Introduction

Relevance ➔ Business Continuity

- Assessment of Existing Infrastructure Vulnerability
  - Southern Ontario Climate
  - Application of PIEVC Protocol to 3 Institutional Buildings
- Design Criteria for Future Adaptation
  - Asset Level ➔ Re-engineering, retrofit/renewal, or retirement
  - Organizational Level ➔ Policy development, Management Actions
  - Regulatory Level ➔ Codes & Standards Development, and/or Updating
- Verification of Adaptive Capacity
  - Linkage to Building Durability
Acknowledgement

We would like to thank:

- Infrastructure Ontario,
- Natural Resources Canada
- Environment Canada; and
- Engineers Canada
as partners in this case study.

Ice Road Case Study

Trend in Alaskan winter tundra travel days (Gore, 2006)
Introduction

• Winter Roads and Ice Bridges: Anomalies in Their Records of Seasonal Usage and What We Can Learn From Them (Rawlings et al. 2009)
  – Case Study of winter roads and ice bridges across the NWT.

• Climatic indicators that were included in the study:
  – average temperatures; and
  – precipitation (water equivalent).

• Trend Analysis, NWT
  – Mean annual temperature is generally increasing across the NWT.
  – Operating time of winter roads and ice bridges is decreasing in most areas, but increasing for some areas.

Climate Considerations

– Changes in precipitation may have over-ridden trends in temperature.

– Drier winters may result in lengthening of operating season.

Operational Considerations

– Adaptation practices may help lengthen operating seasons. These practices include:
  • flooding winter roads to thicken ice structure;
  • monitoring ice sheet thickness with ground penetrating radar;
  • plowing snow off the road enhances the freezing effect (snow has an insulating effect); and
  • restricting hauling to hours of darkness towards the end of the season when the ice sheet is stronger.
Climate Basics

- Climate is what you expect, weather is what you get
- All Weather is local
- Seasonal averages (Normals) and weather extremes influence design
- Future projections provide monthly data for temperature and precipitation
- Look backwards to establish trends and background data
- Develop climate indices to better understand weather drivers for design and assessment
- Use all future projections to establish confidence intervals and probabilities for future events
- Downscale with caution

Annual Snowfall – St. Catharines

![Graph showing annual snowfall data from 1971 to 2000.](image)
Annual Snowfall – London

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End of February Snow – London

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End of March Snow – London

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1971 to 2000 Climate Data
- Observed Data
- Climate Normal
- Trend Line

Projected Future Temperature

Annual Projected Temperatures:
Showing 90% of the London data range
Projected Temperature Distribution

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Projected Rate of Climate Change

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Expected Projected Rate of Climate Change

— Climate Change: -6.00 to +6.00
— Precipitation: -30% to +30%

Extreme Events

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• Implications for Canada’s climate and weather include:
  – Higher and more frequent hot extremes;
  – Longer and more frequent heat waves; and
  – More frequent, higher intensity precipitation events.

• Implications for ecosystems and socio-economic infrastructure:
  – Increased number of hot days and heat spells, leading to increased summer energy requirements for space cooling
  – Increase in intense precipitation events with implications for water resource management and flooding
  – Increased risk of summer drought, particularly in regions where the stream-flow is provided by spring and summer runoff, due to a decrease in snow-pack

Planning for the Future

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Planning for the Future

Investment in Infrastructure $

Risk of Climate Impacts $

React to impacts of climate change

Public Infrastructure Engineering Vulnerability Committee (PIEVC)

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- Partnership between Engineers Canada and Natural Resources Canada
- Conducting a national engineering assessment of the vulnerability of public infrastructure to climate change
- Developing:
  - Best engineering practices for climate change adaptation
  - Updates to infrastructure codes and standards
  - Case studies to demonstrate “no regrets adaptation planning”
  - International Capacity

- PIEVC Engineering Protocol for Climate Change Infrastructure Vulnerability Assessment, April 2009

http://www.pievc.ca/e/index_.cfm
• Five step evaluation process
• A tool derived from standard risk management methodologies
• Intended for use by qualified engineering professionals working with climate scientists, other disciplines (e.g. hydrologists, geologists), managers, operators and maintenance staff
• Requires contributions from those with pertinent local knowledge and experience
• Focused on the principles of vulnerability and resiliency
Climate Change Risk Mitigation through Adaptation

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Climate Change/Development

Engineering Vulnerability Assessment

Risk Mitigation

Golder Associates
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• Identify nature and severity of climate risks to infrastructure components
• Optimize more detailed engineering analysis
• Quick identification of most obvious vulnerabilities
• Structured, documented approach ensures consistency and accountability – due diligence
• Adjustments to design, operations and maintenance
• Application to new designs, retrofitting, rehabilitation and operations and maintenance
• Reviews and adjustments of codes, standards and engineering practices (underway in Canada)

Case Study Context

Owner Perspective – Infrastructure Ontario

• IO Jurisdictional Review on Adaptation 2008
• MOE Expert Panel Working Group: Adaptation to Climate Change in Ontario – November 2009
• IO License with Engineers Canada and Selection of Golder/MH for study – 2010
• MOE: Climate Ready- Ontario’s Adaptation Strategy and Action Plan – November 2011
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Case Study Context

Building Section and Climate Criteria
Consideration factors - large portfolio:

- Provincial climate vulnerability
- Willing facility hosts
- Facility program diversity
- Age
- Facility Condition Index
### IO Candidate Properties for PIEVC

**St Catharines**
- 1998 – 330K SF

**Brantford**
- 1850 - 45K SF

**London**
- 1982 - 16K SF

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### Garden City Tower

- 301 St. Paul St, St. Catharines, ON
- 11 floor office tower
- Office space for government operations including Ministry of Transportation Headquarters
- Bus terminal included as part of structure
- Achieved BOMA BEST Level 3 certification in 2008
Brantford Courthouse

Includes Land Registry Office & Jail

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- 105 Market Street & 50-70 Wellington Street, Brantford, ON
- Various additions including the construction of a land registry office in 1919
- Recently underwent heritage restorations in 2006
- Building is considered a significant historical building and continues to operate as a courthouse, jail and land registry office

Police Facility

Southwest Regional Detachment

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- 6355 Westminster Drive in London, Ontario
- 16 acres of land with several buildings including the OPP Headquarters Building as well as garage and salt storage buildings (not considered in this study)
Building Interactions with Climate

Major Infrastructure Categories

- Building Envelope & Structure
- Mechanical Systems
- Electrical Systems
- Exterior Landscaping & Walkways
- Stormwater & Wastewater

Performance Considerations

- Structural Integrity
- Functionality
- Operations & Maintenance
- Emergency Response
- Policies & Procedures
- Tenant Comfort
- Insurance Considerations
- Health & Safety
- Environmental Effects
Climate & Historic Structures

- Predicted Climate events
- Response of historic materials to new climate
  - Stone, metal, brick, wood
- Behaviour of structure in new climate
  - Drainage
- Microbial decomposition/biological attack of organic materials

Identifying Interactions

<table>
<thead>
<tr>
<th>Infrastructure Component</th>
<th>Climate Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freeze-thaw</td>
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<tr>
<td></td>
<td>Slight increase based on increasing winter precipitation and average temperatures</td>
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<table>
<thead>
<tr>
<th>Infrastructure System</th>
<th>Y/N</th>
<th>Y/N</th>
<th>Y/N</th>
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<th>Y/N</th>
<th>Y/N</th>
<th>Y/N</th>
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<tbody>
<tr>
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<td>Y</td>
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<tr>
<td>Glazing</td>
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<tr>
<td>Water &amp; Wastewater Systems</td>
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<td>Supporting Infrastructure</td>
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Priority Thresholds

<table>
<thead>
<tr>
<th>Proposed Risk Range</th>
<th>Proposed Classification</th>
<th>Proposed Response</th>
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<tbody>
<tr>
<td>&lt; 12</td>
<td>Low Risk - interactions represent no immediate vulnerability and there is very low potential climate change vulnerability associated with the infrastructure component.</td>
<td>No immediate action necessary</td>
</tr>
<tr>
<td>12 – 36</td>
<td>Medium Risk - interactions represent a potential vulnerability or integrations has a potential EHS component or significant uncertainty in climate projections</td>
<td>Action may be required to increase adaptive capacity or Further Engineering Analysis may be necessary because a clear, unambiguous, determination of the vulnerability is not possible. Consider development of Best Management Practices / Codes of Practices</td>
</tr>
<tr>
<td>&gt; 36</td>
<td>High Risk - interactions represent an identified vulnerability</td>
<td>Immediate action may be required. Consider development of Best Management Practices / Codes of Practices / Regulations</td>
</tr>
</tbody>
</table>

Key Findings

General & St. Catharines Site

- Interactions categorized by infrastructure sub-component
- Current Capacity/Performance, Future Load, Adaptation Considerations
  - Garden City Tower → highest vulnerability scores → 2 high-severity, 33 medium
  - HVAC Example - Current Capacity:
    • Reduced cooling performance and thermal comfort
    • Exceeding humidity limits occasionally
    • Re-balancing needed → Re-Cx
    • Improved control logics for differing seasonal requirements → selected elevations
### Key Findings

#### St. Catharines Site

- **HVAC Example - Future Load**
  - Cooling load
  - Energy + Maintenance
  
  - HVAC Example - Adaptation Considerations
    - Re-Cx chillers → 100% future load requirements
    - Renewals → higher trends to accommodate RH & T
    - Free cooling
    - Address solar heat gain in near-term

#### Brantford and London Sites

- **Brantford Cladding Example – Current Capacity**
  - Good water shedding
  - Robustness to freeze-thaw
  - Cultural heritage impacts → High Severity

- **Future Load**
  - Wind, rain, sun, thermal expansion → potential degradation
  - Rain and wind → Water penetration
  - Damage and possible mould

- **Adaptation**
  - Periodic re-pointing and isolated replacements
  - Increase repair and replacement cycles

**London site infrastructure components** → generally operating as intended/required under current loads.
### Recommendations

#### ST CATHARINES SITE
- Track thermal comfort + Re-Cx M&E Systems
- BE Cx for curtain wall system → Water, Air, Solar Heat
- Track water penetration and failed glazing
- Assess current emergency plans → Electrical system redundancy
- Implement and document regular maintenance inspections
- Replace roofing
- Review metal panel connections → high wind risk
- On-site SWM plan
- Reduce/eliminate irrigation needs

#### BRANTFORD SITE
- Review and implement assessment and restoration protocols
- Assessment and renewal of older window glazing
- Regular review of timber elements → Cultural heritage & Structure
- Foundation wall review and risk mitigation
- Reduce/eliminate irrigation needs
- Cooling system design changes → Higher RH & T
- Effective roofing replacements
### Recommendations

#### LONDON SITE
- Track thermal comfort
- Track water penetration
- Ongoing Cx for all systems
- Ongoing renewal & maintenance of all systems

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#### Recommendations

**PIEVC Process and Code Implications**

**PIEVC PROCESS**
- Stakeholder integration
- Multiple points of feedback
- Ability to incorporate extreme events

**CODE IMPLICATIONS**
- Protection against extreme events
- Review of hurricane survivability
- Energy codes and climate trending
- Thermal comfort implications
- Moisture management performance criteria
- User-prepared standards
- Invasive insect species
- SWM strategies
23 Canadian case studies and counting
• Recommendations by infrastructure type
• Engineers Canada & World Federation of Engineering Organizations
  → Delivery of training workshops and international case studies
• Expansion of protocol to include adaptation costing
  → Triple bottom line approach well as
  → No adaptation
• Goal of “no regrets” adaptation

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