The Changing Climate and the Increasing Vulnerability of Infrastructure: What Lies Ahead?

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Ecosystem and Community Impacts of 2001-2002 Droughts: Extreme Needs for Ag Water Conservation Standards

- 2001 and 2002 droughts among major droughts of North America (over 100 yrs)
- Moderate-severe drought: southern B.C.—srn & central Ab-Sk—srn Ont-Que—parts of Maritimes
- Extremely low groundwater levels
- Southern Ontario: irrigation-days increased 4-5 fold in 2002
- Southern Ontario flows ~30% of lowest average summer flows
- Non-irrigated crops in Annapolis Valley lost 50-100% of yields
- Prairie dugouts ran dry… Prairie sloughs lowest number on record
- Waterfowl decreased significantly (habitat, disease)
- Decreased biodiversity and habitat
Rising Losses from Severe Weather Events

Global Costs of Great Natural Disasters (1950-2000) in US$ Billions, including economic and insured losses

(Great natural disasters defined as > 100 deaths and/or US$ 100M in claims)

Is vulnerability increasing??
Are extremes increasing??

Hurricane Katrina
Global surface temperatures are rising
...although changes in temperature are unevenly distributed

Trends for 1950-98

Degrees C
Ontario

- GETTING WARMER
- NON-LINEAR

Mean Annual Temperature °C
1971 - 2000
Most of Canada is becoming wetter

Percent change in precipitation 1950-98
Ontario

- GETTING WETTER
- NON-LINEAR
Trends in # of Days with Precipitation ≥ 20 mm / 54 yrs (1950 – 2003)

- Statistically Significant Increase
- Non-significant Increase
- Non-significant Decrease
- Statistically Significant Decrease
- Station with > 20% missing data, no trend calculated

Circles indicate trends significantly differ from zero at the 5% confidence level for 1950 - 2003.

Source: Vincent and Mekis
Trends in
Highest 1 Day Snowfall / 54 yrs
(1950 – 2003)

- Statistically Significant Increase
- Non-significant Increase
- Non-significant Decrease
- Statistically Significant Decrease
- Station with > 20% missing data, no trend calculated

Source: Vincent and Mekis
2005
MAYBE IN THE YEAR 2006, YOU CAN REMEMBER TO TAKE YOUR MOOD SWING MEDICATION.
Under climate change, the world will become MUCH, MUCH warmer than during the past millennium.
Measures under the Kyoto Protocol will only delay projected warming

Based on IMAGE 2 model output
Annual Temperatures (difference C above baseline) 2080s
Annual Precipitation (% difference from baseline)  
2080s
Summer Temperatures (difference C above baseline) 2020s
Summer Temperatures (difference C above baseline) 2080s
Future Climate Change and Impacts in Southern Ontario

**Climate Changes**
- Temperature
- Precipitation
- Lake levels
- Storms/waves

**Impacts on Great Lakes:**
- Lowered lake levels
- Less winter ice
- Decreased water quality

**Water Resource Impacts:**
- Decreased water supply and quality
- Infrastructure may not be adequate
- Increased competition for water

**Health Impacts:**
- More heat waves
- Air quality illnesses
- Migration of diseases

**Infrastructure:**
- Increased risk from storms
- Reduced hydroelectricity capacity
- Changed heating and cooling

**Species and Natural Areas:**
- Altered habitats
- Changes in ecological zones
- Biodiversity changes / extinctions
The Certainties

• Increased uncertainty
• Return periods becoming uncertain
• Long-term planning needs to include climate change
• Past may no longer be representative of the future
• Require disaster management planning and
• Require more careful daily and seasonal management & prediction
Extreme precipitation events are likely to become more frequent.
Climate Change Means…
The frequency and severity of droughts are likely to increase in southern Canada.

Central North America

![Graph showing expected changes in drought frequency and severity in Central North America.](image-url)
Climate Change Impacts

Affect water availability, security of supply, water quality, sewer capacity, infrastructure safety

- Warmer temperatures, more intense rainfalls, rising sea levels, ice jamming risks
- Risk of unsustainable water and wastewater services in future
- Erosion issues
Agriculture and Water Impacts

• Changing crops and practices … demands for irrigation
• Drainage issues (heavier short duration rainfalls)
• Water quality impacts from changed pests and pathogens
Groundwater

Greater reliance on groundwater for baseline flow

Surface runoff and evapotranspiration rather than infiltration to groundwater?
Waterborne Disease Outbreaks & Heavy Rainfall

Heavy accumulated rainfall … a contributing factor to Walkerton waterborne disease outbreak

U.S. studies:
• 68% of outbreaks associated with upper 20% rainfall amounts (2 month lag)
• Canadian studies…temperature important
Threats to Infrastructure

- Maintenance… soil erosion, freeze-thaw cycles
- Surface water intakes … wells
- Need for more storage infrastructure (drought management) AND
- Stormwater ponds, culverts (and sewers) overwhelmed
MONITORING & DETECTING CHANGE

EXAMPLE... UPPER GRAND RIVER WATERSHED

August Mean Air Temperatures Upper Grand Watershed
Upper Grand River Basin Fish Surveys: Changes from 1983 to 1996

- Healthy aquatic ecosystem both periods
- Warm water species colonizing upper Grand watershed
- Trout disappearing in 1983; Sculpin disappeared by 1996

**Increasing**

Pike, Smallmouth Bass, Central Stoneroller, Roseyface Shiner, Northern Hog Sucker, Pumpkinseed, Bluegill, Johnny Darter (warm-water fish)

Least Darter, Pearl Dace, Finescale Dace, Northern Redbelly Dace, Mottled Sculpin (cold-water fish)

**Decreasing**
Measures under the Kyoto Protocol will only delay projected warming.

Based on IMAGE 2 model output.
ADAPTATION is....

An adjustment in response to an actual or expected change

Like mitigation, adaptation requires:
- short term solutions
- long-term adaptive adjustments to society

ADAPTATION means...
Making decisions and acting sustainably in a complex and changing world
Adaptation Options

- Designs to consider antecedent rainfall (and snowmelt)
- Updated climatic design information
- Climate change projections for design
- Changed drainage infrastructure (tile drains, culverts, storage ponds)
- Low water table management through drainage systems?
Managing Drought Conditions in Canada: Ontario Low Water Response Framework

**Three thresholds:**
- Level I (<70% normal flow)... encourage conservation
- Level II (<50% normal summer flow or <60% precipitation)... conservation and 10% voluntary reduction
- Level III (<30% normal summer flow and <40% precipitation)... conservation, restriction and mandatory reduction
Adaptation Options

• Water reuse, aquifer storage, desalination
• Demand management
• Water availability issues will remain
• Coastal areas... restrict groundwater pumping
Agri Water Conservation Standards

- Water conservation to ensure that enough water is available for all users, including ecosystems and dilution, on a sustainable basis to consider dry years;
- Agricultural water storage projects be managed to ensure reliable water supplies, particularly during years of low precipitation, and to reduce the impacts of damages from high runoff.

Conservation = “last oasis”
Small Increases = Escalating Infrastructure Damages

“small increases in weather and climate extremes will have the potential to bring large increases in damages to existing infrastructure”
Past will no longer indicate extremes of the future

Adaptation planning for infrastructure

“No regrets” means adapting to developing conditions
ADAPTATION PLAN: (i) Updated and Regularly Revised Structural Codes & Standards, Climatic Design Values

Address existing deficiencies and uncertainties

Update climatic design values … compare climatic design values against climate trends to identify vulnerabilities

Develop analytical techniques to incorporate climate scenarios into weather/climate extremes
ADAPTATION PLAN: (ii) Assess engineering practices in light of the changing climate …

Enforce compliance to standards and develop new standards

Change safety factors or introduce Climate Change Adaptation Factors (CCAF) to reflect growing uncertainties and risks

Reduce premature deterioration rates for infrastructure… standards?
ADAPTATION PLAN: (iii) Education and Outreach of Engineering and Planning Communities and Public

Link engineering, planning and climate communities…

“Since planning is a future oriented profession, adaptation to climate change is a challenge that this profession must accept and act upon as soon as possible”

“professionals coming out of engineering and architectural programs as well as practicing professionals will need to have greater exposure … to disaster resistant construction and awareness of climate change impacts and the need for adaptation”
ADAPTATION PLAN… Improved Disaster Planning

• More accurate and timely weather warnings
• Forensic studies (adaptation learning) & risk reduction learning
• Mandatory community disaster management planning
Weather Hazard Risk Assessment (Vulnerability Assessment)

- Involves assessment of risks to weather hazards:
  - Fog
  - Heavy Rain
  - Hurricanes
  - Extreme Heat/Cold
  - Drought
  - Extreme Air Quality Events
  - Lightning
  - Heavy Snow
  - Wind Storms
  - Ice Storms
  - Tornadoes

Ontario Emergency Management Act
Atmospheric Hazards - Selection Results
Map: .Ontario South Boreal(2300)
Selected 586 places on this map

Parameters:
- Hail Frequency in Ontario (Etkin) between 0.50 and 2.00 # Days/Year
- Tornado Frequency in Ontario (Newark) between 0.80 and 2.40 # Events/Year

Moderate-High Hail Frequencies AND Moderate-High Tornado Frequencies
Challenges for the Future?

Climate change will impact agriculture & infrastructure

Design & costs sensitive to small changes in extremes

Adaptation actions needed sooner … not later

Think precautionary and “no regrets”