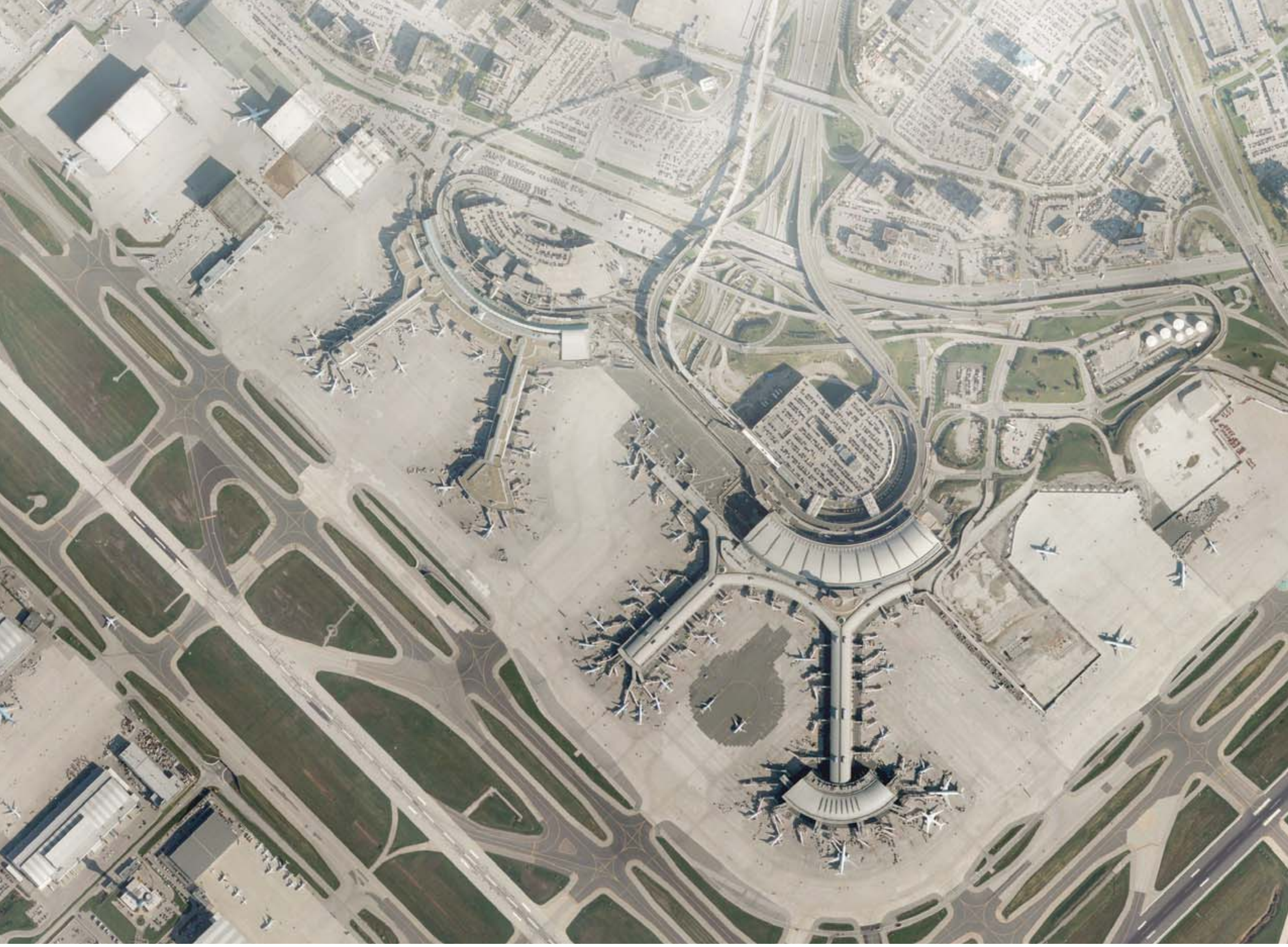

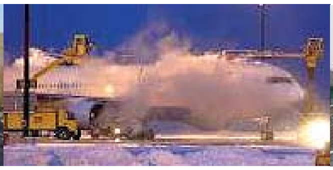

Climate Change Vulnerability Assessment

for Selected Stormwater Infrastructure at Toronto Pearson International Airport

August 2014

Toronto Pearson
For You. The World.

FINAL

Executive Summary

Introduction

The Greater Toronto Airports Authority's (GTAA's) mandate is to ensure that the Airport's facilities and air services match the needs of the growing population of the GTA and south-central Ontario. The Greater Toronto Area (GTA) is a 7,125 km^2 area consisting of the City of Toronto plus the neighbouring regional municipalities of Halton, Peel, York, Durham, and their 24 constituent municipalities. Toronto Pearson is the principal airport for southern Ontario. To address this significant responsibility, the GTAA embarked on a 30-year vision for the development of Toronto Pearson in 1996. Since that time, the GTAA's primary focus has been to replace obsolete airport infrastructure in order to improve the facilities and services that Toronto Pearson has to offer the region it serves.

Toronto Pearson is located 25 km northwest of Toronto's central business district in the heart of the southern Ontario region. The Airport is surrounded by a variety of industrial, commercial and residential land uses and is bound by a series of major highways and regional arterial roads. The area of land within the current operational boundary of Toronto Pearson covers 1,867 ha (4,613 acres) and encompasses airside facilities, passenger and cargo terminals, parking, access roads, business aviation, and aviation support facilities.

Due to its favourable location within Canada and North America, Toronto Pearson not only serves those visiting or living within south-central Ontario, but also the growing number of passengers using the Airport as a connecting point for onward journeys. Toronto's central gateway location means that an estimated 60 per cent of North America's population is within a 90-minute flight from Toronto Pearson.

PIEVC Engineering Protocol

To assess the potential impacts of climate change on public infrastructure and to advance planning and prioritization of adaptation strategies, Engineers Canada and its partners have established the Public Infrastructure Engineering Vulnerability Committee (PIEVC). Co-funded by Engineers Canada and Natural Resources Canada, the PIEVC is comprised of representatives from all three levels of government as well as non-governmental organizations. The Committee oversees the planning and execution of a national engineering assessment of the vulnerability of Canadian public infrastructure to climate change. The work of the PIEVC commenced in 2007 with a scoping study to examine the current state of infrastructure, the availability of climate data, and indicators of adaptive capacity during the development of the PIEVC Protocol for infrastructure vulnerability assessment. The Protocol was subsequently evaluated through seven pilot studies, which were included in the first national assessment report completed by the PIEVC in April 2008. Based on the success of these early studies and the interest among public infrastructure stakeholders in the results, Engineers Canada is continuing to promote the application of the PIEVC protocol in additional case studies in four priority infrastructure categories: buildings, roads and associated structures, stormwater and wastewater systems and water resources infrastructure. The results of these studies will be used to continue to refine and improve the protocol and further the program goals of supporting vulnerability assessment and adoption of best practices at the national scale.

The GTAA decided to undertake an engineering vulnerability assessment of infrastructure in the context of both the existing climate and future climate change, using the PIEVC Protocol. The PIEVC Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment (Version 10, October, 2011), hereafter referred to as the Protocol, is a step-by-step process to conduct an engineering vulnerability assessment on infrastructure due to climate change.

Potential issues and concerns arising from changing climate:

- Airport infrastructure is considered vulnerable to the types of weather related stresses that will be exacerbated by climate change;
- Climate change could threaten airport infrastructure;
- Potential flooding of runways, taxiways, aircraft manoeuvring areas, access roads could cause operational delays and physical damage to airport property;
- Stormwater runoff may exceed capacity of drainage and drainage systems;
- Potential wind damage to terminals, navigation equipment and signage;
- Disruption of airport operations, ground access, services supplied to the airport;
- Change in de-icing operations (increase, decrease of de-icing fluid quantities); and,
- Different needs for snow clearance and de-icing include combination of less snow but more ice.

The five steps within the Protocol carried out to complete the vulnerability assessment were as follows:

Step 1 – Project Definition
The boundary conditions for the vulnerability assessment were determined in Step 1. A description of the infrastructure including its location, age, loads, historical climate, and other relevant factors were developed.

Initially, only certain components of the drainage and stormwater management system and the Spring Creek triple cell box culvert at Toronto Pearson will be assessed in detail. Ultimately, other infrastructure at Toronto Pearson will be assessed.

Step 2 – Data Gathering and Sufficiency
The specific features of the infrastructure to be considered in the assessment as well as the applicable climate information were identified and evaluated for sufficiency in Step 2.

Step 3 – Risk Assessment
The interactions between the infrastructure, the climate, and any other factors that could lead to vulnerability were identified in Step 3. This included identifying specific infrastructure components, specific climate change parameter values, and specific performance goals.

In this step, the infrastructure’s response to the climate parameters was identified. Based on the Protocol, the overall risk value associated with an interaction between an infrastructure component and a climate related event was determined by multiplying the probability of the event occurring by the severity of the impact.

Scales of 0–7 were established for the probability of the interactions occurring and the severity resulting from the interaction. The Protocol provides three alternate methods each for the probability and severity scales from which the most appropriate method for this assessment was selected.

Performance response categories were established based on the most likely response of an infrastructure component to contemplated climate events. The performance response categories were based on professional judgment and experience. Instead of assessing the severity scale factor of each performance response for individual infrastructure components, all the performance responses that were relevant were check marked, and only one severity scale factor was applied. The severity scale factor that was applied was based on judgment of the performance response that was most critical to the individual infrastructure-climate interaction.

The following points summarize the risk assessment findings for Toronto Pearson:

- Out of the 11,640 interactions identified for the risk assessment, about 27% had a risk score of above 12 and were therefore considered to be relevant for further consideration during engineering analysis. No interactions had a risk score of above 36, therefore none were considered to be high risk as defined by the Protocol;
- About 10% of low risk interactions increased to a medium risk score as a result of climate change. The highest increases were associated with extreme heavy rainfalls, heavy rainfalls, freezing rain, ice storms, and hurricanes/tropical storms.
- About 10% of medium risk interactions decreased to a low risk score as a result of climate change. The highest decrease was by a score of 6. This was associated with potential future decreases in cold waves and freeze-thaw cycles.
- Approximately 90% of interactions maintained their risk classification.

Step 4 – Engineering Analysis

The impact on the infrastructure and its capacity resulting from the projected climate change loads was assessed in Step 4. This included a focused engineering analysis on the relationships determined to have vulnerability in Step 3.

The infrastructure-climate interactions that scored a medium risk value (between 12 and 36) in Step 3 were analyzed further under this step. The analysis included a determination of the relationship between the loads placed under both existing and future conditions and the infrastructure components and their capacity.

Vulnerability exists when the infrastructure has insufficient capacity to withstand the loads placed upon it. Therefore, there is a capacity deficit when vulnerability exists. There is adaptive capacity when the infrastructure is resilient i.e. it has sufficient capacity to withstand the climate change effects without compromising the ability of the infrastructure to perform as required. The Protocol dictates that the total loading and total capacity be used to calculate the Vulnerability Ratio.

In general, data was insufficient to complete the engineering analysis in the specific quantitative method prescribed by the Protocol. In determining the climate load from the results of the Climate Analysis and Projections, the units were generally represented by number of occurrences per year, or a probability of the event occurring in a given year. This definition allowed the assignment of an existing and future climate load, however made the determination of the capacity of a component impossible in any meaningful, scientific way. For example, it is impossible to determine how many ice storms the bridge deck could withstand in a given year, or to put any number to the capacity of the operation buildings and tornadoes.

In light of the above, experience and professional engineering judgment were utilized to estimate whether or not the component was vulnerable or not, to a singular, or multiple, occurrences of the climate parameter. Therefore, the vulnerability ratio was qualitatively assessed to being either greater or less than one. If the total capacity was estimated to be greater than the total load, then the vulnerability ratio was listed as less than one. A vulnerability ratio of less than one means that the infrastructure component was resilient and not vulnerable to the climate parameter. If the total capacity was estimated to be less than the total load, then the vulnerability ratio would be greater than one, indicating that vulnerability exists.

The Engineering Analysis generally resulted in a determination of the vulnerability of the infrastructure components to a single occurrence of the climate event, rather than the probability or frequency of the event. For example, personnel could be identified as being vulnerable to a freezing rain event for both existing and future conditions, with no distinction made regarding whether personnel are more or less vulnerable in the future with an increased probability of freezing rain events, as there is no information available with which to determine whether a change in frequency would increase the vulnerability of the components.

The above notwithstanding, it was possible to make a determination of the difference between existing and future risk for the components and interactions identified as 'vulnerable' by revisiting the results of the Risk Assessment completed in Step 3. In that assessment, the probability scores did change for some climate events, from the existing to future conditions, and the associated risk scores changed as well. Based on a comparison of those existing and future risk scores for vulnerable components and interactions, the potential effect of climate change in modifying risk to those components could be determined. The following sections provide a summary of the results for Toronto Pearson.

The following points summarize the vulnerabilities identified in the engineering analysis step:

- A total of 3199 interactions were considered in the engineering analysis step;
- There were 7 interactions assessed to be vulnerable; and,
- Generally, the vulnerabilities exist to the following climate events: Extreme Heavy Rainfall, Heavy Rainfall and 5-Day Heavy Rainfall.

Step 5 – Recommendations

The limitations and recommendations on the observations and findings of the infrastructure vulnerability assessment in Steps 1 to 4 were determined in Step 5.

The main objective of this assessment is to identify components of the infrastructure which are at increased risk of failure, damage, deterioration, reduced operational effectiveness, and/or reduced life cycle from potential future changes in climate. Additionally, the study contains recommendations for remedial action to minimize the vulnerability and/or complete further study to further quantify the risks.

During the completion of Step 5, recommendations were provided for actions to be taken to address the potential vulnerabilities, or for further investigations for GTAA to determine the extent of the vulnerability. These recommendations were provided for each of the components which were determined to be vulnerable.

Climate Analysis and Projections

The study involved an assessment of the vulnerabilities of the facilities to current climate (existing and/or historical conditions), as well as future climate change at the 2050 time horizon. This study included assessment of the existing risks and vulnerabilities associated with the current climate, assessment of future risks and vulnerabilities, and an analysis of the change between the two.

The climate analysis and projections portion of this study included the establishment of a set of climate parameters describing climatic and meteorological phenomena relevant to the geographic areas of the Toronto Pearson.

The following climate parameters were selected for analysis in this study: High Temperature, Low Temperature, Heat Wave, Cold Wave, Extreme Diurnal Temperature Variability, Freeze Thaw, Extreme Heavy Rain, Heavy Rain, Heavy 5-Day Total Rainfall, Rain Frequency, Wet Days, Winter Rain, Freezing Rain, Ice Storm, Heavy Snow, Snow Accumulation, Blowing Snow/Blizzard, Lightning, Hailstorm, Hurricane/Tropical Storm, High Wind, Tornado, Drought/Dry Period, Heavy Fog, Dust Storm, Frost and Acid Rain.

Specific definitions for the climate parameters analyzed were established and were based on three factors: a) the usefulness of the climate parameter in determining vulnerability, b) the availability of information, and c) the ability to relate this information to a probability. In addition, two tiers of parameter definitions were established based on the nature of each specific climate phenomenon. “Tier one” definitions refer to commonly occurring climate phenomena and were defined as the probability of exceeding the historical average occurrence, whereas “Tier Two” definitions refer to extreme events and were defined as the frequency of occurrence in a given year.

The most common time frame used for analysis of historical climate data was 1971 to 2000, as this is the most recent 30-year climate normal period.

Wherever possible, the time frame used for future projections was the 30-year period of 2041 to 2070, or more commonly expressed as “the 2050s”. Assessment of vulnerability beyond this horizon was not conducted as it was agreed among the study team members that this would likely surpass the design life of the infrastructure without the undertaking of significant reconstruction or rehabilitation efforts. The level of uncertainty associated with future climate projections also increases significantly beyond the middle of this century, which would potentially call into question the usefulness of the results.

The following Climate Parameters experienced no change in Probability Score from historical to future: Winter Rain, Heavy Snow, Blowing Snow/Blizzard, Lightning, Hailstorm, High Wind, Tornado, Dust Storm, Acid Rain and Heavy Fog.

In addition to determining Probability Scores, known or calculated climate parameter frequencies were used as climate loads in the Engineering Analysis phase of the project.

The study did not include a detailed hydrologic or hydraulic assessment of the stormwater facilities. A separate study by Cole Engineering Group Ltd is being undertaken to update the Master Stormwater Implementation Plan and Flood Risk Analysis. Through previous studies, the stormwater infrastructure have generally been found to be resilient to a variety of high inflow conditions below design magnitudes. For the purposes of this study, changes to high inflow regimes were examined only from a general, qualitative basis in the assessment in consideration of indirect or secondary effects.

Recommendations

Some specific key recommendations from the study are as follows:

- GTAA should review the emergency operational plans currently in place to ensure they are adequate for all types of climate events – rain, snow, ice, high winds. From this review, it would be prudent to extrapolate for the extreme events considered in this assessment to ensure operations personnel are comfortable with the safeguards in place.
- There were a number of climate-component interactions that had an overall low risk score under both existing and future conditions due to a low probability of occurrence, but for which impacts would be extremely severe. These risk interactions were considered to be important, since the high severities indicated the potential for a critical loss of function; it is therefore advisable to consider the potential impacts and consequences of these "high-impact" events, and potentially to also develop mitigation or response plans to address them. The main climate conditions involved in these interactions with low risk scores and high severities are extreme heavy rainfalls, tornados, and hurricane/tropical storms.
- Many of the recommendations of the study are based on assessed risk and vulnerability that are considered to remain the same or become greater as a result of the potential outcomes of climate change. However, assumptions regarding climate change outcomes were based on analysis of current climate understanding and predictive science, which in itself involves a great deal of uncertainty. It is therefore suggested that the recommendations of this study be revisited with updated climate analysis and projections if climate science is able to provide more precision or certainty in the future.
- Generally, the results of the engineering analysis demonstrate that the stormwater facilities have relatively low vulnerability to potential future climate change. Part of the reason for the relatively low vulnerability is the excellent condition that the stormwater facilities are in; this is due to combination of resilient design, a high quality of construction, consistent inspections and maintenance on the part of GTAA staff.
- The PIEVC protocol recommends that an adaptive management process be utilized to revisit the vulnerability assessment at defined intervals to incorporate new information including improved climate science and future climate projections. Considering the manner in which the climate analysis and projections portion of this study is organized, and the thorough documentation of the assumptions regarding the use of the information in the risk and vulnerability assessment, incorporating new climate-related information should be a relatively straightforward process. Additional climate parameters may also be incorporated by following the format in which the existing climate parameters are provided. The remaining portions of the study (Risk Assessment and Vulnerability Analysis) have been presented in this document according to the procedures prescribed by the PIEVC Protocol.

Conclusions

Having utilized the protocol to assess the stormwater facilities and Spring Creek triple cell box culvert, the project team determined that, in general, the facilities have the capacity to withstand the existing and projected future climate (i.e. to the 2050s).

The climate analysis revealed some changes in frequency of climate events that will result in a decrease in vulnerability for the infrastructure. With the generally higher temperatures projected for the study area, there will be less probability, or less frequency of the low temperature dependant events such as freeze/thaw, snow accumulation and cold wave. This reduced frequency of occurrence will result in a decreased potential vulnerability from the events. This can be viewed as a potential positive impact of future climate change.

The climate events posing the highest vulnerability to the stormwater facilities, particularly in terms of number of components potentially vulnerable, are generally extreme events such as extreme heavy rainfalls. While this was an expected outcome, it should be highlighted that the current climate science indicates that the possibility of these events occurring is going to increase in the future.

Many of the vulnerabilities exist to extreme weather events such as tornados or hurricanes, and while it is difficult to completely protect the infrastructure from events such as these, there are actions which can be taken to minimize the operational risks and prepare for the events. These include: reviewing emergency response plans, and completing operational tests where power, communication and back-up systems are “lost”.

While the overall conclusion of the report is that the stormwater facilities are generally able to withstand expected changes in climate in the future, it will continue to be important to monitor some of the risks and vulnerabilities identified through the assessment, particularly as components continue to age. It will be important to preserve the high standard of maintenance and management that GTAA has devoted to the stormwater facilities to this point. It will also be prudent to monitor the progress in climate science so that if future projections are updated or improved, the infrastructure assessment can be revisited.