Adapting to Climate Change

Canada's First National Engineering Vulnerability Assessment

of

Public Infrastructure

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Climate Change Vulnerability

A Case Study of Public Buildings

Prepared for

Public Works and Government Services Canada and Engineers Canada

June 5, 2008

HOK ARCHITECTS

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Prepared By:
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Executive Summary

It is widely accepted that the emissions generated by human activity (e.g. the burning of fossil fuels) are rapidly increasing the concentration of Greenhouse Gases (GHGs) in the atmosphere. There is scientific consensus that these rising concentrations will increase the average temperature of the Earth resulting in rising sea levels, shifts in climatic zones and increased frequency and severity of weather extremes. To respond to these expected changes, Engineers Canada established the Public Infrastructure Engineering Vulnerability Committee (PIEVC) to oversee the planning and execution of a broad-based National Engineering Assessment of the vulnerability of Canadian public infrastructure to changing climatic conditions. The National Engineering Assessment will evaluate the changes anticipated to the risks to Canadian public infrastructure posed by climate change. Using a draft engineering protocol to assess the vulnerability of infrastructure to potential future climatic changes, Engineers Canada has conducted a pilot study and several case studies on different types of infrastructure, including roads, stormwater and wastewater systems and water resource systems. This case study is the last in this series and applies the draft protocol to assess the vulnerability of buildings to climate change.

Public Works and Government Services Canada (PWGSC) is collaborating in this effort and chairs the Buildings Experts Working Group (BEWG) that is part of PIEVC. To complete the vulnerability assessment, PWGSC agreed to consider three public buildings located on the Federal Government Campus of Tunney's Pasture in Ottawa, Ontario. Tunney's Pasture is a 46-hectare Campus located approximately three kilometres west of Downtown Ottawa and Parliament Hill. Within Tunney's Pasture, the roads and servicing infrastructure are owned and maintained by the federal government and connected to off-site city owned services. The three test buildings selected for the case study are:

- Main Statistics Canada Building was built in 1952 and is 20 years into it's 2nd life cycle phase and is of low rise masonry construction;
- Brooke Claxton Building was built in 1964 and is 10 years into it's 2nd life cycle phase and is a high rise with first generation curtain wall construction; and
- Jean Talon Building was built in 1979 and is at the end of its 1st life cycle phase and is a high rise of precast concrete panel construction.

All three test buildings are connected to the Campus's Central Heating and Cooling Plant that provides steam and chilled water for their heating and cooling. HOK Canada with support from Nielsen Design Consulting Inc. conducted the vulnerability assessment of the three test buildings according to the PIEVC Draft Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment. The project team received excellent support from SNC-Lavalin-Profac, the building managers under contract with PWGSC. SNC-Lavalin-Profac assisted in the assessment by providing building tours, review and development of the vulnerability assessments and evidence of current and past building performance and condition. In addition, detailed building condition reports were used to understand the current state of repair and integrity of the key building components and systems for all three buildings.

The project team used climate change projections completed by Ouranos and other research to determine the expected changes in the regional climate for two time horizons of 2020 and 2050. The main expected changes in climate for these time horizons are:

- Increase in temperatures throughout the year;
- More precipitation in spring, winter and fall in the form of rain and snow;
- Less precipitation (rain) in June, July and August;
- Increase in rain on snow events;
- Increase in freeze-thaw events;
- Significantly shorter frost season where temperatures are below 0°C;
- Significantly less Heating Degree Days below 18°C; and
- Significantly more Cooling Degree Days above 18°C.

To understand the possible affects of these changes, the PIEVC Engineering Protocol was used to identify and rank the vulnerability of building components and systems to climate change. The assessment found that the highest priority considerations for the three buildings due to climate change are:

- The walkways, parking areas, stairs and ramps are vulnerable due to increased freeze-thaw cycles and higher temperatures. The accelerated deterioration of these building components can pose potential risk to human health, safety, injury, falling etc.
- Building envelops are vulnerable due to increased precipitation in fall, winter and spring, increased temperatures in summer and increased freeze-thaw cycles. Accelerated deterioration of the envelops will affect the structural integrity of the buildings.
- The cooling systems may be vulnerable in terms of its adequacy of meeting demand of increased spring, summer and fall temperatures. The chilled water cooling system provided by the Central Heating and Cooling Plant and roof-top units will see increased loads. Increased internal building temperatures can directly affect occupant comfort and productivity while the increased cooling loads could also pose significant cost increases to PWGSC.
- Finally, the reliability and provision of power (electricity) to the building may be vulnerable due to increased temperatures in spring, summer and fall. These increased temperatures will create increased electricity demand (for cooling) throughout the region on Hydro Ottawa. The reliability and provision of electricity is critical to the daily work and productivity of occupants and the operation of the computer/LAN room.

This being said, the project team found that the current building management processes can help ensure that many building components (e.g. stairs, walkways, ramps, windows, doors) adversely affected by climate change (i.e. premature deterioration) will be identified and subsequent remedial action taken to reduce or eliminate any specific impacts. In other words, this management approach indirectly guards against climate change vulnerabilities for several building components and systems. This is because

Federal buildings are managed under a rigorous process that includes Asset Management Plans, Building Condition Reports and Building Management Plans, to name a few.

From these high level findings, several recommendations were developed that address these as well as the gaps in information and data identified during the project. These are summarized below:

A. In the Main Statistics Canada building, the building envelop is high priority area that warrants the research and application of a building envelop technology that can mitigate freezing pipes in winter as well as manage the affects of increased precipitation and potential moisture migration into the envelop due to climate change.
B. The Brooke Claxton Building's envelop will require the application of a technology that will keep the interior warm and dry, without affecting its structural integrity.
C. PWGSC should investigate and determine the optimum flat roof technology, design options, mitigation strategies that will accommodate the potential effects of increased freeze thaw and ice build-up.
D. A detailed engineering evaluation needs to be conducted on the anticipated cooling loads due to climate change and the optimum solution for each building on the Campus. Such an evaluation should assess the suitability of various adaptive measures/technologies such as exterior shading devices, passive cooling techniques, etc. It should also recognize potential changes/engineering options for the building envelop to ensure systems are optimally sized for the existing and projected loads.
E. A separate or integrated cooling load evaluation based on the "Campus as a system of buildings" should be conducted for the Central Heating and Cooling Plant. The evaluation/assessment should model and consider various technologies/adaptive measures for the CHCP itself such as co-generation and geothermal heating and cooling, the ability to meet or exceed the Government of Canada's objectives to reduce GHG emissions and Air Pollutants and potential changes to the Ottawa River (used by the Plant for cooling) such as water temperature, flow, height etc. that may be due to climate change.
F. PWGSC should begin working with the local electrical utility (e.g. Hydro Ottawa) to study and plan for the cumulative effects on electricity loads, demand, consumption, etc. during spring, summer and fall from all the buildings at the Tunney's Pasture Campus.
G. A detailed research study should be conducted that investigates the loads from potential increases in precipitation on the site rain and storm water drains and tunnels. This would address a data and information gap identified during the assessment.
H. In conjunction to the above recommendation, PWGSC should consider and assess how climate change will affect Federal Real Property that is in close proximity to the Ottawa River, its watershed and flood plain.

I. PWGSC should maintain current practices and budget for snow/ice clearing and Building Condition Reporting will help ensure occupant and public safety for all walkways, stairs, and parking areas.

While the Vulnerability Assessment focused on the three test buildings, the project team believes that particular elements of the findings and recommendations can be applicable to other buildings in the region, especially those of similar vintages and construction. These are threefold:

- First, increased freeze-thaw cycles will likely have similar effects on buildings and other types of infrastructure in the region. Landlords and owners would be prudent to ensure close monitoring of site drainage, roof systems and building envelops and components that may be affected by these expected changes.
- Second, increases in precipitation in the form of rain particularly in fall, winter and spring will put increased loads on building envelops and flat roofs in the region. Again, landlords and owners should pay particular attention to the state of repair of these systems.
- Third – and perhaps most important from a climate change perspective – the increases in spring, summer and fall temperatures in the region will put higher demands on cooling systems and utilities during these seasons. The projet team believes strategies will need to be implemented at various levels in order to manage the demand and ensure that increases in electricity consumption do not result in increased GHG emissions – resulting in further climate change.

Finally, the project team was asked by PIEVC and PWGSC to evaluate the overall Protocol and the climate change data provided by Ouranos and their applicability to the building sector. The Team found that improvements can be made to aid applicability and ease of use of the Protocol and climate change data in future Assessments of buildings. The following suggestions should be considered by PIEVC prior to undertaking the broader National Engineering Assessment:

- The Project Team believes there is potential to align the terminology in the Protocol to that used by climate and weather specialists as well as engineers and architects (e.g. National Building Code, CSA, ISO and ASHRAE). For example, the protocol uses such terms as “climate change factor” and “climate change parameter” while Environment Canada and Ouranos refer to changes in “climatic indices” (e.g. change in average annual maximum temperature) that is expected in the future. The Project Team recognizes that for future assessments of buildings, specific climatic indices that relate to such things moisture infiltration, freeze-thaw cycles, temperature and humidity extremes could become important to ensure consistency in application of the overall Assessment and Protocol.
- Readability and ease of use of the Protocol needs to be considered. For example, repetition of terms and data fields in the Protocol and supporting Worksheets were also found to create confusion. Elimination of repeated terms, including illustrations, diagrams and examples, and consistency in terminology are other areas that will ease of use and readability.

- Finally, there is potential to improve the utility or presentation of the climate change indices and scenarios. Engineers and architects could benefit from a layperson's indication of what climate would be like in 10, 20, 50 year time horizon. This would allow research and comparison of building codes and best design practices of these regions to understand what may or may not work in terms of adaptation or mitigation techniques and technologies.

Introduction

Project Background

It is widely accepted that the emissions generated by human activity (e.g. the burning of fossil fuels) are rapidly increasing the concentration of Greenhouse Gases (GHGs) in the atmosphere. There is scientific consensus that these rising concentrations will increase the average temperature of the Earth resulting in rising sea levels, shifts in climatic zones and increased frequency and severity of weather extremes.

Baseline historical climatic data is used in engineering and architecture professions to design buildings and other infrastructure to suit their regional climate. However, under a changing climate, this data may not be appropriate and could result in buildings that do not have the "resiliency" to accommodate new climatic norms or weather extremes. Furthermore, these factors may create vulnerabilities in existing buildings as well. Engineers Canada established the Public Infrastructure Engineering Vulnerability Committee (PIEVC) to oversee the planning and execution of a broad-based National Engineering Assessment of the vulnerability of Canadian public infrastructure to changing climatic conditions. This is a priority for the engineering profession since the uncertainty caused by changing climatic conditions may be undermining the meteorological data used to design infrastructure.

The National Engineering Assessment will evaluate the changes anticipated to the risks to Canadian public infrastructure posed by climate change. In order to determine how best to tackle this large and complex assessment, the PIEVC completed a pilot study using a draft engineering protocol to assess the vulnerability of a water supply system to the impacts of future potential climate changes. Following this pilot, several case studies using the methodologies and protocols were conducted on other types of infrastructure, including roads, stormwater and wastewater systems and water resource systems. This case study is the last in this series and applies the draft engineering protocol to assess the vulnerability of buildings to climate change.

Public Works and Government Services Canada (PWGSC) is collaborating in this effort and chairs the Buildings Experts Working Group (BEWG) that is part of PIEVC. PIEVC and the BEWG believe that there are likely common impacts of climate change on buildings across Canada that will increase their vulnerability and will require remedial action. In addition, members of the BEWG have been involved in developing the draft PIEVC Engineering Protocol used in the pilot and case studies.

PIEVC Protocol

The PIEVC Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment (hereafter the Protocol) is a procedure to analyze specific climatic and infrastructure information to understand the potential interactions between a changing climate and the components of the infrastructure. The Protocol outlines a series of steps for defining, analyzing, evaluating and prioritizing both infrastructure information and climate information to understand the potential vulnerability of the infrastructure to

climate change. The outcomes of applying the Protocol are intended to inform decision-making about the infrastructure's operation, maintenance, planning and development – facilitating the effective management of a changing climate on the infrastructure.

The key steps of the protocol are:

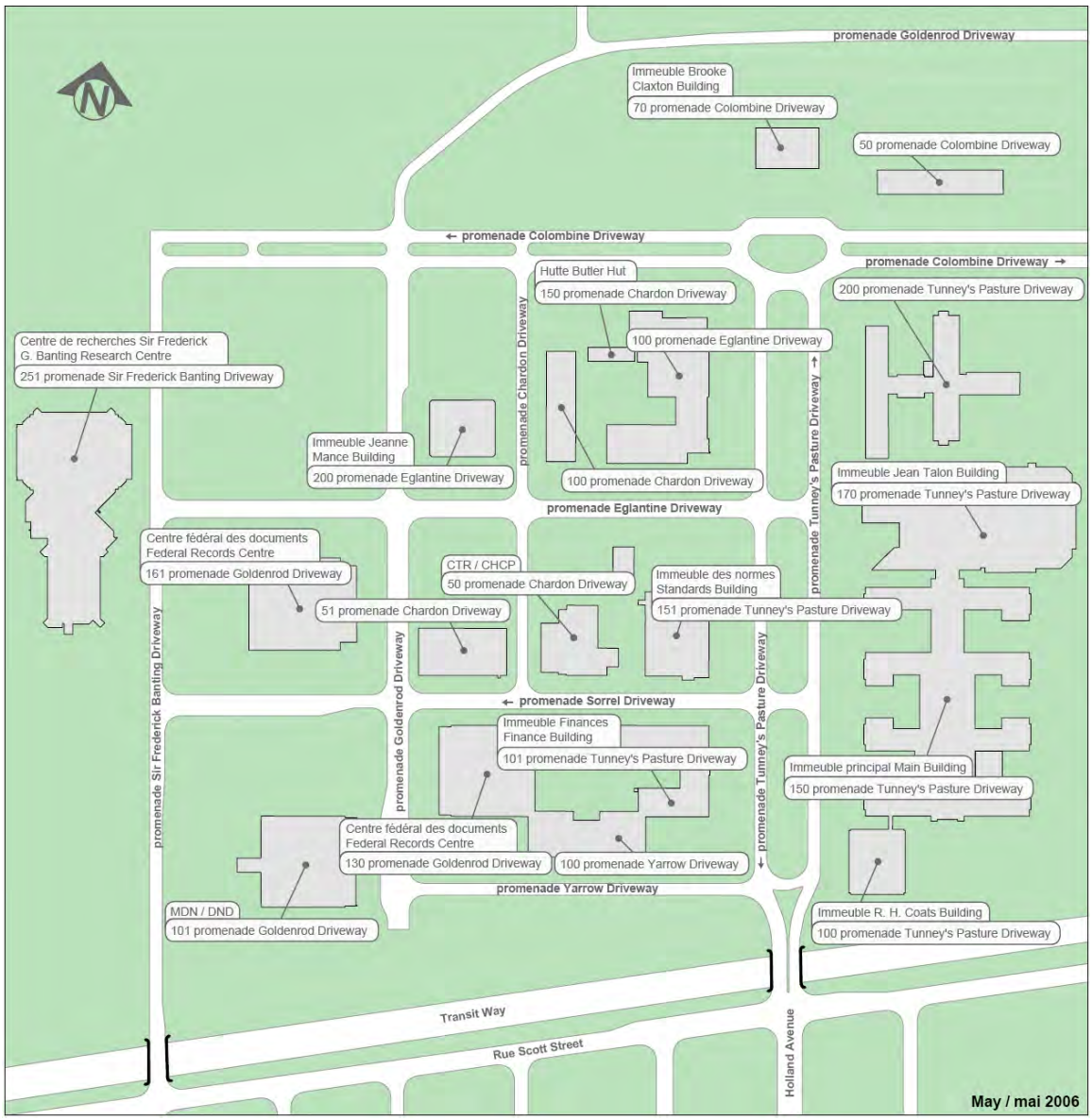
1. Project Definition
2. Data Gathering and Sufficiency
3. Vulnerability Assessment (Qualitative Assessment)
4. Vulnerability Assessment (Quantitative Assessment)
5. Recommendations

A copy of the full draft Protocol as used in this case study is provided in Appendix C.

Study Scope and Time Frame

To complete the vulnerability assessment, PWGSC agreed to consider three buildings located on the Tunney's Pasture campus in Ottawa. Tunney's Pasture is a 46-hectare Federal Government Campus located in the City of Ottawa, Ontario. The Campus is approximately three kilometres west of Downtown Ottawa and Parliament Hill. The Campus is bounded by the Ottawa River Parkway (and the Ottawa River) to the north, Parkdale Avenue to the east, Scott Street to the south and Northwestern Avenue on the west. The buildings on the campus offer excellent views of the Ottawa River and Gatineau Hills, as well as convenient access to the Ottawa River Parkway. Within Tunney's Pasture, the roads and servicing infrastructure are owned and maintained by the federal government and connected to off-site city owned services. The figure below provides an illustration of the overall Campus layout and indicates the location of the three test buildings.

Figure 1 Site plan of Tunney's Pasture Campus.



The three test buildings selected for the Project are:

- Main Statistics Canada Building, 150 Promenade Tunney's Pasture Driveway
- Jean Talon Building, 170 Promenade Tunney's Pasture Driveway
- Brooke Claxton Building, 70 Promenade Columbine Driveway

The boundary and scope delineation for this project was very important given that the campus has a Central Heating and Cooling Plant (CHCP) to deliver steam and chilled water. For this reason the project boundary is limited to the near vicinity of the building and did not include the heating plant. The Project Team, however, recognizes that the Central Heating and Cooling Plant is integral element in the daily operation of these buildings and the findings in this assessment should be recognized in this context.

The time frame selected for this study is 2020 and 2050 because they align with the projected design life of the buildings in this study. Further future time horizons such as 2080 (as provided by Ouranos in the climate change assumptions) was considered outside the expected life cycle of any of the buildings tested. Furthermore the uncertainty of the use, overall long term plan and future investments for Tunney's Pasture Campus by the Federal Government did not warrant consideration of time horizons past 2050.

Project Team

This project is a joint initiative between Engineers Canada (through PIEVC) and Public Works and Government Services Canada.

HOK Architects is the lead consultant with support from Nielsen Design Consulting Inc.

The project team acknowledges the excellent support of SNC-Lavalin-Profac staff who participated in interviews, led tours and a workshop.

The Project Team is as follows:

Organization	Role	Individuals
PIEVC	National Engineering Assessment Funding Partner	David Lapp
Public Works and Government Services Canada	Building Owner Funding Partner	Brian Kyle Ed Morofsky Ed Kutrowski
HOK Canada	Prime Consultant	Vince Catalli Greg Allen
Nielsen Design Consulting	Sub-Consultant	Ralf Nielsen
SNC-Lavalin-Profac	Building Manager	Susan Kehoe Shelly LeBlanc Peter Morris Michael Murawnik Brian Drier Brent Dagg
Ouranos	Climate Change Data	Caroline Larrivee Travis Logan Diane Chaumont

Project Approach

The overall approach of the Team to the project was as follows:

1. Determination of test buildings for assessment;
2. Building tours and facility management meetings;
3. Review of Building Condition Reports and Investment Plans;
4. Building infrastructure component identification;
5. Identification of relevant climate change factors;

6. Vulnerability assessment using the PIEVC Engineering Protocol; and
7. Development of recommendations and report development.

The PIEVC Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment was applied by HOK on the three test buildings located on the Tunney's Pasture – Federal Government Campus in Ottawa and included: the Brooke Claxton, Jean Talon and Main Statistics Canada Building. The Project Team applied the Protocol first to the Main Statistics Canada Building as it was the oldest building of the representative sample used for this case study. The protocol was then applied to the other two buildings, Brooke Claxton and Jean Talon. However, during this process the project team found that the majority of data and analysis required for Steps 1, 2 duplicated the work already done for the Main Statistics Canada Building. It also found that the most critical step of the Protocol was the climate change vulnerability assessment (Step 3) and the development of recommendations (Step 5). Thus, for the Brooke Claxton and Jean Talon buildings, the team used only the critical steps of the PIEVC process while avoiding duplication of effort in other steps of the Protocol.

It is important to note that for all buildings the project approach included review of the Building Condition Reports; interviewing the Property Managers and Maintenance Team Leader; touring the facility; conducting the Vulnerability Assessment; analyzing the assessment and developing conclusions and recommendations.

Climate Change

Current Climate

Ottawa has a humid continental climate with a range of temperatures from a average daily maximum of 26.3 °C in July to average daily minimums of -16.4 °C in January. Snow and ice are dominant during the winter season. Ottawa receives on average 714 mm of rain and 208 mm (snow water equivalent) of snowfall annually. The winter and snow season is quite variable; in an average winter, a lasting snow cover is on the ground from mid-December until early April. Freeze-thaw cycles occur in the winter with some days well above freezing followed by nights well below 0 °C. Freezing rain and high wind chills are also common in the winter.

Summers are fairly warm and humid in Ottawa, although they are typically short in length. The average July maximum temperature is 26.3 °C although temperatures of 30 °C or higher occur frequently. Cool northerly air can drop humidity levels. Ottawa annually averages 41 days with humidex readings above 30 °C. Extreme summer weather events such as tornadoes, major flash floods, extreme heat waves, severe hail and remnant effects from hurricanes are rare, but all have occurred in the region.

Spring and fall are again variable with hot days above 30 °C occurring as early as March or as late as October. Although unusual, snow has been seen into May and early in October. There are about 2,060 hours of average sunshine annually (47% of possible).

Expected Changes

The Fourth Assessment Report on the Physical Science Basis of Climate Change released by the Intergovernmental Panel on Climate Change (IPCC) in 2007 describes how climate change is expected to evolve differently globally and regionally. The changes in climate conditions in Canada are expected to be different across its regions. In general however, the expected climatic changes in Canada are as follows[1]:

- Nearly all of Canada is expecting increases in temperature.
- More moisture from storm tracks in Northern regions.
- The coastal regions are expecting rising sea levels.
- The frequency and longevity of heat waves is expected to increase.
- The frequency and intensity of heavy precipitation events and thunderstorms is expected to increase.
- Winter snowfalls will likely increase due to more atmospheric moisture particularly in the lee of the Great Lakes.
- Permafrost will likely be severely impacted by climate change particularly in southern portions of the semi-discontinuous and discontinuous permafrost zones where permafrost might outright disappear.

[1] Auld, H. and D. MacIver, Changing weather patterns, uncertainty and infrastructure risks: Emerging adaptation requirements. 2007, Adaptation and Impacts Research Division, Environment Canada: Toronto.

Variation in these changes across Canada's regions is also expected and is primarily due to such factors as proximity to oceans, topographical features and patterns of atmospheric processes.

Geography of the Study Area

As mentioned above, Tunney's Pasture is situated in the western sector of Ottawa approximately 3km west-south-west of Downtown. The campus is bounded on the north by the Ottawa River Parkway and the Ottawa River whose flow is largely dominated by snowmelt and rainfall. The southern most point of the Gatineau Hills (100-450m above sea level) are approximately 3km North of the Campus, across the Ottawa River. The campus, and the City of Ottawa are situated in the Ottawa River Valley (75-100m above sea level) that stretches to the northwest and east of the city, eventually flowing to meet the St. Lawrence River just west of Montreal.

Climate Factors

Only the climate data that is relevant to the design, development and ongoing operation of the buildings are considered in this study. Based on the consideration of the buildings and the baseline climate data, the following climate factors were deemed relevant to the study:

- Temperature – average monthly and annual max and min
- Rain – average total rain
- Rain - frequency of 6h and 1 day rain events
- Wetspell conditions
- Dryspell/drought conditions
- Snow – average total snow
- Rain on Snow events
- Frost Season Length
- Heating Degree Days
- Cooling Degree Days
- Wind speed
- Humidity

It is noted that this list includes both extreme weather events and climatic conditions.

Climate Change Assumptions

A data request was made to Ouranos in the early part of the study to determine the baseline values and projected change in climate values for the time frames of the study. Ouranos provided both historical norms from Environment Canada for the study area and projections based on two climate change models. The modelling parameters and conditions used by Ouranos are:

- Geographic area of 45 km around the study area was used to include 5 Environment Canada reporting stations (temp, rain, snow).
- Minimum data series length of 20 years to calculate baseline norms.

- There was only one Environment Canada station that recorded wind over the 20 year period.
- Modelling included projections for the 2020, 2050, 2080 forecast horizons

The following table provides a summary of the projected changes in climatic values for the area in which the three buildings in this study are located and the 2020 and 2050 time horizons. The full Ouranos report with detailed seasonal data and projections for the 2080 time horizon as well is provided in Appendix A.

Table 1 Summary of expected change in climatic values for the study area.

Climate Factor and Baseline	Expected Change	Comment and Summary
Temperature		
Temperature – monthly avg. tmax Observed baseline (°C): See Apppendix A for detailed monthly baselines	2020: 0.5 to 3 degrees warmer 2050: 2.3 – 4.4 degrees warmer	Varies by month, but overall average monthly maximum temperatures expected to be higher.
Temperature – Monthly avg. tmin Observed baseline (°C): See Appendix A for detailed monthly baselines	2020: 1.0 – 3.7 degrees warmer 2050: 2.4 – 5.8 degrees warmer	Varies by month, but generally, average monthly minimum temperatures expected to be higher.
Temperature – annual max and min Observed baseline (°C): Annual max: 33.43 Annual min: -32.24	Annual Max: 2020: 1.67 – 2.33 degrees warmer 2050: 3.55 – 4.12 degrees warmer Annual Min: 2020: 2.14 - 2.30 degrees warmer 2050: 5.01 – 5.58 degrees warmer	Generally, annual minimum and maximums expected to be higher.
Rain		
Rain – Avg. total rain Observed baseline (mm): 713.98	Annual: 2020: 6-9% increase 2050: 14-18% increase	Fall, winter and spring rain fall totals will increase. Summer (June, July, August) expected to be drier.
Rain – dry spells/wet spells Observed baseline (days): Avg. max dryspell: 8.19 Avg. max wetspell: 2.81	Avg. Max Dryspell: 2020: inconclusive 2050: 0.13 to 1.18 days shorter (2-15%) Avg. Max Wetspell 2020: 0.09 to 0.12 days shorter (3-4%) 2050: inconclusive	By 2050, dryspells will be shorter. Wetspells expected to be minimally shorter by 2020. Other time horizons are inconclusive.

Climate Factor and Baseline	Expected Change	Comment and Summary
Rain – Avg. Max rain Observed baseline (mm) 1 day period: 46.66	1 day period: 2020: 2-8% increase 2050: 3-14% increase	In general, there will be an increase in 1 day period rain amounts. Similar increases are expected for 2 and 5 day period amounts (See Appendix A).
Rain – 6h frequency Observed baseline (frequency): 5mm cutoff: 0.023	5mm cutoff: 2020: 6-10% increase 2050: 19-23% increase	Increases are expected in the frequency of 6h rain events, however the baseline frequency is very low and therefore any change will not be very noticeable.
Rain – 1 day frequency Observed baseline (frequency): 5mm cutoff: 0.12	5mm cutoff: 2020: 6-7% increase 2050: 15-16% increase 2080: 20-23% increase	Increases are expected in the frequency of 1 day rain events. Similar increases are seen for 10 and 20 mm cutoff values (see Appendix A).
Rain – Simple Daily intensity index Observed baseline (mm/day): 8.42	2020: 2-4% increase 2050: 6-9% increase	Increases are expected in rain intensity for both time horizons.

Snow

Snow – average total snow Observed baseline (Snow-water-equivalent in mm): Annual: 208.69	Annual: 2020: 10-11% decrease 2050: 16-22% decrease	There are expected to be decreases in the overall amount of snow. Largest decreases will occur in the fall.
Snow – annual max snow Observed baseline (mm): 1 day period: 21.21	1 day period: 2020: inconclusive 2050: 0-2% increase	No noticeable changes are expected in annual maximum snow in 1 day periods.
Snow – 1 day frequency Observed frequency: 5mm SWE cutoff: 0.038	5mm SWE cutoff: 2020: 7-21% decrease 2050: 17-27% decrease	Decreases are expected in the frequency of 1-day snow events, however the baseline frequency is very low and therefore any change will not be very noticeable.
Snow – simple daily intensity index Observed baseline (mm/day): 5.39	2020: 0-1% decrease 2050: inconclusive	No noticeable changes are expected in daily intensity of snow.
Snow – Rain on Snow events Observed baseline (frequency): 5mm cutoff: 0.015	5mm rain cutoff: 2020: 8% increase 2050: 11-23% increase	Increases are expected in rain on snow events. However the baseline frequency low and therefore any change may not be noticeable. Similar increases are seen for 10 mm cutoff values (see Appendix A).
Wind		
Wind – Monthly avg wind6h Observed baseline: see Appendix A	Generally projected change varies between a decrease of 9% to an increase of 11% in observed wind speed in km/h for avg. 6h period. See Appendix A for details	Varies by month and time horizon. Generally windier winters, calmer summers. However, this is inconclusive as the models are based on only one station's historical wind data.
Wind – Avg. annual max wind6h Observed baseline: 48.03 km/h	2020: inconclusive 2050: 1-2% decrease	Small decreases in average annual maximum 6h wind events speeds.

Frost, Freeze-thaw		
Frost Season Length – days Observed baseline: 125.14 days	2020: 16-24 days less 2050: 28-38 days less	Significant decreases in the frost season length.
Freeze Thaw Events – frequency Observed baseline: 0.21 frequency	2020: 2-6 % decrease 2050: 5-8% decrease Historical trend indicates increase in freeze-thaw events between December and March. [2]	The models and historical trend contradict each other. To err on the side of caution, an increase in the number of freeze-thaw events was assumed in the assessment.
Heating, Cooling and Humidity		
Heating Degree Days – Observed baseline: 4376.73 HDD	2020: 567-810 days less 2050: 1178-1287 days less	Significant decreases in heating degree days. This corresponds with frost season length decreases.
Cooling Degree Days: Observed baseline: 234 CDD	2020: 95-121 days more 2050: 216 days more	Significant increases in cooling degree days. This corresponds with frost season length decreases.
Humidity: Observed baseline: see Appendix A	2020: 0-7% increase during fall, winter and spring, 0-1% decrease in summer 2050: 0-7% increase in fall, winter, spring and 0-2% decrease in summer	Slightly more humid in fall, winter and spring and slightly drier conditions in summer. This corresponds to the general increases expected in precipitation.

Summary of Climate Change Assumptions

Based on the climate change projections completed by Ouranos and other research for this project, the main regional affects in the Ottawa region are likely to be as follows:

- Increase in temperatures throughout the year.
- More precipitation in spring, winter and fall in the form of rain and snow.
- Less precipitation (rain) in June, July and August.
- Increase in rain on snow events.
- Increase in freeze-thaw events.
- Significantly shorter frost season where temperatures are below 0°C.
- Significantly less Heating Degree Days below 18°C.
- Significantly more Cooling Degree Days above 18°C

[2] Heather Auld, personal communication with Vince Catalli and Environmental Canada historical data for Ottawa, CDA, Number of Days in Dec-Mar with Max >0ºC and Min<0ºC (1940-2004).

The above assumptions, detailed climate change information and expected changes in specific climate factors were used by the Project Team throughout the Vulnerability Assessment of the three test buildings.

Buildings

Rationale for Selecting Test Buildings

As mentioned above, three buildings in the Tunney's Pasture Campus have been selected for Assessment using the PIVEC Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment. The project team selected these test buildings (over the other possible buildings on the Campus) together with PWGSC and based on information provided by SNC-Lavalin Profac. The following provides the general rationale for selecting these buildings:

- They comprise a range of building years, for example:
  - Main Statistics Canada Building was built in 1952 and is 20 years into it's 2nd life cycle phase;
  - Brooke Claxton Building was built in 1964 and is 10 years into it's 2nd life cycle phase; and
  - Jean Talon Building was built in 1979 and is at the end of its 1st life cycle phase.
- They exhibit varying types of construction that includes both low rise and high rise office towers. Specifically, the buildings exhibit the following:
  - Main Statistics Canada Building uses low rise masonry construction;
  - Brooke Claxton Building uses high rise first generation curtain wall construction; and
  - Jean Talon Building uses high rise precast concrete panel construction
- They exhibit a range of occupant populations:
  - 814 occupants for Brooke Claxton; and
  - 1700 each for Jean Talon and Main Statistics Canada Building.
- There are "as built" construction drawings currently available for the Jean Talon and Main Statistics Canada Building and drawings related to subsequent renovations for all buildings.
- They exhibit a mix of general building form and site positioning. The Main Statistics and Jean Talon have a campus/cluster type layout generally oriented North-South, while the Brooke Claxton Building is an isolated tower at the northern edge of the Campus.

Overview of the Test Buildings and their Components

This section of the case study provides a general overview of the current state of each of the buildings tested. The insights and understanding of the buildings was obtained by the project team through several building tours and meetings with the SNC-Lavalin Profac managers. A desktop review of the latest Building Condition Reports and Investment Plans followed by discussions with SNC-Lavalin Profac and PWGSC experts assisted the team in identifying an initial set of building components that may be vulnerable to climate change. This section also provide a general indication of key inputs the team used in the first steps of applying the PIEVC Engineering Protocol.

Main Statistics Canada Building

The Main Stats Building comprises 39,445.9 m^2 useable floor area and was built in 1952. In 2005 the Federal Heritage Buildings Review Office designated the building as a heritage building. It is a two-storey building with a full basement and partial third and fourth floors. Overall it is considered to be in "average" condition and is reasonably functional. It has received periodic upgrades and refurbishments over the years and in recent years various tenant and common areas have been upgraded to meet current accommodation standards.

The building is occupied primarily by Statistics Canada and is part of a larger node for that tenant which includes the adjacent (and internally linked) Jean Talon (to the North) and R.H. Coats (to the South) buildings. The building provides space for roughly 1,700 full-time equivalent civil service employees and a dedicated computer / LAN room (fourth floor). Other building occupants include Health Canada, SNC-Lavalin Profac and PWGSC. The building serves many functions that include office space, some storage, class/training rooms, a daycare centre, cafeteria and gym.

Building Envelope:

The exterior brick masonry with terracotta backup walls was constructed without proper drainage. Thus, water or moisture can become trapped within the wall system. According to the original construction documents, the wall insulation consists of 50 mm of cork. Property management has indicated that during the various repairs on the exterior wall, they have found little evidence of the cork. During cold weather, the lack of sufficient insulation affects both the comfort level for the occupants and the performance of the mechanical hot water radiators located on the perimeter walls. With only minimum insulation between the radiator and the exterior brick, the supply/return piping can freeze.

Granite stone surrounds the window and the main entrances and is predominant on the eight end wings of the building. There are few random cracks in the stone pieces and some of the windowsills have spalled on the exterior surface. Mortar joints are in varying condition with some cracked and some being replaced with sealant that has failed in many areas and requires replacement. The windows, main and secondary entrance doors and curtainwall assembly above the entrance doors were replaced in 1993-1994 and are in fair to good condition.

Based on the above building envelope information, the exterior wall construction is considered thermally deficient and requires comprehensive upgrading, including new air barrier, insulation and retrofit of the heating system. Assessment of the window systems (i.e. window sills) should also be considered in the retrofit.

There are 16 different roof areas associated with the building. They vary in age from 1 to over 20 years with their condition varying from excellent to fair. Due to their varying age, replacement will be staggered throughout the next 30 years. There have been no recent reports of moisture infiltration.

Structural:

The structural system is generally in average condition with no apparent sign of significant problems. Recently, seismic screening has been performed with the intent to identify buildings where “reasonable doubt” as to the seismic adequacy exists. Base on the screening the Structural Index is 17.15 and Non-structural Index is 9.0 with the Seismic Priority Index being 26.15. As such, the SPI indicates a high priority and further investigation is warranted at this time.

Exterior Elements:

Although we could not physically inspect the exterior site conditions (due to snow cover at time of assessment), based on the building condition report the site components are generally in fair condition. However, some of the grass covered areas adjacent to the building have a reverse slope towards the building foundation walls and are known to require prompt attention. The settlement around foundations walls has caused the reversed slopes around the building. Other exterior elements of note that need to be examined as part of the assessment are as follows:

- Concrete and masonry walls, including retaining walls
- Stairs (both in metal and concrete)
- Plazas, decks and loading bays
- Window and stair wells
- Manhole and other access point to site services and mechanical systems
- Exterior mechanical units (i.e. generators, etc.)
- Areas of storm water discharge being too close to the building
- Walkways and areas (bituminous, concrete and pavers)
- Parking lots
- Some foundation walls have areas of water infiltration

Mechanical Systems:

The central air handling systems have been replaced between 1997 and 2007 with only a few systems that have not been replaced yet. Some of the computer room cooling units were replaced in 2006. Washroom fixtures and piping have been replaced since 2001, and is ongoing. The majority of the chilled water piping has been replaced in 1995.

Electrical Systems:

The building voltage was converted to 347/600V 3ph 4W in the late 90’s and the lighting is being converted to 347V (about 60% completed) the exit lighting and emergency lighting has been reviewed and upgraded in 2006. One of the original generators was removed in the generator room, and a new 1250 KW generator set added adjacent to the building in the courtyard, for the fourth floor data centre.

Jean Talon Building

The Jean Talon Building is also located on the Tunney’s Pasture campus at 170 Promenade Tunney's Pasture Driveway and is connected (internally) to both the Main Statistics Canada Building. The structure was built in 1979 and consists of a 13-storey office tower with a Mechanical penthouse on the 14th level. Statistics Canada is the sole

tenant of the Jean Talon Building with a total useable area of the building of 60,907 m^2 and accommodating roughly 1,700 full time employees.

Building Envelope:

The roofs are comprised of inverted membrane assemblies, with waterproofing completely hidden by insulation and ballast. The existing roof has a service life of approximately 25 years with a replacement required in 2019. With the exception of the sloped glazing, the window systems are the original and should be scheduled for complete replacement in 2029. Window coverings throughout the building are either horizontal metal slat blinds or roller sunshades. The primary entrance doors have a remaining life expectancy of just over twenty years. Service doors are in good condition with replacement required between 15 to 25 years. The cladding of the building is a precast concrete curtain-wall. Localized bowing was evident along with failed joint sealant.

Exterior Elements:

Site components are generally in fair condition. Some of the areas adjacent to the building have a reverse slope towards the building foundation walls and require prompt attention.

Structural:

The structural system is generally in good condition with no apparent sign of significant problems. According to the drawings provided, all footings bear on limestone bedrock having allowable bearing pressure capacity as follows: Columns – 120 ksf; Elevator Core, Stairs, Elevator Pits - 50 ksf ; Perimeter Wall, Retaining Walls – 15 ksf.
The drawings available for review did not indicate design loading of the concrete slabs. Therefore maximum floor loading is not known. The building has been in service for 28 years with no reporting or evidence of problems with respect to floor or roof loading.

Recently, seismic screening has been performed with the intent to identify buildings where “reasonable doubt” as to the seismic adequacy exists. Base on the screening the Structural Index is 3.04 and Non-structural Index is 1.2 with the Seismic Priority Index being 4.24. As such, the SPI indicates a low priority and further investigation is not warranted at this time.

Mechanical:

Most of the mechanical equipment and materials are original from 1976, thus making them 32 years old at the time of this report. Generally, setpoints, flow rates, temperatures and capacities have all changed since the building was originally designed. Thus all replacement equipment might be resized to a different capacity from original.
The building is equipped with sprinklers throughout. The sprinkler and standpipe systems are combined above grade but separate below grade.

Mechanical equipment is being run to Treasury Board Secretariat standards. Based on this requirement a random sample was performed on the 6th floor with supply air from all systems at about 21,236 l/sec (45,000 cfm) and the approximate general airflow rate at

about 5.87l/sec per m^2 (1.15 cfm/ft^2). These flow rates are conventional and do not indicate an insufficient overall airflow rate. Carbon dioxide levels are monitored with sensors that control outdoor air dampers through the Building Automation System (BAS) so that carbon dioxide levels don't reach unacceptable levels and that outdoor air is maintained to all floors.

Electrical:

The electrical systems in the building are in good condition. The base building lighting fixtures have been upgraded to T-8 fluorescent fixtures. The emergency diesel generator is regularly tested and in good condition. Variable speed drives for the air-handling units will have to be replaced with new drives. The fire alarm and voice communication system is relatively new and should continue to provide reliable service for many years to come.

Brooke Claxton Building

The Brooke Claxton Building is a 19-storey office tower, including a single level podium and two mechanical penthouse levels. Constructed in 1964, the building serves as the Headquarters for Health Canada with the upper two floors housing the Minister, Deputy Minister and other executive offices. In total, the building comprises a rentable floor area of approximately 21,089.4 m^2 and accommodates approximately 815 full time employees.

The main office floors (2-16) each have a useable floor area of 1,045 m^2 and are primarily dedicated to office space with a central service core. The basement podium (all on one level) is substantially larger than the typical floor plate for the office tower having 5,624.2 m^2. Most of the podium is finished and dedicated into office space. It also houses a cafeteria, fitness centre, print shop, Health Canada Crisis Centre and the main boardroom facility. An aboriginal 'wellness lodge' is also located in this area. The podium is at grade on the north end of the site and has exterior and dock loading facilities, as well as a small amount of storage space. The south end of the site is oriented toward pedestrian entry into the office building.

It is in good condition, having undergone a major modernization program between 1990 and 1995 with new interior finishes and mechanical / electrical systems.
In 2004, the Brooke Claxton Building was declared a "Classified" Federal Heritage Building because of its historical associations, and its architectural and environmental values. The designation is confined to the footprint of the building.

Building Envelope:

The office tower is clad with a combination of precast concrete panels finished with a rough slate green finish and smooth finished light granite column covers none of which exhibit evidence of generalized distress or movement. There is some minor deterioration of the granite, with one soffit piece previously fallen. Brick walls are used around the mechanical areas on the roof top. Regular maintenance of the brick will help to maintain these components and will also reduce leakage into the building by installing through-

wall flashing. The mechanical area wells are visible only from the roof level or from within the area wells. These wells should (recommended in the Building Condition Report) be covered with a roof to reduce further deterioration while potentially gaining use of the area.

The windows are in fair condition. The windows are double glazed clear anodized aluminium windows with fixed uppers and formerly operable awning style lower lights that have been fixed shut and hardware removed. The basement level windows are of similar construction. The glazing system has a remaining service life of less than 10 years and as such requires ongoing maintenance. There is reported to be damage of ground level glazing panels due to the damage from high winds while condensation and breakage of window seals is also problematic throughout the building. Continued deterioration of the sealed units, possible air or water infiltration, which may eventually affect other building components, can result in more costly repairs/replacement. Reduce visibility through failed sealed units and reduced aesthetics in the lobby and on the Minister's floor is taking place. The cafeteria window wall in the basement is about the only window fully replaced in 2001. The main entrance doors on the south side of the ground floor consist of two sets of four single glazed – clear anodized aluminium doors in clear anodized aluminium frames creating an enclosed vestibule. There are also two single glazed aluminium doors to the 16th floor terrace however the terrace is no longer accessed by tenants and the doors are locked and only used for maintenance access. The main and basement entrance doors were repaired in the major renovation in 1995 and this extends the life of these doors. Other doors have no major signs of deterioration and appear to be serviced regularly. During the winter, ice formation due to condensation increases the door maintenance requirements. The overhead doors are in good condition and were replaced in 1997.

The tower roof is comprised of inverted loose laid reinforced PVC Sarnafil membrane system with concrete topped (CT) insulation and was last replaced in 1990. Deterioration of the CT boards have made them susceptible to wind blow-off. The podium level is comprised of an inverted modified bitumen membrane system with type 4 polystyrene and precast panels and was last replaced in 1997. The 16th floor terrace was recently retro-fitted in 2007 with an inverted modified bitumen system. A gutter system is located along the north edge of the podium overlooking the parking area and was last replaced in 1995.

Site Features:

Items requiring attention in the short term include asphalt crack sealing in the north parking lots, re-finishing of all exterior steel railings and repair/replacement of loading dock lift table. Surface drainage at the site include area drains on the podium, catch basins located in the parking lots and on the City streets and to drainage swales located between adjacent properties. These storm water management systems were last replaced in 1996. Between 1993 and 1998 concrete walkways/areaways, paved parking lots and roadways were replaced.

Exterior stairs, ramps and loading docks are in good condition due to their recent replacement. Podium stairs and exterior concrete ramp replaced in 2004; loading dock and stairs replaced in 1995.

Structural:

The building is in good condition. The tower structure is concrete encased steel columns around the perimeter and reinforced shearwalls in the core of the building that support concrete encased steel beams. The core of the building is the only interior structure that minimizes remodelling impacts of the building and thus there is significant flexibility in this regard. The podium level structure consists of reinforced concrete columns and basement walls that support reinforced concrete beams. It is anticipated that the frame will last the life of the building (beyond the next 30 years).

The foundation systems consists of reinforced concrete spread footings and foundation / basement walls. The reinforced concrete basement walls on the north side of the building are exposed on the exterior and regular, routine repairs are imminent. The exterior finishes are average with some stains from moisture runoff primarily from the podium level. Overall the foundations are considered to be in good condition.

The roof structure consists of reinforced concrete slabs on concrete encased steel beams. The podium structure consists of reinforced concrete slabs on concrete beams. There is some deterioration along the edge of the podium slab walls and potentially this area is subject to greater deterioration that will require regular maintenance.

There is some deterioration and leakage around the perimeter of the podium slab. The terracotta wall cover in the penthouse exhibits movement, which should be reviewed. The seismic system of the building does not comply with the most recent building code and will require reinforcement during any major renovation to the building.

Mechanical:

The building is heated and cooled via a perimeter 2 pipe induction system and interior variable air volume systems. Controls are pneumatic, with Direct Digital Control front-end controls of the main equipment. The induction system was installed in 1994, as were the lobby and cafeteria air handling systems. The systems are in good condition; however, the tower air handling systems have insufficient capacity during the shoulder seasons and peak summer cooling loads.

Electrical:

Much of the power distribution system has been replaced starting in about 1995, however some of the original cabling and conduit for the distribution from the main secondary switchboard remains in service. The electrical distribution system can be generally characterized as in good condition. The emergency power system was installed in 1985 and is in average condition. Extensive renovations have been undertaken to the indoor lighting and emergency lighting systems. The overall condition is considered good, with adequate free space for expansions or additions.

Applicable Jurisdictional Considerations, Codes and Standards

To inform the project team in terms of how the test buildings are managed, an overview and scan was conducted on the jurisdictions and instruments used to oversee, plan and manage the buildings on the Campus. This section of the case study provides an overview of the Acts, Policies, Codes and Standards that apply to the test buildings. Federal Government of Canada via Public Works and Government Services Canada has jurisdiction and direct control or influence on the planning, operation and daily maintenance of the buildings in Tunney's Pasture. The following Government of Canada Legislation applies to the legal structure for the buildings:

- Financial Administration Act;
- Federal Real Property and Federal Immovables Act;
- Surplus Crown Assets Act; and
- Public Works and Government Services Act.

Note: The National Capital Commission, under the National Capital Act, also has legislated responsibilities for real property within the National Capital Region (NCR). These responsibilities include the approval of all sales or transfers of federal lands within the NCR, approval of demolition of buildings on federal lands within the NCR, approval of land use or development plans, approvals for exterior alterations and additions to buildings on federal lands in the NCR.

The following Building compliance acts/regulations are applicable to all the buildings considered in this Assessment:

- Canada Labour Code – Part II (1985);
- Canada Occupational Safety and Health Regulations (SOR/86-304);
- National Building Code of Canada (2005); and
- National Fire Code of Canada (2005).

A range of standards provided by Canadian Standards Association (CSA) and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) support the Labour Code and Canada Occupational Safety and Health Regulations. Of note as it relates to the health, safety and comfort of the building occupants are:

- ASHRAE Standard 55-1981, Thermal Environmental Conditions for Human Occupancy; and
- ASHRAE Standard 62-2001n, Ventilation for Acceptable Indoor Air Quality

NOTE: The Treasury Board of Canada Secretariat Occupational Safety and Health Directive (effective January 1st 2006) stipulates that for in office accommodation, air (dry bulb) temperatures during working hours should be maintained within the 20-26 °C range. Temperatures between 17-20 °C and above 26 °C can be uncomfortable, and occupancy should not exceed 3 hours daily or 120 hours annually in each of these

extremes. Temperatures above 26 °C are deemed to be uncomfortable when the humidex reading to a given temperature equals 40 or less.

SNC-Lavalin-Profac, the building managers, are contracted by PWGSC to be primarily responsible for daily operation and maintenance of all the test buildings. They are also involved in assisting and informing the development of the Building Condition Reports every 5 years that are then used to budget and plan for upgrades, renovations, rebuilding, etc. through Investment Plans.

In addition to the above Acts, Policies, Codes and Standards, the the following federal environmental Acts apply to all buildings on the Tunney's Pasture site:

- Federal Real Property Act, brought into force on September 15, 1992.
- Canadian Environmental Assessment Act (CEAA), January 19, 1995.
- Canadian Environmental Protection Act (CEPA), 1988 (currently under review)
- Auditor General Act
- Fisheries Act
- Migratory Birds Convention Act

These Acts, however, are more applicable when new buildings are constructed or when major renovations are planed on existing facilities or Campuses.

Vulnerability Assessment

As outlined above in the Project Approach section, the Project Team used the PIEVC Protocol to assess the vulnerability of the three test buildings to climate changes. This section of the report, primarily discusses how the Team applied Steps 3 through 5 of the Protocol (the Climate Change and Buildings sections above have already discussed the main elements of Steps 1 and 2). Step 3 can be considered to be the "heart" of the Vulnerability Assessment, whereas Steps 4 and 5 are intended to screen through, prioritize and develop recommendations for the infrastructure (building) components that have been identified to be vulnerable to climate change.

Objectives and Methodology

Appendix C provides the full PIEVC Engineering Protocol and an explanation of the overall Vulnerability Assessment methodology. The project team followed the main steps in the Protocol where possible by using the PIEVC provided Worksheets. A copy of the completed Worksheets for the Main Statistics Canada Building are provided in Appendix B. A full application of the Steps 1 and 2 in the protocol was not conducted for the Jean Talon or Brooke Claxton Buildings as it would be for the most part identical to the Main Statistics Canada Building (see Project Approach above). Instead, emphasis was placed on Step 3, 4 and 5 of the Assessment in order to identify the core differences in possible vulnerability of components between the three buildings. As well, the team noted any possible recommendations for the Main Statistics Canada Building that would not be applicable to the Jean Talon or Brooke Claxton Buildings.

Step 3 primarily involves a qualitative assessment in which professional judgement is used to determine the likely affect of changes in the climate factors (identified in Step 2) will have on the building components (also identified in Step 2). To achieve this the project team developed a Vulnerability Assessment Matrix based on the template provided in Step 4.3.6 of the PIEVC Protocol. As per the Protocol, the Probability (S_C) and Severity Scale (S_R) factors were used to calculate the priority of the affect of climate change factor on each building component. The team selected values along the 0 to 7 scale based on the probability of the expected climate change factor influencing the building component and severity of the potential impact this change would have on the component. Method A and Method E were used to select values for probability and severity respectively as shown in Table 2 below.

Table 2 Probability and Severity Scale Factor methodologies used in the Vulnerability Assessment of the three test buildings.

Scale	Probability Scale (S_c) Factor - "Method A"	Severity Scale (S_R) Factor – "Method E"
0	negligible or not applicable	negligible or not applicable
1	improbable /	very low / unlikely / rare /

	highly unlikely	measurable change
2	remote	low / seldom / marginal / change in serviceability
3	occasional	occasional loss of some capability
4	moderate / possible	moderate loss of some capacity
5	often	likely regular / loss of capacity and loss of some function
6	probable	major / likely / critical / loss of function
7	certain / highly probable	extreme/ frequent/ continuous /loss of asset

This method was chosen to align with current prioritization schemes and risk management methodologies used by Public Works and Government Services Canada in the management of its Real Property portfolio.

The Vulnerability Assessment Matrix automatically calculated the "priority of climate change effect" (P_c) for each building component. As per the Protocol this calculation was done following the formula of $P_c = S_c \times S_R$. The building components were then ranked according to their P_c values as follows:

- P_c values between 12 and 35 identified building components where climate change will possibly have a major effect; and
- P_c values 36 and above indicated components that have a strong probability of severe effect.

Those building components with P_c values between 12 and 35 were then subjected to an "indicator analysis" according to Step 4 in the Protocol (see Worksheet 4 in Appendix B). The outcomes of Step 4 and the building component that obtained P_c values of 36 or higher, formed the input into Step 5 – Recommendations (See Worksheet 5 in Appendix B). Step 5 in the Protocol structured the development of recommendations for each of the building components that:

- Are identified as having a strong probability of severe effect due to climate change; and
- Are identified as having a lack of adaptive capacity due to climate change.

In addition to relying on the outcomes of Step 3 and 4 of the Protocol to develop recommendations, the project team relied on the data from the building condition reports (e.g. current conditions of building components), interviews and building tours.

Findings

Consultations and Building Tour Findings

The project team had several consultation meetings with representatives from SNC-Lavalin Profac – the building managers contracted by PWGSC – to gather more information and data concerning:

- details on the buildings, the important components and the current interactions between these components and the weather and climate;
- current condition, state of repair, construction, materials and expected life cycle of building components;
- anecdotal evidence of interactions of building components with the weather and climate;
- current capacities and loads on specific building components; and
- the rating of probability and severity scale factors for specific building components.

The key observations and outcomes from these consultations and meetings are:

- Building operators have excellent experience with the current status of building components and the affects of weather and climate on their deterioration and expected remaining life cycle.
- Current patterns and strength of winds affects the snowdrift patterns at the building envelope and along the parapet such that snow needs to be moved so as to not cause damage and danger to pedestrians below.
- Water staining was observed at the windowsill and lintel (precast and stone) that is affecting the integrity of these systems (Main Statistics Canada Building)
- Operators have observed extended and more extreme periods of hot, humid weather in summer that need to be factored into the probability/severity ratings of some components.
- The heating and cooling systems needed to maintain the humidity and temperature levels for LAN/computer rooms are critical to ensure the security of computer services to employees.
- Operators are very concerned about increased freeze thaw cycles and their effect on masonry mortar, walkways, parking area and building envelops where joints and different materials are fastened together.
- Soil settling combined with potentially increased rain/snow may decrease the ability to manage storm water.

The above and other more detailed information gained during these meetings and tours are integrated into this report. In particular the observations and outcomes of building tours helped the project team to determine the Probability and Severity Scale factors required in Step 3 – Vulnerability Assessment (see Table 2). For example, the observation by Building Managers that extended and more extreme periods of hot, humid

weather in summer are having an affect, provided the project team with additional rationale to increase the probability/severity ratings of building components relating to cooling, humidity and ventilation. Specific details can be found in Appendix B, Worksheets 1, 2 and 3.

Main Statistics Canada Building

The major findings regarding the Main Statistics Canada Building are that there are a range of different building components that are, to varying degrees, vulnerable to climate change. Table 3 shows the outcomes of the Vulnerability Assessment Matrix applied to the Main Statistics Canada Building. Building components were assigned a "priority of climate change effect" score (P_c) using professional judgement in rating the Probability and Severity Scale factors for each building component. Building components with a Pc value of 36 or higher were identified as having a strong probability of severe effect due to climate change (indicated by * in Table 3). Building components with P_c values between 12 and 35 were identified for further analysis in Step 4 to understand the possible vulnerability due to climate change.

Table 3 List of building components identified in Step 3 – Vulnerability Assessment of the Protocol as potentially vulnerable to climate change.

Building Component	Priority of climate change effect (P_c)
Exterior Systems	
• Site Drainage	12
• Storm Drains*	36
• Tunnels, manholes and access doors	35
• Freestanding walls – concrete and masonry	20-25
• Retaining Walls	12
• Walkways – asphalt, concrete, unit pavers*	42
• Stairs – concrete and metal*	30-36
• Ramps*	36
• Parking Areas – asphalt, concrete, unit pavers*	42
Building Systems	
• Masonry walls*	36
• Stone Panels*	36
• Precast Concrete Window Sills	30
• Glazed Curtain Wall	16
• Metal Cladding	16
• Windows – aluminium	16
• Doors – steel and aluminium	12
• Flat Roof Systems	30
Mechanical and Electrical Systems	
• Heating System and Adequacy	12
• Cooling System and Adequacy*	42
• Provision/Supply and Reliability of Electrical Power:	35

Based on Steps 3 and 4 of the Protocol and the building condition reports, results from interviews and building tour, the Project Team determined a set of findings for the Vulnerability Assessment of the Main Statistics Canada Building. These are discussed below according to the main groupings of building components.

Main findings, Exterior Systems:

1. Storm Drains: Although the design parameters of the storm drains were not available, the Project Team used professional judgment and civil engineering input[3] to determine that the existing storm drains meet and are potentially at full capacity. Based on projected increased precipitation, these systems will potentially be inadequate and as such may need to be supplemented with storm water retention areas or with ground water recharge systems.
2. Tunnels, manholes and access doors: This infrastructure component is below grade and throughout the campus supplying all buildings with critically needed steam and chilled water. Although the Tunnels are currently being maintained and managed by PWGSC, no technical information was available for this system at the time of the assessment. Due to the sites proximity to the river and increase in precipitation year round, ground water issues may affect this infrastructure so much so that it could require draining / pumping systems.
3. Walkways and Parking Areas: Due to increased freeze thaw and rain over the winter months it can be expected that there will be more ice build-up on walkways. The Tunney's Pasture campus has well over 10,000 people with only about 1000 parking spots. It therefore has a strong pedestrian component given its proximity to the transit way and parking restrictions. Health and safety of pedestrians and prevention of injury on ice is very important. At the same time the freeze thaw cycle will cause heaving and material deterioration making the condition of the walkways prone to tripping hazards. This will pose a significant risk and cost to maintaining this infrastructure component. Higher Temperatures will affect walkways especially asphalt walkways as it will cause the material to soften thus affecting its wear. For example, shoe heels will puncture into the walkway and create crevices that in the winter will be subjected to freeze thaw and cause the walkway to breakdown.
4. Stairs: Increased freeze thaw cycles will cause heaving and material deterioration making the stair areas prone to occupant tripping/falling/injury. This could pose a significant risk during emergencies and evacuations. Stairs should be kept clear of snow and ice during winter months to ensure dry conditions and prevent material deterioration. Note, because of the public nature of this building and the unionized civil service occupants, snow clearing on steps is promptly dealt with in accordance with PWGSC standards.
5. Ramps: Increased freeze thaw cycles will cause heaving and material deterioration making the ramps an area prone to occupant tripping/falling/injury. This could pose a significant risk during emergencies and evacuations. Stairs should be kept clear of snow and ice during winter months to ensure dry conditions and prevent material deterioration. Note, because of the public nature of this building and the unionized civil service occupants, snow clearing on ramps is promptly dealt with in accordance with PWGSC standards.

Main findings, Building Systems:

[3] Trevor Kealey, R.V. Anderson Associates Ltd., Ottawa.

6. Building Envelop: Due to increased rain over the year, moisture will make its way into the building envelope. The result of this will mean increased brick failure. Building Management is currently seeing some evidence of this. With no drainage cavity it will make it more difficult to keep the envelop dry. The only means of drying out the envelop is through building heat migrating out and solar radiation throughout the year. In the winter months any moisture within the envelope will be subjected to freeze thaw cycles therefore affecting the structural integrity of the building envelop materials. Higher humidity levels in the summer months may have the same effect in that moisture will migrate into the envelop that can cause damage. Alterations on the interior and exterior side of the building envelop will require serious consideration before any action is taken as it can significantly alter the performance and negatively impact the system. In addition such changes will have significant affects on heating, cooling and ventilation loads and requirements for the building.
7. Flat Roof Systems: Given that flat roofs will retain some water and that freeze thaw cycles are expected to increase over the winter months, this will pose a significant strain on the integrity of the system so much so that the life cycle will be shortened. Unexpected leaks may take place and therefore compromise the structure and finishes below. This system is vital to the well being of a building's operations and as such is critical system that requires constant monitoring. NHote that current building management practices require annual review of this system such that it will safeguard the system.

Main findings, Mechanical Systems:

8. Heating System and Adequacy: It was found that at times during the winter the hot water heating system (supply from the CHCP) has a hard time keeping up with the interior heating demands causing the interior environment to be cold and uncomfortable. This is primarily due to the fact that there is little to no insulation in exterior walls often resulting in the heating pipes freezing. However, based on the projected increases in temperature during the winter months, and a reduced frost season, the adequacy of the system to meet demands may prove to be reduced or eliminated. It should be noted that currently, because of a lack of insulation, the exterior building envelop relies on a certain amount of heat to keep it warm and dry, that in turn ensures the envelops structural integrity. Therefore the heating system and its adequacy are intimately linked to the condition and technology of building envelop. Therefore, the main weakness related to heating the building is actually the building envelop itself.
9. Cooling System and Adequacy: Climate change impacts the capability of the cooling system to meet loads for the Tunney's Pasture facilities in two ways:
    a. Outdoor temperature and humidity increases load through higher sensible and latent cooling of make-up air supply and infiltration as well as increases in envelope conduction gains. As the relative humidity projections are relatively constant, the projected rises in temperature result in increases of make-air and infiltration loads at a rate of about 5kJ/m3 or 5W/l/s, mostly latent. Assuming a combined air change rate of 1 ACH, the

load increase can be estimated thus: building floor area (m2) x temperature rise (0K) x 5 (W) = additional cooling load (W). Building envelope gains are smaller and require envelope areas and U-values. The cooling coils and air distribution may be insufficient to maintain acceptable conditions.

b. The central chilling plant depends on sufficiently cool water and pumping rates from the Ottawa River to maintain capacity and possibly operation. A combined effect of lower summer rainfall and higher ambient temperatures will raise temperatures and lower flow rates of the Ottawa River. Increased usage for heat rejection and urbanization upstream will have similar effects. Although current capacity exceeds demand by a 50% margin currently, the combination of lower capacity due to condenser temperature rise and higher loads may reduce the margin to criticality. The older steam turbines will be called in to duty more frequently and shorten their serviceable life.

10. Provision/Supply and Reliability of Electrical Power: As temperature and humidity levels will increase, electrical demands will also increase with no guarantee that the utility will be able to supply enough power city wide. Power supply and reliability is therefore very vulnerable. This element is not reviewed as part of typical building condition management practices and therefore will require special attention and monitoring.

The project team also found through Step 4 of the Protocol – Indicator Analysis – that the following building components have adaptive capacity through typical building science best practices that could be implemented as part of the building management program through regular scheduled building maintenance activities:

Exterior Systems:

1. Site Drainage – related to slopes away from the building and includes soil permeability and hard surfaces like stairs / ramps
2. Freestanding walls - concrete and masonry
3. Retaining walls – concrete
4. Stairs – metal

Envelop Systems:

1. Precast Concrete - Window Sills
2. Glazed Curtain wall
3. Metal Cladding
4. Aluminium windows and steel doors

In summary, for the Main Statistics Canada Building, the project team found that the highest priority building components due to climate change are:

- the walkways, parking areas, stairs and ramps because of potential risk to human health, safety, injury, falling etc.

- the building envelop because accelerated deterioration will affect the structural integrity of the building
- the adequacy of the cooling system because is poses significant costs to PWGSC and directly affects occupant comfort and productivity
- the reliability of power (electricity) to the building because it is critical to the daily work and productivity of occupants and the operation of the computer/LAN room.

Jean Talon Building

The main findings with respect to the Jean Talon building were very similar to the Main Statistics Canada Building. The highest priority considerations are similar in that the exterior systems (e.g. walkways, ramps, parking areas and stairs), building envelop, cooling systems and reliability of power are the key vulnerabilities. However, there are specific differences in the findings:

1. Retaining Concrete Walls – This element is one difference when compared to the other 2 test sites. The loading area for this building requires that there is a retaining wall on the north side of the building. The wall is easily 1.5 stories in height. Freeze thaw cycles and increases in moisture content in the earth along with water infiltration at grade between the earth and wall structure could cause movement or deterioration.
2. Building Envelop – The most note worthy element is the precast detailing at the parapet level. It was observed that snow was making its way behind the precast panel and between the structure that supports the panel. Upon closer observation, at the top of the parapet wall there is no cap to neither cover the cavity nor shed water away from this cavity. As well, bowing precast walls were observed in several locations and must be noted as unique to the 3 buildings studied. Both of these situations are not necessarily climate change related but are rooted in buildings science. Through typical building management practices, these issues should be adequately monitored and hopefully resolved.
3. High Parapet Walls – Typically, a parapet well is not greater than 2 feet high. In the case of Jean Talon some of the parapets are easily the height of one storey. The high parapet wall produces unique situations for snow drifts and wind patterns that would require further study. At this point we can not be conclusive about this unique building condition.

Brooke Claxton Building

The main findings with respect to the Brooke Claxton building were very similar to the Main Statistics Canada Building. The highest priority considerations are similar in that the exterior systems (e.g. walkways, ramps, parking areas and stairs), building envelop, cooling systems and reliability of power are the key vulnerabilities. However, there are specific differences in the findings:

1. Metal Gutters - Unlike most buildings at Tunney's Pasture, the Brooke Claxton building uses metal gutters on the north end of the podium so as to not drain directly on the users of the building entry points and loading dock facility located below. Over the winter months ice accumulation can form along the edge of the podium not only on the north side but also the west and east side. From a building science perspective this can case deterioration of the roof and exterior wall. On a health and safety level this may also pose some risk to pedestrians especially on the north side. Generally, typical building management practices should guard against this risk and in our professional opinion is part of standard building best practices currently underway.
2. Tunnels, manholes, access doors – The elevation of the tunnel system at Brooke Claxton is at a slightly lower elevation and is in closer proximity to the Ottawa River. Due to greater levels of precipitation year round and like all tunnels on site it will be affected by water infiltration as was evident during the Brooke Claxton building tour.
3. Building Envelop – Like the Main Stats Building, Brooke Claxton has an aging building envelope that is mostly of the original construction vintage. It is over 40 years into its life cycle and as such will require maintenance and upgrades to preserve its integrity especially since this building has an exterior based structural system. Current building science places the structure on the interior so that it is kept warm and dry.
4. Podium Roof – Generally, the podium roof has been detailed in such a way that there is little to no roof overhang. With this existing scenario, rain water drains directly on the east podium wall as staining is evident on this elevation. This condition is unique yet similar to the Jean Talon building which has a similar podium walk-up for ground floor entry to the building. Deterioration on the wall, especially over the winter months, can take place and can be accelerated due to increased freeze thaw cycles.

Summary of Findings

As mentioned above, the findings and highest priority considerations resulting form the Vulnerability Assessment are very similar across all three test buildings in that the exterior systems (e.g. walkways, ramps, parking areas and stairs), building envelop, cooling systems and reliability of power are the key vulnerabilities. There is however, differences in considerations regarding roofs, building envelop, tunnels and retaining walls that are specific to each building. Details of the Vulnerability Assessment (Step 3) for each building can be found at the end of Appendix B.

Other Potential Changes

The project team identified three main potential changes/variables that may affect the vulnerability of the three test buildings due to climate change. The first, is that changes occupant/employee density and space dedicated to computers/servers/mainframes will affect the loads put on the building power, ventilation, heating and cooling systems. The

future changes in occupancy and space usage are currently unknown and therefore this can also be seen as a limitation of the Assessment.

Second, the Tunney's Pasture Campus is currently the focus of a Master Planning exercise being undertaken by Public Works and Government Services Canada. The outcomes of this study are unknown at this time and difficult to predict. However, they may affect the investment plans and budgets and resulting priorities for the three test buildings.

Finally, there is uncertainty and fluctuating budgets surrounding the investment and long-term capital plans for these buildings as administered by Public Works and Government Services Canada. This can result in deferred maintenance that can affect the ability to maintain the building to the required performance standards. They can also change the operating and maintenance priorities for the building as well as planned capital upgrades. Thus, the planned upkeep and replacement of specific building components is difficult to predict. However, one can see that the results of this assessment could inform the future development and prioritization of these budgets, reports and plans for the test buildings and the Tunney's Pasture Campus in general.

Data Sufficiency and Limitations

The building data from the 2007 and 2008 building condition reports are assumed to be accurate. Current building management practices by PWGSC and SNC-Lavalin Profac ensure that all building components are reviewed on a 5-year cycle. The resulting Building Condition Reports inform the planning, prioritization and budgeting of service, upgrades, renovations, rehabilitation etc. for the buildings. These reports and supporting processes as well as qualified and informed building managers provided the project team with high quality information to inform the vulnerability assessment.

With respect to limitations of the climate change data, the models used can be considered to be the best available estimates. Most of climate change factors relevant to the test buildings and their performance were provided by Ouranos (see Appendix A). However because sensitivity or uncertainty analysis is still under development in the climate change modelling field, the expected changes developed through the climate change models and scenarios were considered to be general estimates in the assessment.

In terms of other limitations, the Project Team identified the following:

- Making predictions about the service life of building materials and components requires in-depth knowledge of materials, their composition, manufacture and their response to a number of different weather and climate related factors. This in-depth knowledge is outside the scope and areas of expertise of the project team and the purpose of this assessment. That being said, the team has identified the building components that require additional analysis or research.
- The inability to predict the occurrence of extreme weather events that cause building components or materials to fail prematurely.
- The Heritage designation of the Main Statistics Canada and Brooke Claxton Buildings could affect the potential priorities and plans to improve, upgrade or

refurbish the building, particularly the building envelop. This factor was not included or researched as part of this assessment.

- Because the test buildings rely on the Central Heating and Cooling Plant (CHCP) for heating and cooling for much of their space, the efficiency and affects of increased loads on the CHCP need to be studied further. The central heating and cooling plant was recently modernized, one would assume that they did take into account more recent data. This is a major limitation of the current assessment as the building and its components should be considered to be an integrated system working to provide the necessary functions for its occupants, for example changes to the building envelope will impact heating and cooling loads. This in turn can affect the demands placed on the CHCP and roof-top units for the computer/LAN rooms.

Conclusions & Recommendations

First, for the three buildings, the project team found that the highest priority considerations due to climate change are:

- the walkways, parking areas, stairs and ramps because of potential risk to human health, safety, injury, falling etc.
- the building envelop because of accelerated deterioration will affect the structural integrity of the building.
- the adequacy of the cooling system because is poses significant costs to PWGSC and directly affects occupant comfort and productivity.
- the reliability of power (electricity) to the building because it is critical to the daily work and productivity of occupants and the operation of the computer/LAN room.

Specific recommendations for the three buildings include:

J. A detailed research study should be conducted that investigates the loads from potential increases in precipitation on the site rain and storm water drains and tunnels. The study should consider the existing site drainage capacity, soil types, site slopes/topography, ground water tables and bedrock topography to investigate if there are any possible risks/vulnerabilities to these component. As well the study should have a scope that examines the potential effects on the function of the buildings, footings, foundation walls, slab on grade and retaining walls. Ideally the study should also consider any possible future changes to the overall plan/layout/building density (i.e. Master Plan) of the Campus and explore the optimum engineering solution such as ground water recharge or storm water retention areas.

K. In conjunction to the above recommendation, PWGSC should consider and assess how climate change will affect Federal Real Property that is in close proximity to the Ottawa River, its watershed and flood plain. This may warrant that PWGSC initiate or involve themselves in studies on the climate change effects on the Gatineau River, Rideau River or Rideau Canal. In either case, this would also provide more information for subsequent assessments on the Campus that could include flood plain considerations/risk.

L. It is crucial that all walkways, stairs, and parking areas be kept clear of snow and ice in the winter in accordance with current building management practices. This will help ensure an optimal life cycle and structural integrity for these asphalt, concrete and unit paver surfaces. Maintaining current practices and budget for snow/ice clearing will help ensure occupant and public safety in these areas. As these surfaces reach the end of their life cycle, PWGSC should consider replacement with materials that will withstand increased freeze-thaw cycles. These materials should also try to minimize heat gain in the areas surrounding the building in order to reduce possible cooling loads on the building during the summer.

M. In the Main Statistics Canada building, the heating system pipes can freeze and burst in the winter months, resulting in building envelop water damage. This in turn can affect the structural integrity of the building. This is high priority area that warrants the research and application of a building envelop technology that can mitigate this problem as well as manage the affects of increased precipitation and potential moisture migration into the envelop due to climate change. It should be emphasized that changes to the building envelop will affect the performance and loads on the heating, cooling and ventilation systems. Thus, any changes to the envelop will require modification of the heating, cooling and ventilation systems to ensure optimum building performance in line with current building science and codes. As mentioned above, the building's Heritage status may need to be considered in any changes to the structure or envelop.

N. The Brooke Claxton Building, as with the Main Statistics Canada Building, has an aging building envelope that is mostly of the original construction vintage. It is over 40 years into its life cycle and as such will require maintenance and upgrades to preserve its integrity especially since this building has an exterior based structural system. Research and application of a envelop technology that will keep the interior warm and dry, without affecting structural integrity is recommended. As mentioned above, the building's Heritage status may need to be considered in any changes to the structure or envelop.

O. The flat roof systems will be particularly vulnerable to climate change due to increase freeze-thaw cycles and summer temperatures. Roof deterioration is likely to be accelerated. Therefore, PWGSC should investigate and determine the optimum flat roof technology, design options, mitigation strategies that will accommodate the potential effects of increased freeze thaw and ice build-up. It is recommended that such a study should investigate current best practices in climates that are currently similar to the predicted climate change for the Ottawa Region (i.e. warmer, more freeze thaw) and also investigate the feasibility of adapting a technology that sheds more easily/reliably moisture, snow and rain.

P. The potential increased spring, summer and fall temperatures due to climate change can have a direct affect on all the buildings cooling systems. A detailed engineering evaluation needs to be conducted on the anticipated loads due to climate change and the optimum solution for each building. Such an evaluation should evaluate the suitability of various adaptive measures/technologies such as exterior shading devices, passive cooling techniques, etc. It should also recognize potential changes/engineering options for the building envelop (discussed above) to ensure systems are optimally sized for the existing and projected loads. Secondly, PWGSC should conduct a separate or integrated evaluation based on the Campus as a system of buildings, each presenting differing loads and responses to climate change to the Plant. This could be in the form of a climate change vulnerability assessment based on the PIEVC Protcol on the Central Heating and Cooling Plant. In any case, the evaluation/assessment should model and consider:
    a. the projected loads on each building and as a Campus;
    b. current and future CHCP capacities;

c. the various technology options/adaptive measures for the buildings on the Campus;
d. the future Master Plan for the Campus;
e. various technologies/adaptive measures for the CHCP itself such as co-generation and geothermal heating and cooling; and
f. that the engineering solution meet or exceed the Government of Canada's objectives to reduce GHG emissions and Air Pollutants.
g. Any potential changes to the Ottawa River (used by the Plant for cooling) such as water temperature, flow, height etc. that may be due to climate change.

Q. PWGSC should being working with the local electrical utility (e.g. Hydro Ottawa) to study and plan for the cumulative effects on electricity loads, demand, consumption, etc. during spring, summer and fall from all the buildings at the Tunney's Pasture Campus. This work should also be done in conjunction or at least consider the evaluation/assessment of the CHCP and the potential technologies (e.g. co-generation) that can reduce demands and loads on the local electrical utiliy. These efforts will help ensure that the electrical power supply is reliable for the buildings on the Campus and in the region.

R. PWGSC and other building landlords and operators should begin to plan for the expected changes in climate. This is particularly the case for buildings of similar vintages and construction types as the test buildings. Those owners and operators with buildings requiring renewal, major renovation or complete rebuilding within the next 10-15 years, should be planning and designing these buildings to meet future climatic conditions.

Action on these recommendations should be initiated within the next 6-18 month timeframe.

Secondly, the Project Team recommends that the current building management processes be maintained to help ensure that many building components (e.g. stairs, walkways, ramps, windows, doors) adversely affected by climate change (i.e. premature deterioration) will be identified and subsequent remedial action taken to reduce or eliminate any specific impacts. In other words, we find that this management approach indirectly guards against climate change vulnerabilities for several building components and systems. This is because Federal buildings are managed under a rigorous process that includes Asset Management Plans, Building Condition Reports and Building Management Plans, to name a few. This building management process is based on sound financial and building science best practices and overall ensures that the building asset is kept in the best condition, practically speaking. The review of these reports and subsequent meetings and consultations with PWGSC and SNC-Lavalin Profac provided excellent sources of data and practical information about the buildings and their components, current state of repair and expected lifespan.

Thirdly, despite the rigorous building management processes in place and utilized by PWGSC and SNC-Lavalin-Profac, there are gaps in the Building Condition Reports related to how the building operates as a system. In other words, current emphasis in

condition reporting and operations is focused on a “component by component” basis, whereas, a “building as a system” approach (Figure 2) could prove beneficial in terms of planning and responding to changes in climate that affect numerous building components/systems simultaneously. For example the inter-relationship between heating and cooling systems and the building envelop, insulation levels and ventilation could be further elaborated in order to prioritize building investments and budgets.

Figure 2 Building as an interrelated group of systems.

Finally, the project team recognizes that the Main Statistics Canada and Brooke Claxton Buildings have Heritage designation. The Project Team recommends that this be considered when possible engineering solutions are evaluated and implemented. Mitigation and adaptation techniques will need to factor in this designation. This may be particularly important for changes required in the building envelop that may or may not affect the building façades, profiles and aesthetics.

Applicability to other buildings

While the Vulnerability Assessment focused on the three test buildings, particular elements of the findings and recommendations can be applicable to other buildings in the region, especially of similar vintages and construction. First, increased freeze-thaw cycles will likely have similar effects on buildings and other types of infrastructure in the region. The Project Team, in the course of the assessment noted that the City of Ottawa has been studying and responding to increases in freeze-thaw cycles with respect to sidewalk and road clearing activities.

Second, increases in precipitation in the form of rain particularly in fall, winter and spring will put increased loads on building envelops and flat roofs in the region. It could be anticipated that many landlords and building managers will be addressing problems associated with increased moisture infiltration into building envelops either through failed roofing systems or cladding systems, sills, etc.

Third – and perhaps most important from a climate change perspective – the increases in spring, summer and fall temperatures in the region will put higher demands on cooling systems. This in turn will increase loads on the electrical utilities during these seasons. Strategies will need to implemented at various levels in order to manage the demand and ensure that increases in electricity consumption do not result in increased GHG emissions – resulting in further climate change. The Project Team believes that increases in cooling demand could be managed by a combination of building technologies (e.g. external shading, envelop upgrades, passive cooling, ground source heat pumps), changing occupant behaviour, increased utility capacity and renewable/green electricity generation, etc.

Finally, it should be noted that the availability of data and information for the test buildings and commitment of the building managers aided the vulnerability assessment process. However, this may not be the case with other buildings, landlords or jurisdictions. The Project Team believes that the amount and quality of building component information should be well evaluated and their limitations identified if similar assessments are conducted on other buildings.

Recommendations to Improve the Protocol

As discussed above, the project team applied the PIEVC Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment to the buildings in this project. The team was asked by PIEVC and PWGSC to evaluate the overall Protocol and the climate change data provided by Ouranos and their applicability to the building sector. This section of the case study summarizes the Project Teams evaluation of the Protocol and the cliamte change data.

The Protocol

The following points summarize the evaluation of the Protocol and suggest specific improvements that may also be applicable to other infrastructure sectors.

The Project Team believes there is potential to align the terminology in the Protocol to that used by climate and weather specialists as well as engineers and architects (e.g. National Building Code, CSA, ISO and ASHRAE). For example, the protocol uses such terms as “climate change factor” and “climate change parameter” while Environment Canada and Ouranos refer to changes in a climatic indices (e.g. change in average annual maximum temperature) that is expected in the future. The Team recommends that the Protocol and Worksheets be revised to ensure consistency in terminology between climatologists and the engineering profession. Where possible the revision should use established terminology being used in the disciplines to aid future project teams in

understanding the Protocol and the basic methodology. A second step could be a collaboration, through PIEVC, between CSA, ASHRAE and climate change modelers/scenario developers such as Ouranos to revise the Protocol specific to the infrastructure sectors being assessed.

Also in relation to terminology, the Protocol and Worksheets also use such terms as "climate change baseline" and "climate change trends" that are not properly defined in the Glossary. Thus, it is recommended that PIEVC create a revised Glossary of Terms that encompasses all the terminology being used in the Protocol and supporting Worksheets.

Repetition of terms and data fields in Protocol and supporting Worksheets were also found to create confusion as to their meaning. For example, the Protocol asks the user to consider and document "Jurisdictional Considerations" in Step 1 and Step 2. Furthermore, Step 5 requires a restatement of "Limitations" that have previously been documented in Steps 1, 2. Furthermore, the Protocol does not clearly explain what is being requested in these different Steps or why data from one Step should also be copied or reiterated in another. Other terms that appear frequently that warrant some clarification include "limitations, data sufficiency, other change factors and infill data." The Team recommends that the Protocol be reviewed in order to assess where repetition of these and other terms and data fields can be reduced and/or simplified along with an explanation of the significance of the data field.

To aid readability, clarity and understanding around the considerations, tasks or analysis the user of the Protocol should undertake at different Steps, the Team recommends that a set of illustrations or text examples be inserted into the Protocol. The existing Protocol does include several flowcharts to assist the reader in understanding the methodology and logic, however, these too could be improved by making references in the charts to the numbered Steps and sub-Steps. For example, in Step 3 when trying to assess the probability and severity it is initially not apparent what is being looked at. Is the analysis about the probability and severity of climate change or is it about the effect of climate and the impact that it will have on the infrastructure component? Upon reflection the later made more sense even though initial the former was what came to mind based on Step 2 work completed.

Finally, at times, the Protocol and Worksheets are unclear in their instructions and/or there is an inconsistency in terminology. For example, in Step 4.2.1, Data Gathering and Sufficiency in the Protocol, the bulleted items "a, b and c" should relate to Table 4.2.1 in Worksheet 2. However there is discrepancy in terminology between these bulleted items and the columns in the table. Bulleted item "c" states "provide references," whereas the corresponding column in Table 4.2.1 states "References and Assumptions: on data and infill data." To eliminate confusion and between the Protocol and the Worksheets, it is recommended that a thorough revision of both be undertaken to ensure consistency.

Climate Data/Scenarios

The Project Team found that the current set of climate change data, models and scenarios as provided by Ouranos for this case study are particularly relevant to the building sector. The key climate indices investigated in the Assessment (Temperature, Rain, Snow, Wind, HDDays, CDDays, Frost Season, Rain on Snow) are adequate to do a high-level vulnerability assessment of buildings in Canada. However, it was recognized and accepted that there are specific limitations regarding the uncertainty of extreme weather events, freeze-thaw cycles, humidity and solar radiation/cloud cover that would aid the assessment of other buildings. It should be mentioned that some of these could be extrapolated from long (+25 year) trends and data sources not specific to Environment Canada climatic data.

Of key interest to the assessment of buildings are: the potential for moisture infiltration into the envelop; freeze-thaw cycles that deteriorate building materials, especially roof membrane, concrete and masonry; and temperature and humidity extremes that can affect the ability of HVAC systems to maintain an acceptable indoor environment. The Project Team recognizes that for future assessments of buildings, specific climatic indices that relate to these key interests could become important to ensure consistency in application of the overall Assessment and Protocol. As discussed above, such indices should be aligned to current ASHRAE modeling/design data tools, codes or standards. Possible additional indices include: dew point frequency distribution; enthalpy frequency distribution; wind speed frequency distribution; a dry/wet bulb-wind joint index; and a humidity-temp joint index.

In addition, there is potential to improve the utility or presentation of the climate change indices and scenarios. First, engineers and architects could benefit from a layperson's indication of what climate would be like in 10, 20, 50 year time horizon (e.g. in 2050 Ottawa's climate will be roughly similar to Philadelphia). This would allow research and comparison of building codes and best design practices of these regions to understand what may or may not work in terms of adaptation or mitigation techniques and technologies.

The project team found that that the spatial parameter of a 20-50km radius around the test buildings was very reasonable and that micro climatic factors would be too detailed/focused for the level of the assessment. However, the factors of elevation/topography data would be important for buildings closer to rivers, streams, lakes etc. Naturally, the climate data and scenarios did not address or encompass changes to the Ottawa River or water table/ground water. Availability to this data is important as Tunney's Pasture Campus relies on the Ottawa River given that the central heating and cooling plant is connected to this natural resource. This is outside the scope of such scenarios, but indicates a need for future assessment projects to look at the affects changes in climate indices will have on other natural systems that may in turn affect the infrastructure.

In terms of temporal climate change horizons/scenarios, the +10, 25, 50 year time horizons are also reasonable at this time, given the typical design life of the majority of

Canada's building stock. However it is recognized that historical or culturally valuable buildings may need longer time horizons.

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Appendix A – Climate Change in Canada, climate scenarios for the public infrastructure vulnerability assessment: Ottawa Buildings case study

Climate change in Canada
Climate scenarios for the public infrastructure vulnerability assessment

Ottawa Buildings case study

Produced for the *Public Infrastructure Engineering Vulnerability Committee* (PIEVC)

By Ouranos

February 2008

Ouranos, a research consortium on regional climatology and adaptation to climate change, is a joint initiative of the Government of Québec, Hydro-Québec, and the Meteorological Service of Canada with the participation of UQAM, Université Laval, McGill University, and the INRS. Valorisation Recherche Québec collaborated on the establishment and financing of Ouranos. The opinions and results presented in this publication are the sole responsibility of Ouranos and do not reflect in any way those of the aforementioned organizations.

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1. Introduction

The Canadian Council of Professional Engineers set up the Public Infrastructure Engineering Vulnerability Committee (PIEVC) to examine the vulnerability of public infrastructure to climate change across the nation. A series of case studies serve to assess infrastructure vulnerability with the protocol proposed in Phase 1 of the PIEVC initiative and provide feedback on the state of different categories of infrastructure throughout the country. The current study is located in the Ottawa region (Ontario) and focuses on buildings.

The draft engineering protocol requires information on a variety of climatic elements to use as input towards estimating the vulnerability of infrastructure to climate change. Estimates of climatic elements enable quantitative estimations of the exposure of the infrastructure and help identify which changes in climatic conditions will have the most impact on its vulnerability.

In order to provide coherent and comparable results for all of the case studies, the vulnerability analyses must be based on plausible and equi-probable scenarios of climate change for the various regions of the country where the case studies are being conducted. Ouranos has been mandated to provide this data.

This report provides historical climate data and climate change scenarios for the Ottawa region on the vulnerability of a government building complex.

The data provided in this report is intended for the use of this case study only and should not be used for any other purpose because the results are specific to the characteristics of this project (location, timeframe, etc.).

2. Methodology

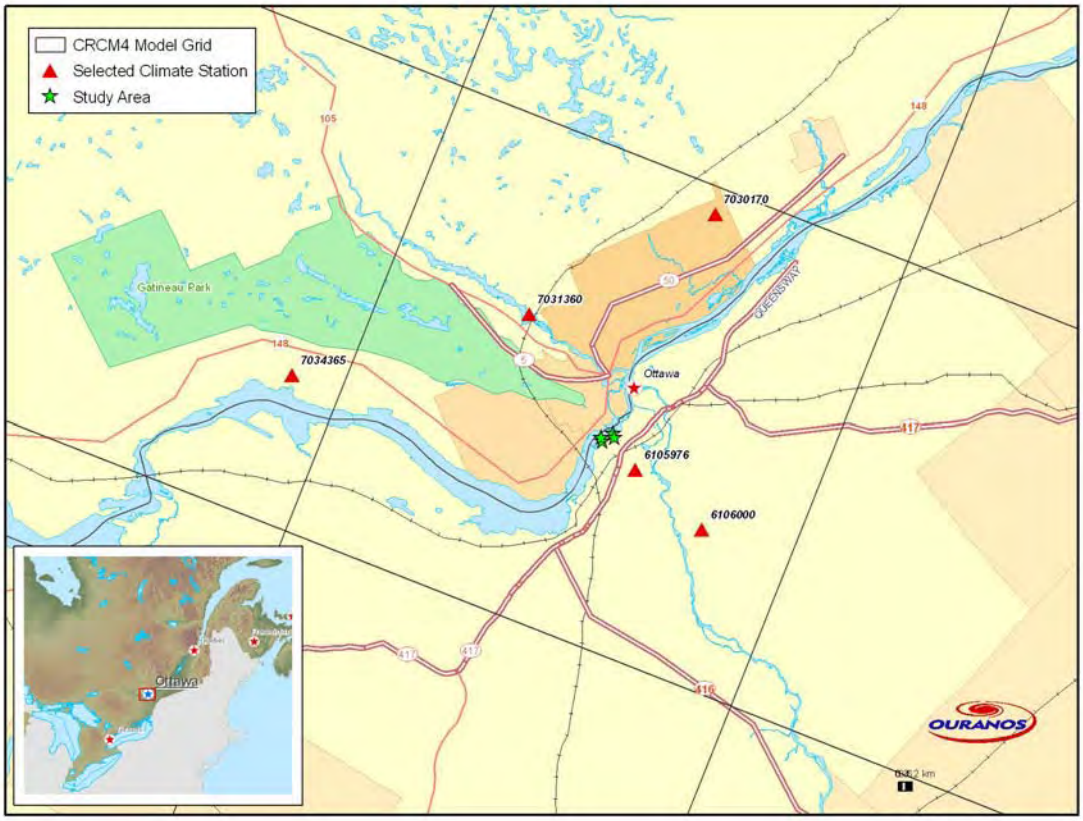
2.1. Selection of weather stations

Observed weather station data was obtained from Environment Canada's national archives for the area of interest. Archived data were screened in order to select stations deemed to have a sufficiently long/complete record. Selection criteria included: a data series minimum length of 20 years, with less than 10% missing data and a final year being no earlier than 1995. A summary of the selected stations is presented in Table 2.1. The distribution of the stations within the study region is shown in Figure 2.1.

Table 2.1 Selected Environment Canada station data for variables of Temperature, Precipitation, Snow and Wind
(Selection was based on the criteria of a minimum record length of 20 years and a maximum of 10% missing data, and final year no earlier than 1995).

	Climatic Variables					
ID	TMAX	TMIN	SNOWFALL	RAINFALL	SNOW ON GROUND	WIND
6105976	yes	yes	yes	yes	yes	no
6106000	yes	yes	yes	yes	yes	yes
7030170	yes	yes	yes	yes	yes	no
7031360	yes	yes	yes	yes	yes	no
7034365	yes	yes	yes	yes	yes	no

Figure 2.1 Canadian Regional Climate Model (CRCM4) grid and location of selected climate stations within the study area.



2.2. *Choice of climate model*

Impacts and adaptation projects should be based on projections of multiple climatic simulations in order to ensure that uncertainty of future climate projections is fully explored and incorporated in decision-making processes. Furthermore, in a regional context, such as the current PIEVC case study, downscaling of coarse resolution Global Circulation Model (GCM) output is desirable. Regional climate modeling employing the commonly termed approach of dynamical downscaling is one area of expertise covered by the Ouranos consortium and its research partners. Ouranos has contributed to the development of the Canadian Regional Climate Model (CRCM; Caya and Laprise, 1999) which, like other regional climate models (RCMs), uses principles of conservation on energy, mass and movement to generate temporal series of *physically coherent climatic variables*. Developed using the same physical principles as GCMs, RCMs concentrate on a portion of the globe and allow production of simulations at higher spatial resolution (approximately 45km for the CRCM compared to the several hundred seen with typical GCMs). Dynamical downscaling can have a particular advantage in simulating meso-scale weather events when compared with global models. As such, extreme events (particularly precipitation events) are typically better reproduced by regional modeling

efforts. Plummer *et al*. (2006) showed that general observed patterns of precipitation and temperature are relatively well reproduced over North America by the CRCM (version 3.7.1). In a study by Mailhot *et al.* (2007), regional comparison of CRCM precipitation output (again version 3.7.1) and corresponding intensity-duration-frequency curves showed favourable results versus observed values for southern Quebec. Mailhot *et al*. (2007) also state that there is good indication that CRCM results are statistically consistent with observations in terms of extreme rainfall estimates.

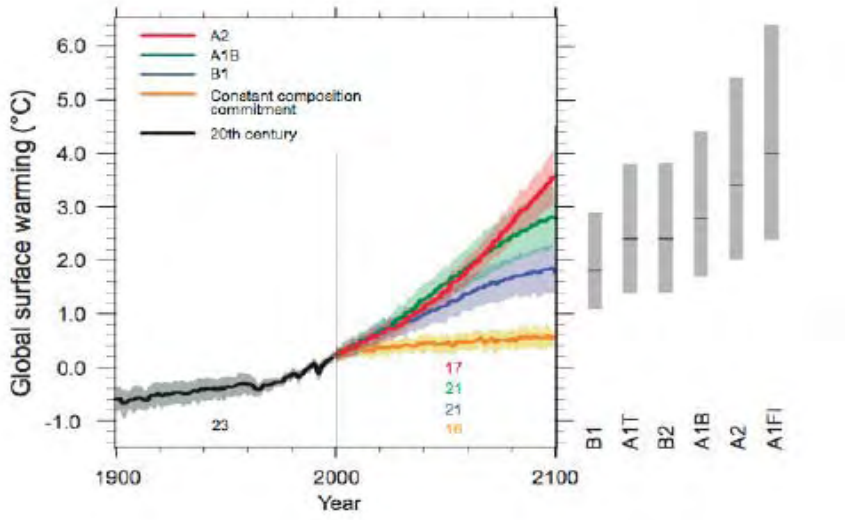
In general, the majority of CRCM simulations produced by Ouranos for impacts and adaptation purposes focus on the future period of 2041-2070 (termed horizon 2050). However, due to increasing demand for climatic scenarios for different future periods a small number of continuous simulations have been produced for the period 1961-2100. Two of these simulations have been selected for use in this case study. The simulations were produced using the CRCM, version 4.1.1 (Music and Caya, 2007; Brochu and Laprise, 2007). This selection was based on the advantages of having increased spatial resolution (compared to GCMs), the availability of continuous future daily series for the period 1961-2100 (the future horizons of interest in the case study being horizons 2020, 2050 and 2080). The choice was also due to the time constraints imposed for completion of the project.

NB - it is important to note that, due to the restricted number of simulations, caution is required in the interpretation of any modeling effort or analysis based on the scenarios provided. Use of only 2 simulations is sufficient for sensitivity analyses but lacks the robustness provided by the use of a large ensemble of simulations (recommended for decision-making or policy planning; see Conclusions - section 4 of this report).

The two simulations (CRCM 4.1.1 ACU; CRCM4.1.1 ADC) were carried out for a domain centred over Québec and covering an area of approximately 5,050 km by 4,000 km with a horizontal grid-size mesh of 45 km (true at 60 degrees north latitude) for the period 1961-2100. The simulations were driven at their boundaries by atmospheric fields taken from simulation output of the 4th and 5th members of the third generation coupled Canadian Global Climate Model (CGCM3) (Scinocca and MacFarlane, 2004). Both global and regional simulations were performed using the IPCC SRES A2 greenhouse gas (GHG) and aerosol projected evolution[1]. Figure 2.2 shows the simulated mean global temperature evolution according to the multiple GCM output grouped under various SRES scenarios. It is interesting to note that the emissions scenarios diverge very little before approximately 2050.

[1] "The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines." (Nakicenovic *et al*., 2000)

Figure 2.2 Mean global temperature evolution according to the multiple GCM output grouped under various SRES different scenarios.



2.3. Climate model simulations and time periods

A total of 9 CRCM grid cells, centred on the study area of interest (see figure 2.1), were selected for analysis. Corresponding grid cell data from the two CRCM 4.1.1 simulations described in section 2.2 (ACU and ADC) were extracted and used to calculate the climate indices listed in section 2.4. Future changes in indices were determined for three future periods or horizons: **horizon 2020** (2011 – 2040); **horizon 2050** (2041-2070); and **horizon 2080** (2071-2100) with respect to the present period (**1961-1990**).

Changes (or deltas) in indices are calculated as either the difference or ratio between simulated future conditions and simulated present day conditions. Deltas can then be applied to calculated observed values either through addition (difference) or multiplication (ratio).

2.4. Description of climate indices

The choice and priority of climate indices was made in consultation with the client in terms of project needs as well as in terms of the limitations of the climate model simulations. Calculated indices were chosen from those having been known and used in the climate literature in the past.

Temperature indices

a. Monthly average maximum temperature (Monthly AVG TMAX):
   - average daily maximum temperature for a given month over the time period

b. Monthly average minimum temperature (Monthly AVG TMIN):
- *average daily minimum temperature for a given month over the time period*

c. Average annual daily maximum temperature (annual_max):

$$annual_\max = \left(\sum_{i=1}^{I} (t\max 365i) \right) / I$$

Calculated as the sum of $t\max 365i$ for years *i* through I divided by the number of years. Where $t\max 365i$ is the highest daily temperature for a given year *i*

d. Average annual daily minimum temperature (annual_min):

$$annual_\min = \left(\sum_{i=1}^{I} (t\min 365i) \right) / I$$

Calculated as the sum of $t\min 365i$ for years *i* through I divided by the number of years. Where $t\min 365i$ is the lowest daily temperature for a given year *i*

Rain indices
Rain indices refer in all cases to precipitation in **liquid form*

a. Rainfall Frequency 6 hour (6h_frequency)
- *cutoff values of 5, 10 and 20 mm*
- *frequency of events that are greater than cutoff(s)*

b. Rainfall Frequency 1 day (1day_frequency)
- *cutoff values of 5, 10 and 20 mm*
- *frequency of events that are greater than cutoff(s)*

c. Yearly Max. Rainfall (annual_max_rain):

- *average maximum yearly rainfall event for 1, 2 and 5-day periods*

$$annual_\max_rain = \left(\sum_{i=1}^{I} (rain365ix) \right) / I$$

Calculated as the sum of $rain365ix$ for years *i* through I divided by the number of years. Where $rain365ix$ is the highest rainfall amount for a given year *i summed over period of x days.*

d. Average total annual / seasonal rainfall (Avg_total_rain)
- *average sum of liquid precip for the year and 4 seasons (DJF, MAM, JJA, SON)*

e. Simple Daily Intensity Index (SDII)
   - *mean rainfall amount per wet day (wet day > 1mm)*

f. Drought : Average maximum annual dryspell length (Avg_max_dryspell
   - *average yearly maximum number of consecutive 'no rain days' (< 1mm) for the season April 1 – Oct 31st*

$$Avg_MAX_dryspell = \left(\sum_{i=1}^{I} (dSPELLi) \right) / I$$

Calculated as the sum of $dSPELLi$ for years *i* through I divided by the number of years. Where $dSPELLi$ is the maximum dryspell length for a given year *i.*

g. Wetspell: Average maximum annual wetspell length (Avg_max_wetspell)
   - *average yearly maximum number of consecutive 'rain days' (> 1 mm) for the season April 1 – Oct 31st*

$$Avg_MAX_wetspell = \left(\sum_{i=1}^{I} (wSPELLi) \right) / I$$

Calculated as the sum of $wSPELLi$ for years *i* through I divided by the number of years. Where $wSPELLi$ is the maximum wetspell length for a given year *i.*

Snow indices

**Snow index values in mm indicate values of Snow Water Equivalent (SWE) in all cases.*
***Observed snowfall values from EC stations had units of cm of snow and were converted to SWE using an assumed conversion ratio of 10:1 (i.e. 10 mm of fresh snow = 1mm SWE)*

a. Snowfall Frequency 1 day (1day_frequency)
   - *cutoff values of 5, 10 and 20 mm*
   - *frequency of events that are greater than cutoff(s)*

b. Yearly Max. Snowfall (annual_max_snow):
   - *average maximum yearly rainfall event for 1, 2 and 5-day periods*

$$annual_\max_snow = \left(\sum_{i=1}^{I} (snow365ix) \right) / I$$

Calculated as the sum of $snow365ix$ for years *i* through I divided by the number of years. Where $snow365ix$ is the highest rainfall amount for a given year *i summed over period of x days.*

c. Average Total annual / seasonal rainfall (Avg_total)
   - *average sum of solid precipitation for the year and 4 seasons (DJF, MAM, JJA, SON)*

d. Simple Daily Intensity Index (SDII)
   - *mean snowfall amount per wet day (wet day > 1mm)*

e. Rain on snow events
   - *occurrence defined as presence liquid precipitation > 1mm combined with presence of snow on ground (> 0)*
   - *cutoff values of 1, 5 and 10 mm*
   - *frequency of events that are greater that cutoff(s) over 1-day period*

Wind indices

**Wind index values in m/s indicate values of average wind speed over a 6h period.*
***NB – A 6hour timestep was used as this is the minimum timestep available for analysis for the CRCM4 data.*

a. Monthly average 6h Windspeed (Monthly AVG WIND6h):
   - average 6h windspeed for a given month over the time period

b. Yearly Max. 6hour Wind (*Avg annual MAX6h*):

   - average maximum yearly 6h Wind

$$Avg_annual_MAX6h = \left(\sum_{i=1}^{I} (wind365i) \right) / I$$

   Calculated as the sum of $wind365i$ for years *i* through *I* divided by the number of years. Where $wind365i$ is the highest 6h mean windspeed for a given year *i.*

Frost indices

a. Frost Season (fr_seas_dys)
   - average annual max length in days that the 30 day moving average of daily average temperature remains consecutively below 0 degrees celsius

b. Freeze Thaw Cycles (frz_thw_freq)
   - frequency of days where tmax > 0 degrees C and tmin < 0 degrees C

Other indices

c. Heating Degree Days (HDD)
- average annual heating degree days with a reference temperature of 18°C

Calculated as :

$$HDD = \left(\sum_{x=1}^{X} \sum_{i=1}^{365} (18 - TavgDAILYix) \right) / X$$

Where HDD is the average annual heating degree days and $TavgDAILYix$ is the average daily temperature (°C) for day i of a given year x.

2.5. Regionalization of climate indices

Climate indices listed in section 3.1 were calculated for each climate station and each RCM grid cell individually. A regional value for each index is then determined by taking the average of all stations (grid points) within the study area. These regional values are presented in the results section of this report.

3. Results

3.1 Climate scenarios for Temperature, Rain, Snow, Wind, Frost and Other indices

TEMPERATURE indices

TEMPERATURE : Monthly AVG TMAX

Month	*Observed (°C)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(°C)*	***2050*** *(°C)*	***2080*** *(°C)*	***2020*** *(°C)*	***2050*** *(°C)*	***2080*** *(°C)*
January	-6.20	0.43	2.99	4.77	2.00	4.16	5.76
February	-4.24	1.57	3.13	4.90	2.92	4.40	5.15
March	1.72	1.34	2.81	4.23	2.43	2.62	4.34
April	10.75	1.54	3.15	5.31	2.05	2.68	4.03
May	18.64	1.82	2.36	4.63	1.95	3.87	6.13
June	23.85	1.35	3.20	4.88	1.84	3.14	4.55
July	26.36	1.38	3.64	5.34	2.65	3.59	5.95
August	25.07	2.05	3.62	6.26	1.66	3.34	5.22
September	19.99	0.88	2.46	4.94	1.49	3.11	4.94
October	12.75	1.24	2.77	4.61	2.13	2.93	5.04
November	4.78	1.26	2.32	2.98	1.28	2.34	4.13
December	-3.09	1.26	3.03	4.22	2.56	3.24	4.32

TEMPERATURE : Monthly AVG TMIN

Month	*Observed (°C)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(°C)*	***2050*** *(°C)*	***2080*** *(°C)*	***2020*** *(°C)*	***2050*** *(°C)*	***2080*** *(°C)*
January	-16.43	1.30	4.57	7.50	2.54	5.21	8.24
February	-15.36	2.69	4.62	7.46	3.70	5.88	8.02
March	-8.54	2.69	4.65	7.39	3.44	4.26	6.87
April	-0.22	2.34	4.32	6.78	2.58	3.66	5.40
May	6.33	2.06	3.19	5.23	2.59	4.33	6.21
June	11.69	1.22	2.82	4.40	1.61	2.83	4.02
July	14.24	1.70	3.33	4.88	2.32	3.11	5.04
August	13.10	2.08	3.39	5.47	1.63	3.13	4.53
September	8.63	1.04	2.52	4.82	1.71	3.08	4.84
October	2.73	1.39	2.45	4.42	1.92	2.98	5.10
November	-2.87	1.12	2.40	3.33	1.61	2.70	4.45
December	-11.71	1.63	3.79	5.48	2.73	4.19	5.95

TEMPERATURE : annual max /annual min							
Month	*Observed (°C)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(°C)*	***2050*** *(°C)*	***2080*** *(°C)*	***2020*** *(°C)*	***2050*** *(°C)*	***2080*** *(°C)*
annual maximum	33.43	1.67	3.55	5.73	2.33	4.12	5.94
annual minimum	-32.24	2.30	5.01	8.99	2.14	5.58	9.14

RAIN indices

RAIN : 6h_Frequency							
Cutoff (mm)	*Observed (frequency)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
5	0.023	1.06	1.23	1.35	1.10	1.19	1.37
10	0.009	1.21	1.58	1.74	1.13	1.26	1.69
20	0.002	1.55	2.13	2.90	1.24	1.67	2.73

RAIN : 1day_Frequency							
Cutoff (mm)	*Observed (frequency)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
5	0.12	1.06	1.16	1.20	1.07	1.15	1.23
10	0.06	1.06	1.21	1.31	1.09	1.18	1.37
20	0.02	1.18	1.57	1.76	1.20	1.27	1.77

RAIN: Avg_Max_rain							
Period (days)	*Observed (mm)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
1	46.66	1.08	1.14	1.18	1.02	1.03	1.15
2	55.52	0.97	1.06	1.10	1.03	1.07	1.20
5	72.41	1.00	1.06	1.09	1.01	1.05	1.15

RAIN : Avg_total_rain

Total rain	*Observed (mm)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
Annual	713.98	1.06	1.18	1.25	1.09	1.14	1.28
DJF	63.80	1.31	2.11	2.46	1.48	1.75	2.60
MAM	169.76	1.13	1.40	1.56	1.35	1.40	1.60
JJA	257.01	1.00	0.97	0.95	0.91	0.95	0.91
SON	224.22	1.02	1.10	1.18	1.09	1.10	1.30

RAIN : Simple Daily Intensity Index (SDII)

Observed (mm/day)	*Future Change ACU*			*Future Change ADC*		
	2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
8.42	1.04	1.09	1.12	1.02	1.06	1.15

RAIN : Dry spells / Wet_spells

	Observed (days)	*Future Change ACU*			*Future Change ADC*		
		2020 *(days)*	***2050*** *(days)*	***2080*** *(days)*	***2020*** *(days)*	***2050*** *(days)*	***2080*** *(days)*
Avg MAX Dryspell	8.19	0.30	-0.13	0.58	-0.83	-1.18	-0.21
Avg MAX Wetspell	2.81	-0.09	-0.01	0.16	-0.12	0.07	-0.07

SNOW indices

SNOW : 1day_Frequency

SWE cutoff (mm)	*Observed (frequency)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
5	0.038	0.79	0.73	0.59	0.93	0.83	0.68
10	0.013	0.83	0.86	0.76	0.96	0.82	0.75
20	0.002	1.67	1.11	1.63	0.74	1.02	0.84

SNOW`: Annual_Max_snow

Period (days)	*Observed (mm)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
1	21.21	1.07	1.02	1.09	0.86	1.00	0.87
2	25.95	1.04	1.04	1.07	0.88	1.01	0.88
5	33.07	1.03	1.05	1.03	0.87	0.97	0.83

SNOW : Avg_total_snow

Total snowfall (SWE)	*Observed (mm)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
Annual	208.69	0.89	0.78	0.67	0.90	0.84	0.71
DJF	146.02	0.90	0.81	0.78	0.95	0.97	0.85
MAM	41.46	0.85	0.77	0.45	0.87	0.73	0.57
JJA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SON	20.64	0.86	0.60	0.51	0.69	0.40	0.32

SNOW : Simple Daily Intensity Index (SDII)

Observed (mm/day)	*Future Change ACU*			*Future Change ADC*		
	2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
5.39	0.99	0.99	1.03	1.00	1.01	1.02

SNOW : Rain_on_Snow_events

Rain cutoff (mm)	*Observed (frequency)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
1	0.030	0.95	1.05	1.04	1.05	0.98	1.08
5	0.015	1.08	1.23	1.17	1.08	1.11	1.26
10	0.007	1.08	1.33	1.23	1.23	1.18	1.61

WIND indices

WIND : Monthly AVG WIND6h							
Month	*Observed (km/h)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
January	15.38	0.97	1.04	1.08	1.02	1.08	1.11
February	15.24	0.99	0.95	1.01	1.05	1.03	1.06
March	15.57	0.99	1.04	1.04	1.08	1.05	1.06
April	15.94	1.03	1.07	1.11	1.00	1.03	1.08
May	13.93	1.02	1.01	1.05	1.06	1.06	1.04
June	12.48	0.98	0.99	0.96	0.99	0.96	0.98
July	11.33	0.96	0.95	0.93	1.00	1.00	0.99
August	10.92	0.96	0.91	0.92	1.00	0.97	0.94
September	12.06	0.98	0.98	0.94	0.96	0.95	0.94
October	13.35	0.97	1.01	0.98	0.97	1.00	0.98
November	14.58	1.03	1.04	1.06	1.02	0.99	1.06
December	14.76	0.97	1.03	1.04	1.04	0.97	1.02

WIND : AVG Annual MAX WIND6h						
Observed (km/h)	*Future Change ACU*			*Future Change ADC*		
	2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
48.03	0.96	0.99	0.97	1.01	0.98	0.96

FROST indices

FROST SEASON LENGTH : fr_seas_dys						
Observed (days)	*Future Change ACU*			*Future Change ADC*		
	2020 *(days)*	***2050*** *(days)*	***2080*** *(days)*	***2020*** *(days)*	***2050*** *(days)*	***2080*** *(days)*
125.14	-16.66	-38.28	-61.29	-24.77	-28.58	-51.59

FREEZE THAW EVENTS: fr_thw_freq						
Observed (frequency)	*Future Change ACU*			*Future Change ADC*		
	2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
0.21	0.94	0.92	0.86	0.98	0.95	0.87

OTHER indices

HEATING DEGREE DAYS: HDD						
Observed (HDD)	*Future Change ACU*			*Future Change ADC*		
	2020 *(HDD)*	***2050*** *(HDD)*	***2080*** *(HDD)*	***2020*** *(HDD)*	***2050*** *(HDD)*	***2080*** *(HDD)*
4376.73	-567	-1178	-1889	-810	-1287	-1950

3.2 Literature review for other climate indices

While climate scenarios for temperature changes and changes in precipitation patterns are quite reliable, there is far greater uncertainty linked to projections for relatively small-scale or very localized atmospheric phenomena. Most authors agree that GHG concentrations do have an effect on these events; however, it remains difficult to find reliable projections that indicate future trends of intensity, direction or frequency for events such as storms, intense winds or other extreme events (Maarten, 2006). Climate scenarios are therefore difficult to produce for certain very localized events (wind gusts, tornadoes, thunderstorms) or events where processes are complex and depend on a number of factors (hurricanes, ice storms). The observed data is insufficient to validate the model outputs for these events.

Moreover, any seemingly apparent trend stemming from the observed data must be interpreted carefully as an increase could result from a combination of factors such as:

- increased weather station coverage
- improved quality of the data collected
- changes in land use (and corresponding increases in damage claims).

Consequently, among the list of climate elements that were requested for the Ottawa case study, it is not possible to provide sound numerical climate scenarios that could be used for the infrastructure vulnerability assessment. The following is the list of climate variables that fall under this category with a review of the literature explaining possible changes.

WIND (hurricanes, tornadoes, thunderstorms, winds gusts)

According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007), it is “more likely than not” that the observed trend of hurricane intensification since the 1970s is linked to human-induced greenhouse gas emissions. The report also claims that “it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures.” However, there is no clear trend in terms of the frequency of tropical cyclones. Although some authors claim that there has been an increase in the frequency of hurricanes, namely in the North Atlantic (Holland *et al.* 2007, Webster *et al.* 2005), there remains much debate as to the possible mechanisms explaining this.

Results from some model simulations suggest that the atmosphere over mid-latitude land areas could become more unstable in the future, suggesting that an increase in convective activity is quite probable (Balling *et al.* 2003). However, researchers have been unable to identify significant increases in overall severe storm activity as measured in the magnitude and/or frequency of thunderstorms, hail events, tornadoes, hurricanes, and winter storm activity in North America. Increasing trends in damages caused by these events seem to be more closely linked to changes in demography and land use (Balling *et al.* 2003)

ICE (ice build-up, ice accretion, freezing rain)

Ice build-up, caused by melting blocks of ice that accumulate and obstruct water ways or pile up around infrastructure components, can be triggered by:
- rapid melt events when there is a significant accumulation of snow and ice
- heavy precipitation events in spring when there is still a cover of ice
- heavy rain on snow events

Warmer average temperatures throughout the year (see climate scenarios in section 3.1) suggest that the length and severity of the cold season will decrease. However, depending on precipitation patterns, this could mean either an increase or decrease in river or lake ice build-up, because of the nature of the precipitation as well as the intensity of the events that cause ice build-up.

Very few studies have been conducted on the possible impacts of climate change on freezing rain events and ice storms. A study conducted over northern and eastern Ontario (Cheng *et al.* 2007) suggests that freezing rain events could move further north as the boundary between snowfall and rainfall shifts northward. However, as the temperatures increase in the Fall and Spring (beginning and end of the winter season), freezing rain events could decrease since precipitation falling as freezing rain could fall as liquid rain under warmer conditions. At present, it remains unknown how climate change could affect the frequency and severity of freezing rain events and ice storms (Irland, 2000, Cheng *et al.* 2007).

SNOW (rapid melt events)

Variations and trends in temperature significantly influence snow covered areas, namely by determining whether precipitation falls as snow or rain and determining snowmelt (IPCC, 2007). However rapid snowmelt events are difficult to predict because they depend on a number of factors, including:
- temperature and precipitation conditions at the time of the melt
- total amount of snow on the ground

Because these events occur as the result of a combination of factors and can be very localized (in both time and space), it is difficult to establish reliable scenarios of change in future climate conditions. Moreover, the inherent variability of the climate makes it difficult to predict whether this type of event will occur more frequently or more intensely, as a change in only one of the determining factors can determine whether rapid snowmelt will happen or not.

Nevertheless, it is recognized that changes in average temperature will impact precipitation and wind patterns and influence the change in probability distributions of many atmospheric processes. Indeed, a warmer atmosphere increases the chances for convective activity. This is already the case in warmer regions of the world during warmer seasons (Balling *et al.* 2003). This will impact the frequency, intensity, duration and direction of extreme events such as tornadoes, hailstorms, thunderstorms. However, it remains difficult to determine quantitatively precisely how these events will change.

Climate change will also influence the variability of the climate, including inter-annual events such as El Nino. However, climate scenarios on this type of climate phenomenon or event have not yet been developed.

To assess the vulnerability of infrastructure to changes in these parameters where numerical scenarios are not reliable, it can be useful to conduct “what if” scenarios, using a plausible factor of change to add to historical trend data and local knowledge of climate events. These sensitivity analyses help to determine at what threshold the infrastructure can become vulnerable to climatic events and estimate the likelihood of such events happening based on the physics of climate change and on local observations of climate events.

4 Conclusion

The case studies carried out within the PIEVC initiative to assess infrastructure vulnerability to climate change using the protocol developed in Phase 1 of the initiative require plausible and reliable climate scenarios based on similar methodologies in order to compare the relative vulnerability of various infrastructures throughout the country.

This report provides historical climate data and climate change scenarios for the Ottawa region case study on the vulnerability of a government building complex.

Prudence is required in the interpretation of analyses based on the future scenarios provided. Climate scenario production was limited to the use of only 2 simulations. Furthermore, these simulations were produced by the same regional climate model (CRCM 4.1.1), driven by two runs of the same GCM (CGCM3) and the same GHG emissions scenario (SRES A2). In short, the predicted changes cover only a small portion of the spectrum or envelope of changes that would be produced via the use of multiple SRES scenarios and multiple driving models (or even multiple RCMs). **As such, it is recommended that any decision or policy making activities be based on an expanded version of the present case study.**

At present, large ensemble analyses using strictly RCM output are not possible over North America. However, Ouranos continues to produce RCM simulations, and is also actively involved in the North American Regional Climate Change Assessment Program (NARCCAP http://www.narccap.ucar.edu/), an international program that will serve the high resolution climate scenario needs of the United States, Canada, and northern Mexico, using regional climate model, coupled global climate model, and time-slice experiments. The needs of the PIEVC (i.e. simulations with a fine spatial resolution, and inclusion of a number of extreme indices) would be best addressed using an ensemble of multiple RCM driven by multiple pilot GCMs such as will be produced with NARCCAP project This approach would allow a large inclusion of possible futures and thus better cover the envelope of uncertainty. Further research continues to be needed in climate modeling and climate scenarios in order to provide reliable data for climate change vulnerability and impacts assessments.

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ADDENDUM TO

Climate change in Canada
Climate scenarios for the public infrastructure vulnerability assessment

Ottawa Building case study

Produced for the *Public Infrastructure Engineering Vulnerability Committee* (PIEVC)

By Ouranos

April 2008

Ouranos, a research consortium on regional climatology and adaptation to climate change, is a joint initiative of the Government of Québec, Hydro-Québec, and the Meteorological Service of Canada with the participation of UQAM, Université Laval, McGill University, and the INRS. Valorisation Recherche Québec collaborated on the establishment and financing of Ouranos. The opinions and results presented in this publication are the sole responsibility of Ouranos and do not reflect in any way those of the aforementioned organizations.

Scenarios for relative humidity and solar radiation were considered important for the vulnerability assessment of buildings in the Ottawa case study. This addendum report provides scenarios of change for these two variables developed using the same methodology described in the final report for climate scenarios.

Other indices

a. Monthly average relative humidity (Monthly AVG RH)
- Average daily relative humidity for a given month over the time period

b. Monthly average solar radiation (Monthly AVG SR)
- Average daily solar radiation (direct and diffuse received on a horizontal surface) for a given month over the time period

c. Cooling Degree Days (CDD)

- Average annual cooling degree days with a reference temperature of 18°C . Calculated as :

if *TavgDAILYix > 18* $HDD = \left(\sum_{x=1}^{X} \sum_{i=1}^{365} (TavgDAILYix - 18) \right) / X$

Where CDD is the average annual cooling degree days and TavgDAILYix is the average daily temperature (°C) for day i of a given year x. NB – calculated only for days when TavgDAILYix is greater than 18 degrees C.

HUMIDITY indices

RELATIVE HUMIDITY : Monthly AVG RH

Month	*Observed (%)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
January	70	1.01	1.00	1.02	1.02	1.02	1.02
February	67	1.01	0.99	1.00	1.02	1.01	1.01
March	65.5	1.01	1.02	1.03	1.01	1.04	1.03
April	61.5	1.02	1.07	1.11	1.07	1.08	1.11
May	62	1.01	1.04	1.03	1.02	1.02	1.02
June	65.5	1.00	1.00	1.00	0.99	0.99	0.99
July	67.5	1.00	0.99	0.98	0.99	0.98	0.96
August	71	1.00	0.99	0.97	1.00	0.99	0.97
September	73.5	1.01	1.00	0.99	1.00	0.99	0.99
October	72	1.02	1.01	1.02	1.01	1.02	1.03
November	76	1.00	1.01	1.02	1.01	1.02	1.03
December	76	1.01	1.01	1.02	1.03	1.04	1.03

SOLAR RADIATON indices

SOLAR RADIATION : Monthly AVG SR							
Month	*Observed ($MJ/m^2/day$)*	*Future Change ACU*			*Future Change ADC*		
		2020 *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*	***2020*** *(ratio)*	***2050*** *(ratio)*	***2080*** *(ratio)*
January	5.51	0.98	0.926	in progress	0.975	0.93	in progress
February	9.29	0.95	0.997	in progress	0.954	1.00	in progress
March	13.10	0.96	0.95	in progress	0.96	0.95	in progress
April	16.70	1.00	0.95	in progress	1.00	0.95	in progress
May	19.30	0.99	0.94	in progress	0.99	0.94	in progress
June	21.38	1.02	1.03	in progress	1.02	1.03	in progress
July	21.10	0.99	1.04	in progress	0.99	1.04	in progress
August	17.71	1.02	1.05	in progress	1.02	1.05	in progress
September	12.89	1.00	1.04	in progress	1.00	1.04	in progress
October	8.39	0.98	1.03	in progress	0.98	1.03	in progress
November	4.72	1.02	0.97	in progress	1.02	0.97	in progress
December	3.89	0.96	0.94	in progress	0.96	0.94	in progress

COOLING DEGREE DAYS indices

COOLING DEGREE DAYS: CDD						
Observed (CDD)	*Future Change ACU*			*Future Change ADC*		
	2020 *(CDD)*	***2050*** *(CDD)*	***2080*** *(CDD)*	***2020*** *(CDD)*	***2050*** *(CDD)*	***2080*** *(CDD)*
234	95	216	397	121	217	386

DRAFT

Appendix B – Completed Worksheets and Other Working Material

Worksheet 1 Project Definition – Main Statistics Canada Building

4.1.1 Identify Infrastructure which is to be evaluated for climate change vulnerability
Choose Infrastructure: Main Statistics Canada Building #3 150 Promenade Tunney's Pasture Driveway Ottawa, Ontario Canada
General Description: The Main Stats Building (Building #3) is located in Tunney's Pasture, a 46 hectare federal government campus, in the western sector of the City of Ottawa. Bounded by the Ottawa River Parkway (north), Parkdale Avenue (east), Scott Street (south) and Northwestern Avenue (west). This location offers excellent views of the Ottawa River and Gatineau Hills, as well as convenient access to the Ottawa River Parkway. Within Tunney's Pasture, the roads and servicing infrastructure are owned and maintained by the federal government and connected to off-site city owned services. The asset comprises 39,445.9 m2 rentable area and was built in 1952. In 2005 the building was designated as a FHBRO heritage building. It is a two-storey building with a full basement and partial third and fourth floors. Overall the asset is considered to be in "average" condition and is reasonably functional. It has received periodic upgrades and refurbishments over the years and in recent years various tenant and common areas have been upgraded to meet current accommodation standards. The building is occupied primarily by Statistics Canada and is part of a larger node for that tenant which includes the adjacent (and internally linked) Jean Talon and R.H. Coats buildings. Other building occupants include Health Canada, BLJC and PWGSC. The building serves many functions that include office space, some storage, class/training rooms, a daycare centre, cafeteria and gym.

Additional background & detailed information sources	
	Links and references
Asset Management Plan (September 2003)	
Building Condition Report (December 2007)	

4.1.2 Identify Climate Factors of Interest
State general Climate factors to be considered
Temperature – average monthly, annual max and min
Rain – average total rain, average seasonal rain
Rain - frequency of 6h and 1 day rain events
Snow – average total snow
Rain on Snow – frequency of events
Frost Season – length of frost season

Heating Degree Days – average annual number of HDD, and days above 18 degrees Celsuis
Humidity – average monthly, average seasonal
Ground water, water table
Flood events - from Ottawa River
Additional background & detailed information sources
Ouranos – Climate Scenarios Report (February 2008)

4.1.3 Identify the Time Frame
Three separate time horizons were used for assessing the climate change vulnerability of this building: horizon 2020 (2011-2040 in the model); horizon 2050 (2041-2070 in the model); and horizon 2080 (2071-2100 in the model). Baseline climate data with respect to the present period (1961-1990) was developed as follows: Observed weather station data was obtained from Environment Canada's national archives for the area of interest. Archived data were screened in order to select stations deemed to have a sufficiently long/complete record. Selection criteria included: a data series minimum length of 20 years, with less than 10% missing data and a final year being no earlier than 1995.
Notes: The following climate factors where not covered by the Ouranos Climate Scenarios Report: Humidity – average monthly, average seasonal Ground water, water table Flood events - from Ottawa River However, the other climate factors were deemed to have an impact on these
4.1.4 Identify the Geography
Building: The Main Statistics Canada Building is situated in Tunney's Pasture, a Government of Canada campus of federal buildings that has been planned and landscaped with generous green space between buildings. It is flanked on the North by the Jean Talon Building and on the South by the R.H. Coats Building, both occupied by Statistics Canada. The building foundation is believed to be sitting on limestone bedrock. At its closest point, the Ottawa River is approximately 610 metres to the NNW of the building. The Ottawa River Parkway (vehicle roadway) separates the Tunney's Pasture campus and partially manicured/maintained public green space along the Ottawa River. The site geography is flat although other, more recent buildings (1970s/80s) seem to be situated higher than the Main Statistics Canada Building. Geographic coverage of climate change scenarios: The future climate change scenarios were developed based on a spatial area as follows: Two modelling simulations (CRCM 4.1.1 ACU; CRCM4.1.1 ADC) were carried out for a domain centred over Québec and covering an area of approximately 5,050 km by 4,000 km with a horizontal grid-size mesh of 45 km (true at 60 degrees north latitude) for the periods 1961-2100. Greater spatial resolution is not currently available in the climate change models.

Notes:

4.1.5 Identify the Jurisdictional Considerations	
	Notes:
The following Building compliance acts/regulations are applicable to the Main Statistics Canada Buiding: ASHRAE Standard 55-1981, Thermal Environmental Conditions for Human Occupancy ASHRAE Standard 62-2001n, Ventilation for Acceptable Indoor Air Quality Canada Labour Code – Part II (Labour Code) Canada Occupational Safety and Health Regulations National Building Code of Canada (2005) National Fire Code of Canada (2005)	
The following federal environmental Acts apply to all buildings on the Tunney's Pasture site including the Main Statistics Canada Building: Federal Real Property Act, brought into force on September 15, 1992. Canadian Environmental Assessment Act (CEAA), January 19, 1995. Canadian Environmental Protection Act (CEPA), 1988 (currently under review) Auditor General Act Fisheries Act Migratory Birds Convention Act	
No provincial acts or regulations apply to federal real property including this building.	

4.1.6 Site Visit
Summary of findings from interviews[4]
Summer months have extended and more extreme periods of hot, humid weather.
Due to Space Optimization there is an increased occupancy load well beyond what the buildings were designed for.
During the summer, energy conservation measures are implemented building wide. These include reduced lighting levels, slight increases in air temperature (i.e. chilled water temperature was typically 4 degrees now is 7 degrees to conserve energy).
Power outages and energy reliability are of concern. During the summer months this is likely to happen once per year.
Has observed changes in vegetation, for example some trees lose leaves earlier – end of August.
Soil settlement is due to truck drivers who access two courtyard areas that is causing soil settlement.
Roof top condensing units are used to keep the LAN Room cool. 45% RH is maintained in this space.
Non climate change related - Acid content in rainwater is affecting material durability like metal siding.
Proximity of Transit Way to R. H. Coats and in particular air intakes can affect air quality.

[4] Notes from interviews shall be kept by Consultant for future reference. There will be no need to append these documents to the Worksheets.

Masonry mortar has very course sand, as such is being affected by acid rain. No weeping holes exist therefore freeze thaw cycles affect the building envelop.
Water quality is being affected by heavy rain or quick thaw which causes lots of turbulence in Ottawa River such that it affects taste and smell. Had an incident in 2002.
NCC is responsible for snow removal at Tunney's Pasture.
Combined sanitary and storm water systems due to building vintage. In heavy storms you can get flooding. As well, because the road elevation is higher than the building, storm water tends to run towards the building. The building has storm water related pumps to deal with this problem.
Wind tends to come from the river to Tunneys Pasture. Generally the campus is very windy.
4th floor Computer / LAN Room is critical to the operation. This room is kept at 45% RH throughout the year. Power outages cripple operations and regularly happen about once per year. It is feared to be an increasing problem due to general power reliability.
Ultra Violet light is believed to affect materials and their durability
Key Observations
Building operator has very good experience with the site and is knowledgeable. He is keen on being Green / Sustainable which helps with our work and being successful.
Wind affects the snow drift patterns at the building envelop and along the parapet such that snow needs to be moved so as to not cause damage.
Water staining was observed at the window sill and lintel (precast and stone) which is affecting the integrity of these systems.
Areas for follow-up in subsequent steps
▪ Observed extended periods and more extreme periods of hot, humid weather in summer will be noted and may be factored into the probability/severity rating for some building components. ▪ Increased occupancy load well beyond what the buildings were designed may be factored in Step 3. ▪ The potentially increased load on the heating and cooling system to maintain the humidity and temperature levels for the LAN/computer room will try to be assessed in subsequent steps. ▪ Increased freeze thaw cycles and its effect on masonry mortar will try to be assessed in subsequent steps. ▪ Soil settling combined with potentially increased rain/snow may increase vulnerability to manage melt/storm water – to be noted in subsequent steps.

4.1.7 Assess Data Sufficiency	
State Assumptions proposed for the assessment, if any	
	Rationale
Building data is assumed to be accurate.	Building condition reports are current to Dec. 2007.
Climate baseline and climate change projections for temperature, rain, snow, frost season and heating degree days are assumed to be best available.	Ouranos used best available data and models in producing baseline and future estimates.
Historical data on humidity is considered accurate.	Data gathered from Environment Canada databases for McDonald Cartier station(ID 6106000), Ottawa. Canadian Climate Normals (1971-2000)

4.1.7 Assess Data Sufficiency	
Where insufficient information currently available	
Identify process to develop data	**Process**
Future projections for humidity are not currently available and insufficient.	Climate change models factor in humidity, but data cannot be extracted from the current method of developing simulations.
Baseline flood plain data and water table, ground water/water table were not available at the time of the case study.	Project schedule did not allow data gathering from relevant sources.
Where data cannot be developed, identify the data gap as a finding in Step 5 of the Protocol – Recommendations. **List Data Gap as findings to be sent to STEP 5 (Worksheet 5: Section 4.5.2)**	
1. Future projections for humidity are not currently available and insufficient.	
2. Baseline (historical) flood plain data and water table, ground water/water table were not available at the time of the case study.	
3. Future projected flood plain and water table, ground water/water table information was not available at the time of the case study.	

Date:	March 20, 2008
Prepared by:	Vince Catalli

Worksheet 2 Data Gathering and Sufficiency – Main Statistics Canada Building

4.2.1 State Infrastructure Components which are to be evaluated for climate change vulnerability[5] (reference Appendix A – Global Infrastructure Listing)		
General Description	**Data Infill Missing Data using reasonable assumptions**	**Reference and Assumptions on data and infill data**
EXTERIOR SYSTEMS		**Exterior systems are one of the key infrastructure components that interface directly with climate change.**
1.1 Site Drainage – related to slopes away from the building and includes soil permeability and hard surfaces like stairs / ramps	Because there is an increase in precipitation over the year except for the summer, it is unclear what impact this will have on soil conditions around and under the building. Tracking changes in soil conditions is a must as structural and below grade systems will be affected. At this time soil related data is a gap.	Systems related to site drainage are critical to ensure that water infiltration will not take place. Water infiltration can cause significant damage to various building systems and can pose a significant risk.
1.2 Site Drains – storm/rain water	The design parameters for site drains are unknown and were unavailable. Due to a projected increase in precipitation of up to 30% along with a substantial increase in extreme events it is critical to investigate this item further.	
2.0 Walls		
2.1 Freestanding		The Main Stats Building uses freestanding walls as an architectural feature to define various courtyards (i.e. entry courtyard, delivery area).
2.1.1 concrete	Depending on hairline cracks combined with an increase in wind driven rain and freeze thaw cycles material stability is of concern. Climate	Freestanding walls are a special breed of walls that are exposed to weather all-round. Wind driven rain along with freeze thaw cycles will

[5] Where available, review operations incident reports, daily logs. Interview infrastructure owners and operators to identify historical events that may not be documented or retrievable from databases.

	change will more than likely have an impact on durability of materials over a life cycle that may be reduced. Information on material weathering due to climate change is unknown with no data to support it.	affect the material stability of these walls given that both concrete and brick masonry are relatively porous materials that will allow moisture to penetrate. If deterioration is taking place (due to significant snow fall we could not examine) then the structural integrity of these walls may come into question and eventually become a safety hazard.
2.1.2 masonry	In the case of the brick masonry walls which have no weeping holes to allow for drainage it is unclear on the rate of material deterioration that is taking place based on today's standard building science know how. It may be accelerated as a result of climate change factors (refer to item above).	
2.2 Retaining		There are a number of retaining wall scenarios at all three study sites. These include window and exit stair wells and loading dock related walls due to below grade access. All are concrete built.
2.2.1 concrete	Sizable concrete walls that retain significant earth loads exist on site. In one case between Main Stats and the R.H. Coats building the wall is moving at the top. Freeze thaw may be the culprit due to increase in moisture content in the earth along with water infiltration at grade between the earth and wall structure. Information on changing soil conditions would be helpful to understand this situation.	A retaining wall was observed to be shifting. As a result, this issue merits further analysis and study.
3.0 Walkways		Walkways are an important means of accessing the site at a pedestrian level. At the same time, climate change may pose a health and safety risk (ice related) while also affect material stability and durability.
3.1 Asphalt	Material property information and the impact that climate change will have on these materials is unknown. More data would be beneficial so that better decisions can take place.	Increases in temperature, especially in the summer, may impact asphalt surfaces due to increases in heat gain. This affects the material stability while it may also affect the life cycle. Material property information due to accelerated weathering cased by climate change is

		unknown. In addition when we couple the summer event with winter rain events and freeze thaw we may find that material deterioration will be accelerated and produce tripping hazards for users. Increased ice on pathways along with salt usage will again make material stability worse.
3.2 Concrete		Hairline cracks in concrete along with winter rain and freeze thaw will affect the material stability / durability. Refer to above and below for related information.
3.3 Unit pavers		Increases in winter rain events coupled with freeze thaw may result in shifting unit pavers. This may then cause tripping hazards for users. Material property considerations as per Asphalt above would also apply.
4.0 Stairs		Exterior stairs are the primary means of entering all three buildings. They are also a means of egress in emergency situations. They are critical to the effective operation of these federal offices.
4.1 Concrete	Material property information and the impact that climate change will have on these materials is unknown. More data would be beneficial so that better decisions can take place.	Hairline cracks in concrete along with winter rain and freeze thaw will affect the material stability / durability. Increased ice on stairs along with salt usage will again make material stability worse. As well, any earth beneath the stair may result in heaving against the stair that will further impact the stair's structural stability / durability.
4.2 Metal		Increases in precipitation year round along with higher levels of humidity may impact the material stability of the metal stairs. Since these stairs are painted in dark colours it will accelerate the melting of snow and ice. In years of heavy snow it may take more time to accomplish melting. Use of salt will aggravate the situation by causing increased levels of material deterioration.
5.0 Ramps		Exterior ramps are the primary means for accessible entry to the buildings and as such

		they are a vital infrastructure component. Refer to 3.2 and 4.1 above for more details.
6.0 Loading dock		All three case study buildings rely heavily on use of the loading dock. In all cases these areas are sloped down below grade and are exposed to weather conditions year round. Given increased precipitation, storm water drainage is important.
7.0 Window / Stair wells		Window and stair wells are sunken areas that can be sensitive to snow and water accumulation. In the case of the Main Stats Building, heat loss during the winter can cause snow melting near the building which then will freeze overnight. Due to increased precipitation throughout the year except for the summer months, flooding and water infiltration may take place. This infrastructure also retains earth on one side that may complicate the situation as indicated above in the retaining wall section 2.2.1.
7.1 Concrete	Refer to 2.2.1 above	
8.0 Parking, vehicle areas		Parking and vehicle access are an important means of accessing the site while it also has a pedestrian level function. At the same time, climate change may pose a health and safety risk (ice related) while also affecting the system's material stability and durability.
8.1 Asphalt	Refer to 3.1 above	
8.2 Concrete	Refer to 3.2 above	
8.3 Unit pavers	Refer to 3.3 above	
9.0 Manholes/access doors	With an increase in precipitation, it is expected that water infiltration will increase. The current tunnel has a storm water system in place and it is unclear whether it will be adequate. More data about the storm water system in the tunnel is required.	Tunney's Pasture relies on tunnels that deliver heating plant steam and chilled water. At various locations on campus there are exterior and interior access points to the tunnel system for routine operation and management considerations.

BUILDING SYSTEMS		
10.0 Foundation, Floors and Roofs 10.1 Footings – concrete 10.2 Walls - concrete 10.3 Slab on grade - concrete	Because there is an increase in precipitation over the year except for the summer, it is unclear what impact this will have on soil conditions around and under the building. Tracking changes in soil conditions is a must as structural and below grade systems will be affected. At this time soil related data is a gap.	Below grade structure has a strong connection to a number of climate change impacts. Higher levels of precipitation will affect site drainage issues around the building perimeter. Higher precipitation will affect below grade soil conditions as we can expect higher levels of moisture content against foundation walls. Because the building foundation is believed to rest on bedrock, any changes (increase) in the water table may affect hydrostatic pressure against the foundation walls. Any cracks in the foundation may allow water infiltration. Warmer winters along with freeze thaw cycles will affect surface level ground conditions. All of these will affect the integrity of below grade structural systems.
10.4 Precast Light Weight Concrete Panel Roof	The roof membrane is one of the key components of the roof system. Information gaps exist in terms of roof membrane weathering due to climate change. The roof membrane has a direct relationship to the roof structure mostly in terms of keeping the structure dry. If moisture makes its way into the roof structure then the structure may experience freeze thaw related stress not to mention water damage to the office space below. The Jean Talon building is an example of this situation having recently to deal with a winter roof leak.	Roofing structures are strongly tied to other components of the roofing system. This includes the roof membrane, insulation, ballast material, roof drains, parapet walls, window washing anchors, rooftop units, mechanical penthouse connections, etc. It is critical to understand that other systems may impact the roof structure so there is an interdependency among different systems.
ENVELOP SYSTEMS		
11.0 Cladding	The wetter fall, winter and spring along with the more humid summer may result in more / accelerated cladding system failures. The acidic properties of the precipitation may also play into	Primary function of the building cladding system is to delineate interior and exterior conditions so that a comfortable work environment is produced. Since climate change is taking place

	this scenario. Data gaps exist on a material property level to understand these conditions fully, while at the same time knowing the chemical properties of the precipitation may allow for more accurate judgement on the impact these conditions will have on the cladding.	this system will be affected by temperature, rain, wind driven snow, freeze thaw, reduced heating degree days and increased humidity levels. In summary the hotter, wetter, humid condition along with freeze thaw cycles in the winter will have impact on the cladding.
11.1 Precast Concrete	Data gaps exist with wind driven rain and snow especially during the winter. It is critical to get a better understanding on this especially when freeze thaw is factored in. Material property data is also missing, especially related to material weathering which may be accelerated due to more precipitation and other climate change impacts.	At the penthouse level of Jean Talon building snow was observed between the precast concrete panel and the building structure. This indicates that there is rain and snow making its way behind the precast concrete cladding that can affect the system adversely at the anchors and with the office space below. This situation calls to question detailing issues at the parapet wall. Further analysis is required. In addition the joints between panels will need to be looked at as calking details are a limiting factor with this cladding system. Higher temperatures along with the increases in temperature range can cause precast systems to bow with some evidence of this at the Jean Talon building. Lastly, wall cavity drainage is also critical to allow for moisture and water to escape.
11.2 Glazed Curtain wall		There are small areas of curtain wall at the Main Stats Building that were replaced in 1993-1994 along with all windows. At the Jean Talon building, with the exception of the sloped glazing, all of it's original windows are still in place. Typically glazed systems are designed to tolerate a certain amount of water infiltration due to wind driven snow and rain. No issues have been raised in the Building Condition Reports related to water infiltration.
11.3 Masonry wall	Given increased wind driven precipitation over the winter months it is unclear what will take place with the material integrity of the Main Stats	Masonry walls are used at the Main Stats building only and are made using a Flemish bond technique that relies on a double layer of

	exterior masonry walls. There is moisture related staining on the walls at the present time that will not be helped by the window sills that are cracked and generally in poor condition. Any moisture that enters the masonry wall has no easy way out other than to rely on solar radiation and/or the heating system to dry the wall out.	brick with alternating bricks being used lengthwise to bond the two layers. On the inside face of the exterior wall is a third layer made up of terracotta block. The exterior wall has neither drainage cavity nor any weeping holes to allow for water / moisture to drain.
11.4 Stone Panels (including lintels and sills)	Increases in wind driven precipitation over the winter months will affect the material integrity of the Main Stats exterior stone walls. Signs of moisture related staining is visible. The situation is similar to the masonry wall situation (reference 11.3 above).	Stone is used on the Main Stats building as an architectural accent. There appears to be no drainage cavity as these exterior walls are built similar to the masonry walls 11.3 above. Evidence of material cracking and water infiltration staining are resulting in the system's weathering that may start to show failure and cause other damage.
11.5 Metal Cladding		Metal cladding is used at the penthouse level of the Main Stats Building. It shows modest signs of material stress that relates to staining from precipitation.
12.0 Windows / Doors	There is limited technical information that identifies how these systems are being affected by changing climate.	Windows and doors are part of the exterior wall system and as such are affected by similar weather related conditions. Unlike precast concrete, masonry and stone, windows and doors maybe affected less by wind driven precipitation. However, increases in temperature will expose the system and cause other failures to take place. For example the metal window spacer and seal will undergo expansion and contraction that may accelerate the failure of the system.
12.1 Aluminum Windows	Refer to 11.2 above.	Refer to 11.2 above.
12.2 Doors (Steel / Aluminum)	Refer to 12.0 above	Refer to 12.0 above.
13.0 Flat Roof Systems	The affect of freeze thaw and higher temperatures, including temperature swings in winter may result in more accelerated rates of material deterioration. Conclusive data on the roof	The flat roof system is made up of various material layers that include roof membrane, ballast material, roof structure, insulation and sometimes ceiling finish materials. The most

	membrane and the impact that climate change will have on the membrane is unknow. As well, the effect of ballast material to mitigate increases in temperature is unknown. More data would help to evaluate this system.	critical component of the system is the membrane that sheds water away from the building structure and interior. Freeze thaw cycles will affect the durability of the roof membrane that can result in system failures.
MECHANICAL SYSTEMS		
14.0 HVAC		The Central Heating Plant is a key system that supplies Tunney's Pasture with steam and chilled water. The plant has recently been modernized and updated to today's standards in order to keep up with campus requirements. It draws upon a natural gas energy supply in order to function. The Ottawa river plays a key role as the plant uses the body of water to condition water used on the campus.
14.1 Heating System and Adequacy	The building is connected to the Tunney's Pasture central heating and cooling plant. The plant relies on the Ottawa river to condition water used on campus. Overall, river water temperatures are generally increasing due to a warmer climate and is therefore affecting the heating and cooling plant. Current and some historic data is available on river water temperature changes.	The Main Stats Building is the oldest building (1952) that is being reviewed by this study. As such it has little to no insulation and relies on a certain amount of heat to keep the building envelope warm and dry so that it maintains its structural integrity. At times during the winter the hot water heating system has a hard time keeping up with the interior heating demands. Often the pipes will freeze and cause the interior environment to be cold and uncomfortable. Based on projected increases in temperature this may prove to be reduced or eliminated.
14.2 Cooling System and Adequacy	The building is connected to the Tunney's Pasture central heating and cooling plant. The plant relies on the Ottawa river to condition water used on campus. Overall, river water temperatures are generally increasing due to a warmer climate and is therefore affecting the heating and cooling plant. Current and some historic data is available on river water temperature changes.	Projected temperatures are expected to increase along with the humidity levels. As such this will very likely be an issue for summer building operations as they are having a difficult time of keeping the space cool and comfortable. At the same time, the federal government has instituted an energy conservation program that has resulted in delivering chilled water to all facilities at higher temperatures. Space optimization and higher use of computers and other technologies

		have resulted in higher heat levels being produced within the space. This has resulted in making the space very hard to keep cool and condition, especially during the summer months. It should be noted that the heating plant relies on river water for cooling and if the solar radiation is affecting river water temperatures (e.g. increasing) then the cooling capacity of the plant will be affected and become vulnerable. This may be compounded by dryer/lower rainfall conditions in summer effectively reducing the flow of the river during June, July and August. The lower the water level the easier it will be to affect even higher water temperatures during the summer. This is a climate change affect that requires more information and study that is outside the scope of this assessment.
ELECTRICAL SYSTEMS		
15.0 Emergency power systems / generators (including fuel supply)		Emergency power systems are available on this campus strictly to keep vital systems operational. It is not a backup system for 100% of the building functions but rather serves such functions as the main data centre, emergency lighting, etc. This element has a direct relationship with 16.0 below.
16.0 Power Supply and Reliability	Power supply is not just a function of the Tunney's Pasture Campus infrastructure as it is a more far reaching component that is city wide. The scope of this study focuses strictly on the boundaries of the building and relies on a very reliable energy supply (electricity, natural gas, oil, etc.). Overall, power supply and reliability is difficult to evaluate as a risk as it would require further research and discussion with the various local utility companies.	Power supply and reliability is a key concern for the Statistics Canada operation at Tunney's Pasture. During the summer months, due to higher temperatures and more humid conditions, use of air conditioning is very prevalent throughout the city of Ottawa. So much so that power reliability will be compromised and has fail during the summer for periods of up to 48 hours. Statistic Canada relies on the main data centre as its core business function. Without power employees are sent home as their operation

		grinds to a halt.
4.2.2 State Climate Baseline		
State general Climate Parameters for use in STEP 3 of Assessment (Reference Appendix B – Climate Change Parameters List) (Additional Reference – PIEVC Data Integrity and Availability Review)		**Climate information source**
Temperature parameters a. Monthly average maximum temperature (Monthly AVG TMAX): b. Monthly average minimum temperature (Monthly AVG TMIN): c. Average annual daily maximum temperature (annual_max): d. Average annual daily minimum temperature (annual_min):		Ouranos – Climate Scenarios Report (February 2008)
Rain parameters (precipitation in liquid form) a. Rainfall Frequency 6 hour (6h_frequency) b. Rainfall Frequency 1 day (1day_frequency) c. Yearly Max. Rainfall (annual_max_rain) d. Average total annual / seasonal rainfall (Avg_total_rain) - average sum of liquid precip for the year and 4 seasons e. Simple Daily Intensity Index (SDII) - mean snowfall amount per wet day (wet day > 1mm) f. Drought : Average maximum annual dryspell length (Avg_max_dryspell) - average yearly maximum number of consecutive 'no rain days' (< 1mm) for the season April 1 – Oct 31st g. Wetspell: Average maximum annual wetspell length (Avg_max_wetspell) - average yearly maximum number of consecutive 'rain days' (> 1 mm) for the season April 1 – Oct 31st		Ouranos – Climate Scenarios Report (February 2008)
Snow parameters a. Snowfall Frequency 1 day (1day_frequency) b. Yearly Max. Snowfall (annual_max_snow): c. Average Total annual / seasonal rainfall (Avg_total) d. Simple Daily Intensity Index (SDII) e. Rain on snow events		Ouranos – Climate Scenarios Report (February 2008)
Wind parameters a. Monthly average 6h Windspeed (Monthly AVG WIND6h) b. Yearly Max. 6hour Wind (Avg annual MAX6h)		Ouranos – Climate Scenarios Report (February 2008)
Frost parameters a. Frost Season (fr_seas_dys) b. Freeze Thaw Cycles (frz_thw_freq) - frequency of days where tmax > 0		Ouranos – Climate Scenarios Report (February 2008)
Heating Degree Days (HDD) parameter average annual heating degree days with a reference		Ouranos – Climate Scenarios Report (February

temperature of 18°C	2008)
Humidex (monthly average): ▪ Extreme Humidex ▪ Days with Humidex >= 30 ▪ Days with Humidex >= 35 ▪ Days with Humidex >= 40 Relative humidity Humidity (monthly average): ▪ Average Vapour Pressure (kPa) ▪ Average Relative Humidity - 0600LST (%) ▪ Average Relative Humidity - 1500LST (%)	Data gathered from Environment Canada databases for McDonald Cartier station (ID 6106000), Ottawa. Canadian Climate Normals (1971-2000)

List Extreme Climate event		
Frequency	**Duration**	**State Justification** for infill of missing data
No extreme climatic events considered in this assessment due to the uncertainty of future projections of extreme events.		

4.2.3 State Climate Change Assumptions			
Relevance & applicability of **Observed global or regional climate change trends**	**Incremental changes** to infrastructure	**% increase or decrease to Climate Change Baseline based on TRENDS**	**Infill data** (where appropriate) **& reference sources** - Provide written justification
Relevance & applicability of **Observed global or regional climate change trends**	**Incremental changes** to infrastructure	**% increase or decrease to Climate Change Baseline based on SENSITITY ANALYSIS**	**Infill data** (where appropriate) **& reference sources** - Provide written justification
Climate change futures not assessed using sensitivity analysis. Therefore, no trends included in this section.			

State and Describe Climate Change Models used, if any	
Three separate time horizons were used for assessing the climate change vulnerability of this building: horizon 2020 (2011-2040 in the model); horizon 2050 (2041-2070 in the model); and horizon 2080 (2071-2100 in the model). Baseline climate data with respect to the present period (1961-1990) was developed as follows: Observed weather station data was obtained from Environment Canada's national archives for the area of interest. Archived data were screened in order to select stations deemed to have a sufficiently long/complete record. Selection criteria included: a data series minimum length of 20 years, with less than 10% missing data and a final year being no earlier than 1995. Geographic coverage of climate change scenarios: The future climate change scenarios were developed based on a spatial area as follows: Two modelling simulations (CRCM 4.1.1 ACU; CRCM4.1.1 ADC) were carried out for a domain centred over Québec and covering an area of approximately 5,050 km by 4,000 km with a horizontal grid-size mesh of 45 km (true at 60 degrees north latitude) for the periods 1961-2100.	**Reference** Ouranos – Climate Scenarios Report (February 2008)

Greater spatial resolution is not currently available in the climate change models.	

Climate Factor	Possible Impact on infrastructure	Increase or decrease to Climate Change Baseline based on modelling	Reference
Temperature – monthly avg. tmax Observed baseline (°C): See Ouranos Report	Increased cooling requirements during summer. Decreased heating requirements in winter.	Based on climate models. Varies by month, but overall: For 2020: 0.5 to 3 degrees warmer For 2050: 2.3 – 4.4 degrees warmer For 2080: 2.9 – 6.1 degrees warmer	Ouranos – Climate Scenarios Report (February 2008)
Temperature – Monthly avg. tmin Observed baseline (°C): See Ouranos Report	Increased cooling requirements during summer. Decreased heating requirements in winter.	Varies by month, but overall: For 2020: 1.0 – 3.7 degrees warmer For 2050: 2.4 – 5.8 degrees warmer For 2080: 3.3 – 8.2 degrees warmer	Ouranos – Climate Scenarios Report (February 2008)
Temperature – annual max and min Observed baseline (°C): Annual max: 33.43 Annual min: -32.24	Increased cooling requirements during summer. Decreased heating requirements in winter.	Annual Max: For 2020: 1.67 – 2.33 degrees warmer For 2050: 3.55 – 4.12 degrees warmer For 2080: 5.73- 5.94 degrees warmer Annual Min: For 2020: 2.14 - 2.30 degrees warmer For 2050: 5.01 – 5.58 degrees warmer For 2080: 8.99 – 9.14 degrees warmer	Ouranos – Climate Scenarios Report (February 2008)

Rain – Avg. total rain Observed baseline (mm): Annual: 713.98 DJF: 63.80 MAM: 169.76 JJA: 257.01 SON: 224.22	Shed and drain increasing amounts of rain. Increased water table/pressure on foundation and footings. Drought impact on site flora during summer.	Annual: 2020: 6-9% increase 2050: 14-18% increase 2080: 25-28% increase DJF: 2020: 31-48% increase 2050: 75-111% increase 2080: 146-260% increase MAM: 2020: 13-35% increase 2050: 40% increase 2080: 56-60% increase JJA: 2020: 0-9% decrease 2050: 3-5% decrease 2080: 5-9% decrease SON: 2020: 2-9% increase 2050: 10% increase 2080: 18-30% increase	
Rain – dry spells/wet spells Observed baseline (days): Avg. max dryspell: 8.19 Avg. max wetspell: 2.81	Plant selection for landscaping and need for irrigation.	Avg. Max Dryspell: 2020: inconclusive 2050: 0.13 to 1.18 days shorter (2-15%) 2080: inconclusive Avg. Max Wetspell 2020: 0.09 to 0.12 days shorter (3-4%) 2050: inconclusive 2080: inconclusive	Where the future change models of ACU and ADC disagreed in terms of an increase or decrease, the projection was assumed to be inconclusive.
Rain – Avg. Max rain Observed baseline (mm) 1 day period: 46.66 2 day period: 55.52 5 day period: 72.41	Increased demand on handling volume of rainwater from roof and site.	1 day period: 2020: 2-8% increase 2050: 3-14% increase 2080: 15-18% increase 2 day period:	

		2020: inconclusive 2050: 6-7% increase 2080: 10-20% increase 5 day period: 2020: 0-1% increase 2050: 5-6% increase 2080: 9-15% increase	
Rain – 6h frequency Observed baseline (frequency): 5mm cutoff: 0.023 10mm cutoff: 0.009 20mm cutoff: 0.002	Increased demand on handling short bursts of high volume rainwater from roof and site.	5mm cutoff: 2020: 6-10% increase 2050: 19-23% increase 2080: 35-37% increase 10mm cutoff: 2020: 13-21% increase 2050: 26-58% increase 2080: 69-74% increase 20 mm cutoff: 2020: 24-55% increase 2050:67-113% increase 2080: 173-190% increase	Note that the observed (baseline frequency is very low, making these increases relatively insignificant).
Rain – 1 day frequency Observed baseline (frequency): 5mm cutoff: 0.12 10mm cutoff: 0.06 20mm cutoff: 0.02	Increased demand on handling short bursts of high volume rainwater from roof and site.	5mm cutoff: 2020: 6-7% increase 2050: 15-16% increase 2080: 20-23% increase 10mm cutoff: 2020: 6-9% increase 2050: 18-21% increase 2080: 31-37% increase 20mm cutoff: 2020: 18-20% increase 2050: 27-57% increase 2080: 76-77% increase	Note that the observed (baseline frequency is very low, making these increases relatively insignificant).
Rain – Simple Daily intensity index Observed baseline (mm/day): 8.42	Increased demand on handling one day events of rainwater from roof and site.	2020: 2-4% increase 2050: 6-9% increase 2080: 12-15% increase	
Snow – average total snow Observed baseline (SWE): Annual: 208.69	Decreased snow load on roofing systems.	Annual: 2020: 10-11% decrease 2050: 16-22% decrease	

DJF: 146.02 MAM: 41.46 JJA: 0 SON: 20.64		2080: 29-33% decrease DJF: 2020: 5-10% decrease 2050: 3-19% decrease 2080: 15-22% decrease MAM: 2020: 13-15% decrease 2050: 23-27% decrease 2080: 43-55% decrease JJA: Zero change for all futures (zero snow) SON: 2020: 14-31% decrease 2050: 40-60% decrease 2080: 49-68% decrease	
Snow – annual max snow Observed baseline (mm): 1 day period: 21.21 2 day period: 25.95 5 day period: 33.07	Ability to handle short intense snowfall events – snowclearing, snowload.	1 day period: 2020: inconclusive 2050: 0-2% increase 2080: inconclusive 2 day period: 2020: inconclusive 2050: 1-4% increase 2080: inconclusive 5 day period: inconclusive for all futures	Where the future change models of ACU and ADC disagreed in terms of an increase or decrease, the projection was assumed to be inconclusive.
Snow – 1 day frequency Observed frequency: 5mm SWE cutoff: 0.038 10mm SWE cutoff: 0.013 20mm SWE cutoff: 0.002	Decreased demand to handle short intense snowfall events – snowclearing, snowload.	5mm SWE cutoff: 2020: 7-21% decrease 2050: 17-27% decrease 2080: 32-41% decrease 10mm SWE cutoff: 2020: 4-17% decrease 2050: 14-18% decrease 2080: 24-25% decrease 20mm SWE cutoff: 2020: inconclusive 2050: 2-11% increase	Where the future change models of ACU and ADC disagreed in terms of an increase or decrease, the projection was assumed to be inconclusive. Note that the observed (baseline frequency is very low, making these increases relatively insignificant).

		2080: inconclusive	
Snow – simple daily intensity index Observed baseline (mm/day): 5.39	Snowclearing and snowload demand on roof and site.	2020: 0-1% decrease 2050: inconclusive 2080: 2-3% increase	Where the future change models of ACU and ADC disagreed in terms of an increase or decrease, the projection was assumed to be inconclusive.
Snow – Rain on Snow events Observed baseline (frequency): 1mm cutoff: 0.030 5mm cutoff: 0.015 10mm cutoff: 0.007	Increased need to shed/drain rain during winter/cold days.	1mm rain cutoff: 2020: inconclusive 2050: inconclusive 2080: 4-8% increase 5mm rain cutoff: 2020: 8% increase 2050: 11-23% increase 2080: 17-26% increase 10mm rain cutoff: 2020: 8-23% increase 2050: 18-33% increase 2080: 23-61% increase	Where the future change models of ACU and ADC disagreed in terms of an increase or decrease, the projection was assumed to be inconclusive.
Wind – Monthly avg wind6h Observed baseline: See Ouranos Report	Wind driven snow and rain during winter against façade and walls. Less wind driven rain in summers.	Varies by month and future. Generally projected change varies between a decrease of 9% to an increase of 11% in observed wind speed in km/h for avg. 6h period. Generally windier winters, calmer summers.	
Wind – Avg. annual max wind6h Observed baseline: 48.03 km/h	Less wind load on physical structure, windows and walls, doors, etc.	2020: inconclusive 2050: 1-2% decrease 2080: 3-4% decrease	Where the future change models of ACU and ADC disagreed in terms of an increase or decrease, the projection was assumed to be inconclusive.
Frost Season Length – days Observed baseline: 125.14 days	Increased growing season affects types of flora for landscaping. Less demand for heating during winter.	2020: 16-24 days less 2050: 28-38 days less 2080: 51-61 days less	
Freeze Thaw Events – frequency Observed baseline:	Less frost heaving of walkways, stairs, pavers, masonry	2020: 2-6 % decrease 2050: 5-8% decrease	

0.21 frequency	deterioration, etc.	2080: 13-14% decrease	
Heating Degree Days – Observed baseline: 4376.73 HDD	Decreased heating load during winter. Increased growing season affects types of flora for landscaping.	2020: 567-810 days less 2050: 1178-1287 days less 2080: 1889-1950 days less	
Humidex (monthly average): Extreme Humidex Days with Humidex >= 30 Days with Humidex >= 35 Days with Humidex >= 40 Relative humidity Observed baseline: See Ottawa Climate Normals 1971-2000.xls	Decreased ability for CHCP and roof top units to maintain adequate cooling to building during summer.	No future projections available.	
Humidity (monthly average): Average Vapour Pressure (kPa) Average Relative Humidity - 0600LST (%) Average Relative Humidity - 1500LST (%) Observed baseline: See Ottawa Climate Normals 1971-2000.xls	Decreased ability for CHCP and roof top units to maintain adequate cooling to building during summer.	No future projections available.	

Practitioner Defined Climate Change Assumptions	**Rationale**

4.2.4 State Time Frame

Infrastructure Safe Operation Time Period	**Time (Years)**
Design Life of Infrastructure components	
Infrastructure Component	

Infrastructure Component/System	**SERVICE LIFE (Years)**		**SERVICE LIFE REMAINING (Years)**
EXTERIOR SYSTEMS			
Site Drainage – related to slopes away from the building and includes soil permeability and hard surfaces like stairs / ramps	30 to 60		10 to 25
Site Drains – storm/rain water [added]	80		25
Walls			
Freestanding			
concrete	80		35
masonry	75		35
Retaining			
concrete	40		10 to 20

4.2.4 State Time Frame

masonry	not applicable		
Walkways			
Asphalt	22		3 to 20
Concrete	30		3 to 15
Unit pavers	30		18
Stairs			
Concrete	30		20
Metal	20		20
Ramps	30		25
Loading dock	20		15
Window / Stair wells			
Concrete	40		10 to 20
Masonry	not applicable		
Gutters - metal			
Parking, vehicle areas			
Asphalt	20		10
Concrete	not applicable		
Unit pavers	not applicable		
Manholes/access doors			
BUILDING SYSTEMS			
Foundation Floors and Roofs			
Footings – concrete	110		55
Walls - concrete	110		55
Slab on grade - concrete	110		55
Precast Light Weight Concrete Panel Roof	110		55

4.2.4 State Time Frame

Envelop Systems			
Precast Concrete	not applicable		
Glazed Curtain wall	50		35
Masonry wall	75		plus 30
Stone Panels (including header and sills)	50 to 90		25 to 35
Metal Cladding	50		10 to 15
Windows / Doors			
Aluminum Windows	50		35
Doors (Steel / Aluminum)	45 to 50		25 to 40
Flat Roof Systems	20 to 25		1 to 20
MECHANICAL SYSTEMS			
Heating System and Adequacy	25 to 40		1 to 25
Cooling System and Adequacy	25		4 to 15
ELECTRICAL SYSTEMS			
Emergency power systems / generators (including fuel supply)	25 to 35		10 to 35
Power Supply and Reliability			

Other Relevant Comments

Design life and expected service life remaining based on Building Condition Report, December 2007.

4.2.5 Geography	
Major Components of local geography	**Reference**
For introduction, see 4.1.4	
Microclimate around the infrastructure is influenced by proximity to the Ottawa River. This is assumed to create a moderation of the temperature during spring time while ice and cold melt water flow. In the fall, the effect is assumed to be reverse, elevating the temperature slightly. However, these effects are probably minor in nature and heavily dependant upon the wind.	- none -
It was noted that winds can be particularly strong on the site due to the layout of the Tunney's Pasture campus and the NNW-SSE axis orientation of Promenade Tunney's Pasture Driveway along which many of the campuses buildings are oriented.	By interview with SNC-Lavalin Profac building managers and PWGSC representatives.

4.2.6 Specific Jurisdictional Considerations	
For introduction, see 4.1.5	
Jurisdiction that have direct control or influence on infrastructure	
Federal Government of Canada via Public Works and Government Services Canada	
Sections of laws and bylaws that establish legal structure for the infrastructure	**Reference**
The following Government of Canada Legislation applies to the legal structure for the buildings: • Financial Administration Act • Federal Real Property and Federal Immovables Act • Surplus Crown Assets Act • Public Works and Government Services Act Note: The National Capital Commission, under the National Capital Act, has legislated responsibilities for real property within the National Capital Region (NCR). These responsibilities include the approval of all sales or transfers of federal lands within the NCR, approval of demolition of buildings on federal lands within the NCR, approval of	

4.2.6 Specific Jurisdictional Considerations	
land use or development plans, approvals for exterior alterations and additions to buildings on federal lands in the NCR.	
Sections of regulations that establish legal structure for the infrastructure	**Reference**
The following federal regulations apply to the legal structure of the Main Statistics Canada building: • Federal Real Property Regulations • Procurement Trade Regulations • Government Contracts Regulations	Real Property Management, Treasury Board of Canada Secretariat. URL: http://www.tbs-sct.gc.ca/rpm-gbi/site/home-accueil.aspx
Relevant Standards to the design, operation and maintenance of the infrastructure	**Reference**
National Building Code of Canada 2005	
Canada Labour Code, Part II (1985) and the supporting Canada Occupational Health and Safety Regulations (SOR/86-304). The Labour Code and Regulations are subsequently supported by a range of standards provided by Canadian Standards Association (CSA) and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Detailed listing of these applicable standards to all the elements of the building is beyond the scope of this project. Specifically: • ASHRAE Standard 55-1981, Thermal Environmental Conditions for Human Occupancy • ASHRAE Standard 62-2001n, Ventilation for Acceptable Indoor Air Quality	Department of Justice Canada: Canada Labour Code (1985): http://laws.justice.gc.ca/en/L-2/ Occupational Health and Safety Regulations (SOR/86-304): http://laws.justice.gc.ca/en/L-2/SOR-86-304/index.html
Note, other federal organizations play a role in the design and operation of federal buildings, such as: • Parks Canada establishes national goals to protect federal heritage buildings and national historic sites. It also develops policies, standards and guidelines in consultation with other departments. Through the Federal Heritage Buildings	

4.2.6 Specific Jurisdictional Considerations	
Review Office, Parks Canada provides criteria and a process for evaluating and designating heritage character, provides advice and recommendations to other departments, and maintains a register of federal heritage buildings. The minister responsible for the Agency is responsible for approving the heritage designations for federal buildings based on the recommendation of an interdepartmental advisory board. • The Canadian Environmental Assessment Agency administers the Canadian Environmental Assessment Act and advises federal departments (i.e. PWGSC) of their obligations under the Act. • Environment Canada provides advice to PWGSC on environmental matters, including contaminated sites, species at risk and environmental assessment. Through a full consultative process, the department also works with departments to establish federal environmental goals and objectives and to develop regulations, directives, guidelines, standards, or codes that affect them. In co-operation with partners, the department develops environmental quality criteria, site assessment protocols and other environmental tools and technologies. • The Department of Fisheries and Oceans Canada, under the Fisheries Act, has a regulatory function with respect to the protection of fish habitat and the prevention of pollution. Fisheries and Oceans Canada provides advice and support to Environment Canada and custodian departments concerning, among other things, the impact of contamination and remediation strategies on fish habitats. The department is also the competent ministry for aquatic species at risk under the Species at Risk Act. • Human Resources and Skills Development Canada is responsible for and ensures compliance with the Canada Labour Code, Part 2 and attendant health and safety regulations with respect to federal workplaces. Fire protection services are delivered by the department's Labour Program, which has as its mandate "ensuring the protection, conservation and minimization of risks to life, property and the Government's financial position".	
Note that PWGSC contracts with Private Sector Building Management Firms to operate and manage a large portion of the Federal Government’s real property portfolio. For the Main Statistics Canada Building this firm is SNC-Lavalin-Profac.	

4.2.6 Specific Jurisdictional Considerations	
Specific terms of the contract between PWGSC and SNC-Lavalin-Profac were not available at the time of this assessment. However, it is understood that the terms include the design, operation and maintenance of the Main Statistics Canada Building to be in compliance with all relevant legislation, regulation, standards, guidelines and policies for federal real property. Note also that SNC-Lavalin-Profac has continuouse access to PWGSC management and staff to ensure proper management of the building and has access to PWGSC Professional & Technical Services Group, the Centre of Expertise for real property management.	
Relevant Guidelines for design, operation and maintenance of the infrastructure	**Reference**
The guidelines that inform the design, operation and maintenance of the buildings are primarily: • Health Canada Guidelines • Canada Labour Code (1985) • The Canadian Occupational Safety and Health Regulations (COHSR), Part II, Division III - HVAC Systems Note that the Treasury Board of Canada Secretariat Occupational Safety and Health Directive (effective January 1st 2006) is applicable to in office accommodation. It specifies that the air (dry bulb) temperatures during working hours should be maintained within the 20-26°C range. Temperatures between 17-20°C and above 26°C can be uncomfortable, and occupancy should not exceed 3 hours daily or 120 hours annually in each of these extremes. Temperatures above 26°C are deemed to be uncomfortable when the humidex reading to a given temperature equals 40 or less.	
Guide to the Management of Real Property, Treasury Board of Canada Secretariat.	Treasury Board of Canada Secretariat. URL: http://www.tbs-sct.gc.ca/rpm-gbi/gmrp-ggbi/gmrp-ggbi_e.asp
Environmental Guide for Federal Real Property Managers, Treasury Board of Canada Secretariat.	Treasury Board of Canada Secretariat. URL: http://www.tbs-sct.gc.ca/pubs_pol/dcgpubs/tb_g3/enviro_e.asp
Guide to the Monitoring of Real Property Management (Chapter 2-3), Treasury Board of Canada Secretariat.	Treasury Board of Canada Secretariat. URL: http://www.tbs-sct.gc.ca/pubs_pol/dcgpubs/RealProperty/abh2-3t-1_e.asp

4.2.6 Specific Jurisdictional Considerations	
Infrastructure owner/operator administrative processes and policies as they apply to the infrastructure	**Reference**
The following policies apply for the administration of real property within the federal Government of Canada:	
Policy on Investment Planning – Assets and Acquired Services, Treasury Board of Canada Secretariat, June 7, 2007 (to be fully implemented April 1, 2011).	Treasury Board of Canada Secretariat. URL: http://www.tbs-sct.gc.ca/pubs_pol/dcgpubs/TBM_122/ipaas-piasa_e.asp
Policy on the Management of Real Property, Treasury Board of Canada Secretariat.	Treasury Board of Canada Secretariat. URL: http://www.tbs-sct.gc.ca/pubs_pol/dcgpubs/aas-gasa/pmrp-pgbi/pmrp-pgbi_e.asp
Policy on Fire Protection, Investigation and Reporting, Treasury Board of Canada Secretariat.	Treasury Board of Canada Secretariat. URL: http://www.tbs-sct.gc.ca/Pubs_pol/dcgpubs/RealProperty/CHAP2-5_e.asp
Policy on Long-term Capital Plans, Treasury Board of Canada Secretariat.	Treasury Board of Canada Secretariat. URL: http://www.tbs-sct.gc.ca/pubs_pol/dcgpubs/RealProperty/ltcp-pilt_e.asp
Policy Framework for the Management of Assets and Acquired Services, Treasury Board of Canada Secretariat	Treasury Board of Canada Secretariat. URL: http://www.tbs-sct.gc.ca/pubs_pol/dcgpubs/aas-gasa/fmaas-cpgasa/fmaas-cpgasa_e.asp
Policy on Project Management, Treasury Board of Canada Secretariat	Treasury Board of Canada Secretariat. URL: http://www.tbs-sct.gc.ca/pubs_pol/dcgpubs/tbm_122/CHAPT2-2_e.asp
Common Services Policy, Treasury Board of Canada Secretariat.	Treasury Board of Canada Secretariat. URL: http://www.tbs-sct.gc.ca/Pubs_pol/dcgpubs/TB_93/csp-psc_e.asp
Additional mandatory requirements for the management of real property are set out in the following policy instruments: • Directive on the Sale or Transfer of Surplus Real Property; • Accessibility Standard for Real Property; • Appraisals and Estimates Standard for Real Property; and • Reporting Standard for Real Property.	Treasury Board of Canada Secretariat. See: http://www.tbs-sct.gc.ca for detailed descriptions and listings of these policies.

4.2.6 Specific Jurisdictional Considerations	
Note: there are exceptions to these policies in that they are not relevant to some of the provincial employees working in Federal space. Furthermore, PWGSC/SNC-Lavalin-Profac have the practice of following most stringent legislation.	

4.2.7 Other Change Effects	
Changes in use pattern that increase/decrease the capacity of the infrastructure	**Reference**
PWGSC is continuously optimizing space usage with it's real property holdings and in consort with SNC-Lavalin Profac. These changes do affect the capacity of the infrastructure to maintain optimum work environments for building occupants. However, the current standards applied to occupancy density with the Main Statistics Canada building are still within the ability of the building systems to create environments that meet the applicable codes and standards (i.e. Canada Labour Code and Occupational Health and Safety Regulations). Furthermore, increased use (through higher employee/occupant densities) within the building will have an effect on the heating and cooling loads placed on the building systems and the central heating and cooling plant. Higher density of IT/IM equipment also has direct effects on heating, cooling and ventilation systems, often requiring additional cooling, ventilation and humidity control to be implemented. The ratio between employee/workstation space and IT/IM space can have considerable affect on the building systems, particularly heating, ventilation and humidity control.	
Operation and maintenance practices that increase/decrease capacity of infrastructure	**Reference**
The frequency of maintenance and quality of maintenance practices have influence on the capacity of the building, particularly on the longevity of building components and systems. Deferred maintenance and low quality materials will accelerate deterioration of building systems. This is particularly important for buildings that are reaching the end of their design life span.	
Changes in management policy that affect the load pattern on the infrastructure	**Reference**

Changes to the policies governing investments in maintenance and recapitalization of federal buildings may accelerate the refitting and/or complete rebuilding of the Main Statistics Canada Building. Such changes may also indicate the need to decommission the building (as it is near the end of its design life) and build a new facility. However, meeting with PWGSC and SNC-Lavalin Profac indicated that this was unlikely in the near future (5-10 years).	
Changes in Laws, Regulations and Standards that affect the load pattern on the infrastructure	**Reference**
No changes in the laws regulation or standards are expected to affect the load pattern on the infrastructure.	

4.2.8 Assess Data Sufficiency

Comment on using relatively short term measurements to make long term predictions	**Limitations**
The Building Condition Reports that are produced for PWGSC and SNC-Lavalin Profac factor in the life cycles of major and minor building materials and components. Although these reports are produced through short term observations, the science of building maintenance and condition reporting is such that building operators and managers can effectively schedule and budget maintenance duties to maintain the building standards and operational parameters to suit its occupants. In terms of climate change factors, the current models are based on input from 25 year historical data /baselines to make predictions that are 12, 32 and 62 years into the future.	A key limitation to ensuring and making predictions about service life of building materials and components is the available/forecasted budget. Uncertainty and fluctuating budgets can result in deferred maintenance that can in turn affect the ability to maintain the building to the required performance standards. A second limitation is the inability to predict the occurrence of accidents and extreme weather events that cause building components or materials to fail prematurely. With respect to limitations of the climate change models, the models used can be considered to be the best available estimates. However sensitivity or uncertainty analysis is still under development in the climate change modeling

		field.
Data Evaluation	**Comment**	**Effect on Assessment**
Data Gaps	There are no current estimates around the frequency and intensity of extreme weather events for the Ottawa Region. It is uncertain if these will increase, decrease or if there will be changes as to the types of events (i.e. hail storms, tornadoes, etc). Possible changes in soil conditions and water tables are current data gaps – this relates to the ability for the site to drain rain and storm water and hydrostatic pressures against foundation footings and walls. Wind driven rain index/factor is a current data gap that relates to the building envelop's ability to shed and redirect rain and snow. Changes in river water temperature will affect the use of river water at a central plant that relies on it to condition water used on a campus like Tunney's Pasture.	It is assumed that the frequency and intensity of extreme weather events will be within the capacity of the building to withstand. In addition, such estimation and modelling is extremely time and resource intensive and would require additional projects in order to predict in a manner that would be valuable to inform investment, operation and maintenance decisions. Changes in soil conditions and water table were not factored into the assessment. Changes in wind driven rain were assumed to increase based on the climate change scenarios indicating an increase in total rain and intense rain events. It was assumed intense rain events coincide with higher winds, causing wind driven rain. Warmer river water temperatures were assumed such that it will compromise the cooling capacity at Tunney's Pasture especially during the summer months.
Data Quality	Data quality from the Building Condition Report and site visit was considered excellent. Data provided from the climate change modelling was considered the best available for the region.	
Data Accuracy	Data accuracy from the Building Condition Report and site visit was considered excellent. Data accuracy in the climate change modelling was considered to be the best available estimates/predictions possible.	

Applicability of Trends		
Reliability of selected climate models	Reliability of the climate models is still uncertain at this time. However, the models used have been established through a consensus based approach involving international climate change experts. These models used are generally accepted within the field to be applicable to Canada the region.	
Reliability of climate change assumptions/scenarios	Reliability of the climate change scenarios is still uncertain at this time. However, the climate change factors that were generated from the models for the region are in agreement with many of the key changes noted by the IPCC and climate change experts for Canada.	
Other Factors	- none noted -	

4.2.8 part c
Establish Priority in referenced documents

Reference Document	**Reference Priority (highest reliance first)**
Building Condition Report, December 2007.	1st priority
Climate change in Canada: Climate scenarios for the public infrastructure vulnerability assessment – Ottawa Building Case Study. Ouranos, Quebec, February 2008.	2nd priority
Climate change in Canada: Climate scenarios for the public infrastructure vulnerability assessment – Ottawa Building Case Study, Addendum. Ouranos, Quebec, April 2008.	3rd priority
Planning for Atmospheric Hazards and Disaster Management under Changing Climate Conditions. Environment Canada, Occasional Paper 12, 2007.	4th
Changing Weather Patterns, Uncertainty and Infrastructure Risks: Emerging Adaptation Requirements. Environment Canada, Occasional Paper 9, 2007.	5th
Winter Operations Update. City of Ottawa.	6th
Weathering of Building Infrastructure and the Changing Climate: Adaptation Options. Environment Canada, Occasional Paper 11, 2007.	7th

4.2.8 part d
Data Sufficiency

Identify process to develop data, where insufficient	
Data Needed	**Process**
More information was needed on understand the change in freeze-thaw cycles.	Information was provided by Heather Auld from Environment Canada and the City of Ottawa's Department of Public Works to understand the changes in these cycles over the coming years. This information was used in Step 3 of the assessment
Humidity was of interest to the team because it plays a key factor in the efficiency of air condition and cooling systems. The climate change factors provided by the climate models did not include humidity.	Ouranos was contacted to provide humidity indices for the climate change scenarios. This was provided through an addendum to the initial (see above reference documents).
Solar radiation indices were also of interest to the study team as this can affect solar heat gain of buildings. The climate change factors provided by the climate models did not include solar radiation.	Ouranos was contacted to provide solar radiation indices for the climate change scenarios. This was provided through an addendum to the initial (see above reference documents).
Cooling degree days were also of interest because they will allow predictions to be made as to the overall "cooling season" for the building. The climate change factors provided by the climate models did not include cooling degree days.	Ouranos was contacted to provide cooling degree days indices for the climate change scenarios. This was provided through an addendum to the initial (see above reference documents).
Where data cannot be developed, identify the data gap as a finding in Step 5 of the Protocol – Recommendations. List Data Gap as findings to be sent to STEP 5 (Worksheet 5: Section 4.5.2)	
4. Further information and modelling needs to be done to predict changes in extreme weather events in the region. If it is generally accepted that there will be increases in extreme weather events, current building codes that apply should be reviewed to determine if they are sufficient.	
5. Possible changes in soil conditions and water tables are current data gaps – this relates to the ability for the site to drain rain and storm water and hydrostatic pressures against foundation footings and walls.	
6. Wind driven rain index/factor is a current data gap that relates to the building envelop's ability to shed and redirect rain and snow.	
7. Changes in river water temperature is a data gap that will affect the cooling capacity at facilities that rely on this method.	

Date:	March 20, 2008
Prepared by:	Vince Catalli

Worksheet 3 Vulnerability Assessment – Main Statistics Canada Building

In this step, the project team identified the building component responses to the most relevant climate change factors determined through Step 2. This was done by first verifying that the building components response to the climate change factors could affect the overall performance of the building. This is discussed below in Step 4.3.1. Once the list of building components have an associated performance response, a vulnerability assessment was conducted by assessing each component against each climate change factor determined in Step 2. This was done through Step 4.3.2 and 4.3.3, a prioritization exercise that assessed the probability and severity of effect that each climate change factor would have on each building component. This determined which building components are expected to have negative/detrimental responses to climate change (i.e. which are the most vulnerable).

Note: the method used in this Step of the Protocol has been modified from the October 31, 2007 version (7.1). The instructions in version 7.1 directed the practitioner to two different assessment matrices with differing, but overlapping instructions. The project team determined that the performance response relationship provided a "verification" check to understand the influence a particular building component would have on overall building performance, if it is affected by climate change. Second, the team determined, this verified list of components could then be used in the vulnerability assessment matrix (Step 4.3.6 in version 7.1) as originally outlined. The project team suggests this part of the Protocol and corresponding worksheet be revised to avoid any confusion and simplify the process for future practitioners.

4.3.1 Initial assessment of performance response.

The project team created a matrix using spreadsheet software where the column headers were comprised of what was determined as the key performance factors of the building. These were in-line with the template provided in Step 4.3.6 in version 7.1 of the Protocol (Worksheet 3). Although the generic performance factors generic provided in the Protocol were used, to aid the assessment, they were defined the by the project team as follows:

- Structural Integrity: ability of the building structural system and its components (roof trusses, floor trusses, floor panels, I-joists, or engineered beams) to withstand anticipated loads.
- Serviceability: ability of property and building managers to perform regular scheduled maintenance, service and repair on the building's systems and components.
- Functionality: ability of the building to perform it's primary functions of providing space for building occupants in the form of offices, computer facilities, storage, class/training rooms, a daycare centre, cafeteria and gym.
- Operations and Maintenance: regularly scheduled duties for property and building managers to operate the building and maintain it's systems.
- Emergency response risk: any risk posed to building managers, health and safety officers and other first responders such as firefighters, police officers, and ambulance personnel when responding to an emergency in or around the building.

- Insurance Considerations: changes, effects, events or actions that may pose potential insurance/legal liability to the landlord or building management.
- Policies and Procedures: a course or principle of action(s) adopted or used by the landlord or building managers that direct individuals, business and other entities in the short and long term operation and management of the building.
- Economics: a cost or benefit associated with day to day operation and management of the building.
- Public Health and Safety: a cross-disciplinary area concerned with protecting the safety, health and welfare of people engaged in work at the building and members of the public who live in the communities nearby.
- Environmental Effects: the impact that the operation of the building - either positive or negative – has on the natural environment including impacts to land, air, soil, water and flora and fauna.

Once these performance factors were defined, the row titles of the matrix were completed based on the key building components as identified and listed in Step 4.2.1 (see Worksht2_Main Stats). Next the team completed the matrix, based on initial professional opinion, by determining if each building component's response to climate change would affect each key performance factor of the building. Answers were provided as either yes or no. This method was deemed sufficient as a screen or initial assessment to verify that the specific building components identified in Step 4.2.1 have an affect on one or more dimensions of the building's performance. The total number of "yes" responses were calculated in the final column in the matrix. It can be seen that all components identified in Step 4.2.1 were verified to have an affect on at least 3 or more dimensions of building performance. This was anticipated by the team, as the building can be seen as a set of components of an integrated system (i.e. each component plays a separate, but vital role in the overall function and performance of the whole building).

4.3.1 Initial Assessment of Performance Response Relationship - building component response/affect on building performance

Main Statistics Canada Building	Structural Integrity	Serviceability	Functionality	Operations and Maintenance	Emergency response risk	Insurance Considerations	Policies and Procedures	Economics	Public Health and Safety	Environmental Effects	YES SCORES
EXTERIOR SYSTEMS											
Site Drainage – related to slopes away from the building and includes soil permeability and hard surfaces like stairs / ramps	Yes	No	Yes	Yes	No	No	No	Yes	No	Yes	5
Site Drains – storm/rain water	Yes	no	Yes	Yes	Yes	Yes	no	Yes	Yes	Yes	8
Walls											
Freestanding											
concrete	Yes	No	Yes	Yes	No	No	No	Yes	No	No	4
masonry	Yes	No	Yes	Yes	No	No	No	Yes	No	No	4
Retaining											
concrete	Yes	No	Yes	Yes	No	No	No	Yes	No	No	4
Walkways											
Asphalt	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	8
Concrete	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	8
Unit pavers	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	8
Stairs											
Concrete	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	7
Metal	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	7
Ramps (concrete)	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	7
Loading dock (concrete and enclosed area)	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	No	6
Window / Stair wells											
Concrete	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	7
Gutters - metal	No	No	Yes	Yes	No	No	No	No	Yes	No	3
Parking, vehicle areas											
Asphalt	Yes	Yes	Yes	Yes	No	No	No	Yes	No	No	5
Concrete	Yes	Yes	Yes	Yes	No	No	No	Yes	No	No	5
Unit pavers	Yes	Yes	Yes	Yes	No	No	No	Yes	No	No	5
Manholes/access doors	No	yes	yes	yes	yes	Yes	no	Yes	Yes	No	7
BUILDING SYSTEMS											
Foundations, Floors and Roofs											
Footings – concrete	Yes	No	Yes	No	No	Yes	No	Yes	Yes	No	5
Walls - concrete	Yes	No	Yes	No	No	Yes	No	Yes	Yes	No	5
Slab on grade - concrete	Yes	No	Yes	No	No	Yes	No	Yes	No	No	4
Precast Light Weight Concrete Panel Roof	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	No	6
Envelop Systems											
Precast Concrete	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	7
Glazed Curtain wall	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	7
Masonry wall	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	7
Stone Panels (including header and sills)	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	7
Metal Cladding	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	7
Windows / Doors											
Aluminum Windows	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	7
Doors (Steel / Aluminum)	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	7
Flat Roof Systems (including roof drains)	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	7
MECHANICAL SYSTEMS											
Heating System and Adequacy	No	No	Yes	Yes	No	No	No	Yes	No	Yes	4
Cooling System and Adequacy	No	No	Yes	Yes	No	No	No	Yes	No	Yes	4
ELECTRICAL SYSTEMS											
Emergency power systems / generators (including fuel supply)	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	6
Power Supply and Reliability	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	6

4.3.2 Determine key climate change factors

Using the key climate change factors listed in Step 4.2.3, the team developed a Vulnerability Assessment Matrix. The following table was used to populate the column headers in the Matrix.

4.3.2 Key climate change factors (from Worksheet 2 – section 4.2.3)
Temperature - Increases in monthly tmax - Increases in monthly tmin - Increases in annual avg. max - Increases in annual avg. min
Rain - Avg. total rain increases DJF, MAM, SON - Decreases JJA - Avg. Max rain increases for 1, 2 and 5 day periods - 6h frequency increases - 1 day frequency increases - Simple daily intensity index increases
Snow - Average total snow increases - 1 day frequency increases - Rain on Snow events increases
Wind - Monthly avg wind6h increases in winter - Monthly avg. wind 6h decreases in summer - Avg. annual max wind6h - decreases
Frost Season Length - decreases - frequency of freeze/thaw events increases
Heating Degree Days - Less HDDays -
Cooling Degree Days - More CDDays -
Humidity - monthly average increases -

4.3.3 Vulnerability Assessment Matrix: Climate Change Effect vs Infrastructure Component Performance Scaling

The Matrix was developed based on the template provided in Step 4.3.6 from version 7.1 of the PIEVC Protocol. As per the Protocol, the Probability (Figure 7 (S_C)) and Severity Scale (Figure 8 (S_R)) factors were used to to calculate the priority of the affect of climate change factor on each building component as per the following formula:

$$P_C = S_C \times S_R$$

Where:

P_C = Priority of Climate Effect
S_C = Scale factor for Probability
S_R = Scale factor for Severity

The project team prioritized a number of climate-infrastructure interactions, or relationships, according to the default prioritization system is based on a scale of 1 to 10. The team selected values along the scale based on probability and severity of outcomes. Method A and Method E were used to select values for probability and severity respectively.

Figure 7: Probability Scale (S_c)Factors

Scale	Probability		
	Method A (used)	**Method B**	**Method C**
0	negligible or not applicable	<0.1 % <0.1 / 20	negligible or not applicable
1	improbable / highly unlikely	5 % 1 / 20	improbable 1:1 000 000
2	remote	20 % 4 / 20	remote 1:100 000
3	occasional	35 % 7 / 20	occasional 1:10 000
4	moderate / possible	50 % 10 / 20	moderate 1:1 000
5	often	65 % 13 / 20	probable 1:100
6	probable	80 % 16 / 20	frequent 1:10
7	certain / highly probable	>95 % >19 / 20	continuous 1:1

Figure 8: Severity Scale (S_r) Factors

Scale	Magnitude	Severity of Consequences and Effects

	Method D (used)	Method E
0	no effect	negligible or not applicable
1	measurable 0.0125	very low / unlikely / rare / measurable change
2	minor 0.025	low / seldom / marginal / change in serviceability
3	moderate 0.050	occasional loss of some capability
4	major 0.100	moderate loss of some capacity
5	serious 0.200	likely regular / loss of capacity and loss of some function
6	hazardous 0.400	major / likely / critical / loss of function
7	catastrophic 0.800	extreme/ frequent/ continuous / loss of asset

This method was chosen to align with current prioritization schemes and risk management methodologies currently used by Public Works and Government Services Canada in the management of this and other buildings in its Real Property portfolio.

The Vulnerability Assessment Matrix was developed to automatically calculate the value of P_C in the corresponding cell for each building component. For ease of viewing, the P_c values are colour coded, with scores between 12 and 35 as yellow and scores 36 and higher with red.

Potential Cumulative Effects

Where the team determined there was a cumulative impact of different climate change factors, the possibility of compounded factors was given a higher weighting in the probabilyt and severity scale factors based on professional judgement. The Matrix indicates, several of these compound factors through gray cell shading in the column headers and individual matrix cells.

Main Stats Building	Climate Factors																													
	Temperature				Rain				Snow and Wind							Frost Season Length				Heating Degree Days				Cooling Degree Days				Humidity			
Future Change/Infrastructure Component/System	Increases in monthly tmax and tmin and annual avg. max and min				Avg. total rain increases DJF, MAM, SON. Decreases JJA. Avg. Max rain increases for 1, 2 and 5 day periods.6h frequency increases. 1 day frequency increases. Simple daily intensity index increases.				Average total snow increases. 1 day frequency increases. Rain on Snow events increases.				Monthly avg wind6h - windier winters, calmer summers. Avg. annual max wind6h - decreases.			Frost season length decreases, and frequency of freeze/thaw events decreases				Less HDDays				More CDDays				Humidity (monthly average) increases			
	Y/N	Sc	Sa	Pc	Y/N	Sc	Sa	Pc	Y/N	Sc	Sa	Pc	Y/N	Sc	Sa	Y/N	Sc	Sa	Pc	Y/N	Sc	Sa	Pc	Y/N	Sc	Sa	Pc	Y/N	Sc	Sa	Pc
EXTERIOR SYSTEMS																																
Site Drainage – related to slopes away from the building and includes soil permeability and hard surfaces like stairs / ramps	yes	4	3	12	yes	3	3	9	yes	2	2	4			0	yes	2	2	4	no			0	no			0	no			0
Site Drains – storm/rain water	no			0	yes	5	5	25	yes	6	6	36			0	yes	6	6	36	no			0	no			0	no			0
Walls																																
Freestanding																																
concrete	no			0	yes	2	3	6	yes	5	4	20			0				0	no			0	no			0	no			0
masonry	yes	3	3	9	yes	3	3	9	yes	5	5	25			0				0	no			0	no			0	yes	3	3	9
Retaining																																
concrete	no			0	yes	3	4	12	yes	4	3	12			0				0	no			0	no			0	yes	3	3	9
Walkways																																
Asphalt	yes	4	4	16	no			0	yes	7	6	42			0				0	no			0	no			0	no			0
Concrete	no			0	yes	2	2	4	yes	7	6	42			0				0	no			0	no			0	no			0
Unit pavers	no			0	yes	2	2	4	yes	7	6	42			0				0	no			0	no			0	no			0
Stairs																																0
Concrete	yes	3	3	9	yes	2	2	4	yes	6	6	36			0				0	no			0	no			0	yes	2	3	6
Metal	yes	3	3	9	yes	2	2	4	yes	6	5	30			0				0	no			0	no			0	no			0
Ramps (concrete)	yes	3	3	9	yes	2	2	4	yes	6	6	36			0				0	no			0	no			0	yes	2	3	6
Loading dock (concrete and enclosed area)	no			0	yes	2	2	4	no			0			0	no			0	no			0	no			0	no			0
Window / Stair wells																																
Concrete	yes	3	3	9	yes	2	3	6	Yes	3	3	9			0				0	no			0	no			0	no			0
Parking, vehicle areas																																0
Asphalt	yes	4	5	20	no			0	yes	7	6	42			0				0	no			0	no			0	no			0
Concrete	no			0	yes	2	3	6	yes	7	6	42			0				0	no			0	no			0	no			0
Unit pavers	no			0	yes	2	3	6	yes	7	6	42			0				0	no			0	no			0	no			0
Tunnels manholes/access doors	no			0	yes	4	3	12	yes	7	3	21			0				0	no			0	no			0	no			0
BUILDING SYSTEMS																																
Foundations, Floors and Roofs																																0
Footings – concrete	no			0	yes	2	2	4	no			0			0	no			0	no			0	no			0	no			0
Walls - concrete	yes	3	3	9	yes	3	3	9	no			0			0	no			0	yes	3	3	9	no			0	yes	2	3	6
Slab on grade - concrete	no			0	yes	3	3	9	no			0			0	no			0	no			0	no			0	no			0
Precast Light Weight Concrete Panel Roof	yes	3	3	9	no			0	yes	3	3	9			0				0	no			0	no			0	no			0
Envelop Systems																																
Precast Concrete - Window Sills	yes	3	3	9	yes	6	5	30	yes	5	3	15			0				0	yes	4	3	12	yes	4	3	12	yes	3	3	9
Glazed Curtain wall	yes	4	4	16	no			0	yes	3	3	9			0				0	yes	4	3	12	yes	5	4	20	no			0
Masonry wall	yes	3	3	9	yes	6	6	36	yes	5	3	15			0				0	yes	4	3	12	yes	4	3	12	yes	3	3	9
Stone Panels (including header and sills)	no			0	yes	6	6	36	yes	5	4	20			0				0	yes	4	3	12	yes	4	3	12	yes	4	3	12
Metal Cladding	yes	4	4	16	yes	4	3	12	no			0			0	yes	3	3	9	yes	4	3	12	yes	7	2	14	yes	3	3	9
Windows / Doors																																
Aluminum Windows	yes	4	4	16	no			0	no			0			0	no			0	yes	4	3	12	yes	5	4	20	yes	3	3	9
Doors (Steel / Aluminum)	yes	4	3	12	no			0	no			0			0	no			0	yes	3	3	9	yes	3	3	9	yes	3	3	9
Flat Roof Systems (including roof drains)	yes	6	5	30	yes	5	5	25	yes	6	5	30			0				0	yes	4	3	12	yes	5	4	20	no			0
MECHANICAL SYSTEMS																																
Heating System and Adequacy	no			0	no			0	no			0			0	no			0	yes	3	3	9	no			0	no			0
Cooling System and Adequacy	yes	5	6	30	no			0	no			0			0	no			0	no			0	yes	7	5	35	yes	7	6	42
ELECTRICAL SYSTEMS																																
Emergency power systems / generators (including fuel supply)	no			0	yes	2	5	10	no			0			0	no			0	no			0	yes	3	3	9	no			0
Power Supply and Reliability	yes	5	6	30	yes	2	5	10	no			0			0	no			0	no			0	yes	7	5	35	yes	7	5	35

4.3.4 Identify and prioritize vulnerable building components
The following building components had a P_c score of 36 or more for one or more climate change factors in the Vulnerability Assessment Matrix. These are also transferred to Step 5, section 4.5.2.
1. Exterior Systems: a. Site Drains – storm and rain water b. Walkways – concrete, asphalt, unit pavers c. Stairs – concrete d. Ramps – concrete e. Parking vehicle areas – concrete, asphalt, unit pavers
2. Building Systems: a. Envelop Systems: i. masonry walls

ii. stone panels (including headers and sills)
3. Mechanical Systems: a. Cooling System and Adequacy
For components and relationships with P_c score between 12 and 35 for one or more climate change factors in the Vulnerability Assessment Matrix, they were identified for further Indicator Analysis in Step 4 (Section 4.4.4 and 4.4.8 in Worksheet 4)
• Site Drainage – related to slopes away from the building and includes soil permeability and hard surfaces like stairs / ramps
• Exterior Systems: a. Walls: i. Freestanding – concrete, masonry ii. Retaining – concrete b. Stairs - metal c. Tunnels manholes/access doors
• Building Systems: a. Envelop Systems: i. Precast Concrete - Window Sills ii. Glazed Curtain wall iii. Metal Cladding b. Windows / Doors: i. Aluminium Windows ii. Doors (Steel / Aluminium) c. Flat Roof Systems (including roof drains)
• Electrical Systems: a. Power Supply and Reliability

Date:	May 5, 2008
Prepared by:	Vince Catalli

Worksheet 4 Indicator Analysis – Main Statistics Canada Building

The project team determined that key building components vulnerable to climate change (in Step 4.3) should be analysed in Step 4.4 – Indicator Analysis. However, as illustrated below in 4.4.4., the capacity, loads and therefore their vulnerability, on these building components could not be quantified in meaningful terms. This is due to a number of factors:

1. There is complexity to the variables that need to be considered to quantify loads and capacities. For example, the possible loads on the building's envelop system/component are governed by such factors as material characteristics, temperature, temperature fluctuations, solar radiation, incident moisture (rain/snow), freeze-thaw cycles, wind loads, mass of components, thermal expansion coefficients and fastening/joining methods with other materials/components, etc. Thus, the calculation of loads and capacities is multi-dimensional and cannot be easily calculated without detailed science based models.
2. The complexity of determining the deterioration rates and expected reduction of life cycle of the materials used in the components. Such determinations require in-depth knowledge of building material science and often involves the component manufacturers and/or testing laboratories.
3. The systems nature of how building components are connected and work together to ensure the proper functioning and performance of the building to meet the relevant standards.

Therefore an approach was taken by the team based on professional judgement as to determining the key building components that are vulnerable to climate change and those that have adaptive capacity (Steps 4.4.9 and 4.4.10 below).

4.4.4 Calculation of Total Load (L_T)				
Infrastructure Component (from 4.3.5 from Work Sheet 3)	**4.4.1 Existing Load L_E**	**4.4.2 Climate Load L_C**	**4.4.3 Other Load L_O**	**Total Load $L_T = L_E+L_C+L_O$**
1. Exterior Systems: a. Site Drainage – related to slopes away from the building and includes soil permeability and hard surfaces like stairs / ramps	The existing load cannot be calculated in quantitative terms.	Undetermined	Undetermined	Undetermined Refer to BCR 2007 – Pages 25 and 34 to 44.
	Existing drainage does not seem to be causing water infiltration through the foundation. Existing site drainage load calculations would require a detailed survey of soil types, slopes and audit of site drains.	Calculation of climate load would require detailed modelling and analysis that is outside the scope of this assessment.	None known	
2. Exterior Systems: a. Walls: i. Freestanding - concrete and masonry	The existing load cannot be calculated in quantitative terms.	Undetermined	Undetermined	Undetermined Refer to BCR 2007 – Pages 20 and 22.
	Loads on freestanding walls are sunlight, temperature, rain/snow/ice, etc. Estimation of such loads is outside the scope of this assessment.	Additional loads due to climate would primarily be in the form of increased freeze/thaw cycles, temperature extremes and rain/snow amounts. The estimated additional load on the walls from these factors is outside the scope of this assessment.	None known	
3. Exterior Systems: a. Walls:	The existing load cannot be calculated in quantitative	Undetermined	Undetermined	Undetermined

4.4.4 Calculation of Total Load (L_T)				
Infrastructure Component (from 4.3.5 from Work Sheet 3)	**4.4.1 Existing Load L_E**	**4.4.2 Climate Load L_C**	**4.4.3 Other Load L_O**	**Total Load $L_T = L_E+L_C+L_O$**
i. Retaining - concrete	terms.			Refer to BCR 2007 – Pages 30 to 32.
	Loads on retaining walls are related to soil types, soil moisture content, freeze/thaw cycles, rain/snow/ice, etc. Estimation of such loads is outside the scope of this assessment.	Additional loads due to climate would primarily be in the form of increased freeze/thaw cycles, temperature extremes and changes in soil moisture content. The estimated additional load on the walls from these factors is outside the scope of this assessment.	None known	
4. Exterior Systems: a. Stairs – metal	The existing load cannot be calculated in quantitative terms.	Undetermined	Undetermined	Undetermined Refer to BCR 2007 – Page 29.
	Loads on stairs are primarily use and environment related (temp, sunlight, precipitation, etc). Estimation of such loads would require detailed mechanical and material modelling, which is outside the scope of this assessment.	Additional climate related loads on stairs are mostly in the form of increased precipitation and freeze/thaw cycles that may accelerate metal deterioration and means of fastening to the building or substrates used.	None know	
5. Exterior Systems: a. Tunnels manholes/access doors	The existing load cannot be calculated in quantitative terms.	Undetermined	Undetermined	Undetermined Refer to BCR 2007 – Page 33.
	Water penetration into the	Possible infiltration of	None known	

4.4.4 Calculation of Total Load (L_T)				
Infrastructure Component (from 4.3.5 from Work Sheet 3)	**4.4.1 Existing Load L_E**	**4.4.2 Climate Load L_C**	**4.4.3 Other Load L_O**	**Total Load $L_T = L_E+L_C+L_O$**
	system has not been a problem to date. Drainage systems in the tunnel are sufficient should this occur. The existing load could be considered to be zero.	water in the tunnel systems could occur if ground water table rise to exert continuous hydrostatic pressure on tunnel walls. However, this additional climate load cannot be calculated in quantitative terms due to a lack of data for ground water table levels on the site and campus.		
6. Building Systems: a. Envelop Systems: i. Precast Concrete - Window Sills	The existing load cannot be calculated in quantitative terms.	Undetermined	Undetermined	Undetermined Refer to BCR 2007 – Pages 61 to 66.
	Function of window sills is to drain water and support window loads, therefore, existing load cannot be calculated in quantitative terms.	Climate load cannot be calculated in quantitative terms.	None known	
7. Building Systems: a. Envelop Systems: i. Glazed Curtain wall	The existing load cannot be calculated in quantitative terms.	Undetermined	Undetermined	Undetermined Refer to BCR 2007 – Pages 63 to 64.
	The ability of the curtain wall to meet its performance requirements (i.e. water/rain drainage, thermal comfort, ventilation, withstand wind	Climate load cannot be calculated in quantitative terms	None known	

4.4.4 Calculation of Total Load (L_T)				
Infrastructure Component (from 4.3.5 from Work Sheet 3)	**4.4.1 Existing Load L_E**	**4.4.2 Climate Load L_C**	**4.4.3 Other Load L_O**	**Total Load $L_T = L_E+L_C+L_O$**
	loads, access to sunlight) and load cannot be calculated in quantitative terms. This would required detailed analysis and modeling that is outside the scope of this assessment.			
8. Building Systems: a. Envelop Systems: i. Metal Cladding	The existing load cannot be calculated in quantitative terms.	Undetermined	Undetermined	Undetermined Refer to BCR 2007 – Pages 66 to 67.
	The existing load (sunlight, rain/snow, thermal) on the metal cladding cannot be calculated in quantitative terms. This would require detailed analysis and modeling of the cladding material that is outside the scope of this assessment.	Climate load due to increased temperatures and precipitation cannot be calculated in quantitative terms	None known	
9. Building Systems: a. Windows / Doors: i. Aluminum Windows	The existing load cannot be calculated in quantitative terms.	Undetermined	Undetermined	Undetermined Refer to BCR 2007 – Pages 75 to 76.
	Existing load cannot be calculated in quantitative terms Refer to Glazed Curtain Wall above.	Climate load cannot be calculated in quantitative terms	None known	
10. Building Systems: a. Windows / Doors: i. Doors (Steel / Aluminum)	The existing load cannot be calculated in quantitative terms.	Undetermined	Undetermined	Undetermined Refer to BCR 2007 –

4.4.4 Calculation of Total Load (L_T)				
Infrastructure Component (from 4.3.5 from Work Sheet 3)	**4.4.1 Existing Load L_E**	**4.4.2 Climate Load L_C**	**4.4.3 Other Load L_O**	**Total Load $L_T = L_E+L_C+L_O$**
				Pages 68 to 74.
	Existing load cannot be calculated in quantitative terms Refer to Glazed Curtain Wall above.	Climate load cannot be calculated in quantitative terms	None known	
11. Building Systems: a. Flat Roof Systems (including roof drains)	The existing load cannot be calculated in quantitative terms.	Undetermined	Undetermined	Undetermined Refer to BCR 2007 – Pages 78 to 80.
	Calculations of roof drain loads could not be made, as existing design/as built specifications were not available. The ability of the roof to meet its performance requirements and load (i.e. shed water/rain, thermal comfort, withstand wind uplift, withstand sunlight / temperature fluctuations / freeze thaw cycles, keep moisture out to preserve structure and interior finish) cannot be calculated in quantitative terms. This would required detailed analysis and modeling that is outside the scope of this assessment.	Climate load cannot be calculated in quantitative terms	None known	
12. Electrical Systems: a. Power Supply and Reliability	The existing load cannot be calculated in quantitative	Undetermined	Undetermined	Undetermined

4.4.4 Calculation of Total Load (L_T)				
Infrastructure Component (from 4.3.5 from Work Sheet 3)	**4.4.1 Existing Load L_E**	**4.4.2 Climate Load L_C**	**4.4.3 Other Load L_O**	**Total Load $L_T = L_E+L_C+L_O$**
	terms.			Refer to BCR 2007 – Pages 167 to 189.
	The existing and historical electrical power consumption of the building is known. However, the quantification of reliability and provision of electrical supply is too complex to conduct with in the scope of this assessment. Such an exercise would have to involve the local electrical utilities and a modelling of such factors. Power reliability is critical over the spring, summer and fall especially when temperatures and humidity are higher. It has a direct relationship with community usage city wide as during this time it will peak and not be able to satisfy the demand.	The cooling load on the building is expected to increase due to higher temperatures and humidity levels and therefore the electricity consumption and load of the building. This may have an affect on particularly days/periods in the summer. Such periods when the regional load on the electricity utilities could put power supply and reliability at risk. However this effect is difficult to predict or model due to the complex nature of the electricity grid and mitigation measures undertaken by current utility providers. Such predictions are outside the scope of this assessment.	None known	

4.4.8 Calculation of Total Capacity (C_T) **For all the building components below, a calculation of total capacity could not be carried out. Since total loads (4.4.4) could not be calculated or estimated, total capacity calculations were not undertaken. The reasons for this are provided above in the "basis of determination explanations" (4.4.1 and 4.4.2)**				
Infrastructure Component (from section 4.3.5 of Work Sheet 3)	**4.4.5 Existing Capacity C_E**	**4.4.6 Maturing Capacity C_M**	**4.4.7 Additional Capacity C_A**	**Total Capacity $C_T = C_E+C_M+C_A$**
1. Exterior Systems: a. Site Drainage – related to slopes away from the building and includes soil permeability and hard surfaces like stairs / ramps	Undetermined	Undetermined	Undetermined	Undetermined
	Existing capacity cannot be calculated in quantitative terms	No maturing capacity is anticipated.	No increases or decreases in additional capacity is anticipated or being planned.	
2. Exterior Systems: a. Walls: i. Freestanding - concrete and masonry	Undetermined	Undetermined	Undetermined	Undetermined
	Existing capacity cannot be calculated in quantitative terms	No maturing capacity is anticipated.	No increases or decreases in additional capacity is anticipated or being planned.	
3. Exterior Systems: a. Walls: i. Retaining - concrete	Undetermined	Undetermined	Undetermined	Undetermined
	Existing capacity cannot be calculated in quantitative	No maturing capacity is anticipated.	No increases or decreases in additional capacity is	

4.4.8 Calculation of Total Capacity (C_T) **For all the building components below, a calculation of total capacity could not be carried out. Since total loads (4.4.4) could not be calculated or estimated, total capacity calculations were not undertaken. The reasons for this are provided above in the "basis of determination explanations" (4.4.1 and 4.4.2)**				
Infrastructure Component (from section 4.3.5 of Work Sheet 3)	**4.4.5 Existing Capacity C_E**	**4.4.6 Maturing Capacity C_M**	**4.4.7 Additional Capacity C_A**	**Total Capacity $C_T = C_E+C_M+C_A$**
	terms		anticipated or being planned.	
4. Exterior Systems: a. Stairs – metal	Undetermined	Undetermined	Undetermined	Undetermined
	Existing capacity cannot be calculated in quantitative terms	No maturing capacity is anticipated.	No increases or decreases in additional capacity is anticipated or being planned.	
5. Exterior Systems: a. Tunnels manholes/access doors	Undetermined	Undetermined	Undetermined	Undetermined
	Existing capacity cannot be calculated in quantitative terms	No maturing capacity is anticipated.	No increases or decreases in additional capacity is anticipated or being planned.	
6. Building Systems: a. Envelop Systems: i. Precast Concrete - Window Sills	Undetermined	Undetermined	Undetermined	Undetermined
	Existing capacity cannot be calculated in quantitative terms	No maturing capacity is anticipated.	No increases or decreases in additional capacity is anticipated or being planned.	
7. Building Systems:	Undetermined	Undetermined	Undetermined	Undetermined

4.4.8 Calculation of Total Capacity (C_T) **For all the building components below, a calculation of total capacity could not be carried out. Since total loads (4.4.4) could not be calculated or estimated, total capacity calculations were not undertaken. The reasons for this are provided above in the "basis of determination explanations" (4.4.1 and 4.4.2)**				
Infrastructure Component (from section 4.3.5 of Work Sheet 3)	**4.4.5 Existing Capacity C_E**	**4.4.6 Maturing Capacity C_M**	**4.4.7 Additional Capacity C_A**	**Total Capacity $C_T = C_E+C_M+C_A$**
a. Envelop Systems: i. Glazed Curtain wall				
	Existing capacity cannot be calculated in quantitative terms	No maturing capacity is anticipated.	No increases or decreases in additional capacity is anticipated or being planned.	
8. Building Systems: a. Envelop Systems: i. Metal Cladding	Undetermined	Undetermined	Undetermined	Undetermined
	Existing capacity cannot be calculated in quantitative terms	No maturing capacity is anticipated.	No increases or decreases in additional capacity is anticipated or being planned.	
9. Building Systems: a. Windows / Doors: i. Aluminum Windows	Undetermined	Undetermined	Undetermined	Undetermined
	Existing capacity cannot be calculated in quantitative terms	No maturing capacity is anticipated.	No increases or decreases in additional capacity is anticipated or being planned.	
10. Building Systems: a. Windows / Doors: i. Doors (Steel / Aluminum)	Undetermined	Undetermined	Undetermined	Undetermined

4.4.8 Calculation of Total Capacity (C_T) **For all the building components below, a calculation of total capacity could not be carried out. Since total loads (4.4.4) could not be calculated or estimated, total capacity calculations were not undertaken. The reasons for this are provided above in the "basis of determination explanations" (4.4.1 and 4.4.2)**				
Infrastructure Component (from section 4.3.5 of Work Sheet 3)	**4.4.5 Existing Capacity C_E**	**4.4.6 Maturing Capacity C_M**	**4.4.7 Additional Capacity C_A**	**Total Capacity $C_T = C_E+C_M+C_A$**
	Existing capacity cannot be calculated in quantitative terms	No maturing capacity is anticipated.	No increases or decreases in additional capacity is anticipated or being planned.	
11. Building Systems: a. Flat Roof Systems (including roof drains)	Undetermined	Undetermined	Undetermined	Undetermined
	Existing capacity cannot be calculated in quantitative terms	No maturing capacity is anticipated.	No increases or decreases in additional capacity is anticipated or being planned.	
12. Electrical Systems: a. Power Supply and Reliability	Undetermined	Undetermined	Undetermined	Undetermined
	Existing capacity cannot be calculated in quantitative terms	No maturing capacity is anticipated.	No increases or decreases in additional capacity is anticipated or being planned.	

4.4.9 Evaluate Vulnerability (V_R)

Since Total Load (L_T) and Total Capacity (C_T) could not be calculated (see explanations above) a calculation of vulnerability was not conducted. Therefore V_R is undetermined at this time for all the building components identified through Step 3 to be vulnerable to climate change and with P_C scores between 12 and 35. However, based on professional judgement, commentary has been provided to highlight systems that are extremely vulnerable. This matrix has been modified to accommodate the above reality.

Infrastructure Component	Comments
1. Exterior Systems: a. Site Drainage – related to slopes away from the building and includes soil permeability and hard surfaces like stairs / ramps	Based on limited building specific information along with the vintage of construction, it can be expected that below grade foundations and footings may have damp proofing provisions. Drainage around the building perimeter may be in place but is likely to be inadequate. Native soils may be used as backfill along the perimeter wall and as such will have saturated soils directly on the below grade systems and permit eventual water infiltration. However, typical building science and management practices would safeguard deterioration of this system. Given that PWGSC have a detailed review of the building every 5 years to produce an up-to-date Building Condition Report corrective measures would be noted and implemented due to day to day practices.
2. Exterior Systems: a. Walls: i. Freestanding - concrete and masonry	Given that there is no tie in with this system to habited space and that this system has aesthetic and screening properties it was deemed to not be a vital infrastructure component. Having said this, it can pose a health and safety risk due to collapse should the system deteriorate. Drainage of the wall system is critical along with a cap to shed water at the top of the wall. The foundation system to these walls cannot rely on the interior building heat to keep the foundations reasonably warm like the basement foundation walls. As a result, freeze thaw cycles with have a significant impact on the integrity of the wall. The main risk is the structural integrity of the wall that could fall due to deterioration and thus be a health and safety risk. Having said this the comments under item #1 regarding the current building science and management practices on site also apply. These would safeguard the deterioration of this system component.

3. Exterior Systems: a. Walls: i. Retaining - concrete	Given that there is potentially saturated soil condition on one side of the retaining wall, it will be critical to keep water and moisture away from the wall so that it is as dry as possible. If not freeze thaw cycles will have negative impact on the retaining wall. However, comments under item #1 regarding the current building science and management practices on site also apply. These would safeguard the deterioration of this system component.
4. Exterior Systems: a. Stairs – metal	Regular building management practices must prevail in which the stair is painted on a 5 year cycle in order to preserve its integrity. Comments under item #1 regarding the current building science and management practices on site also apply. These would safeguard the deterioration of this system component.
5. Exterior Systems: a. Tunnels manholes/access doors	This infrastructure component is below grade and throughout the campus supplying all buildings with critically needed steam and chilled water. Due to the sites proximity to the river and increase in precipitation year round, ground water issues will affect this infrastructure so much so that it will require draining / pumping systems. The Tunnels have a drainage system that will have to be analysed in order to determine how viable it is. No information was provided as this system is being managed by PWGSC and SNC ProFac had no information on the tunnel system. Further work is required to understand the system and its potential vulnerability.
6. Building Systems: a. Envelop Systems: i. Precast Concrete - Window Sills	Given that there is a two layer brick wall with no drainage cavity, the window sill is critical to shed as much water away from the brick wall below. Regular building management practices as carried out by SNC ProFac will review deficiencies and rectify window sills that have deteriorated and can pose a risk. These would safeguard the deterioration of this system component.
7. Building Systems: a. Envelop Systems: i. Glazed Curtain wall	Glazed curtain wall systems are made up of many components that expand and contract at different rates and therefore affect the system's integrity / performance. Older curtain walls may not be detailed such that moisture / water drains effectively out of the system. Regular building management practices, as carried out by SNC ProFac, will review deficiencies and rectify curtain wall components that have deteriorated and can pose a serious risk. These would safeguard the deterioration of this system component.
8. Building Systems: a. Envelop Systems: i. Metal Cladding	Metal cladding is subjected to typical weathering due to solar radiation, temperature fluctuations and rain / snow events. As climate change is more extreme the cladding is likely to be exposed to harsher weathering

	such that it may fail earlier in the life cycle. Regular building management practices, as carried out by SNC ProFac, will review deficiencies and rectify metal cladding components that have deteriorated and can pose a serious risk. These would safeguard the deterioration of this system component.
9. Building Systems: a. Windows / Doors: i. Aluminum Windows	Comments under item #1 regarding the current building science and management practices on site also apply. These would safeguard the deterioration of this system component. As well refer to item #7 above.
10. Building Systems: a. Windows / Doors: i. Doors (Steel / Aluminum)	The number of door openings is generally much smaller than the amount of glazing throughout the building. This element poses less risk to the building owner, manager and tenant. It is critical for doors to have a good seal so that it mitigates interior and exterior environments, especially during the summer months. Regular building management practices, as carried out by SNC ProFac, will review deficiencies and rectify exterior door components that have deteriorated and can pose a serious risk. These would safeguard the deterioration of this system component.
11. Building Systems: a. Flat Roof Systems (including roof drains)	Given that flat roofs will retain some water and that freeze thaw cycles will increase over the winter months, it can be expected that this will pose a significant strain on the integrity of the system so much so that the life cycle will be shortened. Unexpected leaks may take place and therefore compromise the structure and finishes below. This system is vital to the well being of a building's operations and as such is critical system that requires constant monitoring. Typical management practices require annual review of this system such that it will safeguard the system.
12. Electrical Systems: a. Power Supply and Reliability	As temperature and humidity levels will increase, electrical demands will also increase with no guarantee that the utility will be able to supply enough power city wide. Power supply and reliability is therefore very vulnerable. This element is not reviewed as part of typical building condition management practices and therefore will require special attention and monitoring.
When V_R > 1, the infrastructure component is vulnerable	
Infrastructure Component showing vulnerability should be forwarded to Section 4.5.2 in Work Sheet 5 for STEP 5 Recommendation Evaluation. **List Infrastructure Components forwarded to Section 4.5.2 of Work Sheet 5 for Recommendation Assessment below:**	

1. Exterior Systems: a. Tunnels, Manholes, Access Doors - Further work is required to understand the system and its potential vulnerability.
2. Building Systems: a. Flat Roof Systems - This system is vital to the well being of a building's operations and as such is critical system that requires constant monitoring to compliment current annual review practices in place.
3. Electrical Systems: a. Power Supply and Reliability - This element is not reviewed as part of typical building condition management practices and therefore will require special attention and monitoring.

4.4.10 Adaptive Capacity (A_R)

Since Total Load (L_T) and Total Capacity (C_T) could not be calculated (see explanations above) a calculation of Adaptive Capacity was not conducted. Therefore A_R is undetermined at this time for all the building components identified through Step 3 to be vulnerable to climate change and with P_C scores between 12 and 35. However, due to professional judgement, commentary has been provided to highlight systems that have adaptive capacity. The following matrix has been modified to accommodate the above reality.

Infrastructure Component	Comments
1. Exterior Systems: a. Site Drainage – related to slopes away from the building and includes soil permeability and hard surfaces like stairs / ramps	These systems have adaptive capacity through typical building science best practices that could be implemented as part of the building management program through regular scheduled building maintenance activities.
2. Exterior Systems: a. Walls: i. Freestanding - concrete and masonry	
3. Exterior Systems: a. Walls: i. Retaining - concrete	
4. Exterior Systems: a. Stairs – metal	
5. Building Systems: a. Envelop Systems: i. Precast Concrete - Window Sills	
6. Building Systems: a. Envelop Systems: i. Glazed Curtain wall	
7. Building Systems: a. Envelop Systems: i. Metal Cladding	
8. Building Systems: a. Windows / Doors: i. Aluminum Windows	
9. Building Systems: a. Windows / Doors: i. Doors (Steel / Aluminum)	

4.4.12 Data Sufficiency	
Identify process to develop data, Where insufficient	
Data Needed	**Process**
Building Material Properties	Regular building condition reviews, service life analysis and professional judgement.
River Water Year Round Temperatures	Like the Cliff Street Plant – monitor river water temperature regularly, daily and throughout the day.
Soil Characteristic Monitoring	Develop some soil monitoring stations within the Ottawa region
Ground Water Monitoring	Develop some ground water monitoring stations within the Ottawa region.
Where data cannot be developed, identify the data gap as a finding in Step 5 of the Protocol – Recommendations. List Data Gap as findings to be sent to STEP 5 (Worksheet 5: Section 3.5.2)	
8.	
9.	
10.	
11.	

Date:	May 9, 2008
Prepared by:	Vince Catalli

Worksheet 5 Recommendations – Main Statistics Canada Building

4.5.1 State Limitations	
MAJOR ASSUMPTIONS[6]	
Available infrastructure information and sources	Building data from the 2007 building condition reports is assumed to be accurate. However, because the assessment is focused on future scenarios for the regional climate, a key limitation to ensuring and making predictions about service life of building materials and components is the available/forecasted and/or plans for refurbishment, rehabilitation, reconstruction or demolition and rebuilding of the building. The uncertainty and fluctuating budgets of investment and long term capital plans of Public Works and Government Services Canada. This can result in deferred maintenance that can in turn affect the ability to maintain the building to the required performance standards. They can also change the operating and maintenance priorities for the building as well as planned capital upgrades. However, the results of this assessment can inform the future development of these budgets and plans for the building and the Tunney's Pasture Campus in general. A second limitation is the inability to predict the occurrence of extreme weather events that cause building components or materials to fail prematurely.
Available climate and information	With respect to limitations of the climate change models, the models used can be considered to be the best available estimates. However sensitivity or uncertainty analysis is still under development in the climate change modeling field.
Available Other Change Information and sources	PWGSC is continuously optimizing space usage with it's real property holdings and in consort with SNC-Lavalin Profac. These changes do affect the capacity of the infrastructure to maintain optimum work environments for building occupants. However, the current standards applied to occupancy density with the Main Statistics Canada building are still within the ability of the building systems to create environments that meet the applicable codes and standards (i.e. Canada Labour Code and Occupational Health and Safety Regulations). Furthermore, increased use (through higher employee/occupant densities) within the building will have an effect on the heating and cooling loads placed on the building systems and the central heating and cooling plant. Higher density of IT/IM equipment also has direct effects on heating, cooling and ventilation systems, often requiring additional cooling, ventilation and humidity control

[6] Notionally, these are the same major assumptions that underlie the entire assessment as determined in Step 1 and Step 2 of this Protocol. They may include boundary conditions used to define the study area, time frame, refurbishment schedules, etc.

	to be implemented. The ratio between employee/workstation space and IT/IM space can have considerable affect on the building systems, particularly heating, ventilation and humidity control. The frequency of maintenance and quality of maintenance practices have influence on the capacity of the building, particularly on the longevity of building components and systems. Deferred maintenance and low quality materials will accelerate deterioration of building systems. This is particularly important for buildings that are reaching the end of their design life span.
Use of Generic/specific examples to represent population	none
Uncertainty and related concepts	The Tunney's Pasture Campus is currently the focus of a Master Planning exercise being undertaken by Public Works and Government Services Canada. The outcomes of this study are unknown at this time and difficult to predict. However, they may affect the investment plans and budgets and resulting priorities for the Main Statistics Canada Building. The Heritage designation of the Main Statistics Canada Building could affect the potential priorities and plans to improve, upgrade or refurbish the building, particularly the building envelop. This factor was not included or researched as part of this assessment. Because the Main Statistics Canada Building relies on the Central Heating and Cooling Plant (CHCP) for heating and cooling for much of it's occupied space, the efficiency and affects of increased loads on the CHCP need to be studied further. This is a major limitation of the current assessment as the building and its components should be considered to be an integrated system working to provide the necessary functions for its occupants. I.e. changes to the building envelop will impact heating and cooling loads.
Other	Changes to the policies governing investments in maintenance and recapitalization of federal buildings may accelerate the refitting and/or complete rebuilding of the Main Statistics Canada Building. Such changes may also indicate the need to decommission the building (as it is near the end of its design life) and build a new facility. However, meeting with PWGSC and SNC-Lavalin Profac indicated that this was unlikely in the near future (5-10 years).

4.5.2 Recommendations					
Infrastructure Component / Data Gap	**Remedial Engineering Action**	**Management Actions**	**No further Action**	**Recommendation Priority (low, medium, high)[7]**	**Comments**
Components with Vulnerability Priority values > 36					
4. Exterior Systems: a. Site Drains – storm and rain water	Refer to BCR 2007 pages 25 and 34 to 44.	Research the detailed existing and projected loads on the site drains, soil types, site slopes, water tables and bedrock topography and groundwater tables to determine if optimum engineering solution (e.g. water retention areas or ground water recharge systems).		Medium	This system is not adequately monitored a the BCR level as there is little to no mentio of the site drainage systems. It is our understanding that in the mid 90's work wa done to update the site drainage system, however we could not definitively confirm this. It is highly likely that as a result of this update added capacity was built in. The design parameters of the storm drains wer not available. Based on professional judgment with civil engineering input, the existing storm drains meet and are potentially at full capacity. Based on projected increased precipitatio these systems will potentially be inadequat and as such may need to be supplemente with storm water retention areas or with ground water recharge systems.
5. Exterior Systems: a. Walkways – concrete, asphalt, unit pavers	Refer to BCR 2007 pages 44 to 48.	First, it is recommended that all of these parking surfaces be kept free and clear of snow in accordance with current building management practices.		High	Due to increased freeze thaw and rain ove the winter months it can be expected that there will be more ice build-up on walkway The Tunney's Pasture campus has well over 10,000 people with only about 1000 parking spots. It therefore has a strong

[7] Based on professional judgement and potential impact on overall function and performance of the building.

4.5.2 Recommendations					
Infrastructure Component / Data Gap	**Remedial Engineering Action**	**Management Actions**	**No further Action**	**Recommendation Priority (low, medium, high)[7]**	**Comments**
		Second, management should ensure consistent levels of sufficient budget for snow clearing. Third, all walkway and parking surfaces should use materials that will withstand increased freeze-thaw cycles. In addition, these materials should try to minimize heat gain in order to reduce possible cooling loads on the building during the summer.			pedestrian component given its proximity t the transit way and parking restrictions. Health and safety of pedestrians is key as prevention of injury on ice is very importan At the same time the freeze thaw cycle will case heaving and material deterioration making the condition of the walkways pron to tripping hazards. This will pose a significant risk and cost to maintaining this infrastructure component. Higher Temperatures will affect walkways especially asphalt walkways as it will cause the material to soften thus affecting its wear. For example, shoe heels will puncture into the walkway and create crevices that in the winter will be subjected to freeze thaw and cause the walkway to breakdown faster.
6. Exterior Systems: a. Stairs – concrete	Refer to BCR 2007 pages 56 to 58.	None- continued monitoring through current building management and building condition reporting procedures.		Low	Increased freeze thaw cycles will cause heaving and material deterioration making the stairs an area prone to occupant tripping/falling/injury. This could pose a significant risk during emergencies and evacuations. Stairs should be kept clear o snow and ice during winter months to ensure dry conditions and prevent material deterioration. Note, because of the public nature of this building and the unionized civil service occupants, snow clearing on steps is

4.5.2 Recommendations					
Infrastructure Component / Data Gap	**Remedial Engineering Action**	**Management Actions**	**No further Action**	**Recommendation Priority (low, medium, high)[7]**	**Comments**
					promptly dealt with in accordance with PWGSC standards.
7. Exterior Systems: a. Ramps – concrete	Refer to BCR 2007 pages 58 to 60.	None- continued monitoring through current building management and building condition reporting procedures.		Low	Increased freeze thaw cycles will cause heaving and material deterioration making the ramps an area prone to occupant tripping/falling/injury. This could pose a significant risk during emergencies and evacuations. Ramps should be kept clear o snow and ice during winter months to ensure dry conditions and prevent material deterioration. Note, because of the public nature of this building and the unionized civil service occupants, snow clearing on ramps is promptly dealt with in accordance with PWGSC standards.
8. Exterior Systems: a. Parking vehicle areas – concrete, asphalt, unit pavers	Refer to BCR 2007 pages 48 to 50.	Same recommendations as for walkways above		Medium	Please see discussion on walkways above
9. Building Systems: a. Envelop Systems: i. masonry walls	Refer to BCR 2007 pages 61 to 63.	During the winter months heating system pipes can freeze and burst resulting in building envelop water damage (refer to BCR). As well, the affects of increased precipitation and moisture migration into the envelop needs to be studied further.		High	Due to increased rain over the year, moisture will likely make its way into the building envelope. The result of this will mean increased brick failure. Some evidence of this is currently being seen by Building Management. With no drainage cavity it will make it more difficult to keep the envelop dry. The only means of drying out the envelop is through

4.5.2 Recommendations					
Infrastructure Component / Data Gap	**Remedial Engineering Action**	**Management Actions**	**No further Action**	**Recommendation Priority (low, medium, high)[7]**	**Comments**
		The optimum building envelop technology needs to be researched and applied to the building. The building's Heritage status will also need to be considered in this study. What ever the corrective measure decided, it will require some alterations to the heating, cooling and ventilation systems to ensure optimum building performance in line with current building science and codes.			building heat migrating outward and solar radiation throughout the year. In the winte months any moisture within the envelope will be subjected to freeze thaw cycles therefore affecting the structural integrity o the building envelop materials. Higher humidity levels in the summer months may have the same effect in that moisture will migrate into the envelop that can cause damage. Any future alterations to the building envelop will require serious consideration before any action is taken as it can significantly alter the performance and negatively impact the system. In addition, such changes may have significant affects on heating, cooling and ventilation loads requirements for the building.
10. Building Systems: a. Envelop Systems: i. stone panels (including headers and sills)	Refer to BCR 2007 pages 64 to 66.	See discussion above for masonry walls		High	See discussion above for masonry walls
11. Mechanical Systems: a. Cooling System	Refer to BCR 2007 pages	Detailed engineering evaluation needs to be		High	Climate change impacts the capability of the cooling system to meet loads for the

4.5.2 Recommendations					
Infrastructure Component / Data Gap	**Remedial Engineering Action**	**Management Actions**	**No further Action**	**Recommendation Priority (low, medium, high)[7]**	**Comments**
and Adequacy	139 to 149.	conducted on the anticipated loads relative to heating, cooling and the ventilation system. This study should evaluate the suitability of various adaptive measures/technologies such as exterior shading devices, passive cooling techniques, etc.. In addition, a climate change vulnerability assessment should be conducted on the Central Heating and Cooling Plant that models and considers: a) the various technology options/adaptive measures for the buildings on the Campus; b) predicted loads and capacities; c) the future Master Plan for the Campus; and d) various technologies/adaptive measures for the CHCP itself such as co-generation and geothermal heating and cooling.			Tunney's Pasture facilities in two ways: 1. Outdoor temperature and humidity increases load through higher sensible and latent cooling of make-up air supply and infiltration as well as increases in envelope conduction gains. As the relative humidity projections are relatively constant, the projected rises in temperature result in increases of make-air and infiltration loads at a rate of about 5kJ/m3 or 5W/l/s, mostly latent. Assuming a combined air change rate of 1 ACH, the load increase can be estimated thus: building floor area (m2) x temperature rise (0K) x 5 (W) = additional cooling load (W). Building envelope gains are smaller and require envelope areas and U-values. The cooling coils and air distribution may be insufficient to maintain acceptable conditions. 2. The central chilling plant depends on sufficiently cool water and pumping rate from the Ottawa River to maintain capacity and possibly operation. A combined effect of lower summer rainfall and higher ambient temperatures will raise temperatures and lower flow rates of the Ottawa River. Increased usage for heat rejection and urbanization upstream will have similar

4.5.2 Recommendations					
Infrastructure Component / Data Gap	**Remedial Engineering Action**	**Management Actions**	**No further Action**	**Recommendation Priority (low, medium, high)[7]**	**Comments**
					effects. Although current capacity exceeds demand by a 50% margin currently, the combination of lower capacity due to condenser temperature rise and higher loads may reduce the margin to critical. Th older steam turbines will be called in to dut more frequently and shorten their serviceable life.

Components with Vulnerability Priority values > 12 < 35

• Exterior Systems: a. Tunnels manholes/access doors	Refer to BCR 2007 page 33.	Studies should be conducted that are similar as those discussed above under Site Drains – storm and rain water, above.		Medium	Based on input from SNC ProFac water penetration into the Tunnel System has no been a serious problem. Drainage systems exist within the tunnel that appears to be sufficient should this occur. Given that precipitation is on the increase, this system may be at a higher risk and therefore requires a more detailed analysis.
• Building Systems: a. Flat Roof Systems (including roof drains)	Refer to BCR 2007 pages 78 to 80.	Conduct a research study to determine optimum flat roof technology, design options, mitigation strategies and potential effects of freeze thaw and ice build-up. Such a study should investigate current best		Medium	Due to increased freeze thaw and rain ove the winter months it can be expected that there will be more ice build-up on roofs. This will pose a significant risk and cost to maintaining this infrastructure component given that freeze thaw may result in damaging the roof system. Depending on the type of roof system the effect will vary.

4.5.2 Recommendations					
Infrastructure Component / Data Gap	**Remedial Engineering Action**	**Management Actions**	**No further Action**	**Recommendation Priority (low, medium, high)[7]**	**Comments**
		practices in climates that are currently similar to the predicted climate change for the Ottawa Region (i.e. warmer, more freeze thaw).			When the roof system breaks down water infiltration can result and create damage to other systems below the roof membrane. Higher Temperatures will also affect roofing materials as it will case the material to break down at faster rates due to temperature and UV.
• Electrical Systems: a. Power Supply and Reliability	Refer to BCR 2007 pages 167 to 189.	Research study should be conducted together with the local utility (e.g. Hydro Ottawa) on the cumulative effects (consumption, loads, peaks, demand, etc.) on electricity loads during spring, summer and fall. The study should also include the other buildings at the Tunney's Pasture Campus and factor in the possible changes to building envelops and potential co-generation capabilities at the CHCP.		Medium	Power supply and reliability is critical to Stats Canada's operations. Power outages can dehabilitate operations and affect closures as has been seen in the past especially over the summer months. During the summer, the climate is expected to get hotter and more humid and as a result citizens of Ottawa will rely more on air conditioning. This increase in load throughout Ottawa will pose a strain on the energy grid and affect power reliability throughout the city. Power reliability is beyond the control of Tunney's Pasture as it is a source of energy provided by the utility at a city wide level. The primary means of securing power reliability is to be self sufficient. This will require reduction in power usage and an ability to generate onsite power in whole or in part for Stats Canada's use. More research is required to evaluate options.

4.5.2 Recommendations					
Infrastructure Component / Data Gap	**Remedial Engineering Action**	**Management Actions**	**No further Action**	**Recommendation Priority (low, medium, high)[7]**	**Comments**
Data Gaps (from previous worksheets)					
Baseline (historical) flood plain data and ground water/water table were not available at the time of the case study.		Recommend using the study discussed under Site drains to establish baseline data.		Medium	
Future projected flood plain and ground water/water table information was not available at the time of the case study.		Recommend PWGSC initiate or involve themselves in studies on the climate change effects on the Ottawa River, watershed and flood plain.		High	
Further information and modelling needs to be done to predict changes in extreme weather events in the region. If it is generally accepted that there will be increases in extreme weather events, current building codes that apply should be reviewed to determine if they are sufficient.		Continue monitoring best practices and state of the art in climate change future scenario modeling and research into future climate related changes in extreme weather events in the region.		Low	
Possible changes in soil conditions and water tables are current data gaps – this relates to the ability for the site to drain rain and storm water and hydrostatic pressures against footings, foundation walls, slab on grade and retaining walls.		Recommend using the study discussed under Site Drains to understand effects on footings, foundation walls, slab on grade, retaining walls, etc.		Medium	
Wind driven rain index/factor is a current data gap that relates to the building envelop's ability to		Develop and present a combination wind/rain index in future climate change		Medium	

4.5.2 Recommendations					
Infrastructure Component / Data Gap	**Remedial Engineering Action**	**Management Actions**	**No further Action**	**Recommendation Priority (low, medium, high)[7]**	**Comments**
shed and redirect rain and snow.		scenarios for buildings.			
Changes in river water temperature is a data gap that will affect the cooling capacity at facilities that rely on this method.		Use data and information gathered under the studies recommended above for Cooling System and Adequacy		Medium	

4.5.2.f
Report on the other conclusions, trends, insights and limitations

The following recommendations have been drawn regarding the use of climate change models and scenarios in the vulnerability assessment of buildings. The climate change scenarios and indices should be improved as follows:

- The scenarios should present (in addition to specific indices) a layperson's indication of what climate would be like in 10, 20, 50 year time horizon, e.g. in 2050 Ottawa's climate will be roughly similar to Philadelphia. This would allow research and comparison of building codes and best design practices in those regions to inform changes that need to occur in the local region being studied.
- The terminology and parameters used in the climate change indices and scenarios should be aligned with National Building Code, CSA and ASHRAE standard terminologies. If larger numbers of building assessments are conducted, PIEVC, PWGSC and Environment Canada should explore possible collaboration between CSA, ASHRAE and Scenario Modellers to align terminology used in the PIEVC Protocol and the standards used in the industry.
- Additional climate parameters or indices would aid the assessment process that are aligned with ASHRAE tools and standards, such as:
    - Dew point frequency dist.
    - Enthalpy freq. dist
    - Wind speed freq. dist
    - Dry/wet bulb-wind joint parameter
    - Humidity-temp joint parameter
    - Elevation/topography data would be important for buildings closer to rivers, streams, lakes etc.

The project team recognizes that the Main Statistics Canada Building has Heritage designation. This will and should be strongly considered when possible engineering solutions are evaluated and considered. Mitigation and adaptation techniques will need to factor in

this designation. This may be particularly important for changes required in the building envelop that may or may not affect the building's façade, profiles and aesthetics.
To summarize, of highest priority are: • the walkways, parking areas, stairs and ramps because of potential risk to human health, safety, injury, falling etc. • the building envelop because of accelerated deterioration that will affect the structural integrity of the building • the adequacy of the cooling system because is poses significant costs to PWGSC and directly affects occupant comfort, health and safety, and productivity • Power supply and reliability is also in question such that it will significantly affect the operations. Action on these three areas as per the discussed recommendations should be initiated within the next 6-18 month timeframe

Date:	May 9, 2008
Prepared by:	Vince Catalli

Vulnerability Assessment Matrix – Jean Talon Building

Jean Talon Building	Climate Factors																																	
	Temperature				Rain				Snow and Wind								Frost Season Length				Heating Degree Days				Cooling Degree Days				Humidity							
Future Change/Infrastructure Component/System	Increases in monthly tmax and tmin and annual avg. max and min				Avg. total rain increases DJF, MAM, SON. Decreases JJA. Avg. Max rain increases for 1, 2 and 5 day periods.6h frequency increases. 1 day frequency increases. Simple daily intensity index increases.				Average total snow increases. 1 day frequency increases. Rain on Snow events increases.				Monthly avg wind6h - windier winters, calmer summers. Avg. annual max wind6h - decreases.				Frost season length decreases, and frequency of freeze/thaw events decreases				Less HDDays				More CDDays				Humidity (monthly average) increases							
	Y/N	S_C	S_R	P_r	Y/N	S_C	S_R	P_r	Y/N	S_C	S_R	P_r	Y/N	S_C	S_R	P_r	Y/N	S_C	S_R	P_r	Y/N	S_C	S_R	P_r	Y/N	S_C	S_R	P_r	Y/N	S_C	S_R	P_r				
EXTERIOR SYSTEMS																																		
Site Drainage – related to slopes away from the building and includes soil permeability and hard surfaces like stairs / ramps	yes	4	3	12	yes	4	3	12	yes	4	3	12					yes	4	3	12	no			0	no			0	no	0	0	0			
Site Drains – storm/rain water	no			0	yes	4	2	8	yes	6	6	36					yes	4	3	12	no			0	no			0	no	0	0	0			
Walls																																		
Freestanding																																		
concrete	no			0	yes	4	3	12	yes	4	3	12				0				0	no			0	no			0	no			0			
Retaining																																		
concrete	no			0	yes	4	3	12	yes	4	4	16				0				0	no			0	no			0	yes	4	3	12			
Walkways																																		
Asphalt	yes	4	4	16	no			0	yes	7	6	42				0				0	no			0	no			0	no			0			
Concrete	no			0	yes	4	2	8	yes	7	6	42				0				0	no			0	no			0	no			0			
Unit pavers	n/a			0	n/a			0	n/a			0				0				0	n/a			0	n/a			0	n/a			0			
Stairs																																		
Concrete	yes	4	4	16	yes	4	3	12	yes	6	6	36				0				0	no			0	no			0	yes	2	3	6			
Ramps (concrete)	yes	4	4	16	yes	4	3	12	yes	6	6	36				0				0	no			0	no			0	yes	2	3	6			
Loading dock (concrete and enclosed area)	no			0	yes	4	3	12	yes	5	4	20				0	yes	5	4	20	no			0	no			0	no			0			
Parking, vehicle areas																																		
Asphalt	yes	4	4	16	no			0	yes	4	4	16				0				0	no			0	no			0	no			0			
Tunnel manholes/access doors	no			0	no			0	no			0				0				0	no			0	no			0	no			0			
BUILDING SYSTEMS																																		
Foundations, Floors and Roofs																																		
Footings – concrete	no			0	yes	4	2	8	no			0				0	no			0	no			0	no			0	no			0			
Walls - concrete	yes	4	3	12	yes	4	3	12	no			0				0	no			0	yes	4	4	16	no			0	yes	2	3	6			
Slab on grade - concrete	no			0	yes	3	3	9	no			0				0	no			0	no			0	no			0	no			0			
Envelop Systems																																		
Precast Concrete	yes	4	3	12	yes	4	4	16	yes	5	4	20				0				0	yes	4	4	16	yes	4	4	16	yes	4	4	16			
Glazed Curtain wall	yes	4	3	12	yes	4	4	16	yes	5	4	20				0				0	yes	4	4	16	yes	4	4	16	yes	4	4	16			
Doors																																		
Doors (Steel / Aluminum)	no			0	no			0	no			0				0	no			0	no			0	no			0	no			0			
Flat Roof Systems (including roof drains)	yes	3	3	9	yes	5	4	20	yes	5	4	20				0				0	no			0	no			0	no			0			
MECHANICAL SYSTEMS																																		
Heating System and Adequacy	no			0	no			0	yes	4	4	16				0	no			0	yes	2	2	4	no			0	no			0			
Cooling System and Adequacy	yes	4	4	16	no			0	no			0				0	no			0	no			0	yes	2	2	4	yes	7	6	42			
ELECTRICAL SYSTEMS																																		
Emergency power systems / generators (including fuel supply)	yes	4	4	16	yes	2	2	4	no			0				0	no			0	no			0	yes	2	2	4	no			0			
Power Supply and Reliability	yes	4	4	16	yes	2	2	4	no			0				0	no			0	no			4	yes	7	5	35	yes	7	5	35			

NOTE: Gray shading indicates climate factors that are related to one another and may have cumulative effects on the building components.

S_C – Probability of climate factor affecting building component – Rate on a scale of 0-7. 0 = negligible/not applicable, 7 = certain/highly probable

S_R – Severity of climate factor affecting building component – Rate on a scale of 0-7. 0 = negligible/not applicable, 7 = extreme/frequent/continuous/loss of asset

Vulnerability Assessment Matrix – Brooke Claxton Building

Brooke Claxton Building	Climate Factors																													
	Temperature				Rain				Snow and Wind								Frost Season Length				Heating Degree Days				Cooling Degree Days				Humidity			
Future Change/Infrastructure Component/System	Increases in monthly tmax and tmin and annual avg. max and min				Avg. total rain increases DJF, MAM, SON. Decreases JJA. Avg. Max rain increases for 1, 2 and 5 day periods.6h frequency increases. 1 day frequency increases. Simple daily intensity index increases.				Average total snow increases. 1 day frequency increases. Rain on Snow events increases.				Monthly avg wind6h - windier winters. calmer summers. Avg. annual max wind6h - decreases.				Frost season length decreases. and frequency of freeze/thaw events decreases				Less HDDays				More CDDays				Humidity (monthly average) increases			
	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C	Y/N	S_C	S_R	P_C
EXTERIOR SYSTEMS																																
Site Drainage – related to slopes away from the building and includes soil permeability and hard surfaces like stairs / ramps	yes	2	1	2	yes	5	4	20	yes	2	2	4				0	yes	2	2	4	no			0	no			0	no			0
Site Drains – storm/rain water	no			0	yes	4	5	20	yes	3	3	9				0	yes	3	2	6	no			0	no			0	no			0
Walls																																
Freestanding																																
concrete	n/a			0	n/a			0	n/a			0				0				0	n/a			0	n/a			0	n/a			0
masonry	n/a			0	n/a			0	n/a			0				0				0	n/a			0	n/a			0	n/a			0
Retaining																																
concrete (Podium Walls)	yes	2	1	2	yes	5	4	20	yes	4	3	12				0				0	no			0	no			0	yes	3	3	9
Walkways																																
Asphalt	yes	4	4	16	no			0	yes	7	6	42				0				0	no			0	no			0	no			0
Concrete	no			0	yes	2	2	4	yes	7	6	42				0				0	no			0	no			0	no			0
Unit pavers	no			0	yes	2	2	4	yes	7	6	42				0				0	no			0	no			0	no			0
Stairs																																0
Concrete	yes	3	3	9	yes	2	2	4	yes	6	6	36				0				0	no			0	no			0	yes	2	3	6
Metal	n/a			0	n/a			0	n/a			0				0				0	n/a			0	n/a			0	n/a			0
Ramps (concrete)	yes	3	3	9	yes	2	2	4	yes	6	6	36				0				0	no			0	no			0	yes	2	3	6
Loading dock (concrete and recessed / opened)	yes	3	3	9	yes	2	2	4	yes	3	3	9				0	no			0	no			0	no			0	no			0
Air Intake Wells																																
Concrete	no			0	yes	3	3	9	yes	5	4	20				0				0	no			0	no			0	no			0
Gutters - metal	yes	2	2	4	yes	5	5	25	yes	5	3	15				0				0	no			0	no			0	no			0
Parking, vehicle areas																																0
Asphalt	yes	4	5	20	no			0	yes	7	6	42				0				0	no			0	no			0	no			0
Concrete	no			0	yes	2	3	6	yes	7	6	42				0				0	no			0	no			0	no			0
Unit pavers	no			0	yes	2	3	6	yes	7	6	42				0				0	no			0	no			0	no			0
Tunnels manholes/access doors	no			0	yes	4	5	20	yes	7	3	21				0				0	no			0	no			0	no			0
BUILDING SYSTEMS																																
Foundations, Floors and Roofs																																0
Footings – concrete	no			0	yes	4	3	12	no			0				0	no			0	no			0	no			0	no			0
Walls - concrete	yes	3	3	9	yes	5	4	20	no			0				0	no			0	no			0	no			0	yes	2	3	6
Slab on grade - concrete	no			0	yes	4	3	12	no			0				0	no			0	no			0	no			0	no			0
Concrete Roof	yes	3	3	9	no			0	yes	3	3	9				0				0	no			0	no			0	no			0
Envelop Systems																																
Precast Concrete	yes	3	3	9	yes	4	4	16	yes	3	3	9				0				0	yes	4	3	12	yes	5	3	15	yes	3	3	9
Glazed Curtain wall (original 1964)	yes	4	4	16	yes	4	3	12	yes	3	3	9				0				0	yes	4	4	16	yes	4	2	8	yes	5	3	15
Masonry wall (roof top level)	yes	3	3	9	yes	5	4	20	yes	3	3	9				0				0	yes	2	2	4	yes	2	2	4	yes	3	2	6
Granite covered Columns (over structure)	yes	3	3	9	yes	4	5	20	yes	4	3	12				0				0	yes	4	3	12	yes	2	2	4	yes	3	3	9
Metal Cladding	n/a			0	n/a			0	n/a			0				0	n/a	3	3	9	n/a			0	n/a			0	n/a			0
Windows / Doors																																
Aluminum Windows (original 1964)	yes	3	3	9	yes	4	3	12	yes	3	3	9				0	no			0	yes	4	4	16	yes	5	3	15	yes	5	3	15
Doors (Steel / Aluminum)	yes	3	3	9	yes	3	2	6	no			0				0	no			0	no			0	no			0	yes	3	3	9
Flat Roof Systems (including roof drains)	yes	6	5	30	yes	5	5	25	yes	5	4	20				0				0	no			0	no			0	no			0
MECHANICAL SYSTEMS																																
Heating System and Adequacy	no			0	no			0	no			0				0	no			0	yes	4	3	12	no			0	no			0
Cooling System and Adequacy	yes	5	6	30	no			0	no			0				0	no			0	no			0	yes	7	5	35	yes	7	6	42
ELECTRICAL SYSTEMS																																
Emergency power systems / generators (including fuel supply)	no			0	yes	2	3	6	no			0				0	no			0	no			0	yes	2	2	4	no			0
Power Supply and Reliability	yes	5	6	30	yes	2	3	6	no			0				0	no			0	no			0	yes	7	5	35	yes	7	5	35

NOTE: Gray shading indicates climate factors that are related to one another and may have cumulative effects on the building components.

S_C – Probability of climate factor affecting building component – Rate on a scale of 0-7. 0 = negligible/not applicable, 7 = certain/highly probable

S_R – Severity of climate factor affecting building component – Rate on a scale of 0-7. 0 = negligible/not applicable, 7 = extreme/frequent/continuous/loss of asset