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NUNAMIUTUQAQ
BUILDING FROM THE LAND

Climate Resilience and Adaptation – First Assessment

Assessment of the current and future climate risks to our project:

Interactions between climate and the infrastructure were assessed for various climate parameters to capture hazards associated with temperature increase, precipitation increase, shifts in wind regime, permafrost degradation and coastal hazards. Risk identification included consideration of impacts from extreme events (increased storm intensity) as well as impacts resulting from incremental or slow onset events (permafrost thaw).

- Permafrost degradation: According to the Cambridge Bay Climate Change Adaptation Action Plan (CCAAP), Cambridge Bay lies within a zone of continuous (likely saline) permafrost, with a shallow (<1 m deep) seasonal active layer. Under the current and future influence of climate change, permafrost thawing is of significant concern in the community causing damages to building foundation integrity. Saline permafrost has different properties than normal permafrost, and can be more susceptible to change and less stable. According to a report from the Geological Survey of Canada, the permafrost around Cambridge Bay ranges from -2 to -10°C.
- Drainage of meltwater is an issue in many northern communities. Changes in snow loads and precipitation, contracting snow seasons, warmer temperatures, and rapid snow melt could further exacerbate existing challenging drainage conditions. The future building site is abutting a municipal drainage area and exhibits a 5% slope, as such an increase of precipitation and rapid snow melt could cause foundation wash out and/or impact structural integrity. Water pooling under the building could further accelerate permafrost degradation. There are no conclusive site-specific data available, and more analysis is required.
- Heavier snow falls (up to 45% more) and contracting snow seasons are predicted for northern communities. Snow composition is also changing, becoming denser due to increasing moisture content. These wetter heavier snow loads combined with permafrost degradation can potentially lead to loss of structural integrity and potential collapse of the roof/infrastructure. Renewable energy systems may also be impacted by these heavier snow loads, resulting in damages to the systems and/or loss of power.
- Increase in extreme wind speed and frequency/intensity of storms/lighting have been reported by community members. Snowdrifts, building cooling, and critical damages to building envelopes, roofs, and renewable systems are foreseen as consequences of changing wind patterns. Note that, although data collected from CCCS are inconclusive, staff at the Canadian High Arctic Research Station are studying wind patterns in Cambridge Bay. Once publish, these studies will be reviewed and integrated in the building design.
- Increase in sudden intense precipitation events and winter/freezing rain may impact building structural integrity, cause damage to the building foundations or overwhelm drainage systems. Based on stakeholders' knowledge of the site, the access road to the building becomes icy in the winter, compromising the ability of the sewer and drinking water trucks to deliver essentials

services. There is a risk that these conditions will be exacerbated over time with increase freezing rain/winter rain. The Centre core essential services (access for Elders) could be compromised, affecting the intended functionality of the building.

- Warmer temperature (extreme events and incremental increase): Available data for Cambridge Bay predicts an increase in Heating Degree Days (HDD) and Cooling Degree Days (CDD) in the next 50 years, showing a shift to extreme events. Extreme warm temperatures have become hotter, while extreme cold temperatures have become less cold. Community members reported important passive solar gains that need to be managed during the 24 hours daylight period to control indoor temperature. The building could become uncomfortably hot and compromise building cooling systems for artifacts preservation.

Although coastal erosion and sea level rise are common climate hazards associated with northern communities, Cambridge Bay is within an area currently undergoing uplift due to postglacial isostatic adjustment and data shows a sea level decrease of 24 cm by 2070.

Adaptation/resilience measures that will be taken to improve the climate resilience of the building:

This high-level overview of potential climate risks to our building is our first step. More analysis is required, especially on climate risks for which data is not conclusive. Site specific data will be collected over the next few years (such as wind patterns and site drainage capacity). As our building design progresses, we will assess the severity and probability of identified climate risks, determine the building vulnerabilities and consequences of failure, and build its adaptive capacity through design and O&M considerations (PIEVC protocol, consistent with ISO 31000). Our next steps also include in depth assessments of cascading effects and interacting risks, as well as emergency preparedness. Finally, vulnerabilities of our infrastructure to supply chain (barge/air lift) will be assessed as part of the pilot project.

Heavy snow loads/extreme winds/storms:

- Design: design roof for future snow loads (heavier, wetter snow) and extreme wind patterns. Use simple roof design structure (avoid flat roof), design with prevailing wind to avoid snow accumulation and minimize building cooling, and design for increased wind speed with anchors.
- Snowdrift modelling will be conducted for pilot structure and for the final building to inform their designs.
- Operation and Maintenance (building and renewable energy systems) will develop snow removal plans and frequent structural assessments.
- Prepare emergency plans.
- Renewable systems: Include extra substructure bracing for solar panels. Include known storm wind directions and possible locally sheltered locations in panel placements.
- Refer to CSA S502- Managing changing snow load risks for buildings in Canada's North & CSA S505 - Techniques for considering high winds and snow drifting and their impacts of northern infrastructure.

Permafrost:

- Conduct geotechnical site investigation (CAN/BNQ 2501-500 – Geotechnical Sites Investigations for Building Foundations in Permafrost Zones), assess the suitability of the site, and design building foundations appropriate to current and future site conditions (consider the changes in ground temperature anticipated over the intended service life of the structure). Implement adequate mitigation measures if necessary (such as thermosyphons).

- Operation and maintenance (refer to CSA-S501 – moderating the effects of permafrost degradation on existing buildings):
    - Snow maintenance program: Move snow away from foundations to allow for permafrost regeneration
    - Maintain proper site grading and drainage to facilitate drainage of surface water and prevent water pooling.
    - Assess building structural integrity regularly. Re-level building to mitigate structural damage
- Additional literature: CSA Plus 4011 Technical Guide: Infrastructure in Permafrost: A Guideline for Climate Change Adaptation/ CSA Plus 4011.1 Technical Guide: Design and Construction Considerations for Foundations in Permafrost Regions

Extreme precipitation/Drainage/Rapid spring snowmelt:

- Assess site specific increased rainfall and rapid snow melt and potential impact on the building foundations (monitoring to be implemented once land transfer is completed – December 2021). We will work with Hamlet of Cambridge Bay to identify risks associated with drainage system bordering the site.
- Re-vegetate post construction. Divert water away from foundations, ensure properly vegetated areas/rocks to slow the water down.
- Implement O&M of building drainage systems and protection of foundations.
- Freezing rain and icy road consideration will be included in the building design (ensure water and sewage tanks are located in an easily accessible area) and O&M procedures (emptying sewage tanks and filling potable water prior to large storms) to ensure building functionality.

Temperature:

- Energy modelling based on future projected temperatures under RCP 8.5 to inform building and envelope design.
- Effective cooling systems for preservation of artifacts will be included in the design. This includes efficient equipment and design features to reduce passive solar heat gain during summer months.

Climate data and tools that were consulted to assess any current and future climate risks to our project.

Data was gathered from interviews with local stakeholders (community members and staff at the Canadian High Arctic Research Station), background literature, and a high-level climate data analysis.

- Background research:
    - Cambridge Bay Climate Change Adaptation Action Plan (CCAAP)
    - Climate-Resilient Buildings and Core Public Infrastructure: an assessment of the impact of climate change climatic design data in Canada
    - Infrastructure Canada Climate Lens
    - Nunavut Climate Change Centre

    - Assessment of Climate Change Impacts on Infrastructure in All NWT Communities (WSP Canada) – following PIEVC protocol.
    - KHS has been working with NRCan to develop terrain instability maps for the region through radar interferometry. By charting ground movement, areas most impacted by climate change are mapped. This has been used mostly for archaeological purposes but can be re-purposed to assess potential hazards to foundations integrity (draft map attached to this application). The future building site is located on moderately stable terrain.
- Climate Data
    - ClimateData.ca Data collected for RCPs 4.5 and 8.5. RCP 8.5 being the most likely scenarios within the lifetime of the infrastructure (50 years). Both scenarios utilized data in the 50th percentile.
        - Mean Precipitation
        - Annual Ice Days
        - Mean Temperature
        - Annual Maximum Temperature
        - Heating Degree Days (HDD)
        - Cooling Degree Days (CDD)
        - Sea Level Rise
    - Climate-resilient buildings and core public infrastructure 2020: an assessment of the impact of climate change on climatic design data in Canada / Authors: Alex J. Cannon, Dae Il Jeong, Xuebin Zhang, and Francis W. Zwiers.
        - Near-Surface Permafrost Extent
        - Change in Hourly Wind Pressures
        - Change in Snow Load
        - Change in Ice Thickness
        - Change in Driving Rain Wind Pressure
    - Environment and Climate Change Canada. 2020. Climate-Resilient Buildings and Core Public Infrastructure.
        - Changes in Snow Accumulation
        - Freezing Rain
    - Caliho, C. & Romaine, T. 2010. Cambridge Bay Climate Change Adaptation Action Plan. Canadian Institute of Planners, Government of Canada, Government of Nunavut.
        - Storms (hail and thunder)
        - Extreme Storms
        - Sea Level Rise
    - Blunden, J. and D. S. Arndt, Eds., 2020: State of the Climate in 2019. Bull. Amer. Meteor. Soc., 101 (8), Si–S429 https://doi.org/10.1175/2020BAMSStateoftheClimate.1
        - Sea Ice Extent – Summertime Losses
    - Arctic Report Card: Update for 2020. NOAA. https://www.climate.gov/news-features/understanding-climate/climate-change-minimum-arctic-sea-ice-extent
        - Wintertime Losses in Arctic Sea Ice Extent
    - Smith, S., Riseborough, D., Ednie, M., & Chartrand, J. (2013). A Map and Summary Database of Permafrost Temperatures in Nunavut, Canada. Geological Survey of Canada.

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INTEGRATING CLIMATE CHANGE INFORMATION INTO CLIMATE RESILIENCE ASSESSMENTS: A FIRST ASSESSMENT[1]

Ensuring infrastructure resilience to climate change impacts involves assessing project vulnerability to changing weather and climate impacts, now and in the future. Resilience against climate change impacts will ensure capacity and safety and decrease long-term costs, throughout the infrastructure life span. This worksheet helps users to understand key climate change impacts and develop adaptation responses, for projects supported by Infrastructure Canada. It should form the basis for project learning, outreach to climate experts (e.g. the Canadian Centre for Climate Services), and ultimately, planning to ensure long-term resilience to climate change.

1. PROJECT DEFINITION

1.1 What infrastructure project is proposed? Inuinnait Knowledge Centre, Cambridge Bay, Nunavut

1.2 How long is the new or retrofitted infrastructure expected to last? 50 years

2. MAJOR INFRASTRUCTURE COMPONENTS, CHANGING WEATHER/CLIMATE HAZARDS, AND POSSIBLE ADAPTATION ACTIONS

2.1 Which major infrastructure components may be exposed to weather & climate hazards?	2.2 What weather & climate hazards could affect the component?	2.3 What are the potential consequences of this hazard, to the major component?	2.4 How will hazard-relevant indices change over infrastructure lifetime due to climate change? Use Table 3 to develop this estimate.	2.5 How could the change described in Column 2.4 change the risk to this component?
Roof/exterior walls/windows	Heavy snow loads	Roof/total collapse	+0.2 to 12.5% change in 50 year snow load	Increase
	Extreme Wind	Damage & loss to exterior elements	-6.1% to +10.4% change in 50 year hourly wind pressures	Unknown
Foundation	Permafrost	Damages to foundations integrity	-45% change in near-surface permafrost extent	Increase
	Extreme precipitation	Damages to foundations integrity (wash out)	+9.2 to 13.3% average precipitation in 50 years +0.2 to 12.5% change in 50 year snow load	Increase Increase
	Rapid snow melt	Damages to foundation integrity (wash out). Note: consider building site slope.	Not well known. Most probably increases (based on community members feedback). +0.2 to 12.5% change in 50 year snow load	Unknown Increase Increase

[1] Template provided by Infrastructure Canada – Green and Inclusive Community Buildings.

			+21.1 to 30.7% average annual maximum temperature in 50 years	
Building Envelope and mechanical systems	Increase Temperature/solar gain	Overheating/heat stress on building cooling systems for artifacts preservation	+21.1 to 30.7% average annual maximum temperature in 50 years	Increase
Renewable Systems	Extreme Wind/Winter storms	System dislodged or damaged	-6.1% to +10.4% change in 50 year hourly wind pressures	Unknown
	Snow Loads	System Collapse/power loss due to panel coverage	+0.2 to 12.5% change in 50 year snow load	Increase
Water systems (piping and supply): drinking water and septic tank	Increased freezing rain	Essential services interrupted (road accessibility/prevents trucks from delivering water or removing sewage)	+5.2% to 79% change in 20 year ice accretion loads	Increase
	Winter storm/Blizzard		Increases in winter precipitation. Extreme storms occurring without warning.	Increase Increase
Community drainage system	Rapid snow melt/Increased precipitation	Drainage system abutting building site boundaries. Partial flooding could compromise building foundations.	Not well known. +9.2 to 13.3% average precipitation in 50 years +21.1 to 30.7% average annual maximum temperature in 50 years	Unknown Increase Increase

3. UNDERSTANDING FUTURE HAZARD CHANGES

3.1 Hazard type	3.2 Hazard-relevant climate indices	3.3 Climate information source: include information such as location, resolution, scenario. Include a link for reference.	3.4 Quantitative or qualitative change in metric between present and end of infrastructure lifespan
Permafrost	Near-Surface Permafrost Extent	CanRCM4 LE-CanESM2 RCP8.5 (Figure 6.8). Near-Surface Permafrost Extent based on the Surface Frost Index (SFI). https://climate-scenarios.canada.ca/?page=buildings-report	high confidence that future global warming will result in significant permafrost thawing in the regions studied. Approx -45% (+3°C)

Wind	Change in Hourly Wind Pressures 1/50	CanRCM4 LE (Table 5.1) +3°C ensemble (25p, 75p), North Data. (50-year return period hourly wind pressure) https://climate-scenarios.canada.ca/?page=buildings-report	1986-2016 baseline. 1.6% (-6.1%, 10.4%) Very low confidence
Increase Snow Loads	Change in snow load (1/ 50) Changes in snow accumulation	CanRCM4LE (Table 6.1). +3°C ensemble (25p, 75p) North Data. Projected changes in design snow loads (SLs). https://climate-scenarios.canada.ca/?page=buildings-report Environment and Climate Change Canada. 2020. Climate-Resilient Buildings and Core Public Infrastructure. pg.71	1986-2016 baseline. 5.4% (0.2%, 12.5%) Very low to low confidence Small changes in snow accumulation in the north due to increases in winter precipitation to offset a shorter snow accumulation period (medium confidence).
Increase precipitation/Freezing Rain	Mean Precipitation Annual Ice Days Change in ice thickness (1 /20) Freezing Rain	ClimateData.ca - Annual Total Precipitation Cambridge Bay RCP 4.5 Mean p50 & RCP 8.5 Mean p50 ClimateData.ca - Annual Ice Days Cambridge Bay RCP 4.5 Mean p50 & RCP 8.5 Mean p50 CanRCM4LE (Table 6.2) +3°C ensemble (25p, 75p) North Data. https://climate-scenarios.canada.ca/?page=buildings-report Environment and Climate Change Canada. 2020. Climate-Resilient Buildings and Core Public Infrastructure. pg. 74	2022-2072 RCP4.5p50 +9.2% (17.6mm) average from 2000-2021 2022-2072 RCP8.5p50 +13.3% (25.3mm) average from 2000-2021 2022-2072 RCP4.5p50 -4.1% average ice days from 2000-2021 2022-2072 RCP8.5p50 -6.3% average ice days from 2000-2021 CanRCM4 LE projects overall increases in future design ice accretion loads over most of Canada. 1986-2016 baseline. 33.0% (5.2%, 79.0%) Increased frequency of freezing precipitation over northern parts of North America.
Warmer Temperatures	Mean Temperature	ClimateData.ca - Annual Mean Temp Cambridge Bay RCP 4.5 Mean p50 & RCP 8.5 Mean p50	2022-2072 RCP4.5p50 +2.1 degree change from 2000-2021 2022-2072 RCP8.5p50 +3.1 degree change from 2000-2021

	Annual Maximum Temperature Heating Degree Days (HDD) Cooling Degree Days (CDD)	ClimateData.ca - Annual Maximum Temperature Cambridge Bay RCP 4.5 Mean p50 & RCP 8.5 Mean p50 ClimateData.ca - Annual HDD Cambridge Bay RCP 4.5 Mean p50 & RCP 8.5 Mean p50 ClimateData.ca - Annual CDD Cambridge Bay RCP 4.5 Mean p50 & RCP 8.5 Mean p50	2022-2072 RCP4.5p50 +2.0 degree change from 2000-2021 (+21.1%) 2022-2072 RCP8.5p50 +2.9 degree change from 2000-2021 (+30.7%) 2022-2072 RCP4.5p50 average +754.5 days from 2000-2021 (+6.7%) 2022-2072 RCP8.5p50 average +1103.5 days from 2000-2021 (+9.8%) 2022-2072 RCP4.5p50 average +0.1 days from 2000-2021 (where the average was 0 days) 2022-2072 RCP8.5p50 +0.5 from 2000-2021 (where the average was 0 days)
Storm	Change in driving rain wind pressure (1 /5) Storms (hail and thunder) Extreme Storms	CanRCM4LE (Table 5.3) +3°C ensemble (25p, 75p). North Data. 5-year return period DRWP. https://climate-scenarios.canada.ca/?page=buildings-report *Caliho, C. & Romaine, T. 2010. Cambridge Bay Climate Change Adaptation Action Plan. Canadian Institute of Planners, Government of Canada, Government of Nunavut. [PDF].* *Caliho, C. & Romaine, T. 2010. Cambridge Bay Climate Change Adaptation Action Plan. Canadian Institute of Planners, Government of Canada, Government of Nunavut. [PDF].*	1986-2016 baseline. 22% (11.2%, 30.9%). Very low to medium confidence. Increased hail and thunderstorms from unusual events to events that occur at least once a year. Extreme storms occurring without warning.
Rapid Spring Melt	Sea Ice Extent - Summertime Losses	Blunden, J. and D. S. Arndt, Eds., 2020: State of the Climate in 2019. Bull. Amer. Meteor. Soc., 101 (8), Si–S429 https://doi.org/10.1175/2020BAMSStateoftheClimate.1	1981-2010 baseline. September 2019 -33%. September monthly average trend for the Arctic Ocean is -12.9% +/- 2.2% relative to 1981-2010 average.

	Change in snow load (1/ 50) Mean Temperature	pg. S252 CanRCM4LE (Table 6.1). +3°C ensemble (25p, 75p) North Data. Projected changes in design snow loads (SLs). https://climate-scenarios.canada.ca/?page=buildings-report ClimateData.ca - Annual Mean Temp Cambridge Bay RCP 4.5 Mean p50 & RCP 8.5 Mean p50	1986-2016 baseline. 5.4% (0.2%, 12.5%) Very low to low confidence 2022-2072 RCP4.5p50 +2.1 degree change from 2000-2021 2022-2072 RCP8.5p50 +3.1 degree change from 2000-2021
Sea Level Rise	N/A N/A	*Caliho, C. & Romaine, T. 2010. Cambridge Bay Climate Change Adaptation Action Plan. Canadian Institute of Planners, Government of Canada, Government of Nunavut. [PDF].* ClimateData.ca - Sea Level Rise Cambridge Bay RCP 4.5 p50 & RCP 8.5 p50	Postglacial uplift at Cambridge Bay is 3.7 +/- 2 mm/yr. Rate of sea level rising is 3.1 +/- 0.7 mm/year during 1993-2003. The Fingerprinting effect in the Canadian Arctic decreases the rate of sea level rise in the Arctic. The probable sea level rise in Cambridge Bay from 2010-2100 is -15cm to +30cm, with uncertainties ranging from -35cm to +50cm. Uncertain. (7 m absl) 2070 RCP4.5p50 -30.19 cm. 2070 RCP8.5p50 -24.06 cm.
Earthquake	N/A		
Sea Ice	Wintertime Losses in Arctic Sea Ice Extent	Arctic Report Card: Update for 2020. NOAA. https://www.climate.gov/news-features/understanding-climate/climate-change-minimum-arctic-sea-ice-extent	-2.6% per decade
Wildfire	N/A		
Coastal erosion	N/A	Building located away from shoreline	

Note: Other risks that have been identified for which data is not available: increased UV radiation which leads to shorter life span of infrastructure components, increased dust compromising ventilation and renewable energy systems, and invasive species compromising integrity of museum collection and artifacts. Climate change is also impacting cultural programming; for example, disappearing caribou population will impact traditional workshops such as skin preparation.

4. RISK REDUCTION MEASURES

4.1 Based on the risk changes estimated in Section 2.6, what are some climate change adaptation and resilience actions that could maintain overall infrastructure resilience?
Additional data required (wind patterns in Cambridge Bay are currently being studied by the Canadian High Arctic Research Station in Cambridge Bay, snowdrift modelling will be completed as part of our building design, community drainage system abutting the site will be monitored).
Next steps: geotechnical site investigation will be conducted (CAN/BNQ 2501-500 – Geotechnical Sites Investigations for Building Foundations in Permafrost Zones). Assess the severity and probability of identified climate risks, determine the building vulnerabilities and consequences of failure (PIEVC protocol).
Further analysis required more climate risks for which trends are unclear (e.g. wind gusts & community drainage system).
Design following NISI standards. Design for current and future temperature, snow loads and extreme wind patterns.
O&M: ensure clear O&M protocols are in place for snow clearing to protect permafrost from further degradation, maintain proper drainage around foundations, check building structural integrity.