Climate Change Infrastructure Vulnerability Assessment for

The Quesnell Bridge - Edmonton, Alberta

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CH2MHILL | The City of Edmonton | PIEVC CVIIP | engineerscanada ingénieurscanada

What do engineers do

- plan & design infrastructure
  - support current and projected needs
- loads, serviceability, capacity, safety
  - gravity loads; live loads e.g. traffic; environmental factors
  - climate is one of many in combination
- tools
  - underlying science; practical application
  - codes / standards / guidelines / professional judgement (site/structure specific analysis)
- life cycle considerations = sustainable approach
  - holistic approach; triple bottom line
  - design life
- need practical solutions that can be applied while there are still many unknowns
- risk assessment / management

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What does climate change mean to engineers?

- Climate change is a reality, regardless of cause
- Engineering profession lags scientific research
- Engineers recognize it must be considered
  - IPCC 2007 on our agenda
  - strategies are starting to evolve
- Potential consequences
  - premature weathering & deterioration
  - higher maintenance & operation costs
  - reduced performance and life span / life cycle
- Responsibility
  - assess situation; risk management
  - develop and/or revise policies / standards / guidelines
  - multidisciplinary / multijurisdictional approach

- *Mitigation & Adaptation*

- *Need greater understanding & more tools*

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First National Engineering Vulnerability Assessment of Public Infrastructure

- Engineers Canada
  - develops standards of practice
  - promotes continual development of competence
  - promotes engineering in Canada

- PIEVC study 2007-08
  - national-scale assessment of Canada's public infrastructure to climate change impacts
  - adaptive capacity
  - potential vulnerabilities
  - involved multiple levels of government and consultants

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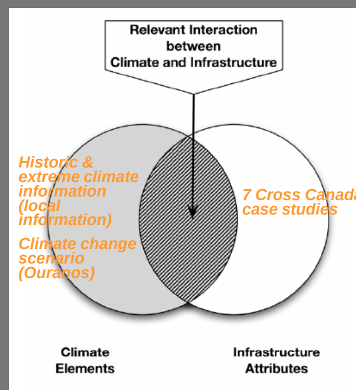
PIEVC Engineering Protocol



- *Objective :*
  To draw the relationship between climate change and infrastructure response
- Screening / prioritization process
- Assessment of data quality / sufficiency
- Engineering vulnerability
  - "Shortfall in the ability of public infrastructure to absorb negative effects, and benefit from positive effects, of changes in climate conditions used to design & operate infrastructure"

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Case Study Infrastructure

- Host City: City of Edmonton
- Infrastructure category:
  - Roads and Associated Infrastructure
- Infrastructure owner: City of Edmonton
- Consultant: CH2M HILL Canada Ltd.
- Infrastructure: Quesnell Bridge over the North Saskatchewan River

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Infrastructure Site

- Host City: City of Edmonton
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- Infrastructure: Quesnell Bridge over the North Saskatchewan River

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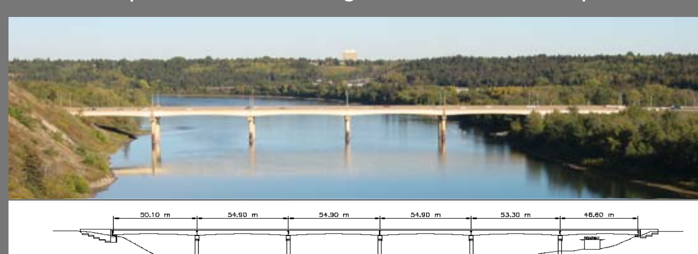
Quesnell Bridge

- Links Whitemud Dr. and access road to Fort Edmonton Park
- Constructed in 1968
- 315 m long
- 6-span over North Saskatchewan River
- 3 lanes each direction
- 114,000 vehicles per day
- Parabolic pre-cast concrete girders, with cast-in-place deck



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Climate Factors

- Edmonton:
  - northern continental climate
  - extreme seasonal temperatures
  - fairly dry
  - frequent thunderstorms, occasionally severe
  - tornadoes, hail storms, etc
- Historical events
  - 1915 flood
  - tornadoes/storms increasing
  - extreme events
  - sequenced events

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Climate Factors

- Relevant climate factors for climate change forecasting
  - temperature (high, low, range)
  - rainfall (frequency, intensity)
  - snow (frequency, intensity)
  - freeze/thaw cycles
- Projections uncertain for:
  - Wind : hurricanes, tornadoes, thunderstorms, wind gusts, rainfall
  - Ice : ice build-up, ice accretion, freezing rain
  - Snow : rapid melt events
  - Hydrological (incl. river ice)
  - Combination & sequenced events

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Climate Baseline

- Wind Pressure Load – Data : to 1990
- Temperature (Daily Max and Min) – Data : 1940 to 1970
- Relative Humidity (Annual Mean) – Data : 1957 to 1966
- Ice Load – Data : to 1976
- Precipitation – Data : to 1995

- Global Climate Model (GCM)
- Supplemental Data
  - Topography of Upper Saskatchewan River Basin
  - Available historical meteorological data
- Regional Climate Model (RCM)
- Forecast horizon 2050
- Data available from 9 weather stations in region

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In Edmonton: A number of extreme climatic events have been recorded since the 1900s

Year	Incident	Cost/Impact
1901	Thunderstorm: Hail the size of pigeons	N/A
1915 *Design flood*	Flood: North Sask. River	2,000 Homeless
'42, '57, '64, '72	Blizzard/Snowstorm	4 dead (1964)
'44, '52, '53	Flood	N/A
1949	Tornado: Outskirts of Edmonton	N/A
'53, '72, '78, '86	Flood: 1978 – high local rainstorm	$4-8M
'87, '89	Tornado: 1989 most severe	$665M, 27 dead
'79, '82, '89, '97	Blizzard/Snowstorm: '82 severe	$1.7M, 2 dead
'92, '93, '95, '04	Hailstorm: 2004 most severe	$21-$74M

- ➢ can determine design, operation/maintenance
- ➢ need comprehensive data base
- ➢ capture local knowledge, experience

Source: City of Edmonton

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Quesnell Bridge – Current Design & Rehabilitation

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Edmonton – Quesnell Bridge

- *Structure generally robust*
- *Bridge has responded well to extreme events to date*

Vulnerabilities	
Climate Effect	*Infrastructure Component*
Flood + peak rain	Drainage system overload - serviceability
Freeze-thaw, ice accretion	Weather surface – increased deterioration Drainage system performance
Snow volume / pattern	Snow clearing increase/decrease

Recommendations

- Design drainage system for increased peak rain
- Review monitoring / maintenance / operations procedures
- Material selection/design (e.g. based on new temperatures ranges)
- Perform sensitivity analyses
- Review / update climatic data in bridge design code
- Assess other bridges that would be sensitive to scour; slope instability; wind; softening foundations / settlement

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Key Considerations

- Type of structure – design, construction, serviceability
- Design life
- Geography / geology
- Maintenance / Rehabilitation
- Climate – trends (global & regional models)
- Climate – extreme & unpredictable events

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Going Forward – The Climate

Climate Data Needs

- Engineers work at very local level
- Finer grid resolution of regional model
- Indirect effects (ground water level, slope instability)
- Regional downscaling data base
- Combination / sequencing events

Identify regions / typologies most sensitive to climate change

- Permafrost regions
- Coastal (east, west, north)
- Hydrology (foundations/slope stability, river behaviour)
- Create data base of climate change parameters focussing on these regions first

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Going Forward – The Structures

Existing & New Structures

- Infrastructure is generally robust & resilient
- Many vulnerabilities can be managed through maintenance, rehabilitation, upgrading activities
- Climate loads are one of several factors
- Prioritize by design life
- Planning should become longer term

Identify critical infrastructure

- Human health & safety
- Life line structures / transportation corridors
- What damage can we live with / repair (economics)
- Component design life
- Incorporate better climate information into planned works (new & upgrades / maintenance)

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Design life-appropriate assessment

Structures	Expected Lifecycle
Houses/ Buildings	Retrofit/alterations 15-20 yrs Demolition 50-100 yrs
Storm/Sanitary Sewer	Base system 100 yrs Major upgrade 50 yrs Components 25 – 50 yrs
Dams/ Water Supply	Base system 50-100 yrs Refurbishment 20-30 yrs Reconstruction 50 yrs
Roads & Bridges	Road surface 10 - 20 yrs Bridges 50 - 100 yrs Maintenance annually Resurface concrete 20-25 yrs Reconstruction 50-100 yrs

- Design life varies
- Component-based vulnerability assessment
- Safety / economics / technical
- There is adaptive capacity because of maintenance & rehabilitation
- Conversely, poor maintenance and lack of rehabilitation contributes to vulnerability

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Design values – design life

Confederation Bridge (1990)
- *100 yr design life*
- *climate change considered : 1 m above sea level*

Panama Canal (current expansion)
- *100 yr design life*
- *climate change : 1.5 m above extreme high tide*

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Slope Instabilities – Aggressive Geology & River Regimes

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Alaskan Bridge – Frost Jacking

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Yukon River Bridge – Ice Jams

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Serviceability Weakness - Poor Drainage Systems

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Poor Maintenance - Increased Vulnerability

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Concorde Overpass Failure – Combination of Causes

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Climate & Infrastructure

Climate Information

- Regional trends mapped
- Update base climate design data in codes
- Cumulative / sequencing events
- Local knowledge captured and shared
- Extreme events – including climate change forecasts
- Level of confidence; range of uncertainty

Infrastructure Information

- Infrastructure inventory (location, condition, life cycle)
- Bridge structures – generally robust; scour
- Planning, operations, maintenance
- Impact of land use planning
- Owners should regularly review local design guidelines and operations procedures
- Cumulative / superimposed effects
- Sensitivity analysis
- Opportunities at new design / rehabilitation

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