repair or replacement.	1	Not likely to cause damage or service disruption assuming robust monitoring and maintenance in place that considers climate change.	3	3	3	4	3	Low Risk	3	Low Risk	3	Low Risk	4	Low Risk
Static Overhead and Roadside Signage	Wildfires	Fire Weather Index above 10	Wildfire could cause physical damage to signage, causing need for repair or replacement.	2	Wildfire could cause localized infrastructure disruption with no permanent damage, considering location and wildfire risk around road signage. Robust monitoring and maintenance considering climate change would mean that any damage that does occur would be within maintenance budget.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Illumination and Traffic Signal Infrastructure	Extreme Heat	Heat wave duration (above 35 deg C)	Extreme heat or extreme cold events could cause power outages and blackouts resulting in network disruption and failure of highway illumination infrastructure.	2	Extreme heat or cold cause power outages could cause localized disruptions, with no permanent damage. Repairs could be undertaken with planned maintenance budget, assuming robust maintenance and monitoring in place.	4	4	4	5	8	Medium Risk	8	Medium Risk	8	Medium Risk	10	Medium Risk
Illumination and Traffic Signal Infrastructure	Extreme Cold	Cold spell duration indicator (-15 deg C)	Extreme heat or extreme cold events could cause power outages and blackouts resulting in network disruption and failure of highway illumination infrastructure.	2	Extreme heat or cold cause power outages could cause localized disruptions, with no permanent damage. Repairs could be undertaken with planned maintenance budget, assuming robust maintenance and monitoring in place.	2	2	1	1	4	Low Risk	4	Low Risk	2	Negligible Risk	2	Negligible Risk
Illumination and Traffic Signal Infrastructure	Freeze-Thaw Cycles	Daily freeze-thaw cycles	Freeze-thaw cycles could cause deterioration or damage to concrete which is a structural component in some illumination. This could cause increased need for repair.	1	Not likely to cause damage or service disruption assuming robust monitoring and maintenance in place.	2	2	2	2	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk
Illumination and Traffic Signal Infrastructure	Extreme Rainfall	Max 1-day precipitation event	Heavy rainfall could cause physical damage to illumination, causing increased need for repair and replacement.	1	Not likely to cause damage or service disruption assuming robust monitoring and maintenance in place.	3	3	3	3	3	Low Risk	3	Low Risk	3	Low Risk	3	Low Risk
Illumination and Traffic Signal Infrastructure	Freezing Rain	Assessed Semi-Qualitatively	Freezing rain could cause power outages and blackouts resulting in network disruption and failure of highway illumination infrastructure.	2	Could cause localized damage and loss of service, repairable within maintenance budget assuming robust monitoring and maintenance in place.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	6	Low Risk
Illumination and Traffic Signal Infrastructure	Extreme Wind	Max daily wind speed	Extreme wind associated with storms could cause damage to illumination with need for repair or replacement.	2	Could cause localized damage and loss of service, repairable within maintenance budget assuming robust monitoring and maintenance in place.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	6	Low Risk
Illumination and Traffic Signal Infrastructure	Lightning	Assessed Semi-Qualitatively	Lightning could cause power outages, causing lighting to be down.	3	Lightning causing power outages could cause localized disruption with need for maintenance.	Not Available	3	Not Available	4	Not Available	Not Available	9	Medium Risk	Not Applicable	Not Available	12	High Risk
Illumination and Traffic Signal Infrastructure	Overland flooding	Days above 20 mm rain	Overland flooding could cause physical damage to illumination, causing increased need for repair or replacement.	2	Could cause localized damage and loss of service, repairable within maintenance budget assuming robust monitoring and maintenance in place that considers climate change.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Illumination and Traffic Signal Infrastructure	Wildfires	Fire Weather Index above 10	Wildfire could cause damage to illumination causing need for repair and replacement.	2	Wildfire could cause localized infrastructure disruption with no permanent damage, considering location and wildfire risk around illumination and traffic signal infrastructure. Robust monitoring and maintenance considering climate change would mean that any damage that does occur would be within maintenance budget.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk

Infrastructure	Climate Variable	Climate Indicator	Focus Risk	Consequence	Consequence Score Rationale	Likelihood Score				Risk Score							
						2050s		2080s		2050s				2080s			
						SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5		SSP5-8.5		SSP2-4.5		SSP5-8.5	
Advanced Traffic Management Systems (ATMS) Infrastructure	Extreme Heat	Heat wave duration (above 35 deg C)	Extreme heat and extreme cold events could degrade electronic boards, overheat systems, and cause controller failures, resulting in network disruption, impacting the ATMS.	2	Could result in localized infrastructure disruption, no permanent damage, repairable through planned operations and maintenance budget, assuming robust monitoring and maintenance including of climate change considerations in place.	4	4	4	5	8	Medium Risk	8	Medium Risk	8	Medium Risk	10	Medium Risk
Advanced Traffic Management Systems (ATMS) Infrastructure	Extreme Cold	Cold spell duration indicator (-15 deg C)	Extended cold spells could cause an increase in frost heave, which could disrupt the signage footings, causing increased need for maintenance and repair.	1	Not likely to cause damage or service disruption assuming robust monitoring and maintenance in place.	2	2	1	1	2	Negligible Risk	2	Negligible Risk	1	Negligible Risk	1	Negligible Risk
Advanced Traffic Management Systems (ATMS) Infrastructure	Freeze-Thaw Cycles	Daily freeze-thaw cycles	Freeze-thaw cycles could cause deterioration or damage to concrete which is a structural component of some ATMS infrastructure. This could cause increased need for repair.	2	Could result in localized infrastructure disruption, no permanent damage, repairable through planned operations and maintenance budget, assuming robust monitoring and maintenance including of climate change considerations in place.	2	2	2	2	4	Low Risk	4	Low Risk	4	Low Risk	4	Low Risk
Advanced Traffic Management Systems (ATMS) Infrastructure	Extreme Rainfall	Max 1-day precipitation event	Heavy rainfall could cause physical damage to signage, causing increased need for repair and replacement. Water ingress during extreme precipitation events could damage the ATMS infrastructure and electronic components causing network disruption.	2	Could result in localized infrastructure disruption, no permanent damage, repairable through planned operations and maintenance budget, assuming robust monitoring and maintenance including of climate change considerations in place.	3	3	3	3	6	Low Risk	6	Low Risk	6	Low Risk	6	Low Risk
Advanced Traffic Management Systems (ATMS) Infrastructure	Freezing Rain	Assessed Semi-Qualitatively	Freezing rain causing ice accretion could cause damage to ATMS, leading to down time. Additionally, freezing rain could cause power outages resulting in downtime.	2	Could result in localized infrastructure disruption, no permanent damage, repairable through planned operations and maintenance budget, assuming robust monitoring and maintenance including of climate change considerations in place.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	not applicable	Not Available	6	Low Risk
Advanced Traffic Management Systems (ATMS) Infrastructure	Lightning	Assessed Semi-Qualitatively	Lightning could cause power outages, causing signage to be down.	3	Lightning causing power outages could cause limited damage and loss of service. Repairable with minor maintenance which may be outside of maintenance budget.	Not Available	3	Not Available	4	Not Available	Not Available	9	Medium Risk	Not Applicable	Not Available	12	High Risk
Advanced Traffic Management Systems (ATMS) Infrastructure	Overland flooding	Days above 20 mm rain	Overland flooding could cause physical damage to signage, causing increased need for repair or replacement.	2	Could result in localized infrastructure disruption, no permanent damage, repairable through planned operations and maintenance budget, assuming robust monitoring and maintenance including of climate change considerations in place.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Advanced Traffic Management Systems (ATMS) Infrastructure	Wildfires	Fire Weather Index above 10	Power outages associated with wildfires could impact ATMS, resulting in blackouts, network disruption, and traffic jams.	2	Wildfire could cause localized infrastructure disruption with no permanent damage, considering location and wildfire risk around ATMS infrastructure. Robust monitoring and maintenance considering climate change would mean that any damage that does occur would be within maintenance budget.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Road Maintenance Activities	Extreme Heat	Heat wave duration (above 35 deg C)	Increase in extreme heat events could limit the number of hours road crew can work due to health and safety concerns for the highway workers. Pavement damage and buckling due to extreme heat could disrupt vehicle movements necessary for maintenance activities. Increase in the frequency and intensity of heat waves could impact establishing of new vegetation and landscaping during the maintenance activities.	3	Extreme heat could impact worker health and safety, causing minor safety risk. Could also cause limited loss of service for road maintenance.	4	4	4	5	12	High Risk	12	High Risk	12	High Risk	15	High Risk
Road Maintenance Activities	Freeze-Thaw Cycles	Daily freeze-thaw cycles	Pavement damage and buckling due to freeze-thaw cycles could disrupt vehicle movements necessary for maintenance activities.	1	Pavement damage from freeze-thaw would likely be undertaken within regular maintenance.	2	2	2	2	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk
Road Maintenance Activities	Extreme Rainfall	Max 1-day precipitation event	Extreme precipitation and associated runoff could wash contaminants from maintenance work sites into nearby waterways, causing contamination.	2	Contaminant washing from road maintenance activities could cause minor, localized environmental impacts not requiring remediation.	3	3	3	3	6	Low Risk	6	Low Risk	6	Low Risk	6	Low Risk
Road Maintenance Activities	Changes in snowfall	Max 1-day snowfall	Changes in snowfall events and winter storms could result in slippery surfaces, causing delays in maintenance activities.	1	Assuming robust snow clearing activities, not likely to cause damage or disruption.	3	3	3	2	3	Low Risk	3	Low Risk	3	Low Risk	2	Negligible Risk

Infrastructure	Climate Variable	Climate Indicator	Focus Risk	Consequence	Consequence Score Rationale	Likelihood Score				Risk Score							
						2050s		2080s		2050s				2080s			
						SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5		SSP5-8.5		SSP2-4.5		SSP5-8.5	
Road Maintenance Activities	Freezing Rain	Assessed Semi-Qualitatively	Freezing rain could cause ice accretion, increasing road maintenance activities. Could impact access to the highways and road maintenance activities.	1	Assuming a robust emergency response plan, and robust snow/ice clearing practices, there would be no service disruption.	Not Available	3	Not Available	3	Not Available	Not Available	3	Low Risk	Not Applicable	Not Available	3	Low Risk
Road Maintenance Activities	Overland flooding	Days above 20 mm rain	Overland flooding could wash contaminants from maintenance work sites into nearby waterways, causing contamination.	2	Contaminant washing from road maintenance activities could cause minor, localized environmental impacts not requiring remediation.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Road Maintenance Activities	Wildfires	Fire Weather Index above 10	Wildfire could impact access to the highways and road maintenance activities.	2	Wildfire could cause localized disruption for maintenance activities with no permanent damage. Assuming robust emergency response plans in place, there would be no health and safety risk.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Environmental mitigations and compensation features	Extreme Heat	Heat wave duration (above 35 deg C)	Extreme heat could cause die off of vegetation in mitigation/compensation features. This could cause need for re-planting/seeding, and could impact selection of species for compensation and mitigation.	1	Assuming robust monitoring and maintenance, need for replanting in compensation areas due to die off of vegetation would be undertaken through regular maintenance.	4	4	4	5	4	Low Risk	4	Low Risk	4	Low Risk	5	Low Risk
Environmental mitigations and compensation features	Extreme Rainfall	Max 1-day precipitation event	Extreme rainfall could cause flooding and damage to mitigation/compensation features, for example bank stabilization, and planted vegetation. Could cause increased need for maintenance.	1	Assuming robust monitoring and maintenance, need for replanting in compensation areas due to die off of vegetation, or additional measures would be undertaken through regular maintenance.	3	3	3	3	3	Low Risk	3	Low Risk	3	Low Risk	3	Low Risk
Environmental mitigations and compensation features	Overland flooding	Days above 20 mm rain	Overland flooding could damage mitigation/compensation features such as seeding and planting efforts and bank stabilization. This could cause increased need for maintenance.	1	Assuming robust monitoring and maintenance, need for replanting in compensation areas due to die off of vegetation, or additional measures would be undertaken through regular maintenance.	3	3	3	4	3	Low Risk	3	Low Risk	3	Low Risk	4	Low Risk
Environmental mitigations and compensation features	Wildfires	Fire Weather Index above 10	Wildfires could cause die-off of vegetation planted as a part of mitigation/compensation areas. This could cause need for re-planting and seeding or reforestation.	2	Die off of vegetation due to wildfire could cause need for replanting however this would be within maintenance budget considering robust maintenance plan considering climate change.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Electric charging stations	Extreme Heat	Heat wave duration (above 35 deg C)	Extreme heat could burn out electrical equipment or cause electrical equipment to overheat. This would cause damage and need to maintenance and repairs.	2	Could result in localized infrastructure disruption, no permanent damage, repairable through planned operations and maintenance budget, assuming robust monitoring and maintenance including of climate change considerations in place.	4	4	4	5	8	Medium Risk	8	Medium Risk	8	Medium Risk	10	Medium Risk
Electric charging stations	Extreme Cold	Cold spell duration indicator (-15 deg C)	Extreme cold could reduce efficiency of charging speed, causing longer charging times.	1	No infrastructure damage or service disruption, no required repairs.	2	2	1	1	2	Negligible Risk	2	Negligible Risk	1	Negligible Risk	1	Negligible Risk
Electric charging stations	Freeze-Thaw Cycles	Daily freeze-thaw cycles	Freeze-thaw cycles could cause increased frost heave which could cause damage and increased need for repairs or maintenance.	1	Increased frost heave causing damage could be maintained within existing maintenance budget assuming robust monitoring and maintenance including climate change consideration.	2	2	2	2	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk
Electric charging stations	Extreme Rainfall	Max 1-day precipitation event	Extreme rainfall could result in flooding, causing damage to electrical charging stations. This could cause increased need for repair and replacement.	2	Flooding from extreme rainfall could cause localized infrastructure disruption with some potential for minor repairs, within planned maintenance budget assuming robust monitoring and maintenance plan inclusive of climate change consideration.	3	3	3	3	6	Low Risk	6	Low Risk	6	Low Risk	6	Low Risk
Electric charging stations	Freezing Rain	Assessed Semi-Qualitatively	Freezing rain could cause damage to EV charging stations, causing increased need for maintenance and repairs.	2	Could result in localized infrastructure disruption, no permanent damage, repairable through planned operations and maintenance budget, assuming robust monitoring and maintenance including of climate change considerations in place.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	6	Low Risk
Electric charging stations	Lightning	Assessed Semi-Qualitatively	Lightning could cause power outages, causing inability for vehicles to be charged.	2	Lightning causing power outages could cause localized disruption of services. Minor restoration work could be required, within maintenance budget, assuming robust maintenance plan considering climate change.	Not Available	3	Not Available	4	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	8	Medium Risk
Electric charging stations	Overland flooding	Days above 20 mm rain	Overland flooding could cause damage to electrical charging stations. This could cause increased need for repair and replacement.	2	Could result in localized infrastructure disruption, no permanent damage, repairable through planned operations and maintenance budget, assuming robust monitoring and maintenance including of climate change considerations in place.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk

Infrastructure	Climate Variable	Climate Indicator	Focus Risk	Consequence	Consequence Score Rationale	Likelihood Score				Risk Score							
						2050s		2080s		2050s				2080s			
						SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5		SSP5-8.5		SSP2-4.5		SSP5-8.5	
Electric charging stations	Wildfires	Fire Weather Index above 10	Wildfire could cause damage to electrical charging stations. This could cause increased need for repair and replacement. It could also cause issues accessing charging stations due to road blockages associated with wildfires.	3	Wildfire could cause limited damage to charging stations will loss of infrastructure beyond planned maintenance. Could result in a safety risk to users who cannot access charging stations, getting stranded.	3	3	3	4	9	Medium Risk	9	Medium Risk	9	Medium Risk	12	High Risk
Roadside safety infrastructure	Extreme Heat	Days above 39 degC	Extreme heat could deteriorate concrete structures such as concrete barriers, and cause need for increased repairs and maintenance.	1	Concrete damage from extreme heat would likely be undertaken within regular maintenance assuming robust maintenance plans in place considering climate change.	3	3	3	4	3	Low Risk	3	Low Risk	3	Low Risk	4	Low Risk
Roadside safety infrastructure	Extreme Cold	Cold spell duration indicator (-15 deg C)	Extreme cold could cause increased frost penetration, which could cause increased heave, cause damage and need for repairs and maintenance.	1	Concrete damage from frost heave would likely be undertaken within regular maintenance assuming robust maintenance plans in place considering climate change.	2	2	1	1	2	Negligible Risk	2	Negligible Risk	1	Negligible Risk	1	Negligible Risk
Roadside safety infrastructure	Freeze-Thaw Cycles	Daily freeze-thaw cycles	Freeze-thaw cycles could cause increased frost heave, which could cause damage and need for repairs and maintenance.	1	Concrete damage from frost heave would likely be undertaken within regular maintenance assuming robust maintenance plans in place considering climate change.	2	2	2	2	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk
Roadside safety infrastructure	Extreme Rainfall	Max 1-day precipitation event	Extreme rainfall could result in flooding, causing damage to roadside safety infrastructure. This could cause increased need for repair and replacement.	2	Flooding of roadside safety equipment could lead to localized disruption with some minor restoration work required that could be within the planned maintenance assuming robust maintenance plan in place considering climate change.	3	3	3	3	6	Low Risk	6	Low Risk	6	Low Risk	6	Low Risk
Roadside safety infrastructure	Changes in snowfall	Total snowfall	Changes in snowfall could change snow clearing needs from highway, which could cause damage to roadside safety infrastructure and increase need for repair.	2	Could result in localized infrastructure disruption, no permanent damage, repairable through planned operations and maintenance budget, assuming robust monitoring and maintenance including of climate change considerations in place.	2	2	2	2	4	Low Risk	4	Low Risk	4	Low Risk	4	Low Risk
Roadside safety infrastructure	Overland flooding	Days above 20 mm rain	Overland flooding could cause damage to roadside safety infrastructure. This could cause increased need for repair and replacement.	2	Flooding of roadside safety equipment could lead to localized disruption with some minor restoration work required that could be within the planned maintenance assuming robust maintenance plan in place considering climate change.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Overhead and underground utilities	Extreme Cold	Cold spell duration indicator (-15 deg C)	Extended cold spells could cause an increase in frost heave, which could disrupt the utility footings, causing increased need for maintenance and repair.	1	Not likely to cause damage or service disruption assuming robust monitoring and maintenance in place.	2	2	1	1	2	Negligible Risk	2	Negligible Risk	1	Negligible Risk	1	Negligible Risk
Overhead and underground utilities	Freeze-Thaw Cycles	Daily freeze-thaw cycles	Freeze thaw cycles could cause deterioration or damage to concrete which is a structural component in some utilities and illumination. This could cause increased need for repair.	1	Not likely to cause damage or service disruption assuming robust monitoring and maintenance in place.	2	2	2	2	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk	2	Negligible Risk
Overhead and underground utilities	Extreme Rainfall	Max 1-day precipitation event	Heavy rainfall could cause physical damage to utilities, causing increased need for repair and replacement.	2	Could cause localized damage and loss of service, repairable within maintenance budget assuming robust monitoring and maintenance in place.	3	3	3	3	6	Low Risk	6	Low Risk	6	Low Risk	6	Low Risk
Overhead and underground utilities	Freezing Rain	Assessed Semi-Qualitatively	Freezing rain causing ice accretion could cause physical damage to utilities, causing increased need for repair or replacement.	2	Could result in localized infrastructure disruption, no permanent damage, repairable through planned operations and maintenance budget, assuming robust monitoring and maintenance including of climate change considerations in place.	Not Available	3	Not Available	3	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	6	Low Risk
Overhead and underground utilities	Lightning	Assessed Semi-Qualitatively	Lightning could strike overhead utilities, causing loss of utility, need for repair or replacement.	2	Could cause localized damage and loss of service, repairable within maintenance budget assuming robust monitoring and maintenance in place.	Not Available	3	Not Available	4	Not Available	Not Available	6	Low Risk	Not Applicable	Not Available	8	Medium Risk
Overhead and underground utilities	Overland flooding	Days above 20 mm rain	Overland flooding could cause physical damage to utilities, causing increased need for repair or replacement.	2	Could cause localized damage and loss of service, repairable within maintenance budget assuming robust monitoring and maintenance in place.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk
Overhead and underground utilities	Wildfires	Fire Weather Index above 10	Wildfire could cause damage to utilities causing need for repair and replacement.	2	Wildfire could cause localized disruption for utilities with no permanent damage. Assuming robust emergency response plans in place that are inclusive of climate change, there would be no health and safety risk.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk

Infrastructure	Climate Variable	Climate Indicator	Focus Risk	Consequence	Consequence Score Rationale	Likelihood Score				Risk Score							
						2050s		2080s		2050s				2080s			
						SSP2-4.5	SSP5-8.5	SSP2-4.5	SSP5-8.5	SSP2-4.5		SSP5-8.5		SSP2-4.5		SSP5-8.5	
Landscaping	Extreme Heat	Heat wave duration (above 35 deg C)	Extreme heat could impact vegetation used in landscaping, and could cause die off of vegetation. This could cause need for re-vegetation or increased maintenance.	1	Assuming robust monitoring and maintenance, need for replanting in landscaping due to die off of vegetation would be undertaken through regular maintenance.	4	4	4	5	4	Low Risk	4	Low Risk	4	Low Risk	5	Low Risk
Landscaping	Extreme Rainfall	Max 1-day precipitation event	Extreme rainfall could cause damage to landscaping features such as vegetation. This could cause increased landscaping maintenance.	1	Assuming robust monitoring and maintenance, need for replanting landscaping due to die off of vegetation, or additional measures would be undertaken through regular maintenance.	3	3	3	3	3	Low Risk	3	Low Risk	3	Low Risk	3	Low Risk
Landscaping	Overland flooding	Days above 20 mm rain	Overland flooding could cause physical damage to landscaping features, causing increased need for repair or replacement.	1	Assuming robust monitoring and maintenance, need for replanting landscaping due to die off of vegetation, or additional measures would be undertaken through regular maintenance.	3	3	3	4	3	Low Risk	3	Low Risk	3	Low Risk	4	Low Risk
Landscaping	Wildfires	Fire Weather Index above 10	Wildfire could cause physical damage to landscaping features such as causing die-off of vegetation, causing increased need for repair or replacement.	2	Die off of vegetation due to wildfire could cause need for replanting however this would be within maintenance budget considering robust maintenance plan considering climate change.	3	3	3	4	6	Low Risk	6	Low Risk	6	Low Risk	8	Medium Risk

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