Climate Change and Flood Resilience Practices

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About OCC

The OCC was established in 2011 as a centre of expertise providing research and analysis services to municipalities, conservation authorities, and the broader public sector.
Because of heat-trapping gases in the atmosphere are rising...

First Time over 400 ppm

409 ppm

406 ppm
The Globe is Warming.. but warming is not the same everywhere

Land & Ocean Temperature Departure from Average Jan–Dec 2016
(with respect to a 1981–2010 base period)

Data Source: GHCN–M version 3.3.0 & ERSST version 4.0.0

2017 January to September 9-month mean is second highest, behind 2016
(compared to the first nine months of other years)
Climate Modeling Scenarios

The diagram illustrates various climate change scenarios, including the Historical, 2012 Estimate, RCP8.5, RCP4.5, RCP6, and RCP3-PD. The y-axis represents Fossil fuel, cement production, and gas flaring emissions (PgC/yr), while the x-axis shows years from 1980 to 2100.

- **Historical** emissions have remained relatively constant.
- **2012 Estimate** shows a slight increase.
- **RCP8.5** (4.0–6.1°C) has the highest emissions, reaching nearly 30 PgC/yr by 2100.
- **RCP4.5** (2.0–3.0°C) and **RCP6** (2.6–3.7°C) have moderate emissions, with RCP4.5 peaking around 2050 and RCP6 peaking around 2080.
- **RCP3-PD** (1.3–1.9°C) shows the lowest emissions, with a gradual increase but remaining under 10 PgC/yr.

The shaded area represents historical uncertainty, and earlier scenarios are indicated by lighter lines.
In Canada the Insurance Sector and the Federal Disaster Financial Assistance are Anticipating...

Estimated DFAA annual weather event costs

- Floods: $19 million
- Convective Storms: $2 million
- Winter Storms: $673 million
- Hurricaines: $18 million

Source: PBO; RMS; IBC; DFAA and Swiss Re.


Uncertainty? Localized Vulnerability and Solutions?
Precipitation Changes Projected for Ontario (2050’s)

Average 6% = 836mm

Source: http://lamps.math.yorku.ca
Precipitation *Likely* to Increase by mid-Century  
(RCP 8.5 - York Region Climate Trends Study)

<table>
<thead>
<tr>
<th>Climate Variable</th>
<th>Historical (1981-2010)</th>
<th>Future (2050s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Precipitation</td>
<td>853.5mm per year</td>
<td>902mm – 937mm per year</td>
</tr>
<tr>
<td>1-Day Max Precipitation</td>
<td>39.3mm</td>
<td>11% to 48% increase</td>
</tr>
<tr>
<td>5-Day Max Precipitation</td>
<td>61.4mm</td>
<td>19% to 36% increase</td>
</tr>
</tbody>
</table>

*Note:* Trends differ depending on the season. Summer Precipitation for example is projected to *Decrease*.
Precipitation Changes Projected for Ontario (2080’s)

Average 11% = 870mm

Source: http://lamps.math.yorku.ca
OCC, TRCA and ESSEX Exploring Implications of Updating IDF Curves

- Toronto and Region Conservation Authority
  - Ryan Ness
- Ontario Climate Consortium
  - Edmundo Fausto
- Essex Region Conservation Authority
  - John Henderson
  - Richard Wyma
- McMaster University
  - Dr. Paulin Coulibaly
- University of Waterloo
  - Dr. Donald Burn
Study Objectives

- To understand implications of using different methods updating climate change into IDF curves
- To compare outcomes of different methods deriving IDF and incorporating CC.

Annual maximum rainfall durations (1hr, 2hr, 3hr, 6hr, 12hr, 24hr)
Figure A-18: IDF Curve Comparison for Pearson Airport, 2090s 100-year Return Period Event (10th–90th Percentile)

- 10th to 90th Percentile Range
- (a) Hist. Gumbel: $R=52.89T^{-0.685}$
- (b) Hist. GEV: $R=49.11T^{-0.688}$
- (c) Fut. Ensemble Min.: $R=37.36T^{-0.675}$
- (d) Fut. Ensemble 10th Percentile: $R=42.78T^{-0.69}$
- (e) Fut. Ensemble 90th Percentile: $R=87.1T^{-0.705}$
- (f) Fut. Ensemble Max.: $R=102.36T^{-0.75}$
Initial Value (weather forecast) vs Boundary Value problem (climate model)

- Initial Value Problem
  - Initial Condition
  - Thermodynamics and Motion
  - Chaos Nature of Atmosphere
  - Forecast

- Boundary Value Problem
  - Initial Condition
  - Energy Budget
  - Sensitivity of Climate Systems
  - System Governed by Boundary Conditions
Sources of Uncertainty in Climate Projections

Evolution of Boundary Conditions
GHG Emissions
Human decisions
Climate model processes, data & uncertainty
Natural variability

Source: IPCC AR5 Figure 11.8
Uncertainty is not Uniform Across Indicators

MORE Certainty

- Warmer winters
- More heat waves
- More intense rainfalls
- Longer growing season (frost-free)

LESS Certainty

- More winter precipitation
- More ice storms
- Increase in wind extremes

*It is important to understand the limitations of climate information used – OURANOS (2014)*
IDF Study Lessons Learned

• GEV distribution function was a better fit for screened stations.

• Climate models aren’t great resolving convective extreme rainfall events, but they provide useful information on how the atmospheric physics may change.
  • Climate model and emissions scenario selection has a profound effect on calculated IDF curves.

• IDF statistics vary widely between stations in the same area: selection of climate station also has a profound effect on calculated IDF. (Regional IDFs?)

• Range of uncertainty for short durations and large return periods at a single station can exceed 100%
Next Steps:

• Characterize existing vulnerability which may influence future risk (Considering Climate Projections)

• Municipal Stormwater Infrastructure Infrastructure Design under Climate Change Project
  – Shift focus away from the derivation of a single, definitive set of future IDF curves to a probability based approach or one focused on risk tolerance
Leverage Existing Vulnerability and Risk Assessment Frameworks

**Scales**

- Community
- System
- Asset

**Examples**

- ICLEI
- City of Toronto Tool (COT)
- Public Infrastructure Engineering Vulnerability Committee (PIEVC)
Determine Existing Risk Tolerance

e.g., City of London (UK)
Municipal Stormwater Infrastructure Design under Climate Change Project

**Objective:** To provide technical guidance for stormwater infrastructure owners on how to incorporate climate change into infrastructure design

- Working Group established among municipal partners
- Literature Review and Mapping adaptation pathways to identify broad patterns, trends and options for asset design & management (ongoing)
- Stakeholder workshop with experts to (late summer)
- Produce Technical Guidelines (early fall)

**Goal:** Shift focus away from the derivation of a single, definitive set of future IDF curves to a probability based approach or one focused on risk tolerance
Flood Resilience Initiatives at TRCA
Utility Management Forum
October 24, 2017

Sameer Dhalla, P.Eng.
Extreme Weather and Flooding on the Rise

Harrow 1989
264mm
50mm/h

Peterborough 2004
290mm
90mm/h

August 19
2005
122mm
237mm/h

July 8
2013
126mm
110mm/h
High Costs of Flooding

Federal Disaster Financial Assistance payments by province and territory
1970-2014

Source – Estimate of the Average Annual Cost for Disaster Financial Assistance Arrangements due to Weather Events (PBO, 2016)
Riverine vs. Urban Flooding

Riverine Flooding

Cost of 2013 Calgary Flood – Approx. $6 billion (Canadian Underwriter)

Cost of 2013 Toronto Flood – Approx. $1 billion (Canadian Underwriter)
Hurricane Hazel and the history of flood control
Hurricane Hazel by the numbers

**ENVIRONMENT CANADA PRECIPITATION TOTALS**

- Snelgrove: 285 mm
- Brampton: 210 mm
- Weston: 127 mm
- University: 90 mm
- Danforth: 76 mm

**HAZEL IN NUMBERS**

- **81**: The number of people in Ontario who lost their lives.
- **32**: The number of houses on Raymore Drive washed away by flood water.
- **155**: Hazel’s maximum wind speed (mph).
- **4,000**: The number of people left homeless in southern Ontario.
- **$100 MILLION**: The cost of the destruction (approximately 1 billion dollars today).
- **300 MILLION**: The number of tons of water that fell during the storm.*

*This equivalent to all the water going over Horseshoe Falls in Niagara in 1.5 days.

**DID YOU KNOW?**

- Member of Conservation Ontario

TORONTO AND REGION CONSERVATION AUTHORITY
Property Acquisition
Land Use Planning

- Living City Policies for Planning and Development in the Watersheds of the Toronto and Region Conservation Authority
TRCA’s Jurisdiction

*Etobicoke Creek
• Mimico Creek
• Humber River
• Don River
• Highland Creek

*Rouge River
• Petticoat Creek
• Duffins Creek
• Carruthers Creek

3,467 km²
(~ 850,000 acres)

2,506 km² on land
961 km² water-based

5.9 Million
Greater Toronto Area Population*

*2013 census, Statistics Canada

4th
Largest city in North America

9 watersheds

The TRCA’s jurisdiction also extends into Lake Ontario to a point defined by the Territorial Divisions Act, R.S.O. 1980
The Challenges We Face

INTENSIFICATION

CLIMATE

POPULATION

ECONOMY
Poor Stormwater Management

- Stream bank erosion and bed degradation
- Increased peak flows - flooding
- Increase pollutant loading (including thermal impacts)
- Reduction of groundwater and baseflow
- Loss of aquatic habitat and natural features
- Risk to Infrastructure
Engineering Services and Flood Resiliency

**Recovery**
- Flood Event Documentation and lessons learned
- Storm analysis

**Response**
- Provide Flood Forecasting and Warning (issuing Flood Messages)
- Operate flood control infrastructure
- Communicate information and advice
- Data management

**Preparedness**
- TRCA’s Flood Contingency Plan
- Emergency Plans
- Emergency Operations Centre
- Training
- Public Education

**Prevention & Mitigation**
- Understanding the risks: climate, geology, watershed response and potential for climate change
- Documenting the risks: floodplain mapping, identification of flood vulnerable areas
- Limiting exposure to risk: implementing TRCA’s Planning and Development regulation and policies
- Reducing the risk: operating a flood forecasting and warning program, maintaining flood control infrastructure, creating a flood protection strategy for flood vulnerable areas and the implementation of remedial works projects
Prevention & Mitigation

- Recovery
- Response
- Preparedness
- Prevention / Mitigation
Floodplain Mapping – What is it

**Floodplain Map:** Riverine flood extents of a storm event – most commonly done for the Regulatory storm (either 100-yr storm or Regional storm *(Hurricane Hazel)*).
Reducing Risks = Preserving Greenspace
77% of urban areas do not have adequate stormwater controls (mostly older areas that were developed prior to the required implementation of stormwater management controls)

- Over 1000 SWM Ponds have been constructed mostly in the “905” area
- SWM Ponds provide approximately 20 million cubic meters of flood storage
- G. Ross Lord Dam provides protection to immediately downstream and provides approximately 5 million cubic meters of flood storage
Championing Green Infrastructure

Mitigating Risk in Existing Areas
Total Risk

- Community Resilience
- Flood Risk
- Other risks

Overlay and query in a GIS environment

- Hazard
  - Hydraulic model outputs
- Exposure
  - Structure / parcel data and attributes
- Vulnerability
  - Depth damage and risk to life curves

- Probability
- Extent
- Buildings / Infrastructure
- Population at risk
- Damages
- People impacts
The Common Operating Picture

Flood Risk

Overlay and query in a GIS environment

Legend
- Building Footprint
- 1m Contours
- Watercourse
  - b2yr
  - b5yr
  - b10yr
  - b25yr
  - b50yr
  - b100yr
  - b350yr
  - Regional
Large Scale Flood Mitigation

Lower Don, Toronto

Vaughan Metropolitan Centre

Downtown Brampton
Questions?

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