APPENDIX B – SWRC CLIMATE CHANGE RESILIENCE ASSESSMENT AND GREENHOUSE GAS MITIGATION ASSESSMENT

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The City of Winnipeg

South Winnipeg Recreation Campus

Climate Lens:

Climate Change Resilience Assessment and Greenhouse Gas Mitigation Assessment

Project number: 60658161

July 15, 2021

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Executive Summary

The City of Winnipeg (the "City") is preparing and planning the construction of a new recreation campus. To complete the planning and design of the South Winnipeg Recreation Campus (SWRC), the City has retained AECOM and has requested the completion of a Climate Lens Assessment to assess climate change impacts on the project and to evaluate the impacts of the project's GHG emissions on climate change. The Climate Lens has two components:

1) The Climate Change Resilience Assessment (CCRA), which employs a risk management approach to anticipate, prevent, withstand, respond to, and recover from a climate change related disruption or impact; and.
2) The Greenhouse Gas (GHG) mitigation assessment, which estimates the anticipated GHG emissions impact of an infrastructure project;

Climate Change Resilience Assessment

The objective of conducting a climate change resilience assessment is to evaluate impacts that climate change may have on the South Winnipeg Recreation Campus (SWRC) project components (6 in total) in terms of health and safety impacts, operational impacts, infrastructure integrity, and financial impacts. The CCRA section presents the methodology and standard used to undertake the assessment, the results of the risk evaluation associated to the interactions between certain climate conditions and the selected project components. With these results in mind, the project team proposed adaptation measures for the design and operations and maintenance phases, in order for the SWRC to be more resilient to the future climate. Documents and conceptual design plans were reviewed to understand the future infrastructure and select the components that would potentially be impacted by climate change. The six (6) project components that guided the assessment are:

1) Building elements
2) Mechanical equipment and HVAC system
3) Power distribution, communication and electrical equipment
4) Utilities
5) Exterior elements
6) People

The climate data analysis was carried out using temperature and precipitation data collected from the Canadian Centre for Climate Services (CCCS) from the weather station based at the Winnipeg Richardson International Airport, including climate means over the 1981-2010 period. The high carbon future (RCP 8.5) scenario was selected as it represents the worst-case scenario, which would overestimate the associated risk and be a more conservative approach. Given that the service life of the structural elements of the SWRC will be 50 years spanning from 2025 to 2074, climate projections were analyzed until 2080, using the 2061-2080 projection timeframe.

In order to determine the climate-related risks to the SWRC, climate indicators and their probabilities of occurring were analyzed for both the historical period (1981-2010) and in the context of the changing climate. First, a total of 25 climate indicators were reviewed at a high-level to estimate the likelihood of climate risks to the project. As a result of this initial review, 15 climate indicators were removed from the analysis as they were considered to have no impact or a very low impact on the project. Ten (10) indicators were selected according to:

- Climate indicators identified in past extreme weather events: past extreme weather events were researched and provided insights on which climate indicators are relevant to the future infrastructure.
- Historical and future annual and seasonal variation for both temperature and precipitation were reviewed and provided insights on future trends
- Relevant climate indicators showing significant increases in probability during the project's timeframe

- Relevance of climate indicators to local reality
- Potential interactions of a certain climate condition with a project component

The ten climate indicators considered in the next step of the assessment are:

1) **Hot temperature**: Days with Tmax ≥ 30°C
2) **Heat wave**: Instances of 3 days with Tmin ≥ 20°C and Tmax ≥ 33°C
3) **Cold temperature**: Days with Tmin ≤ -30°C
4) **Diurnal variation**: Days with Tmax -Tmin ≥ 20°C
5) **Heavy rainfall**: Days with P ≥ 25mm
6) **Snow accumulation**: Instances of SD ≥ 38cm for 5 days
7) **Drought:** Instance of P < 0.2mm for 10 days
8) **Heavy wind**: Days with W ≥ 65km/h
9) **Blowing rain:** Instances of (P ≥ 5mm) and (W ≥ 65km/h)
10) **Blowing snow:** Instances of ((S ≥ 5cm) or (SD ≥ 5cm)) and (W ≥ 65km/h)

Summary of climate change risk analysis

Climate change vulnerability was first assessed, in order to determine the exposure, sensitivity and adaptive capacity of each element to the 10 climate indicators. The risk assessment was conducted to evaluate the impacts of the climate indicators on each of the project components listed above, using an impact ranking matrix from *very low (1)* to *very high (5)* severity of consequences according to four different impact categories, namely health and safety, infrastructure integrity, operational impacts, and financial impacts.

The risk assessment revealed 49 interactions showing risks out of 60 possible interactions, between the 10 climate indicators and the six (6) project components.

Summary of Risk Interactions

Level of risk	1981-2010	2061-2080
Low risk interactions	9	6
Moderate risk interactions	29	34
High risk interactions	0	0
Special cases	11	9
Total	**49**	**49**

From the 1981-2010 towards the 2061-2080 timeframes, five (5) low risk interactions became moderate risk interactions, three (3) special cases became low risk interactions and one (1) low risk interaction became a special case.

Summary of risk treatment and adaptation measures

Key project recommendations from the climate change resilience assessment for the South Winnipeg Recreation Facilities were identified based on the following three types of measures:

- **Design**: Measures to incorporate in the design of assets for these to be resilient to future climate risks.
- **Operations and Maintenance (O&M)**: Measures to incorporate in order for the facility to reach resiliency in its Operations and Maintenance.
- **Policy**: Measures to provide and maintain safe and healthy working conditions.

Greenhouse Gas (GHG) Mitigation Assessment

The greenhouse gas (GHG) mitigation assessment section details the Project's GHG emissions inventory in 2030 and over the asset's lifespan, including both construction as well as Operations and Maintenance (O&M) phases. This section includes a list of GHG emissions sources, and the quantity of emissions anticipated to be released from each source during the asset's lifespan.

The results of this assessment estimate that for the baseline case, emissions from the construction phase are expected to be 1,189 tonnes of CO_2-equivalent (tCO_2e) and 17,693 tCO_2e for the operation and maintenance phase. The Project is anticipated to emit approximately 1,189 tCO_2e during its construction phase and 13,331 tCO_2e during the operation and maintenance phase, spanning 50 years from 2025 to 2074. The GHG reduction cost for 2030 is $362,923/$tCO_2e$ (non-cumulative basis). Over the lifespan of the Project, the GHG reduction cost is $22,336/$tCO_2e$.

This GHG Assessment has been developed in accordance with CAN/CSA-ISO Standard 14064-2:06 Greenhouse Gases – Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements. The GHG assertions presented in this report have not undergone third-party verification.

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Appendix

1. Introduction

1.1 Climate Lens

The City of Winnipeg (the “City”) is preparing and planning the construction of a new recreation campus. To the planning and design of the South Winnipeg Recreation Campus (SWRC), the City has requested the completion of a Climate Lens Assessment, which consists of two components:

The Climate Change Resilience Assessment; and

The Greenhouse Gas Mitigation Assessment.

1.2 Project Overview

The City of Winnipeg (City) is proposing to develop a South Winnipeg Recreation Campus (SWRC) on a site of approximately 77 acres in the southwest of Winnipeg commonly referred to as Waverley West. The SWRC is being developed in phases, with the first phase including a recreation facility with a daycare, a vocational school attached to the adjacent high school, a community spray pad, associated parking and overall site development. Future phases of the SWRC envision athletic fields, pool complex, community library, and possible twin arena facility, along with a potential firehall.

1.3 Project Details

AECOM will use information provided by the City including the South Winnipeg Recreation Campus Feasibility Study completed by Gibbs Gage Architects (Feasibility Study), May 2019. At this time, the Feasibility Study has not been refreshed to consider the revised phasing of the SWRC. The feasibility study explores the option of having the SWRC adjacent to a K-8 school and a high school. It was confirmed that there are multiple benefits of having the SWRC City Site and the Provincial School Site adjacent to each other, including the development of a campus feeling, an efficient use of space, shared field space and shared parking strategies. In addition, the Feasibility Study indicates that the project would seek LEEDs Gold certification which is an aspirational goal for the project at this time and will need to be affirmed as the City’s intent for the project.

1.3.1 Location of the SWRC Project

An initial location for the South Winnipeg Recreation Campus was discussed with joint-use site planning for the SWRC City Site and the Provincial School Site. Figure 1-1 illustrate the initial location (Provincial Site in orange and City Site in green) and the revised location (where the initial Provincial site is shown in red and both the City Site and the new Provincial Site are shown in green) for the City Site and the Provincial School Site. The entire area, including the South Winnipeg Recreation Campus Site is protected by the Red River Floodway which was built in the 1960s. Being beyond the scope of the CCRA, the diversion channel protecting the area will not be included in this assessment.

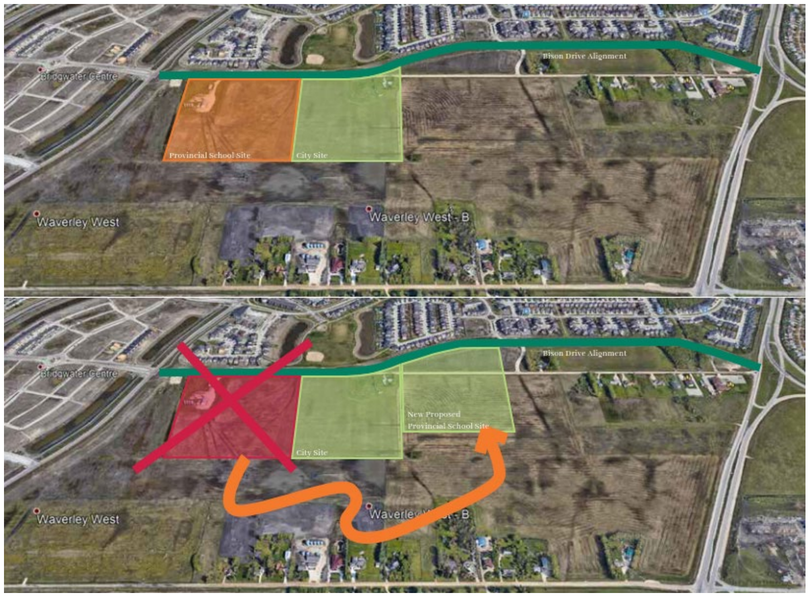


Figure 1- 1: Initial and Revised Location for the City Site and the Provincial School Site
(Source: Gibbs Gage Architects, 2019)[1]

The SWRC Project will be located within the Waverley West. The Area is bounded by Waverley Street and Kenaston Boulevard to the east and the west, by Bison Drive to the north, and by the neighbourhood of South Pointe to the south. The Bison Drive alignment provides direct connections to the retail district of Bridgwater Centre and the University of Manitoba campus. The SWRC is also well connected to the neighbourhood of Waverley Heights and Bridgwater Forest, Centre, Lakes and Trail. Figure 1-2 gives maps out the area, where the SWRC's boundary is delimited in bright pink.

Figure 1- 2: Context Map for the SWRC Location
(Source: Gibbs Gage Architects, 2019)

[1] Gibbs Gage Architects. (2019). *South Winnipeg Recreation Campus: Feasibility study* (Report Project No 18059). City of Winnipeg

1.3.2 Phase 1

The SWRC was determined to be developed in multiple phases due to the scale of the project and urgent need of certain amenities, such as multi purpose spaces, gyms and aquatics.

The first phase of the project would include he construction of the Winnipeg Public Library, the YMCA, the Common Area and the Daycare. The components of Phase 1 of the SWRC include the following:

- A recreation facility of 60,000sf facility with three gymnasium field house, mezzanine 200m track and fitness areas, multi-purpose rooms, offices, and change rooms;
- A childcare facility of approximately 15,000sf incorporated into the recreation facility;
- A vocational wing of 16,489sf fully integrated into the adjacent high school;
- A 5,000sf community spray pad and landscaping in the immediate vicinity of the Phase 1 components;
- Site development and servicing (roads, and utilities);
- Internal site services; and
- Interior road and parking (200 to 250 stalls).

The SWRC Project is expected to obtain approval of ICIP funding and agreement by January 1st, 2022 in order to start construction by summer 2023 and Phase 1 completion by late 2024.

1.3.3 Phase 2

The second phase of the SWRC would include a lap pool, a leisure pool, and the construction of the twin ice arena. Phase 2 is beyond the scope of this Climate Lens Resilience Assessment and this Greenhouse Gas Mitigation Assessment.

2. Climate Change Resilience Assessment

The Climate Change Resilience Assessment (CCRA) has been performed in the context of a preliminary screening to provide input and direction for the design, construction and operations and maintenance of the South Winnipeg Recreation Campus, for Phase 1. A CCRA typically involves adopting a risk management approach to a) anticipate climate change related risks that may impact on the assets or activities under study, and b) identify potential design features or actions to help prevent, withstand, respond to, recover from and adapt to these risks. The CCRA carried out for this Project is based on details in the South Winnipeg Recreation Campus Feasibility Study, a report done by Gibbs Gage Architects (Gibbs Gage Architects, 2019).

2.1 Methodology

The CCRA was undertaken following the five key steps described in the Climate Lens General Guidance[2], based on the ISO 31000 Risk Management Standard. These steps are described below:

1. **Establishing the context:**
    a. Establish the context of the climate risk assessment.
    b. Data collection on project phases and asset components; past experience of extreme weather events and climate data collection and analysis including climate change projections.

2. **Risk Identification:**

[2] Infrastructure Canada, 2019, Climate Lens Guidance Document, Annex G: Methodologies and Resilience Assessment Steps, https://www.infrastructure.gc.ca/pub/other-autre/cl-occ-eng.html

a. Identify potential interactions between specific climate conditions and assets, systems and surrounding environment through a vulnerability assessment.

3. **Risk Analysis:**
    a. Determine a scale of likelihood or probability of a climate condition to occur and a scale for the severity of consequences, such as low, moderate and high.
    b. Use the scales to rate the severity of consequences for each identified interaction between a certain climate condition and each asset component.

4. **Risk Evaluation:**
    a. Compare, evaluate and rank each risk event and opportunity from the risk analysis results.
    b. Validate the risk analysis with the client.
    c. Prioritize risks according to this evaluation for risk treatment and adaptation measures.

5. **Risk Treatment and Adaptation Measures:**
    a. Identify risk treatment and adaptation measures.
    b. Recommend a set of adaptation measures for each phase of the project.

2.2 Establishing the Context

The scope and boundaries of the assessment encompass time periods and areas during and within which the project components are likely to interact with or be influenced by climate risks. The scope of the assessment for this project considers climate change impacts on the design as well as future operation and maintenance phases of the South Winnipeg Recreation Campus Project. The assessment does not include any indirect work that may or may not occur as a result of the project. The structural infrastructure lifespan is estimated to be about 50 years; therefore, the assessment will be carried out using the projections for 2061 to 2080.

2.2.1 Project Components

The following six project components of the South Winnipeg Recreation Campus Project were determined as relevant to the climate change resilience assessment for their potential sensitivity to certain climate conditions:

Table 2-1: List of Project Components and Elements

Project Components	Elements
Building Elements	- Roof - Exterior Walls - Windows - Exterior doors
Mechanical Equipment and HVAC System	- Heat pumps - Heat exchanger - Furnace - Boiler
Power distribution, Communication and Electrical Equipment	- Electrical power supply - Communication systems (intercoms, phones, emergency phones) - Surveillance system - Fire alarm system - Alarm system

Project Components	Elements
Utilities	-Drainage system -Sewer network -Water distribution system -Natural gas heating
Exterior Elements	-Landscaping -Spray pad (plumbing, pavement, and play structures) -Parking lots -Pavements -Pedestrian walkways -Access ramps -Exterior lighting -Signage
People	-Staff service workers -Staff for operation and maintenance -Public users of the recreation center

2.2.2 Climate Data Analysis

The climate data analysis was carried out using temperature and precipitation data collected from the Canadian Centre for Climate Services (CCCS) from the weather station based in Winnipeg Richardson International Airport including climate means over the 1981-2010 period. Figure 2-1 below presents climate normals over the 1981-2010 period for temperature (mean, minimum and maximum) and for overall precipitation and snow and rain separately.

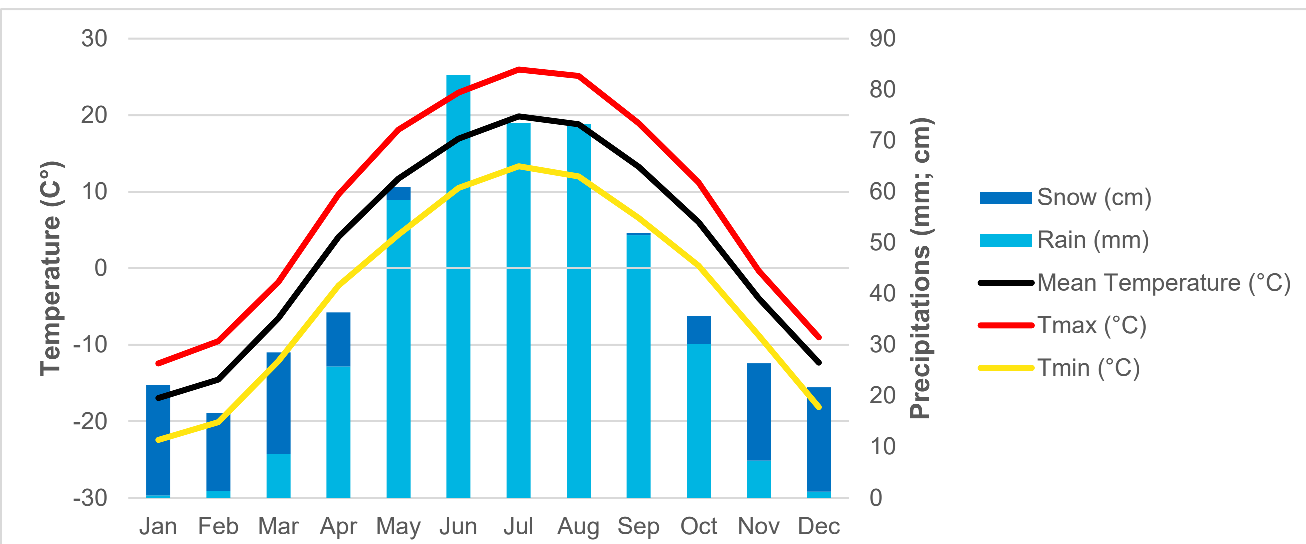


Figure 2-1: Climate Normals from the Weather Station at the Winnipeg Richardson International Airport (1981-2010)

2.2.3 Climate Projections

Climate projections are based on assumptions regarding the evolution of GHG emissions. These are referred to as Representative Concentration Pathways (RCP) and are named after their associated level of radiative forcing or difference between sunlight absorbed on Earth and what is radiated back to space. For instance, RCP 2.6, RCP 4.5, RCP 6 and RCP 8.5 correspond to 2.6, 4.5, 6 and 8.5 W/m² of radiative forcing, respectively for each scenario. Projected carbon dioxide (CO_2) concentration levels are predicted from the anticipated growth in population and energy demand (the type of energy is an important factor), as well as by the anticipated changes vegetation cover and type.[3] High level descriptions of the RCPs are below in Table 2-2.

Table 2-2: RCPs

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

(Source: IPCC, 2014.)[4]

The high carbon future (RCP 8.5) scenario was selected as it represents the worst-case scenario, which would overestimate the associated risk. Climate change projections were also retrieved from the CCCS. Given that the service life of the structural elements of the South Winnipeg Recreation Campus Project will be 50 years spanning from 2025 to 2074, climate projections were analyzed until 2080, using the 2061-2080 projection timeframe.

2.2.4 Identification of Climate Indicators

A climate indicator represents a certain climate condition or a type of event (e.g. number of hot days with + 30°C), defined by a threshold above which the evaluated infrastructure would trigger a reaction resulting in a loss of productivity, damage to the infrastructure or more intensive maintenance plan. The likelihood or probability associated with an indicator is calculated from data recorded at a weather station and applies to a historical dataset or climate prediction.

In order to determine the climate-related risks to the Project, climate indicators and their probabilities of occurring were analyzed for both the historical period (1981-2010) and in the context of the changing climate. First, a total of 25 climate indicators were reviewed at a high-level to estimate the likelihood of climate risks to the project. As a result of this initial review, 15 climate indicators were removed from the analysis as they were considered to have no impact or a very low impact on the project, as shown in Table 2-3.

Ten (10) indicators were selected according to:

- Climate indicators identified in past extreme weather events: past extreme weather events were researched and provided insights on which climate indicators are relevant to the future infrastructure.
- Historical and future annual and seasonal variation for both temperature and precipitation were reviewed and provided insights on future trends
- Relevant climate indicators showing significant increases in probability during the project's timeframe
- Relevance of climate indicators to local reality

[3] Van Vuuren et al. (2011) The representative concentration pathways: an overview. Climatic Change 109:5-31.
[4] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp

- Potential interactions of a certain climate condition with a project component

The ten climate indicators considered in the next step of the assessment are:

1) **Hot temperature**: Days with Tmax ≥ 30°C
2) **Heat wave**: Instances of 3 days with Tmin ≥ 20°C and Tmax ≥ 33°C
3) **Cold temperature**: Days with Tmin ≤ -30°C
4) **Diurnal variation**: Days with Tmax-Tmin ≥ 20°C
5) **Heavy rainfall**: Days with P ≥ 25mm
6) **Snow accumulation**: Instances of SD ≥ 38cm for 5 days
7) **Drought:** Instance of P < 0.2mm for 10 days
8) **Heavy wind**: Days with W ≥ 65km/h
9) **Blowing rain:** Instances of (P ≥ 5mm) and (W ≥ 65km/h)
10) **Blowing snow:** Instances of ((S ≥ 5cm) or (SD ≥ 5cm)) and (W ≥ 65km/h)

Most of the selected climate indicators indicate a high annual risk probability for both current (based on 1981-2010) and future timeframes (2061-2080 timeframe to cover the 2025 to 2074 lifespan of the project), therefore remaining in the "very high" likelihood (see Table 2-4, for the likelihood scoring details). This means that current protective and mitigation measures may already be included in the current design and serve for future impacts as well.

Climate projections for the City indicate that there will be a slight increase in heavy precipitation, especially in spring and winter with a probability of heavy rainfall (>25 mm per day) rising from 83% to 83.5% per year. Increase in temperatures will result in much warmer summers, with a significant increase in the probability of heat waves from 5% to 90.9% and in the probability of hot days (+30°C) increasing from 93.5% to 100% per year by 2061-2080. Probabilities of heavy winds, blowing snow and blowing rain events will all increase. The probability of cold days (Tmin < -30°C) will decrease from 93.7% to 57.3% and may be seen as an opportunity. However, it has a the "high" level of likelihood (4) and will be included in the assessment.

Table 2-3 presents data for each climate indicator for the historical mean (1961-2080) and for both timeframes of climate projections, as well as justifications for excluding 15 of the initial 25 indicators.

Table 2-3 Climate Indicators Included in the Assessment and Their Probabilities for 1981-2010 and 2061-2080 Timeframes

Climate Indicator		Condition			Probability[4] (%)				Included in the assessment (Y/N)	Exclusion Comments
		Variable[1] and threshold	Duration[2]	Freq.[3]	Past (1981-2010)		2061-2080 RCP 8.5			
					Year	Cumul	Year	Cumul		
Daily data										
T_1	Hot temperature	Days with Tmax ≥ 30°C	1	1	93.5	100.0	100.0	100.0	Y	-
T_2	Cold temperature	Days with Tmin ≤ -30°C	1	1	93.7	100.0	57.3	100.0	Y	-
T_3	Heat wave	Instances of 3 days	3	3	5.0	70.7	90.9	99.4	Y	-

		with Tmin ≥ 20°C and Tmax ≥ 33°C								
T_4	Cold wave	Instances of 5 days with Tmin ≤ -30°C	5	1	93.6	100.0	56.8	100.0	N	Probability not significant / Not relevant
T_5	**Diurnal variation**	**Days with Tmax-Tmin ≥ 20°C**	**1**	**1**	**97.5**	**100.0**	**97.1**	**100.0**	**Y**	**-**
T_6	Freeze-thaw	Days with Tmin < 0°C & Tmax > 0°C	1	102	4.7	68.7	0.1	62.4	N	Probability not significant / Not relevant
T_7	Frost	Days with Tmin < 0°C	1	162	99.4	100.0	5.4	100.0	N	Probability not significant / Not relevant
T_8	Frost season length	Days (consec.) with Tmin < 0°C	1	109	71.3	100.0	0.9	100.0	N	Probability not significant / Not relevant
P_1	Extreme heavy rainfall	Days with P ≥ 67mm	1	1	4.9	70.2	8.9	74.6	N	More conservative to use P_2
P_2	**Heavy rainfall**	**Days with P ≥ 25mm**	**1**	**1**	**83.3**	**100.0**	**83.5**	**100.0**	**Y**	**-**
P_3	Rain frequency	Days with P ≥ 10mm	1	35	0.0	0.0	0.0	0.0	N	More conservative to use P_2
P_4	Heavy 5-day rainfall	Instances of P ≥ 130mm within 5 days	5	1	0.0	0.0	0.0	0.0	N	Probability not significant / Not relevant
P_5	Winter rain on snow	Instances of P ≥ 25mm within Jan-Feb-Mar		1	0.0	0.0	0.0	0.0	N	Probability not significant / Not relevant
P_6	Wet days	Days with P ≥ 67mm	1	1	4.9	70.2	8.9	74.6	N	Probability not significant / Not relevant
P_7	Heavy snowfall	Days with S ≥ 20cm	1	1	3.7	59.9	6.7	64.3	N	Probability not significant / Not relevant
P_8	**Snow accumulation**	**Instances of SD ≥ 38cm for 5 days**	**5**	**1**	**51.5**	**100.0**	**51.5**	**100.0**	**Y**	**-**
P_9	**Drought**	**Instance of P <**	**10**	**1**	**90.6**	**100.0**	**90.1**	**100.0**	**Y**	**-**

		0.2mm for 10 days								
W_1	**Heavy wind**	**Days with W ≥ 65km/h**	**1**	**1**	**78.1**	**100.0**	**83.8**	**100.0**	**Y**	**-**
PW_1	**Blowing rain**	**Instances of (P ≥ 5) and (W ≥ 65km/h)**	**1**	**1**	**64.6**	**100.0**	**71.3**	**100.0**	**Y**	**-**
PW_2	**Blowing snow**	**Instances of ((S ≥ 5) or (SD ≥ 5)) and (W ≥ 65km/h)**	**1**	**1**	**71.5**	**100.0**	**79.0**	**100.0**	**Y**	**-**
Hourly data										
H_1	Relative humidity	Days with Hmd ≥ 90%	1	216	37.8	100.0	37.8	100.0	N	Not relevant
H_2	Humidex	Days with Hmdx ≥ 45°C	1	1	0.6	14.0	0.6	14.0	N	Not relevant
H_3	Wind chill	Days with WChill ≤ -45°C	1	1	81.5	100.0	81.5	100.0	N	Probability not significant / Not relevant
H_4	Freezing rain	Days with freezing rain	6	1	1.2	25.5	0.0	21.9	N	Probability not significant / Not relevant
H_5	Fog	Days with fog	1	131	0.0	0.8	0.0	0.8	N	Probability not significant / Not relevant

[1]Variables are temperature (T), precipitations (P) in rain or snow, snow depth (SD), wind speed (W), wind combined with precipitation (PW).

[2]Duration represents the number of days (daily data) or the number of hours (hourly data) during which the threshold must reached for the climate condition associated with the indicator to occur.

[3]The frequency is the number of days per year known to have a significative effect on the studied infrastructure.

[4]Columns under past are linked to the baseline period (1981-2010) and those under "RCP 8.5" show the climate change projections according to the RCP 8.5 scenario for the 2061-2080 horizon. The "Year" columns show the probability that a climate condition occur in a year, while the "Cumul" columns show the probability that a climate condition occur once within the next 60 years (2020 to 2080).

2.3 Risk Identification

Climate change vulnerability was first assessed, to determine the exposure, sensitivity, and adaptive capacity of each element to the 10 climate indicators, listed above. Climate vulnerability assessments evaluate an asset, community, ecosystem or region's exposure to a particular climate-related hazard or extreme weather event, the sensitivity to being exposed to the hazard or extreme weather event, and the asset entities' adaptive capacity. Assets and operations that are exposed, sensitive and have low inherent capacity to adapt proceed to the next stage of Risk Analysis.

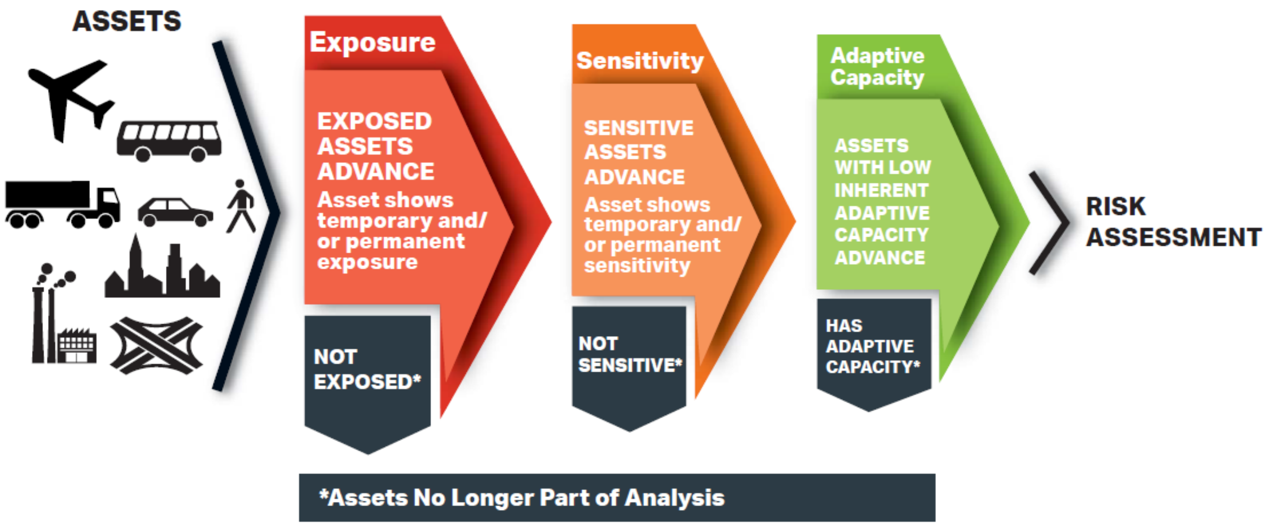


Figure 2-2: Schematic of Climate Vulnerability Assessment Approach

2.4 Risk Analysis

A risk is defined as the product of the likelihood of an event to occur and the consequence or severity on an asset if the event were to occur. A risk assessment was conducted to evaluate the impacts of the climate indicators on each of the project components listed above, using an impact ranking matrix from *very low* to *very high* severity of consequences.

2.4.1 Estimates of Likelihood of an Event to Occur

In order to determine the climate-related risks to the Project, relevant climate indicators were reviewed for the baseline (1981-2010) and in the context of the changing climate for the 2061-2080 timeframe. The probability/ likelihood scoring used is described in Table 2-4:

Table 2-4: Likelihood Scoring Description

Very high	Once every year or more	More than 70% (100%)	5
High	Once every 2 years	40%-70% (50%)	4
Moderate	Once every 5 years	20%-40% (20%)	3
Low	Once every 10 years	4%-20% (10%)	2
Very low	Once every 30 years	4% or less (4%)	1

Considering climate normals and projected changes for the 2061-2080 timeframe, the project team calculated the probability scores for each remaining climate indicator shown in Table 2-5.

Table 2-5: Climate Indicators Probability Scoring

	Code	Climate Indicators	Definitions	1981-2010	2061-2080
Temperature	T1	Hot temperature	Days with Tmax ≥ 30°C	5	5
	T3	Heat wave	Instances of 3 days with Tmin ≥ 20°C and Tmax ≥ 33°C	2	5
	T2	Cold temperature	Days with Tmin ≤ -30°C	5	4
	T5	Diurnal variation	Days with Tmax-Tmin ≥ 20°C	5	5
Precipitation	P2	Heavy rainfall	Days with P ≥ 25mm	5	5
	P8	Snow accumulation	Instances of SD ≥ 38cm for 5 days	4	4
	P9	Drought	Instance of P < 0.2mm for 10 days	5	5
Wind	W1	Heavy wind	Days with W ≥ 65km/h	5	5
	PW1	Blowing rain	Instances of (P ≥ 5mm) and (W ≥ 65km/h)	4	5
	PW2	Blowing snow	Instances of ((S ≥ 5cm) or (SD ≥ 5cm)) and (W ≥ 65km/h)	5	5

2.4.2 Estimates of Consequences of Risks

To estimate the level of consequences, four impact categories were identified based on what is considered most relevant when managing risks for the Project.

These four impact categories are defined as follows:

1) **Impacts on health and safety** include occupational illness and injury to staff or the public as a result of incidents for which the municipality may be liable.
2) **Infrastructure integrity** include damages or deterioration of essential component materials.
3) **Operational impacts** include facility shut down.
4) **Financial impacts** include losses due to additional cost/expense directly attributed to the event, or damage to asset to be fixed immediately to maintain operations, or operations cannot be maintained.

Each impact category was then defined on a scale of 1 (very low) to 5 (very high), as shown in Table 2-6 below.

The table below presents the severity rating (1- very low to 5 - very high) and impact categories which were used to guide the risk analysis.

Table 2-6: Impact Severity Rating and Impact Categories

		Impact categories			
Impact severity rating	**Consequences**	**Health & Safety**	**Infrastructure Integrity**	**Operational impact**	**Financial impact**
1	**Very low**	First Aid Injury	Very low damage; repairable immediately maintenance cost of less than $10k	Facility shut down for less 24 hours (loss of service)	Less than $10k- loss of revenue, or additional cost/expense directly attributed to the event, or minor damage to asset to be fixed in next routine service
2	**Low**	Medical treatment for a minor injury	Minor damage to component materials; Reduction of the service life of the material, maintenance cost of $10k to 50k	Facility shut down for 24 hours to 72 hours (loss of service)	$10k - $50k, loss of revenue, or additional cost/expense directly attributed to the event, or damage to asset to be fixed in advance of next routine service
3	**Moderate**	Bodily injury / Illness with work restrictions	Moderate damage to component materials; Slow deterioration of the materials of certain essential components, maintenance cost of $50k-100k	Facility shut down 72 hours to 1 week (loss of service)	$50k-$100k loss of revenue, or additional cost/expense directly attributed to the event, or damage to asset to be fixed in advance of next routine service
4	**High**	Permanent disabling injury or multiple people injured	Accelerated deterioration of the materials of certain essential components, maintenance cost of $100k to 250k	Facility shut down for 1 week to 1 month (loss of service)	$100k-$250k loss of revenue, or additional cost/expense directly attributed to the event, or damage to asset to be fixed immediately to maintain operations
5	**Very high**	Fatality or significant irreversible disability	Deterioration of materials causing the failure of several elements essential to the functionality of the network, maintenance cost over $250k	Facility shut down for more than 1 month (loss of service)	more than $250k loss of revenue, or additional cost/expense directly attributed to the event, or damage to asset to be fixed immediately to maintain operations, or operations cannot be maintained, and alternatives arranged

2.5 Risk Evaluation

In order to assess and evaluate the risk of each interaction, severity levels were given by using expert judgement and relevant literature. Furthermore, the risk analysis exercise was done on two levels within the AECOM project team, with two risk evaluators and a discussion to assert differences in opinion and come to a consensus. If a consensus cannot be reached, and if there is a lack of information and knowledge, other experts are consulted to further refine the analysis.

The risk assessment revealed 49 interactions showing risks out of 60 possible interactions, between the 10 climate indicators and the seven project components (**Figure 2-3**).

For the 1981-2010 timeframe, out of the 49 interactions:

- 9 interactions result in a low risk;
- 29 interactions result in a moderate risk;
- 0 interaction results in a high risk; and
- 11 interactions result in special cases, which can either be interactions with very low likelihood but very high severity or interactions with high likelihood and very low severity

For the 2061-2080 timeframe, the 49 interactions resulted in the following levels of risks:

- 6 interactions result in a low risk;
- 34 interactions result in a moderate risk;
    - 5 interaction went from low risk to moderate risk
- 0 interaction results in a high risk; and
- 9 interactions result in special cases, which can either be interactions with very low likelihood but very high severity or interactions with high likelihood and very low severity.
    - 3 interactions went from special cases to low risk
    - 1 interaction went from low risk to a special case

Out of these 49 interactions, only moderate risks, high risks and special cases[5] were considered in the rest of the assessment, namely 40 in the current timeframe and 43 in the future timeframe. These were then analysed further to recommend risk treatment and adaptation measures.

[5] Interactions resulting in a risk rated “5” are considered special cases and are considered in the risk evaluation, as these can either be interactions with very low likelihood but very high severity or interactions with high likelihood and very low severity. While the former case may have very severe impacts, the latter case can trigger a slow deterioration of project components due to the high likelihood of the climate condition.

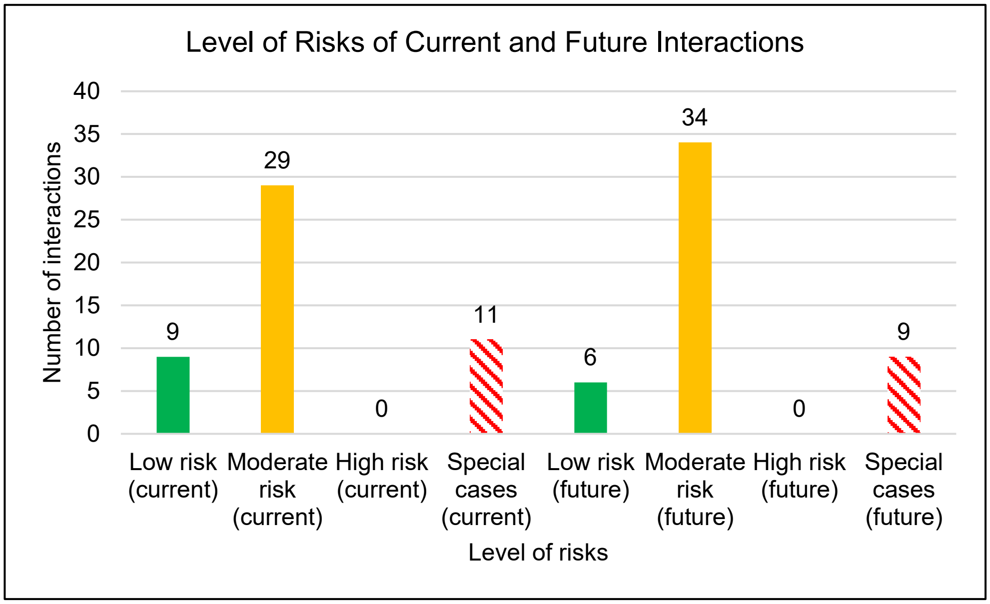


Figure 2-3: Level of Risks of Current and Future Interactions

The detailed results of this risk evaluation are included in the matrix below shown in Table 2-7. The results are combined and presented with proposed mitigation and adaptation measures in the following section. Only the interactions resulting in high risk, moderate risks and special cases are included in the next step of the assessment, namely the recommendation of adaptation measures. Low risk interactions were discarded from further analysis.

The table below presents the summary of the risk analysis per climate indicators for each timeframe, namely the current timeframe based on 1981-2010 climate data and the 2061-2080 timeframe with RCP8.5 climate projections.

Table 2-7: Risk Evaluation Matrix

	Hot temperature		Heat wave		Cold temperature		Diurnal variation		Heavy rainfall		Snow accumulation		Drought		Heavy wind		Blowing rain		Blowing snow		Total number of future special cases, moderate and high risks per infrastructure component
Infrastructure elements	1981-2010	2061-2080	1981-2010	2061-2080	1981-2010	2061-2080	1981-2010	2061-2080	1981-2010	2061-2080	1981-2010	2061-2080	1981-2010	2061-2080	1981-2010	2061-2080	1981-2010	2061-2080	1981-2010	2061-2080	
Building Elements	5	5	6	15	5	4	5	5	15	15	8	8			15	15	12	15	15	15	**8**
Mechanical Equipment and HVAC System	5	5	4	10	5	4			10	10							8	10			**4**
Power, Communication and Electrical Equipment	15	15	6	15	10	8			15	15	8	8			15	15	12	15	15	15	**8**
Utilities					5	4	5	5	15	15	4	4	15	15	5	5	4	5	5	5	**6**
Exterior Elements	10	10	6	15	15	12	5	5	15	15	4	4	10	10	15	15	12	15	15	15	**9**
People	10	10	6	15	10	8	5	5	15	15	4	4			10	10	8	10	10	10	**8**
Total number of risks per climate parameter and horizon	**5**	**5**	**5**	**5**	**6**	**6**	**4**	**4**	**6**	**6**	**5**	**5**	**2**	**2**	**5**	**5**	**6**	**6**	**5**	**5**	

Interactions resulting in a risk rated "5" are considered special cases and are considered in the risk evaluation, as these can either be interactions with very low likelihood but very high severity or interactions with high likelihood and very low severity. While the former case may have very severe impacts, the latter case can trigger a slow deterioration of project components due to the high likelihood of the climate condition.

Risk Evaluation Matrix Scoring

Severity of Consequences		Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
	Very High (5)	5	10	15	20	25
	High (4)	4	8	12	16	20
	Moderate (3)	3	6	9	12	15
	Low (2)	2	4	6	8	10
	Very Low (1)	1	2	3	4	5
		Probability (Likelihood)				

Risk Rating

Risk (R) = Probability (P) x Severity (G)	
Low Risk: < 6	Controls likely not required
Moderate Risk: 7 < R < 16	Some controls required to reduce risks to lower levels
High Risk: R > 20	High priority control measures required
R = 5	Special Cases: Interactions resulting in a risk rated "5" are considered special cases and are considered in the risk evaluation, as these can either be interactions with very low likelihood but very high severity or interactions with high likelihood and very low severity. While the former case may have very severe impacts, the latter case can trigger a slow deterioration of project components due to the high likelihood of the climate condition.

2.5.1 Risks Assessed by Impact Categories

Figure 2-4 below presents how climate risks will impact the four categories of impacts. Three types of interaction were assessed in the risk analysis: very low severity interactions (ranked 1), low severity interaction (ranked 2) and moderate severity interactions (ranked 3). No high severity interactions (ranked 4) nor very high severity interactions (ranked 5) was identified in the risk analysis.

This can be used to lead investments and help prioritize adaptation measures that will minimize financial impacts and health and safety impacts on both staff and public, and operational impacts, depending on the city's priorities.

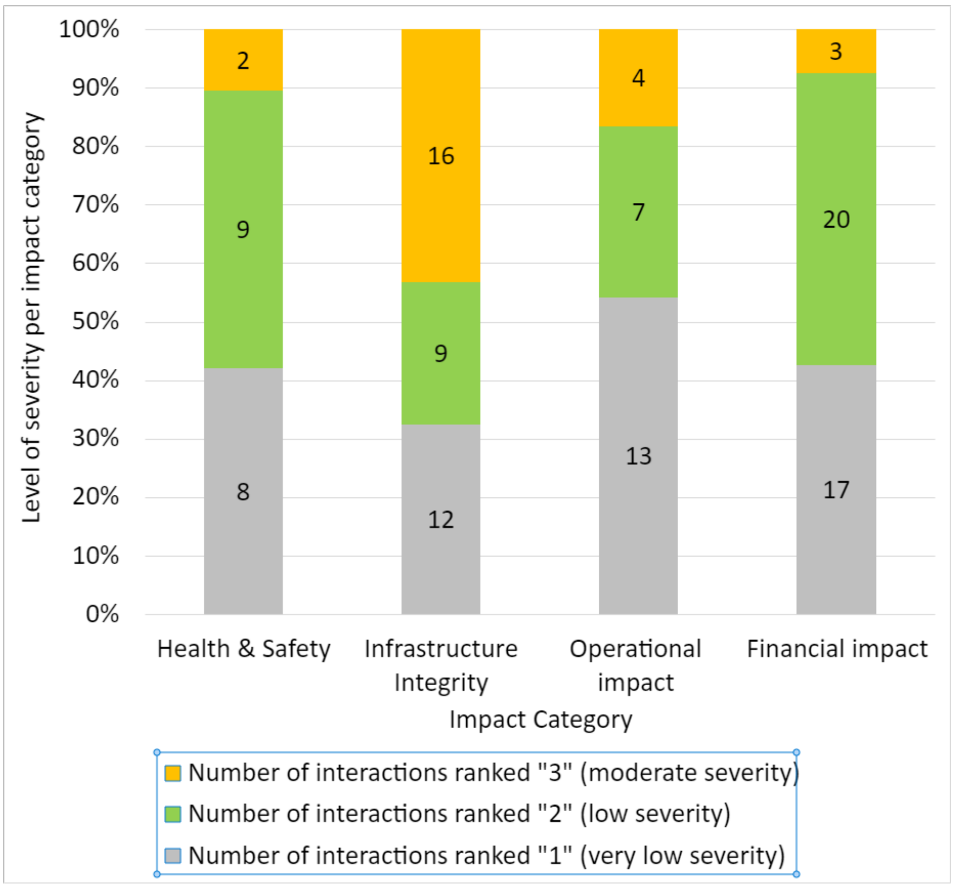


Figure 2-4: Number of Interactions Per Level of Severity for Each Impact Category

In order for the City to use these results further, a pivot table set up in **Appendix B** will allow the City to select and visualize the level of severity for each climate indicator and each infrastructure component, as in the screenshot below shown in Figure 2-5.

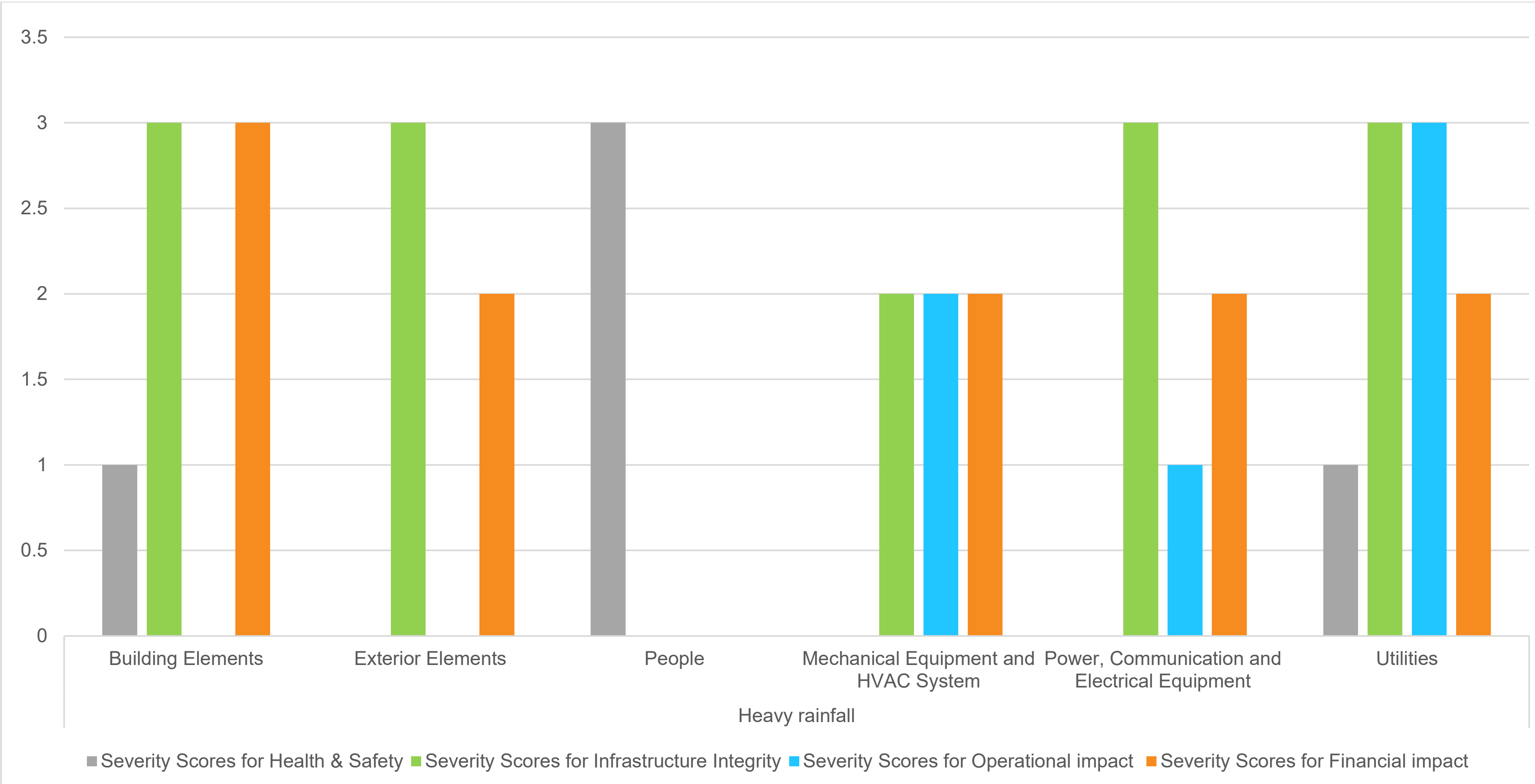


Figure 2-5: Level of Severity for Each Climate Indicator and Each Infrastructure Component (fully displayed and interactive in Appendix B)

2.6 Risk Treatment and Adaptation Measures

The project team identified risk treatment and adaptation measures for reducing unacceptable risks to acceptable levels. These are presented in the table below, according to the risks results from the 2061-2080 timeframes which will bring most severe consequences.

The first column presents the Moderate Risk Interactions and High-Risk Interactions combined by type of event; i.e. events related to heavy winds, blowing snow and blowing rain were combined as their impacts are similar on asset components. The last column describes potential impacts on the project and its elements if adaptation measures were not to be implemented.

A detailed version of this table is also presented in **Appendix A**, with additional information on the effectiveness of the risk or adaptation measures as well as the recommended timeframe for implementing these measures.

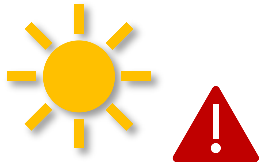
Adaptation measures were identified based on the following three types of measures:

- **Design**: Measures to incorporate in the design of assets for these to be resilient to future climate risks.
- **Operations and Maintenance (O&M)**: Measures to incorporate in order for the facility to reach resiliency in its Operations and Maintenance.
- **Policy**: Measures to provide and maintain safe and healthy working conditions.

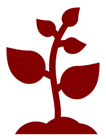
As mentioned in Section 2.2.3, most of the climate probabilities are not changing from current to future, therefore existing design standards should be accommodating projected future climate for most climate indicators. As the South Winnipeg Recreation Center is a new facility, the following recommended measures will make future systems robust to handle future climate change impacts. It is worth noting that the probabilities of wind, blowing rain and blowing snow show increases, while the probability of heat waves shows a significant increase.

At this time, it is not possible to perform any Return on Investment calculations associated with the project.

Table 2-8: Risk Treatment and Adaptation Measures

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments
Risk Event: Moderate and special cases - Hot temperatures / Number of heat waves 	Building Elements	**15**	-Design: Identify optimum building orientation and/or use materials that are resistant to or limit the accumulation of heat, such as light-colored materials such as white (high albedo). Paint roofs with light reflective colors or use materials with high thermal resistance to reduce heat gain -Design: Integrate passive design measures including insulation, air permeability, orientation and shading to help maintain comfortable indoor temperatures -Design: Protect south-facing windows from solar heat gain through increased shading and solar control (e.g., reflective glass, overhangs or natural landscaping) - Design: Consider nature-based approaches, such as green roofs or green walls, to reduce building temperature during heat waves and extremely hot days - Design: Design measures should consider LEED standards in order to obtain LEED Gold certification and promote the design and construction of a green building. -Policy: The SWRC aspires to be LEED Gold certified, therefore it should integrate all the necessary standards regarding design, construction and operation and maintenance of the building.	It is possible that the probability of hot temperature events may result in premature wear and tear and accelerated deterioration the building envelope. Heat waves and extreme temperatures can cause high temperature in buildings exacerbated by solar heat gains. Also, heat waves could exacerbate localized urban heat island effects.
	Mechanical Equipment and HVAC System	**10**	-O&M: Weekly monitoring of energy demand on mechanical HVAC and cooling systems, during the high temperature periods. -O&M: Increase monitoring of HVAC cooling demand during heat wave periods to avoid overheating of the systems. -O&M: Incorporate LEED standards such as precooling the building overnight when possible	Pressure on HVAC system due to increased demands for cooling
	Power, Communication and Electrical Equipment	**15**	-Design: Install an emergency standby generator to provide backup power during an outage -Design: Consider adding an alternate source of power that is combined to a battery in order to provide emergency power during an outage -O&M: Increase inspection after hot temperature events to make sure systems are working correctly.	The heat may cause surveillance cameras to break down or cause them to erode away causing them to malfunction. Heat waves and extreme temperatures can cause blackouts forcing facility shutdown.
	Exterior Elements	**15**	-Design: Encourage the use of heat-resistant materials or materials that limit the accumulation of heat to avoid premature deterioration of the paver (such as honeycombed pavers, composite pavers) -Design: Use reflective (high albedo) materials on pavers, such as light shades, such as white - Design: Consider nature-based solutions, green infrastructure and landscape design, such as planting local species that have a greater heat tolerance or are drought resistant, retaining water. - O&M: Conduct frequent inspections of pavement surfaces to ensure cracks are properly sealed - O&M: Ensure proper maintenance of landscaping during summer months.	Summer temperatures above or equal to 30°C can impact exterior elements and require more landscape maintenance. Higher temperatures may cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking), which could result in increased maintenance costs. Also, heat waves may exacerbate the Urban Heat Island effect due to increased surface temperatures of the pavement.

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments
	People	15	-Design: The main walking and cycling paths should be shaded and greened - Design: Install drinking fountains next to pedestrian areas - O&M: Modify maintenance schedules in anticipation of hot temperatures, shift maintenance work to cooler parts of the day. - Policy: Implement worker safety measures to protect the health and safety of staff -Policy: Include in the site operation plan safety measures to protect the public.	Higher temperatures and heat waves could impact outside working staff wellbeing and productivity and could impact public health (e.g., heat exhaustion and heat stroke, dehydration, heat stress).
Risk Event - Moderate - Cold temperature	Power, Communication and Electrical Equipment	8	- Design: Install an emergency back-up generator to maintain the facility running in case of a prolonged power outage and business continuity	Cold temperatures may impact the electrical equipment, especially when combined with rain and/or snow (e.g. freezing and damaging the equipment). Cold temperatures could result in increased demand for fuel for emergency generators and resulting price increases.
	Exterior Elements	12	- Design : Use paving materials designed to withstand very cold temperatures to reduce damages to pavement (e.g., cracking, rutting) - O&M : Increase inspections during cold days to check for damages to the road and provide maintenance when necessary.	Cold temperatures could cause premature deterioration of access roads, pavements (e.g., potholes, rutting, cracking), resulting in more maintenance costs
	People	8	- Policy: Develop and implement safety measures to ensure workers can stay warm if they are working outside during very cold days (adequate clothes, shoes and equipment, etc.).	Cold temperatures could impact wellbeing and productivity (e.g., frostbite, hypothermia)
Risk Event - Special Cases - Diurnal variation	Building Elements	5	-Design: Use building materials that are resistant to temperature variations -O&M: Increase inspection and maintenance of building envelope after days of diurnal variation events.	Diurnal variation may result in accelerated deterioration of exterior building elements and the building envelope, resulting in increased inspections and maintenance costs.
	Utilities	5	-Design: Use sound passive design techniques and materials that have a high thermal mass potential to regulate temperatures. -Design: Use good thermal insulating materials when building the facilities.	Changes in temperature could result in increased heating costs (natural gas services).
	Exterior Elements	5	- O&M: Conduct frequent inspections of pavement surfaces to and properly seal cracks on pavement surfaces.	Diurnal variation could cause premature deterioration of access roads, pavements (e.g., potholes, rutting, cracking), resulting in more maintenance costs
	People	5	-Design: Install warning signs of the possibility of black ice slipping and falling. -O&M: Apply deicing agents on walkways and other work areas that are vulnerable to ice development.	Variation in temperature during winter can form black ice and could cause slip and fall of staff and public visiting the facility
Risk Event - Moderate - Heavy rainfall	Building Elements	15	-O&M: Inspect door and window seals before winter and in the spring to reduce water infiltration.	Heavy rainfall may result in accelerated deterioration of exterior building elements (e.g., windows, doors, roof) and the building envelope due to water infiltration, resulting in increased inspections and maintenance costs.
	Mechanical Equipment and HVAC System	10	-Design: Design building heating/ cooling/ ventilation services to prevent or reduce damage from precipitation. -O&M: Increase monitoring of HVAC during heavy rainfall events	Flooding and/or lightning strikes resulting in a power surge may put HVAC at risk
	Power, Communication and Electrical Equipment	15	-O&M: Increase inspections and maintenance following heavy rainfall events -O&M: Conduct regular inspections of electrical components and equipment before winter and spring seasons to prevent water-related damages.	Over time, repeated exposure to heavy rain can damage to almost any piece of electronic equipment, even if it is very well protected. This includes cameras. What's more, if rainwater ends up on the lens of a camera, it may distort or partially obscure the image that the camera records. Heavy rainfall may cause water damages to transformers located outside. Electrical systems can be damaged as a result of flooding or standing water

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments
Risk Event - Moderate - Heavy rainfall (continued) 	Utilities	**15**	- Design: Incorporate low impact development practices or green Infrastructure to manage stormwater runoff and prevent flood damages. Some examples include, bioretention planters, bioswales, etc. -O&M: Conduct frequent inspections of drainage systems, before winter and spring seasons. Keep drainage clear of debris to ensure proper drainage with anticipated increases in precipitation. -Policy: Install a real-time Flood Warning System that alerts staff in advance so that necessary resources can be deployed	Heavy rainfall may cause localized flooding in low-lying areas and significant runoff, which could overload drainage systems. Also, flash floods caused by heavy rainfall may damage underground utilities and require additional maintenance and repair costs.
	Exterior Elements	**15**	- Design: Increase the area of permeable surfaces and promote the implementation of rain gardens in order to reduce flood risk of pavement and roads. - Design: in order to limit runoff and erosion, design landscaping with plants that can help hold the soil firmly in place, such as fast-growing ground covers and even flower plants such as daylilies and sages. Make sure that the plants used can absorb a lot of water. -Design: Mulching can help mitigate erosion on moderate slopes in the landscape. applying mulch protects soil, increases surface area and improves water penetration -Design: Install geotextiles to reduce surface erosion in landscaping. -O&M: Schedule landscape inspections after heavy rainfall events.	Heavy rain could wash away and erode the landscaping. Heavy rainfall could cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking) as well as signage. This could result in increased maintenance costs
	People	**15**	- O&M: Modify work schedules under conditions induced by climate-related disruptions. - Policy: Develop and implement an Emergency Preparedness and Management Plan in the case of a heavy rainfall event -Policy: Include in the site operation plan safety measures to protect the public.	Heavy rainfall may cause flash floods, which could make it difficult for the public to access the facility and staff to access the site and conduct regular operations, construction, or maintenance work.
Risk Event- Moderate Snow Accumulation 	Building Elements	**8**	- Design: Consider arched or sloped roof (no flat roof) to prevent snow loads. - O&M: Remove snow loads from building roof during winter months.	Snow accumulation could increase loads on building roofs, which may require additional snow removal costs.
	Power, Communication and Electrical Equipment	**8**	-O&M: Increase inspections and maintenance following snow fall and snow accumulation events	Snow and ice could impact outdoor surveillance system cameras in optic and mechanical disruptions. An unshielded camera can be damaged by ice. If there is moisture around an outdoor camera below the temperatures drop below freezing, the frost that is formed by that moisture and temperature can form on the cameras lens and preventing the viewer to see any activities going on outside besides the crystalline patterns from the snow. This will likely result in increased maintenance cost.
Risk Event - Moderate – Drought 	Utilities	**15**	- Policy Identify water saving measure that could be implemented in drought events such as identifying non-essential uses such as outdoor landscaping. -Design: Chose water efficient toilets, water efficient sinks and water efficient shower heads or flow restrictors	In case of drought, water supply, access to water and water consumption might be restricted, which would limit the facility's provided services.
	Exterior Elements	**10**	- Design: Consider nature-based solutions, green infrastructure and landscape design, such as planting local species that have a greater heat tolerance or are drought resistant. - O&M: Ensure proper maintenance of landscaping during summer months.	Drought can cause reduced soil quality, resulting in loss of vegetation and increased demand for water. Drought may lead to increased landscape maintenance

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments
Risk Event - Moderate and Special Cases - Heavy wind / Blowing rain / Blowing snow 	Building Elements	15	-O&M: Monitor sealant condition twice a year, at the end of winter and summer, and replace sealants on windows and doors -O&M: Increase the frequency of sealant monitoring on windows during periods of high winds combined with rain and snow (spring and fall).	Heavy winds may cause damages the building envelope, windows and doors, which could result in increased inspections and maintenance costs. Blowing rain may result in water infiltration in the building envelope and windows if joints are not properly sealed, which may result in increased inspections and maintenance costs. Blowing snow could increase snow loads on building roofs, which may result in increased snow removal costs.
	Mechanical Equipment and HVAC System	10	-O&M: Increase monitoring of HVAC during blowing rain events	Flooding and/or lightning strikes resulting in a power surge may put HVAC at risk
	Power, Communication and Electrical Equipment	15	-Design: Install a generator to ensure minimal power loss to the building before, during and after a power outage -O&M: Increase inspections and maintenance following blowing rain and blowing snow events	Heavy winds may cause power outages which can cause disruption to the operations. Blowing rain and blowing snow may cause water damages (e.g., infiltration, corrosion) to transformers located outside. Snow and ice impact to outdoor surveillance system cameras in optic and mechanical disruptions. An unshielded camera can be damaged by ice. If there is moisture around an outdoor camera below the temperatures drop below freezing, the frost that is formed by that moisture and temperature can form on the cameras lens and disallowing the viewer to see any activities going on outside besides the crystalline patterns from the snow
	Utilities	5	-O&M: De-ice roof drains to prevent them from becoming clogged and to provide a path for snow and debris to for the flow of melted snow and ice. -O&M: Remove debris (e.g., leaves, branches, etc.) from around the drains in the fall to ensure proper drainage.	Heavy wind may result in an accumulation of debris and objects in the drainage system. Blowing rain may result in an accumulation of debris and objects in the drainage system. Heavy rain and snow accumulation might overload the sewage system and increase maintenance cost.
	Exterior Elements	15	- Design: Consider incorporating windbreaks (e.g., vegetation) in the landscape design. -Design: Select local species that are resistant to strong winds. - O&M: Cover fragile trees, shrubs and other vulnerable plants with protective sheets before winter seasons. - O&M: Properly secure objects, signage, exterior lighting to withstand heavy winds -O&M: Monitor elements that could become projectiles in times of strong winds -O&M: Maintain building accesses to ensure that the path is clear and that there is no debris that can be blown away - O&M: Conduct regular inspection during these extreme weather events and apply necessary measures (snow-clearing, debris clearing, use of abrasive material to de-ice)	The interaction of high wind with certain infrastructure elements poses a significant risk. This include landscaping, exterior lighting, signage, etc. Exterior lighting equipment and landscaping can be damaged during high and gusty winds. There is a risk that these components could hit the building or people. Landscaping elements can become projectiles when they are blown away by strong wind. Blowing rain could wash away and erode landscaping. Heavy rainfall could cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking). Blowing snow may cause reduced accessibility to the building due to snow accumulation, slippery surfaces. This can be an accident hazard in the parking lots and the roadways and walkways around the building. Increased maintenance and repair cost.
	People	10	-O&M: Modify maintenance schedules in anticipation of event of heavy winds, blowing snow or blowing rain -O&M: Install signage in winter to indicate slippery areas and falling snow or ice to ensure safe movement and access to the building - O&M: Conduct regular inspection during these extreme weather events and apply necessary measures (snow-clearing, debris clearing, use of abrasive material to de-ice) - Policy: Implement worker safety measures to protect the health and safety of staff working outdoors -Policy: Include in the site operation plan safety measures to protect the public.	Heavy wind could blow away debris or objects, which could cause injuries to staff and the public using the facility. Blowing rain and blowing snow can cause slippery conditions and snow accumulation can restrict access to the facility. Increased maintenance and/or delay of work.

3. GHG Mitigation Assessment

3.1 Methodology

3.1.1 Boundary of the Assessment

The boundary of the assessment is defined in both a temporal and a technical basis. The temporal boundary defines the life of the Project for which the greenhouse gas emissions are estimated. The construction phase of the Project is expected to happen from 2023 to 2024. The Project lifespan is 50 years from the start of the SWRC operations in 2025; therefore, greenhouse gas emissions will be projected out to the year 2074.

The technical boundary of the assessment is restricted to the construction, operation, and maintenance of the buildings on the site of the proposed SWRC. The assessment does not include any indirect work that may or may not occur as a result of the Project, such as new roads or utility infrastructure.

3.1.2 Greenhouse Gases Considered

This assessment considers the seven gases defined as GHGs under the United Nations Intergovernmental Panel on Climate Change (IPCC):

- Carbon dioxide (CO_2);
- Methane (CH_4);
- Nitrous oxide (N_2O);
- Hydrofluorocarbons (HFCs – a family of gases);
- Nitrogen trifluoride (NF_3);
- Fluorocarbons (PFCs – another family of gases); and
- Sulfur hexafluoride (SF_6).

In the current assignment, GHG will mostly be emitted as CO_2. Small amounts of CH_4 and N_2O are also anticipated and are thus quantified using an appropriate emissions factor. The latter are converted into tonne of CO_2 equivalent (tCO_2e) using global warming potentials (GWP) sourced from the IPCC 4th Assessment Report (Table 3-1).

Table 3-1: Greenhouse Gases Considered

Greenhouse Gas	Chemical Formula	Global Warming Potential (100 years)
Carbon Dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298

3.1.3 Emission Scopes

The scope of the emissions inventory will include all direct emissions (scope 1) and any major indirect emissions (scope 2) from the construction and for the operation and maintenance of the SWRC. The main emission sources are identified in Table 3-2.

Table 3-2: Emission Scopes

Source Scope	Construction Phase (2023-2024)	Operation and Maintenance (2025 – 2074)
Scope 1- Direct Source	Fuel combustion from construction equipment and vehicles	Natural gas consumption
Scope 2- Energy Indirect Emission	None	Electricity consumption

3.1.4 Data and Calculation Procedures

The GHG emission inventory has been completed in line with the ISO 14064-2 standard. The key principles of the ISO 14064-2 standard and how the assessment has addressed them are summarized below:

- **Relevance:** The relevance of GHG sources, data and methodologies must be appropriate for the purpose of the emissions assessment. As described in **Sections 3.1.1, 3.1.2, and 3.1.3** only GHG sources relevant to the construction, operation and maintenance of the Project itself have been considered. The data and methodologies for estimating baseline and Project GHG emissions are at a conceptual level. The Project is in the planning phase and a detailed design has not been completed; therefore, the data and methodologies are relevant to the stage of the Project but should still provide sufficient and relevant information for the purposes of the Climate Lens assessment. Emissions factors and estimates used are sourced from Canada's National Inventory Report or IPCC sources where possible and are referenced in detail.
- **Completeness:** All relevant GHG emissions should be included in the assessment with supporting information on criteria and procedures. **Sections 3.1.3** and **3.1.5** describe what sources are included and excluded.
- **Consistency:** The assessment must enable meaningful comparisons in GHG-related information. A key component of the assessment is the comparison of the Project to a baseline case. The baseline case has been defined as a conservative viable alternative and its design components and associated emission sources have been derived based on the same assumptions as the Project case.
- **Accuracy:** The assessment must reduce bias and uncertainties as far as is practical. Quantification of the Project's anticipated baseline and Project emissions is based on available data, emissions factors and estimation methodologies used, recognizing that uncertainties exist due to the early stage of Project development, and the limited emissions factors available for the relevant activities. Where there is uncertainty, a conservative approach has been taken and described.
- **Transparency:** The assessment must disclose sufficient and appropriate GHG related information to allow conclusions and decisions to be made with reasonable confidence. For each emissions source, description of the information and references used in the emissions calculation has been provided in **Sections 3.2** and **3.3**. All assumptions are identified in **Section 3.1.6**.
- **Conservativeness:** The assessment must use conservative assumptions, values and procedures to ensure that GHG emission reductions are not over-estimated. To avoid over- or under-estimation of emissions, the baseline and Project cases use identical assumptions for the construction equipment fleet, the area of the buildings and the same proportion of both energy sources (electricity/natural gas) used during operation years.

3.1.5 Exclusions from the Assessment

This type of Project could generate indirect (scope 3) emissions such as emissions resulting from workers and staff commuting to site, production and transportation of consumables (e.g. chemicals, supplies) and upstream emissions associated with fuel and energy. However, these emissions have not been quantified, per the Climate Lens guideline that supply chain emissions are not required to be included.

GHG emissions related to the potential increase/decrease in vehicle traffic during construction work on the site have not been quantified in this assessment.

Finally, emissions associated with future major refit and/or decommissioning of the SWRC are not quantified. No emissions or emissions removals associated with this Project are anticipated to occur outside of Canada.

3.1.6 Assumptions

The key assumptions used in the development of the emission inventories are described below.

3.1.6.1 Construction

Baseline construction emissions are assumed similar to the project case.

3.1.6.1.1 On-Site Fuel Combustion

Construction emissions include activities associated with the use of heavy equipment for site preparation, structure build up and the installation of plumbing, drainage, mechanical and electrical services. Based on the construction schedule available at the time of this assessment, the quantities of fuel consumed by the construction fleet were estimated using an average workload. It has been assumed that the equipment will be in operation for an average of five (5) hours a day, six (6) days a week. Emissions from temporary power for welding, power tools and other electrical sources have not been included as well as emissions related to the propane consumption used for temporary heating.

Emission factors for diesel fuel are taken from National Inventory Report 1990-2018: Greenhouse Gas Sources and Sinks in Canada. Emissions factors used for diesel fuel are shown in Table 3-3.

Table 3-3 Emission Factors Associated with Diesel fuel consumption

Energy Type	Emission Factor		
	CO_2	CH_4	N_2O
Diesel[6]	2,681	0.073	0.022

Source: 6. Table A6.1-13 Emissions Factors for Energy Mobile Combustion Sources – Off-road Diesel vehicles, Tier 1-3

3.1.6.2 O&M Emissions

The key assumptions used in the development of the O&M emission inventories are listed below.

General:

O&M emissions for both the project and baseline case have been assumed constant over the project life.

Baseline O&M:

At the time of the assessment, the data available is the net area of the buildings in the SWRC. In order to estimate the energy requirements associated with these buildings, the Canadian Energy Use Intensity by Property Type table[7] is used.

[7] Government of Canada (2018), Canadian Energy Use Intensity by Property Type.

Project O&M:

It is expected that the SWRC buildings will meet LEED Gold standards. According to a 2019 article[8], LEED Gold certified buildings achieve a 27% reduction in non-electric energy use intensity (EUI) and 6% in electric EUI.

Using data published in the City of Toronto's 2019-2024 Energy Conservation and Demand Management Plan[9], the proportion of energy coming from the use of electricity and natural gas for a recreation center and childcare facility is distributed as follow (Table 3-4):

Table 3-4 Percentage distribution of energy used by building type

Energy Type	Electricity Energy Use	Natural Gas Energy Use
Indoor Recreational Facility	46 %	54 %
Childcare Facility	47 %	53 %

Emission factors for electricity and natural gas are taken from the National Inventory Report 1990-2018: Greenhouse Gas Sources and Sinks in Canada. Emissions factors used for electricity and natural gas are shown in Table 3-5.

Table 3-5: Emission Factors Associated with Electricity and Natural Gas consumptions

Energy Type	Emission Factor			
	CO_2	CH_4	N_2O	$CO_{2\,e}$
Electricity[10]				1.4 g $CO_{2\,e}$/kWh
Natural Gas[11]	1,886 g CO_2/m^3	0.037 g CH_4/m^3	0.033 N_2O/m^3	

Source: *10. Table A13-8 Electricity Generation and GHG Emission Details for Manitoba, National Inventory Report 1990-2018: Greenhouse Gas Sources and Sinks in Canada.*
11. Table A6.1-1 and 1-2 Emission Factors for Natural Gas, National Inventory Report 1990-2018: Greenhouse Gas Sources and Sinks in Canada.

3.2 Baseline Case

3.2.1 Description

The baseline scenario is meant to define a business-as-usual emissions trajectory that is representative of the most probable emissions in the absence of the Project. For the SWRC, the baseline scenario has been defined as a similar sized recreation centre with the same functionality and uses but not meeting the LEED Gold standards.

The main emission sources for the baseline are described in **Table 3-6**.

[8] Scofield, John & Brodnitz, Susannah & Cornell, Jakob & Liang, Tian & Scofield, Thomas. (2021). *Energy and Greenhouse Gas Savings for LEED-Certified U.S. Office Buildings. Energies. 14. 749. 10.3390/en14030749.*
[9] City of Toronto (2019). *Energy Conservation and Demand Management Plan (https://www.toronto.ca/wp-content/uploads/2019/07/9686-Energy-Conservation-and-Demand-Management-Plan.pdf)*

Table 3-6: Baseline Case Main Emissions Sources

Equipment / Emissions Category	Description
Construction Non-Road Vehicles	Equipment necessary for the construction of the site
O&M Stationary Fuel Combustion	Fuel for building heating
O&M Electricity Consumption	Electricity for lighting needs and cooling building

3.2.2 Construction Emission

Construction is scheduled to occur in 2023 with an overall completion by 2024. The construction Project emissions inventory breakdown is estimated based on the preliminary Project construction schedule and the results are presented in Table 3-7.

Table 3-7 Project Construction Emissions

Parameter	Units	2023	2024
Diesel for Construction	L / y	162,133	279,846
CO_2 Emission Factor	g CO_2 / L	2,681	2,681
CH_4 Emission Factor	g CH_4 / L	0.073	0.073
N_2O Emission Factor	g N_2O / L	0.022	0.022
CO_2 emissions	g CO_2 / y	434,678,573	750,267,126
	kg CO_2 / d	1,191	2,056
CH_4 emissions	g CH_4 / y	11,836	20,429
	kg CH_4 / d	0.03	0.06
N_2O emissions	g N_2O / y	3,567	6,157
	kg N_2O / d	0.01	0.02
GWP CH_4		25	25
GWP N_2O		25	298
Total CO_2e	**kg CO_{2e} / d**	**1,191**	**2,056**
	tonnes CO_{2e} / y	**1,195**	**2,062**
	tonnes CO_{2e}	**1,189**	

Construction emission have been estimated to be 1,189 tonnes of CO_2e.

3.2.3 Operations and Maintenance Emissions

Electricity and Natural Gas

As stated in Section 3.1.6.2, the annual consumption of electricity and natural gas of the SWRC are estimated from the net area of the buildings and their uses (Table 3-8).

Table 3-8: Estimate of Annual Usage of Electricity and Natural Gas for the Baseline Scenario

Building Type	Net area (m^2)	Energy Use (GJ)	Electricity consumption (kWh)	Natural Gas consumption (m^3)
Recreation facility	5,950	10,275	1,313,295	146,398
Childcare facility	1,394	1,909	251,730	26,469
Baseline TOTAL	7,344	12,184	1,565,025	172,868

For other operation years, the annual electricity and natural gas consumptions are considered to be constant.

The 2030 O&M baseline emissions inventory breakdown is presented in Table 3-9.

Table 3-9: Baseline O&M Emissions

Parameter	Unit	Value
Electricity consumption		
Annual consumption	kWh/y	1,565,025
Emissions GHG = Fuel consumption × Emission Factor	**g CO2 e/kWh**	1.4
Total CO_2e	**kg CO_2e/d**	6
Stationary Fuel Combustion		
Natural Gas Usage	m^3 / y	172,868
Emissions GHG = Fuel Consumption × Emission Factor		
CO_2 Emission Factor	g CO_2 / m^3	1,886
CH_4 Emission Factor	g CH_4 / m^3	0.04
N_2O Emission Factor	g N_2O / m^3	0.03
CO_2 Emission	**g CO_2 / y**	326,028,390
	kg CO_2 / d	893
CH_4 Emission	**g CH_4 / y**	6,396
	kg CH_4 / d	< 0.1
N_2O Emission	**g N_2O / y**	5,705
	kg N_2O / d	< 0.1
BASELINE TOTAL EMISSIONS SWRC AS CO_2 EQUIVALENT		
Total CO_2	**kg CO_2 / d**	899
Total CH_4	**kg CH_4 / d**	< 0.1
Total N_2O	**kg N_2O / d**	< 0.1
GWP CH_4		25
GWP N_2O		298
Total CO_2e	**kg CO_2e / d**	904
	tonnes CO_2e / y	330

GHG emissions associated with 2030 operations are estimated at 330 tons of CO_{2e} for the baseline scenario.

3.2.4 Annual and Cumulative Emissions

Annual and cumulative emissions for the baseline case are summarized in Table 3-10.

Table 3-10: GHG Emission Summary for Baseline Case

Project Year	Calendar Year	Construction	O&M - Annual	Cumulative
		tCO_2e	tCO_2e	tCO_2e
Year 1	2023	436		436
Year 2	2024	753		1,189
Year 3-52	2025-2074		330	17,693

Based on the assumptions made and available data, the total emissions associated with the baseline scenario are estimated at 17,693 tons of CO_{2e} at the end of 2074.

3.3 Project Case

3.3.1 Description

The Project case involves the GHG emissions from the construction and O&M of the SWRC, whereas the buildings would meet LEED Gold standards.

The main GHG emission sources for the Project are described in Table 3-11.

Table 3-11: Project Case Main GHG Emissions Sources

Equipment / Emissions Category	Description
Construction Non-Road Vehicles	Equipment necessary for the construction of the facilities
O&M Stationary Fuel Combustion	Fuel for building heating
O&M Electricity Consumption	Electricity for lighting needs and cooling building

3.3.2 Construction Emission

The project construction emissions have been assumed to be similar to those in the baseline case.
Thus, GHG emissions during construction phase are also estimated at 1,189 tCO_2e.

3.3.3 Operations and Maintenance Emissions

Electricity and Natural Gas

As stated in Section 3.1.6.2, the annual consumption of electricity and natural gas of the SWRC are estimated from the net area of the buildings and their uses (Table 3-12) considering the savings associated with LEED Gold certification.

Table 3-12: Estimate of Annual Usage of Electricity and Natural Gas for the Project Scenario

Building Type	Net area (m^2)	Energy Use (GJ)	Electricity consumption (kWh)	Natural Gas consumption (m^3)
Recreation facility	5,950	8,485	1,224,116	107,637
Childcare facility	1,394	1,584	236,627	19,323
Baseline TOTAL	7,344	10,069	1,460,742	126,959

For other operation years, the annual electricity and natural gas consumptions are considered to be constant.

The 2030 O&M Project emissions inventory breakdown is presented in Table 3-13.

Table 3-13: Project O&M Emissions

Parameter	Unit	Value
Electricity consumption		
Annual consumption	kWh/y	1,460,742
Emissions GHG = Fuel consumption × Emission Factor	**g CO2 e/kWh**	1.4
Total CO_2e	**kg CO_2e/d**	6
Stationary Fuel Combustion		
Natural Gas Usage	m^3 / y	126,959
Emissions GHG = Fuel Consumption × Emission Factor		
CO_2 Emission Factor	g CO_2 / m^3	1,886
CH_4 Emission Factor	g CH_4 / m^3	0.04
N_2O Emission Factor	g N_2O / m^3	0.03
CO_2 Emission	**g CO_2 / y**	239,445,395
	kg CO_2 / d	656
CH_4 Emission	**g CH_4 / y**	4,697
	kg CH_4 / d	< 0.1
N_2O Emission	**g N_2O / y**	4,190
	kg N_2O / d	< 0.1
PROJECT TOTAL EMISSIONS SWRC AS CO_2 EQUIVALENT		
Total CO_2	**kg CO_2 / d**	662
Total CH_4	**kg CH_4 / d**	< 0.1
Total N_2O	**kg N_2O / d**	< 0.1
GWP CH_4		25
GWP N_2O		298
Total CO_2e	**kg CO_2e / d**	665
	tonnes CO_2e / y	243

GHG emissions associated with 2030 operations are estimated at 243 tons of CO_2e per year for the Project scenario.

3.3.4 Annual and Cumulative Emissions Over Project Lifetime

Annual and cumulative emissions for the baseline case are summarized in Table 3-14. Construction emissions represent less than 1% of the lifetime GHG emissions.

Table 3-14: GHG Emission Summary for Project Case

Project Year	Calendar Year	Construction	O&M - Annual	Cumulative
		tCO_2e	tCO_2e	tCO_2e
Year 1	2023	436		436
Year 2	2024	753		1,189
Year 3-52	2025-2074		243	13,331

Based on the assumptions made and available data, the total emissions associated with the Project scenario are estimated at 13,331 tons of CO_{2e} at the end of 2074.

3.4 Estimated Net Reduction in Emissions

The cumulative emission reduction over the lifetime of the Project is summarized in Table 3-15.

Table 3-15: Annual and Cumulative Project Emissions

Project Year	Calendar Year	Baseline Emissions	Project Emissions	Total Net Change - Annual	Total Net Change – Cumulative Reduction
		tCO_2e	tCO_2e	tCO_2e	tCO_2e
Year 1	2023	436	436	0	0
Year 2	2024	753	753	0	0
Year 3-52	2025-2074	17,693	13,331	87	4,361

As shown in Table 3-15, the Project will lower the GHG emissions by 87 tonnes of CO_2e in 2030 compared to the baseline scenario (non-cumulative). Over the Project's lifetime, the accumulated GHG reduction is expected to be 4,361 tonnes of CO_2e.

3.5 Estimated Cost-per-Tonne

The estimated costs for construction and O&M of the Project, as well as the Climate Lens cost-per-tonne indicators are summarized in Table 3-16.

Table 3-16: Climate Lens Cost Indicators

Total O&M Costs Over 50 years	Total Eligible Construction Costs	Total Requested Federal Contribution	Total Project Costs	Total Project Costs to Tonne of CO_2e	Federal Funding per GHG Reductions in 2030
$	$	$	$	$/tonnes CO_2e	$/tonnes CO_2e
8,372,110	79,138,000	31,655,200	97,411,110	22,336	362,923

Notes: 1. The total Project cost to tonne of CO_2e is the total construction costs plus the annual O&M costs over 50 years divided by the cumulative GHG reductions over the 52-year life.

The total eligible costs are $79,138,000. Of these costs, 40% is from Federal contribution. Thus, the GHG reduction cost for 2030 is $362,923/tCO2e (non-cumulative basis). For the Project lifespan, the GHG reduction cost is $22,336 /tCO2e.

3.6 Conclusion

The Project case has been shown to be the preferred option with respect to GHG emissions. Indeed, the assessment showed that over its 52-year lifespan, the project could decrease the GHG emission to a total of 4,361 tonnes of CO_2e compared to the baseline. On an energy basis, the annual savings are estimated at 2,115 GJ.

At the time of the assessment, the choice of heating system was not yet defined, but regarding GHG emissions, the energy savings associated with LEED Gold certification could be greater if the buildings were heated with a geothermal or infrared heating system instead of using natural gas.

Unlike some Canadian provinces, Manitoba's electricity generation is largely hydroelectric, which gives it the lowest GHG emission factor in Canada. When a conventional heating system consumes natural gas, GHG emissions are almost 144 times higher than grid sourced electricity in Manitoba. By moving towards this type of heating system, the project could be among the lowest GHG intensities of recreation centers in Canada.

4. Overall Conclusions and Recommendations

Key Project recommendations from the **climate change resilience assessment** for input into the design include the following:

DESIGN RELATED MEASURES:

- Identify optimum building orientation and/or use materials that are resistant to or limit the accumulation of heat, such as light-colored materials such as white (high albedo). Paint roofs with light reflective colors or use materials with high thermal resistance to reduce heat gain.
- Integrate passive design measures including insulation, air permeability, orientation and shading to help maintain comfortable indoor temperatures.
- Protect south-facing windows from solar heat gain through increased shading and solar control (e.g., reflective glass, overhangs or natural landscaping).
- Consider nature-based approaches, such as green roofs or green walls, to reduce building temperature during heat waves and extremely hot days.
- Install an emergency standby generator to provide backup power during an outage.
- Consider adding an alternate source of power that is combined to a battery in order to provide emergency power during an outage.
- Encourage the use of heat-resistant materials or materials that limit the accumulation of heat to avoid premature deterioration of the paver (such as honeycombed pavers, composite pavers).
- Use reflective (high albedo) materials on pavers, such as light shades, such as white.
- Consider nature-based solutions, green infrastructure and landscape design, such as planting local species that have a greater heat tolerance or are drought resistant, retaining water.
- The main walking and cycling paths should be shaded and greened.
- Install drinking fountains next to pedestrian areas.
- Use paving materials designed to withstand very cold temperatures to reduce damages to pavement (e.g., cracking, rutting).
- Use building materials that are resistant to temperature variations.
- Use sound passive design techniques and materials that have a high thermal mass potential to regulate temperatures.
- Use good thermal insulating materials when building the facilities.
- Install warning signs of the possibility of black ice slipping and falling.
- Design building heating/ cooling/ ventilation services to prevent or reduce damage from precipitation.
- Incorporate low impact development practices or green Infrastructure to manage stormwater runoff and prevent flood damages. Some examples include, bioretention planters, bioswales, etc.
- Increase the area of permeable surfaces and promote the implementation of rain gardens in order to reduce flood risk of pavement and roads.
- To limit runoff and erosion, design landscaping with plants that can help hold the soil firmly in place, such as fast-growing ground covers and even flower plants such as daylilies and sages. Make sure that the plants used can absorb a lot of water.
- Mulching can help mitigate erosion on moderate slopes in the landscape. applying mulch protects soil, increases surface area and improves water penetration.
- Install geotextiles to reduce surface erosion in landscaping.

- Consider arched or sloped roof (no flat roof) to prevent snow loads.
- Choose water efficient toilets, water efficient sinks and water efficient shower heads or flow restrictors.
- Consider nature-based solutions, green infrastructure and landscape design, such as planting local species that have a greater heat tolerance or are drought resistant.
- Consider incorporating windbreaks (e.g., vegetation) in the landscape design.
- Select local species that are resistant to strong winds.
- Design measures should consider LEED standards in order to obtain LEED Gold certification and promote the design and construction of a green building.

OPERATIONS AND MAINTENANCE-RELATED MEASURES:

- Weekly monitoring of energy demand on mechanical HVAC and cooling systems, during the high temperature periods and increase monitoring of HVAC cooling demand during heat wave periods to avoid overheating of the systems.
- Increase inspection after hot temperature events to make sure power, communication and electrical systems are working correctly.
- Conduct frequent inspections of pavement surfaces to ensure cracks are properly sealed.
- Ensure proper maintenance of landscaping during summer months.
- Increase inspections during cold days to check for damages to the road and provide maintenance when necessary.
- Increase inspection and maintenance of building envelope after days of diurnal variation events.
- Apply de-icing agents on walkways and other work areas that are vulnerable to ice development.
- Inspect door and window seals before winter and in the spring to reduce water infiltration.
- Increase monitoring of HVAC during heavy rainfall and blowing rain events.
- Increase inspections and maintenance of power, communication and electrical systems following heavy rainfall, blowing wind and blowing snow events.
- Conduct regular inspections of electrical components and equipment before winter and spring seasons to prevent water-related damages.
- Conduct frequent inspections of drainage systems, before winter and spring seasons. Keep drainage clear of debris to ensure proper drainage with anticipated increases in precipitation.
- Schedule landscape inspections after heavy rainfall events.
- Modify work schedules under conditions induced by climate-related disruptions.
- Remove snow loads from building roof during winter months.
- Increase inspections and maintenance following snow fall and snow accumulation events.
- Monitor sealant condition twice a year, at the end of winter and summer, and replace sealants on critical windows and doors.
- Increase the frequency of sealant monitoring on windows during periods of high winds combined with rain and snow (spring and fall).
- De-ice roof drains to prevent them from becoming clogged and to provide a path for snow and debris to for the flow of melted snow and ice.
- Remove debris (e.g., leaves, branches, etc.) from around the drains in the fall to ensure proper drainage.
- Cover fragile trees, shrubs and other vulnerable plants with protective sheets before winter seasons.

- Properly secure objects, signage, exterior lighting to withstand heavy winds.
- Monitor elements that could become projectiles in times of strong winds.
- Maintain building accesses to ensure that the path is clear and that there is no debris that can be blown away.
- Install signage in winter to indicate slippery areas and falling snow or ice to ensure safe movement and access to the building.
- Incorporate LEED standards for operation and maintenance such as precooling the building overnight when possible

POLICY RELATED MEASURE:

- Implement worker safety measures to protect the health and safety of staff.
- Include in the site operation plan safety measures to protect the public.
- Install a real-time Flood Warning System that alerts staff in advance so that necessary resources can be deployed.
- Develop and implement an Emergency Preparedness and Management Plan in the case of a heavy rainfall event and other climate impacts.
- Identify water saving measure that could be implemented in drought events such as identifying non-essential uses such as outdoor landscaping.
- The SWRC aspires to be LEED Gold certified, therefore it should integrate all the necessary standards regarding design, construction and operation and maintenance of the building.

5. Attestation of Completeness

5.1 Climate Change Adaptation

We the undersigned attest that this Resilience Assessment was undertaken using recognized assessment tools and approaches (i.e., ISO 31000:2009 Risk Management-Principles and Guidelines) and complies with the General Guidance and any relevant sector-specific technical guidance issued by Infrastructure Canada for use under the Climate Lens.

Prepared by:	Omar Daouda, PhD. Environmental Geography Climate Change Resilience and Adaptation Specialist	Date : 2021-07-15
	Emma Orellana-Pepin, M.Env. Resilience and Climate Change Adaptation Specialist	Date: 2021-07-15
Validated by:	Derek R. Gray, P.Eng, A.A.E Manager, Water Resources and Resiliency	Date 2021-07-15

5.2 Greenhouse Gas Mitigation Assessment

We the undersigned attest that this GHG Mitigation Assessment was undertaken using recognized assessment tools and approaches (i.e., ISO 14064-2: Specification with guidance at the Project level for quantification, monitoring, and reporting of greenhouse gas emissions reductions or removal enhancements and, if chosen, the GHG Protocol for Project Accounting) and complies with the General Guidance and any relevant sector-specific technical guidance issued by Infrastructure Canada for use under the Climate Lens.

Prepared by:	Jérémy Lagneau, ing. jr., M. Sc. A. Environmental Scientist	Date
Validated by:	Jacques Langlois, Ph.D. Environmental Scientist	Date

Appendix A Climate Change Resilience Assessment – Excel Spreadsheet

Likelihood

Very high	Once every year or more	More than 70% (100%)	5
High	Once every 2 years	40%-70% (50%)	4
Moderate	Once every 5 years	20%-40% (20%)	3
Low	Once every 10 years	4%-20% (10%)	2
Very low	Once every 30 years	4% or less (4%)	1

	Climate (Probability / Likelihood)			Impact Categories (Consequences)				Severity Rating		Justification	Risk Results	
Infrastructure Components	**Climate Indicators**	**Current**	**Future**	**Health & Safety**	**Infrastructure Integrity**	**Operational impact**	**Financial impact**	**Impacted** (Y/N)	**Impact Severity Rating** (1-5)		**Current**	**Future**
Building Elements												
Building Elements	Hot temperature	5	5	0	1	0	1	Yes	1	It is possible that the probability of hot temperature events may result in premature wear and tear and accelerate deterioration the building envelope. Hot temperatures can cause high temperature in buildings exacerbated by solar heat gains.	5	5
Building Elements	Heat wave	2	5	0	3	0	3	Yes	3	it is possible that the probability of hot temperature events may result in premature wear and tear and accelerate deterioration the building envelope. Heat waves can cause high temperature in buildings exacerbated by solar heat gains. Also, heat waves could exacerbate localized urban heat island effects.	6	15
Building Elements	Cold temperature	5	4	0	1	0	1	Yes	1	Cold temperatures may result in accelerated deterioration of exterior building elements and the building envelope, resulting in increased inspections and maintenance costs.	5	4
Building Elements	Diurnal variation	5	5	0	1	0	1	Yes	1	'Diurnal variation may result in accelerated deterioration of exterior building elements and the building envelope, resulting in increased inspections and maintenance costs.	5	5
Building Elements	Heavy rainfall	5	5	1	3	0	3	Yes	3	'Heavy rainfall may result in accelerated deterioration of exterior building elements (e.g., windows, doors, roof) and the building envelope due to water infiltration, resulting in increased inspections and maintenance costs.	15	15
Building Elements	Snow accumulation	4	4	0	1	1	2	Yes	2	Snow accumulation could increase loads on building roofs, which may require additional snow removal costs.	8	8
Building Elements	Drought	5	5	0	0	0	0	No	0	no impact	0	0
Building Elements	Heavy wind	5	5	0	3	1	2	Yes	3	'Heavy winds may cause damages the building envelope, windows and doors, which could result in increased inspections and maintenance costs.	15	15

	Climate (Probability / Likelihood)			Impact Categories (Consequences)				Severity Rating		Justification	Risk Results	
Infrastructure Components	Climate Indicators	Current	Future	Health & Safety	Infrastructure Integrity	Operational impact	Financial impact	Impacted (Y/N)	Impact Severity Rating (1-5)		Current	Future
Building Elements	Blowing rain	4	5	1	3	1	2	Yes	3	Blowing rain may result in water infiltration in the building envelope and windows if joints are not properly sealed, which may result in increased inspections and maintenance costs. Heavy winds may cause damages the building envelope, windows and doors, which could result in increased inspections and maintenance costs.	12	15
Building Elements	Blowing snow	5	5	1	3	1	2	Yes	3	Blowing snow could increase snow loads on building roofs, which may result in increased snow removal costs. Heavy winds may cause damages the building envelope, windows and doors, which could result in increased inspections and maintenance costs.	15	15
Mechanical Equipment and HVAC System												
Mechanical Equipment and HVAC System	Hot temperature	5	5	0	1	1	1	Yes	1	Pressure on HVAC system due to increased demands for cooling	5	5
Mechanical Equipment and HVAC System	Heat wave	2	5	0	2	2	2	Yes	2	Pressure on HVAC system due to increased demands for cooling	4	10
Mechanical Equipment and HVAC System	Cold temperature	5	4	0	1	1	1	Yes	1	Pressure on HVAC system due to increased demands for heating. Cold temperatures may cause damages to exposed mechanical equipment (e.g., expansion, cracks, leaks).	5	4
Mechanical Equipment and HVAC System	Diurnal variation	5	5	0	0	0	0	No	0	no impact	0	0
Mechanical Equipment and HVAC System	Heavy rainfall	5	5	0	2	2	2	Yes	2	flooding and/or lightning strikes resulting in a power surge may put HVAC at risk	10	10
Mechanical Equipment and HVAC System	Snow accumulation	4	4	0	0	0	0	No	0	no impact	0	0
Mechanical Equipment and HVAC System	Drought	5	5	0	0	0	0	No	0	no impact	0	0
Mechanical Equipment and HVAC System	Heavy wind	5	5	0	0	0	0	No	0	no impact	0	0

	Climate (Probability / Likelihood)			Impact Categories (Consequences)				Severity Rating		Justification	Risk Results	
Infrastructure Components	Climate Indicators	Current	Future	Health & Safety	Infrastructure Integrity	Operational impact	Financial impact	Impacted (Y/N)	Impact Severity Rating (1-5)		Current	Future
Mechanical Equipment and HVAC System	Blowing rain	4	5	0	2	2	2	Yes	2	flooding and/or lightning strikes resulting in a power surge may put HVAC at risk	8	10
Mechanical Equipment and HVAC System	Blowing snow	5	5	0	0	0	0	No	0	no impact	0	0
Power, Communication and Electrical Equipment												
Power, Communication and Electrical Equipment	Hot temperature	5	5	0	2	3	1	Yes	3	The heat may cause surveillance cameras to break down or cause them to erode away causing them to malfunction. Heat waves and extreme temperatures can cause blackouts forcing facility shutdown.	15	15
Power, Communication and Electrical Equipment	Heat wave	2	5	0	2	3	2	Yes	3	The heat may cause surveillance cameras to break down or cause them to erode away causing them to malfunction. Heat waves and extreme temperatures can cause blackouts forcing facility shutdown.	6	15
Power, Communication and Electrical Equipment	Cold temperature	5	4	0	2	2	2	Yes	2	Cold temperatures may impact the electrical equipment, especially when combined with rain and/or snow (e.g. freezing and damaging the equipment). Cold temperatures could result in increased demand for fuel for emergency generators and resulting price increases.	10	8
Power, Communication and Electrical Equipment	Diurnal variation	5	5	0	0	0	0	No	0	no impact	0	0
Power, Communication and Electrical Equipment	Heavy rainfall	5	5	0	3	1	2	Yes	3	Over time, repeated exposure to heavy rain can damage to almost any piece of electronic equipment, even if it is very well protected. This includes cameras. What's more, if rainwater ends up on the lens of a camera, it may distort or partially obscure the image that the camera records. -'Heavy rainfall may cause water damages to transformers located outside. Electrical systems can be damaged as a result of flooding or standing water	15	15
Power, Communication and Electrical Equipment	Snow accumulation	4	4	0	2	0	1	Yes	2	Snow and ice could outdoor surveillance system cameras in optic and mechanical disruptions. An unshielded camera can be damaged by ice. If there is moisture around an outdoor camera below the temperatures drop below freezing, the frost that is formed by that moisture and temperature can form on the cameras lens and preventing the viewer to see any activities going on outside besides the crystalline patterns from the snow. This will likely result in increased maintenance cost	8	8

Infrastructure Components	Climate (Probability / Likelihood) Climate Indicators	Current	Future	Impact Categories (Consequences) Health & Safety	Infrastructure Integrity	Operational impact	Financial impact	Severity Rating Impacted (Y/N)	Impact Severity Rating (1-5)	Justification	Risk Results Current	Future
Power, Communication and Electrical Equipment	Drought	5	5	0	0	0	0	No	0	no impact	0	0
Power, Communication and Electrical Equipment	Heavy wind	5	5	0	3	2	1	Yes	3	Heavy winds may cause power outages which can cause disruption to the operations	15	15
Power, Communication and Electrical Equipment	Blowing rain	4	5	0	3	2	2	Yes	3	Heavy winds may cause power outages which can cause disruption to the operations. Blowing rain may cause water damages (e.g., infiltration, corrosion) to transformers located outside. Increased maintenance cost.	12	15
Power, Communication and Electrical Equipment	Blowing snow	5	5	0	3	2	2	Yes	3	Snow and ice impact outdoor surveillance system cameras in optic and mechanical disruptions. An unshielded camera can be damaged by ice. If there is moisture around an outdoor camera below the temperatures drop below freezing, the frost that is formed by that moisture and temperature can form on the cameras lens and disallowing the viewer to see any activities going on outside besides the crystalline patterns from the snow. Heavy winds may cause power outages which can cause disruption to the operations. Blowing snow may cause water damages (e.g., infiltration, corrosion) to transformers located outside. Increased maintenance cost.	15	15
Utilities												
Utilities	Hot temperature	5	5	0	0	0	0	No	0	no impact	0	0
Utilities	Heat wave	2	5	0	0	0	0	No	0	no impact	0	0
Utilities	Cold temperature	5	4	0	0	1	1	Yes	1	Cold temperatures could result in increased heating costs (natural gas services).	5	4
Utilities	Diurnal variation	5	5	0	0	1	1	Yes	1	Changes in temperature could result in increased heating costs (natural gas services).	5	5
Utilities	Heavy rainfall	5	5	1	3	3	2	Yes	3	Heavy rainfall may cause localized flooding in low-lying areas and significant runoff, which could overload drainage systems. Also, flash floods caused by heavy rainfall may damage underground utilities and require additional maintenance and repair costs.	15	15
Utilities	Snow accumulation	4	4	0	1	1	1	Yes	1	Snow accumulation may overload drainage systems and require additional snow removal costs	4	4

	Climate (Probability / Likelihood)			Impact Categories (Consequences)				Severity Rating		Justification	Risk Results	
Infrastructure Components	Climate Indicators	Current	Future	Health & Safety	Infrastructure Integrity	Operational impact	Financial impact	Impacted (Y/N)	Impact Severity Rating (1-5)		Current	Future
Utilities	Drought	5	5	2	0	3	3	Yes	3	In case of drought, water supply, access to water and water consumption might be restricted, which would limit the facility's provided services.	15	15
Utilities	Heavy wind	5	5	0	1	1	1	Yes	1	Heavy wind may result in an accumulation of debris and objects in the drainage system.	5	5
Utilities	Blowing rain	4	5	1	1	1	1	Yes	1	Blowing rain may result in an accumulation of debris and objects in the drainage system.	4	5
Utilities	Blowing snow	5	5	0	1	1	1	Yes	1	Snow accumulation may overload the drainage system and increase snow removal costs.	5	5
Exterior Elements												
Exterior Elements	Hot temperature	5	5	0	2	0	2	Yes	2	Summer temperatures above or equal to 30°C can impact exterior elements, including the performance of materials (Del lighting) and require more landscape maintenance. Higher temperatures may cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking), which could result in increased maintenance costs. Also, heat waves may exacerbate the Urban Heat Island effect due to increased surface temperatures of the pavement.	10	10
Exterior Elements	Heat wave	2	5	0	3	0	2	Yes	3	Summer temperatures above or equal to 30°C can impact exterior elements, including the performance of materials (Del lighting) and require more landscape maintenance. Higher temperatures may cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking), which could result in increased maintenance costs. Also, heat waves may exacerbate the Urban Heat Island effect due to increased surface temperatures of the pavement.	6	15
Exterior Elements	Cold temperature	5	4	0	3	0	2	Yes	3	Cold temperatures could cause premature deterioration of access roads, pavements (e.g., potholes, rutting, cracking), resulting in more maintenance costs	15	12
Exterior Elements	Diurnal variation	5	5	0	1	0	1	Yes	1	Diurnal variation could cause premature deterioration of access roads, pavements (e.g., potholes, rutting, cracking), resulting in more maintenance costs	5	5
Exterior Elements	Heavy rainfall	5	5	0	3	0	2	Yes	3	Heavy rain could wash away and erode the landscaping. Heavy rainfall could cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking) as well as signage. This could result in increased maintenance costs	15	15
Exterior Elements	Snow accumulation	4	4	1	1	0	1	Yes	1	Snow accumulation may cause reduced accessibility to the building, slippery surfaces. This can be an accident hazard in the parking lots and the roadways and walkways around the building.	4	4

	Climate (Probability / Likelihood)			Impact Categories (Consequences)				Severity Rating		Justification	Risk Results	
Infrastructure Components	Climate Indicators	Current	Future	Health & Safety	Infrastructure Integrity	Operational impact	Financial impact	Impacted (Y/N)	Impact Severity Rating (1-5)		Current	Future
Exterior Elements	Drought	5	5	0	2	0	1	Yes	2	Drought can cause reduced soil quality, resulting in loss of vegetation and increased demand for water. Drought may lead to increased landscape maintenance	10	10
Exterior Elements	Heavy wind	5	5	2	3	0	2	Yes	3	The interaction of high wind with certain infrastructure elements poses a significant risk. This include landscaping, exterior lighting, signage, etc. Exterior lighting equipment and landscaping can be damaged during high and gusty winds. There is a risk that these components could hit the building or occupants. Landscaping elements can become projectiles when they are blown away by strong wind. Increased maintenance and repair costs	15	15
Exterior Elements	Blowing rain	4	5	2	3	0	2	Yes	3	The interaction of high wind with certain infrastructure elements poses a significant risk. This include landscaping, exterior lighting, signage, etc. Exterior lighting equipment and landscaping can be damaged during high and gusty winds. There is a risk that these components could hit the building or people. Landscaping elements can become projectiles when they are blown away by strong wind. Blowing rain could wash away and erode landscaping. Heavy rainfall could cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking) This could result in increased maintenance and repair costs.	12	15
Exterior Elements	Blowing snow	5	5	2	3	0	2	Yes	3	The interaction of high wind with certain infrastructure elements poses a significant risk. This include landscaping, exterior lighting, signage, etc. Exterior lighting equipment and landscaping can be damaged during high and gusty winds. There is a risk that these components could hit the building or occupants. Landscaping elements can become projectiles when they are blown away by strong wind. Blowing snow may cause reduced accessibility to the building due to snow accumulation, slippery surfaces. This can be an accident hazard in the parking lots and the roadways and walkways around the building. Increased maintenance and repair cost.	15	15
People												
People	Hot temperature	5	5	2	0	0	0	Yes	2	Higher temperatures and heat waves could impact outside working staff wellbeing and productivity and could impact public health (e.g., heat exhaustion and heat stroke, dehydration, heat stress).	10	10
People	Heat wave	2	5	3	0	0	0	Yes	3	Higher temperatures and heat waves could impact outside working staff wellbeing and productivity and could impact public health (e.g., heat exhaustion and heat stroke, dehydration, heat stress).	6	15
People	Cold temperature	5	4	2	0	0	0	Yes	2	Cold temperatures could impact wellbeing and productivity (e.g., frostbite, hypothermia)	10	8
People	Diurnal variation	5	5	1	0	0	0	Yes	1	Variation in temperature during winter can form black ice during and could cause slip and fall of staff and public visiting the facility	5	5

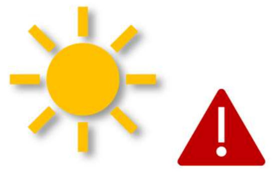
	Climate (Probability / Likelihood)			Impact Categories (Consequences)				Severity Rating		Justification	Risk Results	
Infrastructure Components	Climate Indicators	Current	Future	Health & Safety	Infrastructure Integrity	Operational impact	Financial impact	Impacted (Y/N)	Impact Severity Rating (1-5)		Current	Future
People	Heavy rainfall	5	5	3	0	0	0	Yes	3	Heavy rainfall may cause flash floods, which could make it difficult for the public to access the facility and staff to access the site and conduct regular operations, construction or maintenance work.	15	15
People	Snow accumulation	4	4	1	0	0	0	Yes	1	Snow accumulation may limit access to the site and staff working outside as well as public users of the facility can slip and fall if roadways and pedestrian walkways are not properly cleared.	4	4
People	Drought	5	5	0	0	0	0	No	0	no impact	0	0
People	Heavy wind	5	5	2	0	0	0	Yes	2	Heavy wind could blow away debris or objects, which could cause injuries to staff and the public using the facility. Increased maintenance and/or delay of work	10	10
People	Blowing rain	4	5	2	0	0	0	Yes	2	Heavy wind and blowing rain could blow away debris or objects, which could cause injuries to staff and the public using the facility. Blowing rain can cause slippery conditions. Increased maintenance and/or delay of work	8	10
People	Blowing snow	5	5	2	0	0	0	Yes	2	Heavy wind and blowing snow could blow away debris or objects, which could cause injuries to staff and the public using the facility. Blowing snow can cause slippery conditions and snow accumulation can restrict access to the facility. Increased maintenance and/or delay of work	10	10

Risk Evaluation Matrix

Severity of Consequences						
	Very High (5)	5	10	15	20	25
	High (4)	4	8	12	16	20
	Moderate (3)	3	6	9	12	15
	Low (2)	2	4	6	8	10
	Very Low (1)	1	2	3	4	5
		Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
		Probability (Likelihood)				

Risk Rating

Risk (R) = Probability (P) x Severity (G)	
Low Risk: < 6	Controls likely not required
Moderate Risk: 7 < R < 16	Some controls required to reduce risks to lower levels
High Risk: R > 20	High priority control measures required
R = 5	Special Cases: Interactions resulting in a risk rated “5” are considered special cases and are considered in the risk evaluation, as these can either be interactions with very low likelihood but very high severity or interactions with high likelihood and very low severity. While the former case may have very severe impacts, the latter case can trigger a slow deterioration of project components due to the high likelihood of the climate condition.

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation timeframe	Effectiveness
Risk Event: Moderate and special cases - Hot temperatures / Number of heat waves 	Building Elements	15	-Design: Identify optimum building orientation and/or use materials that are resistant to or limit the accumulation of heat, such as light-colored materials such as white (high albedo). Paint roofs with light reflective colors or use materials with high thermal resistance to reduce heat gain -Design: Integrate passive design measures including insulation, air permeability, orientation and shading to help maintain comfortable indoor temperatures -Design: Protect south-facing windows from solar heat gain through increased shading and solar control (e.g., reflective glass, overhangs or natural landscaping) - Design: Consider nature-based approaches, such as green roofs or green walls, to reduce building temperature during heat waves and extremely hot days - Design: Design measures should consider LEED standards in order to obtain LEED Gold certification and promote the design and construction of a green building. -Policy: The SWRC aspires to be LEED Gold certified, therefore it should integrate all the necessary standards regarding design, construction and operation and maintenance of the building.	It is possible that the probability of hot temperature events may result in premature wear and tear and accelerated deterioration the building envelope. Heat waves and extreme temperatures can cause high temperature in buildings exacerbated by solar heat gains. Also, heat waves could exacerbate localized urban heat island effects.	Design	Very Effective
	Mechanical Equipment and HVAC System	10	-O&M: Weekly monitoring of energy demand on mechanical HVAC and cooling systems, during the high temperature periods. -O&M: Increase monitoring of HVAC cooling demand during heat wave periods to avoid overheating of the systems. -O&M: Incorporate LEED standards such as precooling the building overnight when possible	Pressure on HVAC system due to increased demands for cooling	O&M	Effective
	Power, Communication and Electrical Equipment	15	-Design: Install an emergency standby generator to provide backup power during an outage -Design: Consider adding an alternate source of power that is combined to a battery in order to provide emergency power during an outage -O&M: Increase inspection after hot temperature events to make sure systems are working correctly.	The heat may cause surveillance cameras to break down or cause them to erode away causing them to malfunction. Heat waves and extreme temperatures can cause blackouts forcing facility shutdown.	Design and O&M	Effective

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation timeframe	Effectiveness
Risk Event: Moderate and special cases - Hot temperatures / Number of heat waves (continued)	Exterior Elements	15	-Design: Encourage the use of heat-resistant materials or materials that limit the accumulation of heat to avoid premature deterioration of the paver (such as honeycombed pavers, composite pavers) -Design: Use reflective (high albedo) materials on pavers, such as light shades, such as white - Design: Consider nature-based solutions, green infrastructure and landscape design, such as planting local species that have a greater heat tolerance or are drought resistant, retaining water. - O&M: Conduct frequent inspections of pavement surfaces to ensure cracks are properly sealed - O&M: Ensure proper maintenance of landscaping during summer months.	Summer temperatures above or equal to 30°C can impact exterior elements and require more landscape maintenance. Higher temperatures may cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking), which could result in increased maintenance costs. Also, heat waves may exacerbate the Urban Heat Island effect due to increased surface temperatures of the pavement.	Design and O&M	Very Effective
	People	15	-Design: The main walking and cycling paths should be shaded and greened - Design: Install drinking fountains next to pedestrian areas - O&M: Modify maintenance schedules in anticipation of hot temperatures, shift maintenance work to cooler parts of the day. - Policy: Implement worker safety measures to protect the health and safety of staff -Policy: Include in the site operation plan safety measures to protect the public.	Higher temperatures and heat waves could impact outside working staff wellbeing and productivity and could impact public health (e.g., heat exhaustion and heat stroke, dehydration, heat stress).	Design and O&M and Policy	Very Effective
Risk Event - Moderate - Cold temperature	Power, Communication and Electrical Equipment	8	- Design: Install an emergency back-up generator to maintain the facility running in case of a prolonged power outage and business continuity	Cold temperatures may impact the electrical equipment, especially when combined with rain and/or snow (e.g. freezing and damaging the equipment). Cold temperatures could result in increased demand for fuel for emergency generators and resulting price increases.	Design	Effective
	Exterior Elements	12	- Design : Use paving materials designed to withstand very cold temperatures to reduce damages to pavement (e.g., cracking, rutting) - O&M : Increase inspections during cold days to check for damages to the road and provide maintenance when necessary.	Cold temperatures could cause premature deterioration of access roads, pavements (e.g., potholes, rutting, cracking), resulting in more maintenance costs	Design and O&M	Very Effective
	People	8	- Policy: Develop and implement safety measures to ensure workers can stay warm if they are working outside during very cold days (adequate clothes, shoes and equipment, etc.).	Cold temperatures could impact wellbeing and productivity (e.g., frostbite, hypothermia)	Policy	Very Effective

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation timeframe	Effectiveness
Risk Event - Special Cases - Diurnal variation	Building Elements	5	-Design: Use building materials that are resistant to temperature variations -O&M: Increase inspection and maintenance of building envelope after days of diurnal variation events.	Diurnal variation may result in accelerated deterioration of exterior building elements and the building envelope, resulting in increased inspections and maintenance costs.	Design and O&M	Effective
	Utilities	5	-Design: Use sound passive design techniques and materials that have a high thermal mass potential to regulate temperatures. -Design: Use good thermal insulating materials when building the facilities.	Changes in temperature could result in increased heating costs (natural gas services).	Design	Very Effective
	Exterior Elements	5	- O&M: Conduct frequent inspections of pavement surfaces to and properly seal cracks on pavement surfaces.	Diurnal variation could cause premature deterioration of access roads, pavements (e.g., potholes, rutting, cracking), resulting in more maintenance costs	O&M	Effective
	People	5	-Design: Install warning signs of the possibility of black ice slipping and falling. -O&M: Apply deicing agents on walkways and other work areas that are vulnerable to ice development.	Variation in temperature during winter can form black ice and could cause slip and fall of staff and public visiting the facility	Design and O&M	Effective
Risk Event - Moderate - Heavy rainfall	Building Elements	15	-O&M: Inspect door and window seals before winter and in the spring to reduce water infiltration.	Heavy rainfall may result in accelerated deterioration of exterior building elements (e.g., windows, doors, roof) and the building envelope due to water infiltration, resulting in increased inspections and maintenance costs.	O&M	Effective
	Mechanical Equipment and HVAC System	10	-Design: Design building heating/ cooling/ ventilation services to prevent or reduce damage from precipitation. -O&M: Increase monitoring of HVAC during heavy rainfall events	Flooding and/or lightning strikes resulting in a power surge may put HVAC at risk	Design and O&M	Effective
	Power, Communication and Electrical Equipment	15	-O&M: Increase inspections and maintenance following heavy rainfall events -O&M: Conduct regular inspections of electrical components and equipment before winter and spring seasons to prevent water-related damages.	Over time, repeated exposure to heavy rain can damage to almost any piece of electronic equipment, even if it is very well protected. This includes cameras. What's more, if rainwater ends up on the lens of a camera, it may distort or partially obscure the image that the camera records. Heavy rainfall may cause water damages to transformers located outside. Electrical systems can be damaged as a result of flooding or standing water	O&M	Effective

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation timeframe	Effectiveness
Risk Event - Moderate - Heavy rainfall (continued)	Utilities	15	- Design: Incorporate low impact development practices or green Infrastructure to manage stormwater runoff and prevent flood damages. Some examples include, bioretention planters, bioswales, etc. -O&M: Conduct frequent inspections of drainage systems, before winter and spring seasons. Keep drainage clear of debris to ensure proper drainage with anticipated increases in precipitation. -Policy: Install a real-time Flood Warning System that alerts staff in advance so that necessary resources can be deployed	Heavy rainfall may cause localized flooding in low-lying areas and significant runoff, which could overload drainage systems. Also, flash floods caused by heavy rainfall may damage underground utilities and require additional maintenance and repair costs.	Design and O&M and Policy	Very Effective
	Exterior Elements	15	- Design: Increase the area of permeable surfaces and promote the implementation of rain gardens in order to reduce flood risk of pavement and roads. - Design: in order to limit runoff and erosion, design landscaping with plants that can help hold the soil firmly in place, such as fast-growing ground covers and even flower plants such as daylilies and sages. Make sure that the plants used can absorb a lot of water. -Design: Mulching can help mitigate erosion on moderate slopes in the landscape. applying mulch protects soil, increases surface area and improves water penetration -Design: Install geotextiles to reduce surface erosion in landscaping. -O&M: Schedule landscape inspections after heavy rainfall events.	Heavy rain could wash away and erode the landscaping. Heavy rainfall could cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking) as well as signage. This could result in increased maintenance costs	Design and O&M	Very Effective
	People	15	- O&M: Modify work schedules under conditions induced by climate-related disruptions. - Policy: Develop and implement an Emergency Preparedness and Management Plan in the case of a heavy rainfall event -Policy: Include in the site operation plan safety measures to protect the public.	Heavy rainfall may cause flash floods, which could make it difficult for the public to access the facility and staff to access the site and conduct regular operations, construction, or maintenance work.	O&M and Policy	Very Effective
Risk Event- Moderate Snow Accumulation	Building Elements	8	- Design: Consider arched or sloped roof (no flat roof) to prevent snow loads. - O&M: Remove snow loads from building roof during winter months.	Snow accumulation could increase loads on building roofs, which may require additional snow removal costs.	Design and O&M	Very Effective

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation timeframe	Effectiveness
Risk Event- Moderate Snow Accumulation (continued)	Power, Communication and Electrical Equipment	8	-O&M: Increase inspections and maintenance following snow fall and snow accumulation events	Snow and ice could impact outdoor surveillance system cameras in optic and mechanical disruptions. An unshielded camera can be damaged by ice. If there is moisture around an outdoor camera below the temperatures drop below freezing, the frost that is formed by that moisture and temperature can form on the cameras lens and preventing the viewer to see any activities going on outside besides the crystalline patterns from the snow. This will likely result in increased maintenance cost.	O&M	Effective
Risk Event - Moderate – Drought	Utilities	15	- Policy Identify water saving measure that could be implemented in drought events such as identifying non-essential uses such as outdoor landscaping. -Design: Chose water efficient toilets, water efficient sinks and water efficient shower heads or flow restrictors	In case of drought, water supply, access to water and water consumption might be restricted, which would limit the facility's provided services.	Design and Policy	Effective
	Exterior Elements	10	- Design: Consider nature-based solutions, green infrastructure and landscape design, such as planting local species that have a greater heat tolerance or are drought resistant. - O&M: Ensure proper maintenance of landscaping during summer months.	Drought can cause reduced soil quality, resulting in loss of vegetation and increased demand for water. Drought may lead to increased landscape maintenance	Design and O&M	Very Effective
Risk Event - Moderate and Special Cases - Heavy wind / Blowing rain / Blowing snow	Building Elements	15	-O&M: Monitor sealant condition twice a year, at the end of winter and summer, and replace sealants on windows and doors -O&M: Increase the frequency of sealant monitoring on windows during periods of high winds combined with rain and snow (spring and fall).	Heavy winds may cause damages the building envelope, windows and doors, which could result in increased inspections and maintenance costs. Blowing rain may result in water infiltration in the building envelope and windows if joints are not properly sealed, which may result in increased inspections and maintenance costs. Blowing snow could increase snow loads on building roofs, which may result in increased snow removal costs.	O&M	Very Effective
	Mechanical Equipment and HVAC System	10	-O&M: Increase monitoring of HVAC during blowing rain events	Flooding and/or lightning strikes resulting in a power surge may put HVAC at risk	O&M	Effective
	Power, Communication and Electrical Equipment	15	-Design: Install a generator to ensure minimal power loss to the building before, during and after a power outage -O&M: Increase inspections and maintenance following blowing rain and blowing snow events	Heavy winds may cause power outages which can cause disruption to the operations. Blowing rain and blowing snow may cause water damages (e.g., infiltration, corrosion) to transformers located outside. Snow and ice impact to outdoor surveillance system cameras in optic and mechanical disruptions. An unshielded camera can be damaged by ice. If there is moisture around an outdoor camera below the temperatures drop below freezing, the frost that is formed by that moisture and temperature can form on the cameras lens and disallowing the viewer to see any activities going on outside besides the crystalline patterns from the snow	Design and O&M	Effective

Risk Event	Project Components	Risk	Adaptation Measure or Risk Treatment	Comments	Implementation timeframe	Effectiveness
Risk Event - Moderate and Special Cases - Heavy wind / Blowing rain / Blowing snow (continued)	Utilities	5	-O&M: De-ice roof drains to prevent them from becoming clogged and to provide a path for snow and debris to for the flow of melted snow and ice. -O&M: Remove debris (e.g., leaves, branches, etc.) from around the drains in the fall to ensure proper drainage.	Heavy wind may result in an accumulation of debris and objects in the drainage system. Blowing rain may result in an accumulation of debris and objects in the drainage system. Heavy rain and snow accumulation might increase maintenance cost.	O&M	Very Effective
	Exterior Elements	15	- Design: Consider incorporating windbreaks (e.g., vegetation) in the landscape design. -Design: Select local species that are resistant to strong winds. - O&M: Cover fragile trees, shrubs and other vulnerable plants with protective sheets before winter seasons. - O&M: Properly secure objects, signage, exterior lighting to withstand heavy winds -O&M: Monitor elements that could become projectiles in times of strong winds -O&M: Maintain building accesses to ensure that the path is clear and that there is no debris that can be blown away - O&M: Conduct regular inspection during these extreme weather events and apply necessary measures (snow-clearing, debris clearing, use of abrasive material to de-ice)	The interaction of high wind with certain infrastructure elements poses a significant risk. This include landscaping, exterior lighting, signage, etc. Exterior lighting equipment and landscaping can be damaged during high and gusty winds. There is a risk that these components could hit the building or people. Landscaping elements can become projectiles when they are blown away by strong wind. Blowing rain could wash away and erode landscaping. Heavy rainfall could cause premature deterioration to road pavements and pedestrian asphalt (e.g., potholes, rutting, cracking). Blowing snow may cause reduced accessibility to the building due to snow accumulation, slippery surfaces. This can be an accident hazard in the parking lots and the roadways and walkways around the building. Increased maintenance and repair cost.	Design and O&M	Very Effective
	People	10	-O&M: Modify maintenance schedules in anticipation of event of heavy winds, blowing snow or blowing rain -O&M: Install signage in winter to indicate slippery areas and falling snow or ice to ensure safe movement and access to the building - O&M: Conduct regular inspection during these extreme weather events and apply necessary measures (snow-clearing, debris clearing, use of abrasive material to de-ice) - Policy: Implement worker safety measures to protect the health and safety of staff working outdoors -Policy: Include in the site operation plan safety measures to protect the public.	Heavy wind could blow away debris or objects, which could cause injuries to staff and the public using the facility. Blowing rain and blowing snow can cause slippery conditions and snow accumulation can restrict access to the facility. Increased maintenance and/or delay of work.	O&M and Policy	Very Effective

Appendix B Climate Change Resilience Assessment – Severity Scores per Climate Indicator and Infrastructure Component (Pivot Table)