Public Infrastructure and Our Changing Climate: Achieving Resilience through Adaptation

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New Brunswick Select Committee on Climate Change

Fredericton, NB

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I'D SAY THAT WAS THE BIGGEST POTHOLE WE'VE EVER FILLED...EH, SMITTY ?......SMITTY ?!

Three Messages

1. Civil infrastructure (including) strongly supports public health and public service delivery as well as business and economic prosperity
2. Changing climate poses risks to civil infrastructure (now and in the future)
3. Adapting civil infrastructure to improve climate resilience will serve public health, safety and economic well-being

It’s about addressing climate impacts on people’s health, safety and economic well-being

Climate Change Affects People – Addressing this Social Impact is Crucial to the Quality of Life that Our Infrastructure Provides!

What is Engineers Canada?

STRUCTURE

- National organization for the engineering profession in Canada
- Members - 12 regulators that regulate the practice of engineering e.g. Engineers and Geoscientists of New Brunswick (APEGNB)
- Over 280,000 professional engineers in Canada

FUNCTIONS

- Common approaches for professional qualifications, professional practice and ethical conduct
- Accredits all undergraduate engineering programs in Canada– 279 programs in 43 universities
- National and international voice of the profession
- Climate change work since 2001- focus on infrastructure adaptation and resilience

Engineers, Infrastructure and Climate Change (Changing Climate)

- Professional engineers hold paramount the **health, safety and welfare of the public** with due regard for the environment
- Engineers must consider economic, **social** and environmental factors to achieve sustainable infrastructure
- Changing climate and extreme weather **threatens** our infrastructure – now and in the future

Civil Infrastructure

The services provided by civil infrastructure works touch all of us in many ways

Services

Shelter

Safety and security

Aesthetics

Heat, Light and Power

Mobility for people, goods and services

Health and recreation

Wealth creation

Categories

Homes & Buildings

Transportation networks

Energy networks

Water, Waste, & Storm water networks

Industrial structures

Communications networks

Landfills and waste depots





Changing climates, changing loadings…

- Changing temperature
- Changes in seasonality and type of precipitation
- Changes in extreme wind loadings
- Intensity of precipitation
- Earlier freshet
- Sea level rise and storm surge
- More freeze-thaw cycles
- Melting permafrost

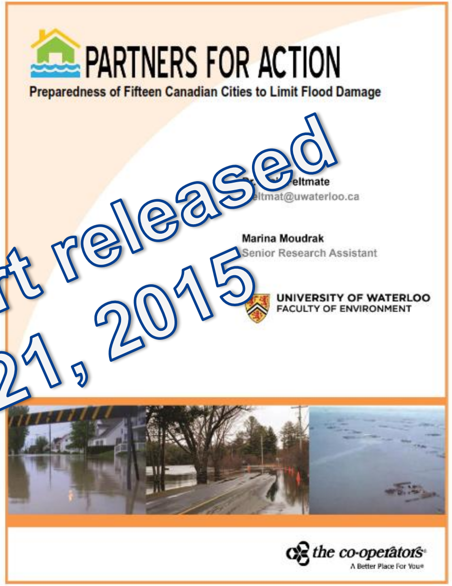
Global NEWS
Montreal
Change Location
TV News Programs
Newscasts & Videos

World Canada Local Politics Money Entertainment Health Lifestyle Tech Science Sports Vi

FLOOD May 21, 2015 6:00 pm Updated: May 21, 20

Major Canadian cities ill-prepared for floods: study

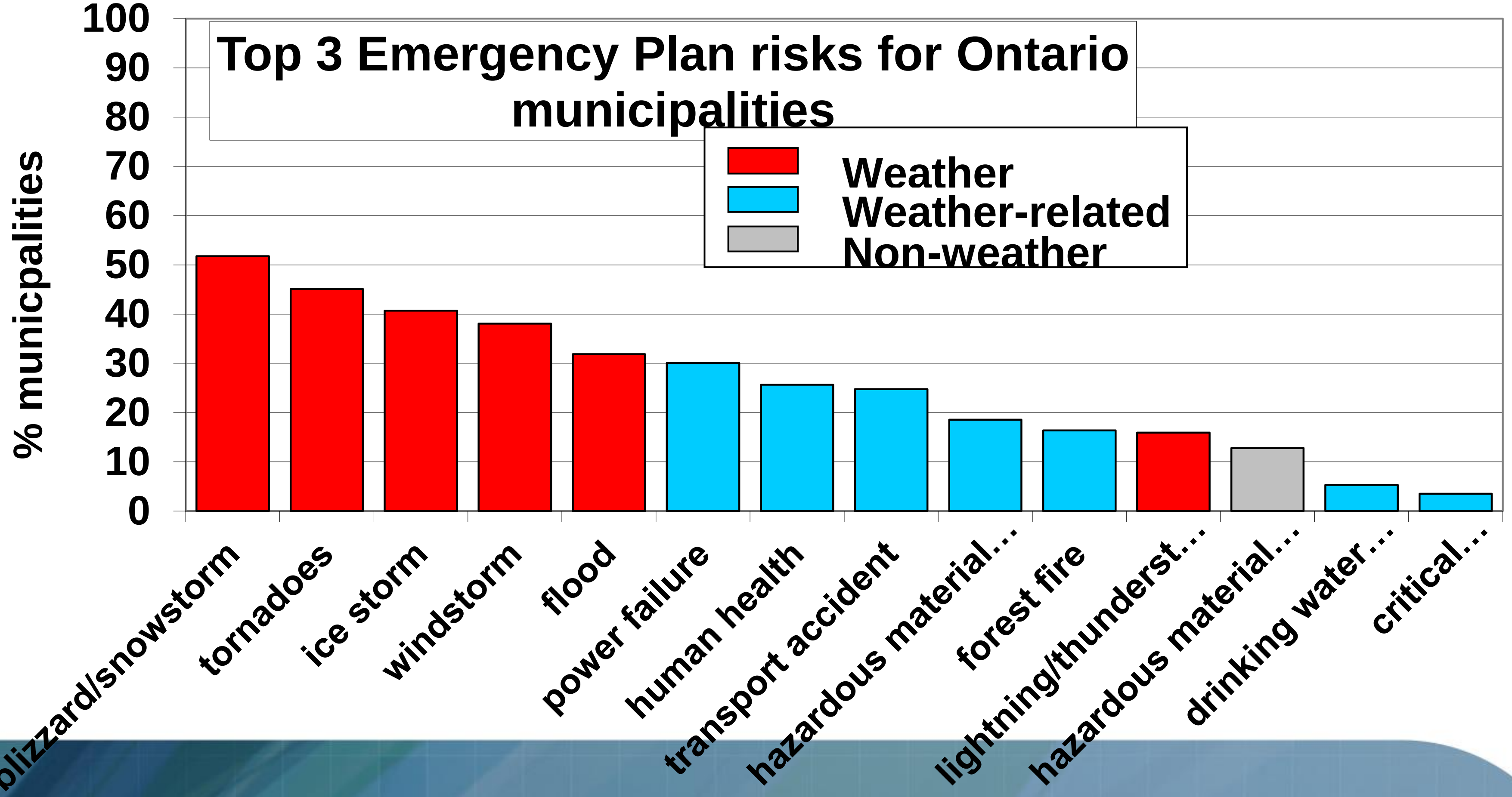
By Joan Bryden The Canadian



UW Report released
May 21, 2015

City	Grade Score
1. Ottawa	A-
2. Winnipeg	B+
3. Calgary	B
4. St. John's	B
5. Toronto	B-
6. Montreal	B-
7. Mississauga	C+
8. Edmonton	C
9. Fredericton	C
10. Whitehorse	C
11. Charlottetown	C-
12. Quebec City	C-
13. Regina	C-
14. Vancouver	C-
15. Halifax	D

Municipal Emergency Plans & Priority Hazards



Climate Impacts on Infrastructure and Its Services

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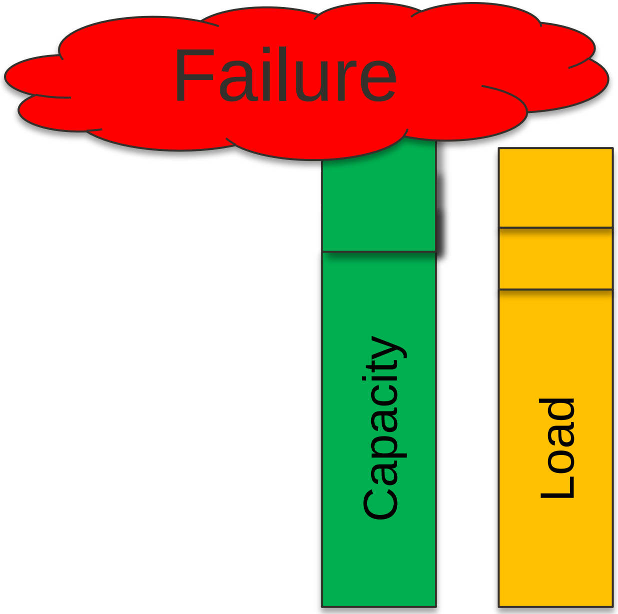
Risks to Various Infrastructure Types from Increasing Climate/Weather Extremes (Frequencies/Intensities)

STRUCTURES	Ice Storms and Wet Snow	Rainfall Intensity & Accum.	Extreme Winds	Summer Storms & Tornadoes	Extreme Snow
Power Lines & Transmission Structures	FAILURE ice + wind	ADDITIVE	FAILURE	FAILURE	SOME
Communication	FAILURE ice + wind	ADDITIVE	FAILURE	FAILURE	SOME
Buildings	SEVERE ICING & WET SNOW	DRAINAGE & FAILURE	FAILURE	FAILURE	FAILURE
Roads, Bridges	OPERATION RISKS	DRAINAGE & EROSION	OPERATION & RISKS	FAILURE RISK	OPERATION
Stormwater & Wastewater	POWER FAILURES	TOTAL FAILURE	POWER FAILURES	FAILURE	RISKS
Water Supply & Distribution	POWER FAILURES	LACK OF - DROUGHT	POWER FAILURE	POWER FAILURE	RISKS

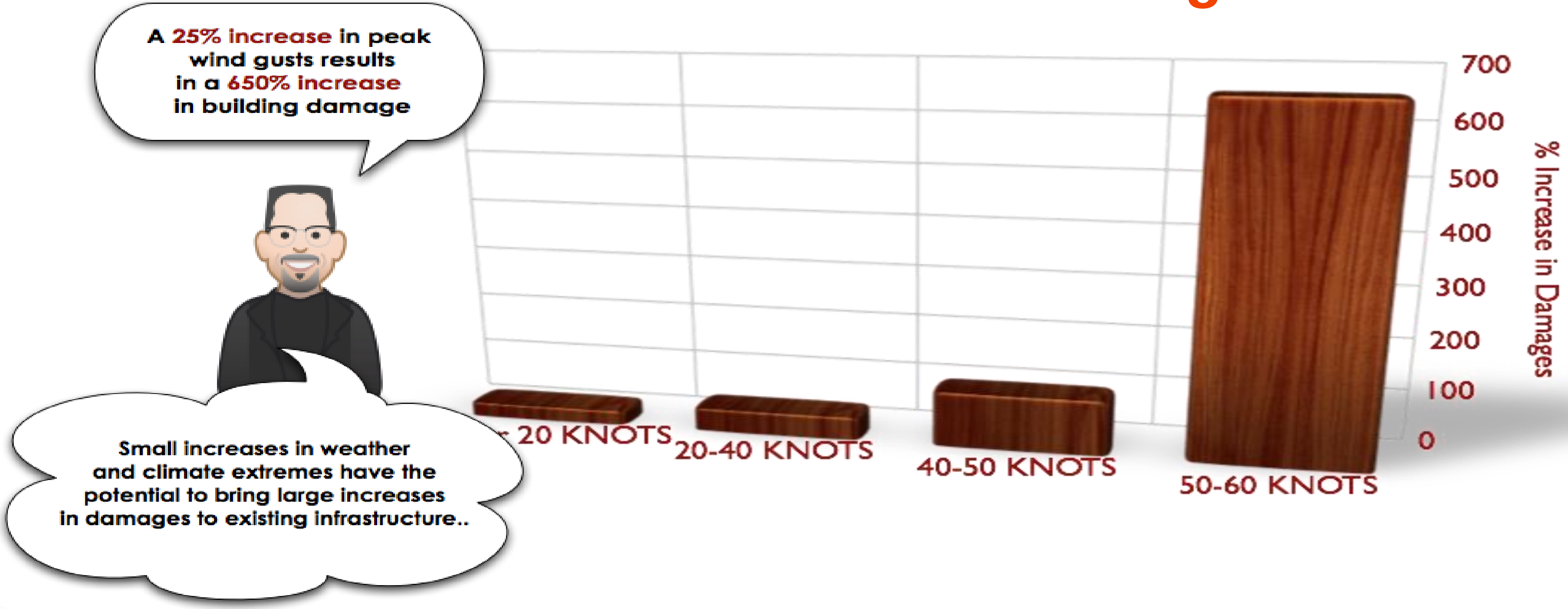
How do Small Changes Lead to Catastrophic Failure?



- Design Capacity
- Safety Factor
- Impact of age on structure
- Impact of unforeseen weathering

- Design Load
- Change of use over time
  - e.g. population growth
- Severe climate event

Small Increases Lead to Escalating Infrastructure Damage



Critical Ice Storm Thresholds

Failures under Extreme Ice Storms - ***freezing rain (mm)***

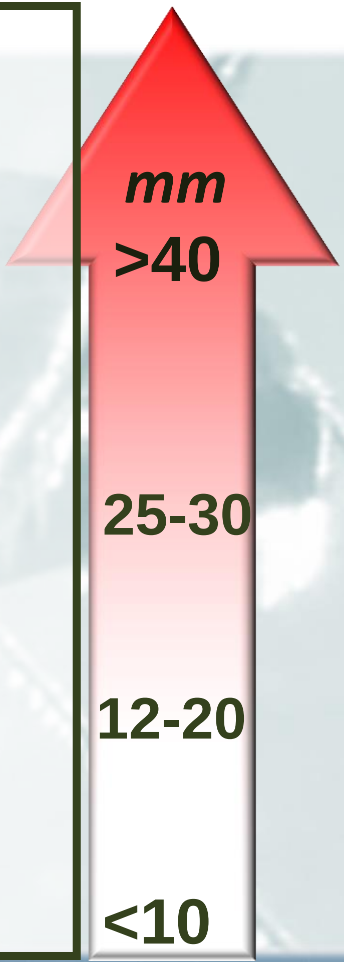
Communication towers

Transmission line failures

Distribution line failures – ice loads

Distribution Line Outages – <u>tree breakage</u>

Slippery roads



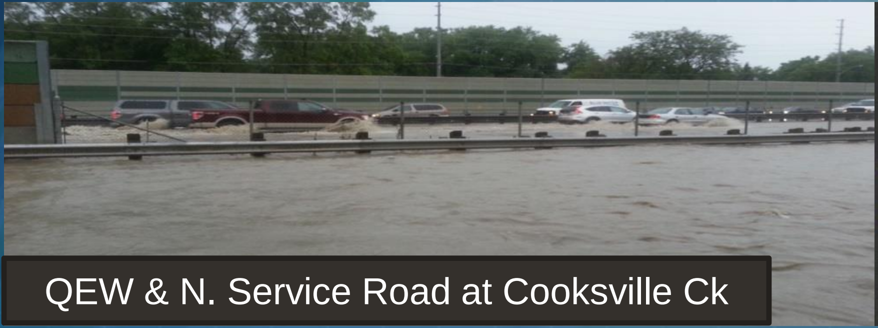
Infrastructure Vulnerability to Extreme Weather

THE CITY OF CALGARY
WATER RESOURCES

Bow River at Center Street Bridge and Chinatown

Existing Vulnerability Outside Floodplain

Source : Credit Valley Conservation Authority



QEW & N. Service Road at Cooksville Ck

Mississauga Valley Blvd at Lolita Gardens

Paisley Blvd East

Dixie Rd north of Lakeshore Rd

Photo by Fred Loek, Mississauga News


August 2005 Storm - Toronto
Photos courtesy
Jane-Finch.com

Interdependencies

Climate and Other Factors can Combine

Combination of events can exacerbate the vulnerability

- Events can occur in rapid succession
- Events can add together
  - Extreme rainfall + hail
- Management or maintenance practices can intensify impacts
  - Infrequent culvert clearing + severe rain
- Change of use can intensify impacts
  - Urbanization → changes in drainage regime → increased drainage flow

Power Disruption – Days/Weeks?

What about back-up power
Reliability? Sufficient for
public health delivery?

Shelter

Heating, cooling?

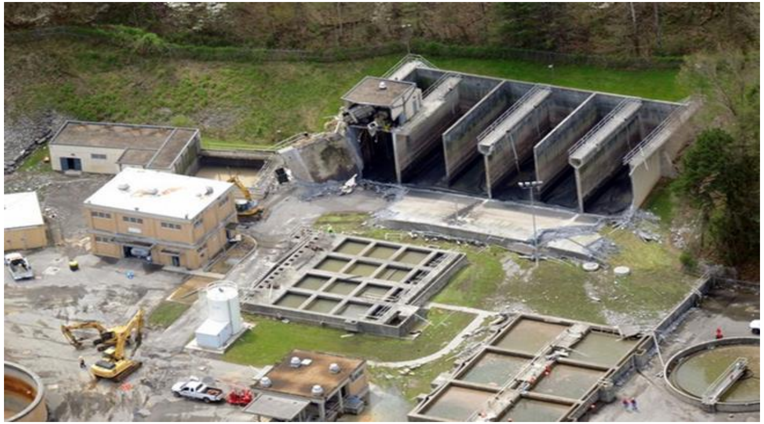
Structural failure?

Access?

Emergency response?

Evacuation?

Sanitation – Water Treatment and Water Quality



Flooding and Public safety?

Access to

health care infrastructure?

Vector and water

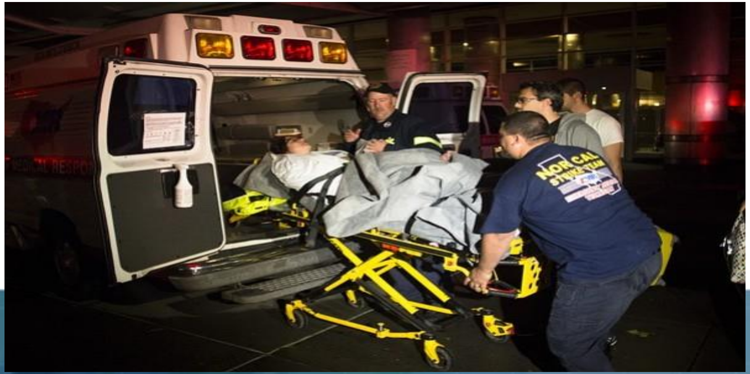
borne diseases

Transportation – Access and mobility of health care services (emergency response)

Parts of Highway 17 were washed out from torrential rains near Wawa. (Martine Laberge/Radio-Canada)

Hurricane Sandy Forces New York City Hospitals To Evacuate

- Patients are evacuated from Bellevue Hospital on October 31, 2012 in New York. The hospitals had been operating on backup generators since losing power during Hurricane Sandy but had to be evacuated once the extent of the damage became clear.



Infrastructure Resilience Strategy #1

Vulnerability and Risk Assessment

www.PIEVC.ca

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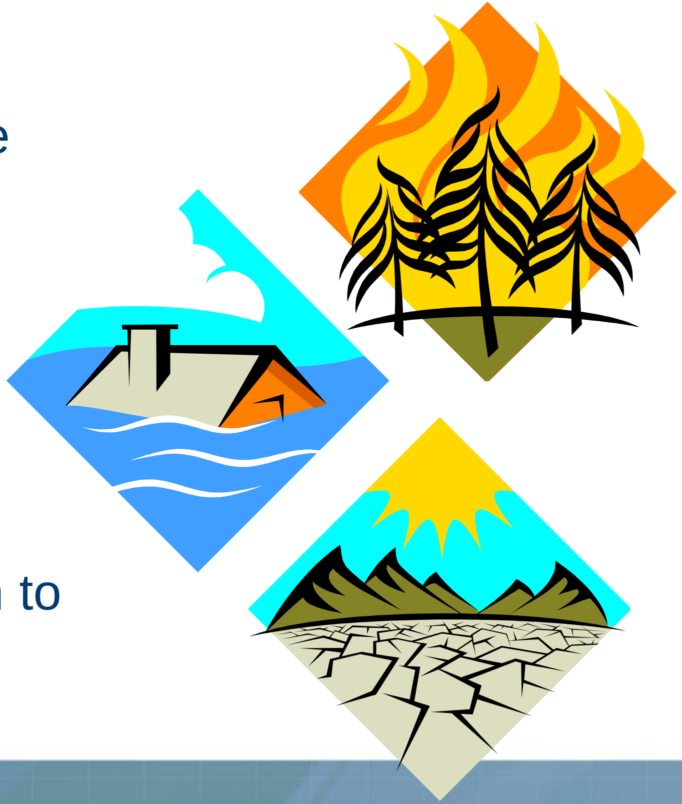
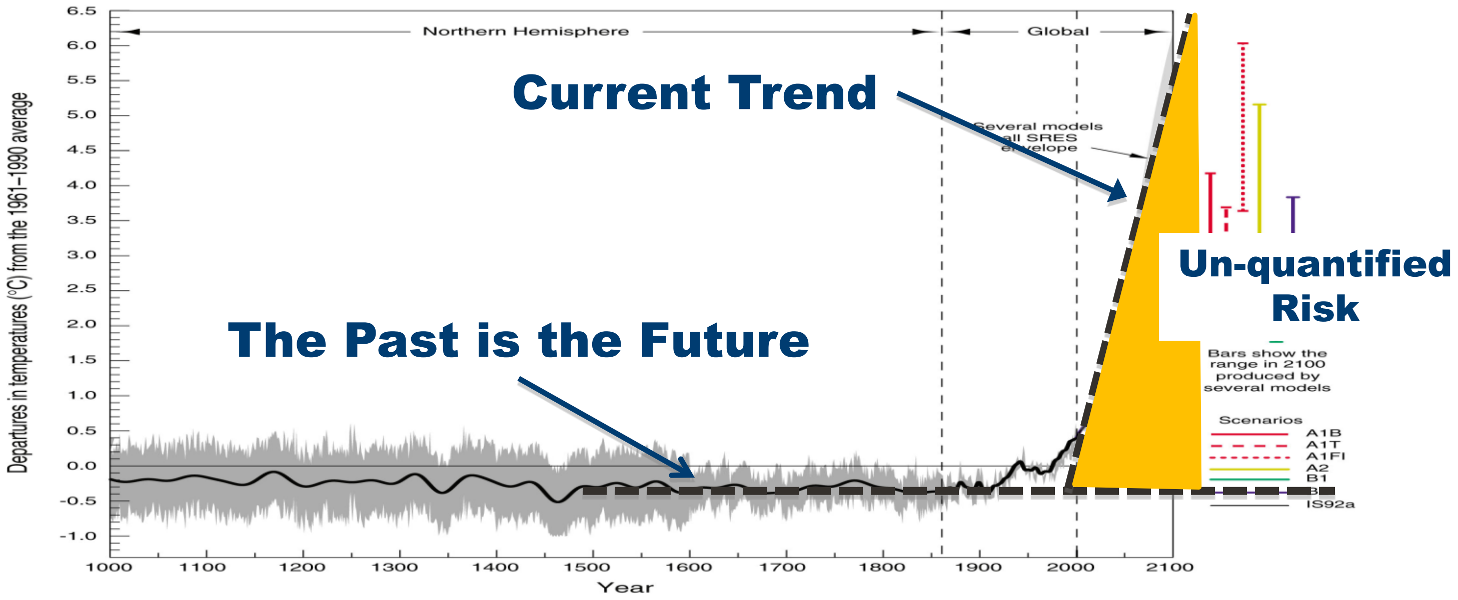
Why Determine Community Infrastructure Climate Risk and Vulnerabilities?

- Minimize service disruptions
- Protect people, property and the environment
- Optimize service
  - Manage lifecycle
  - Manage operations
  - Avoid surprises
  - Reduce/avoid costs
- First step in planning adaptation to improve climate resilience



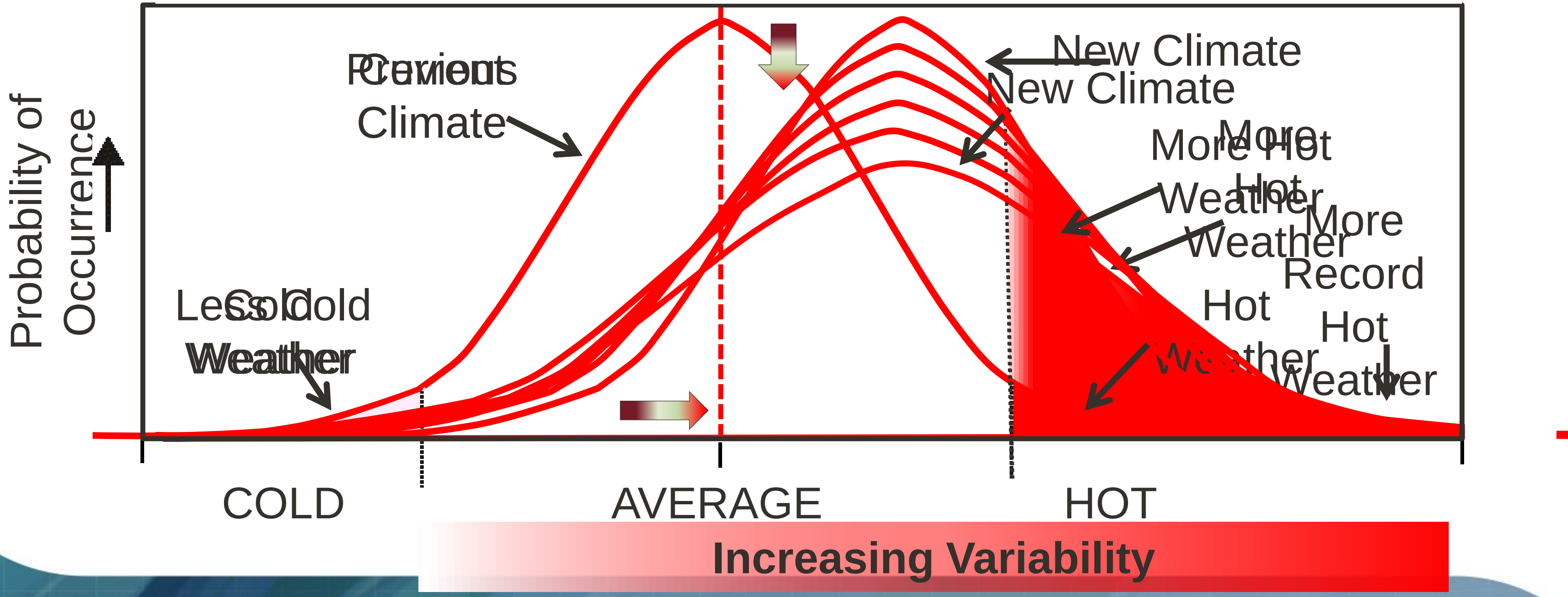
From an Infrastructure Planning, Design and Operations Perspective

- Past climate is not a good predictor of the future

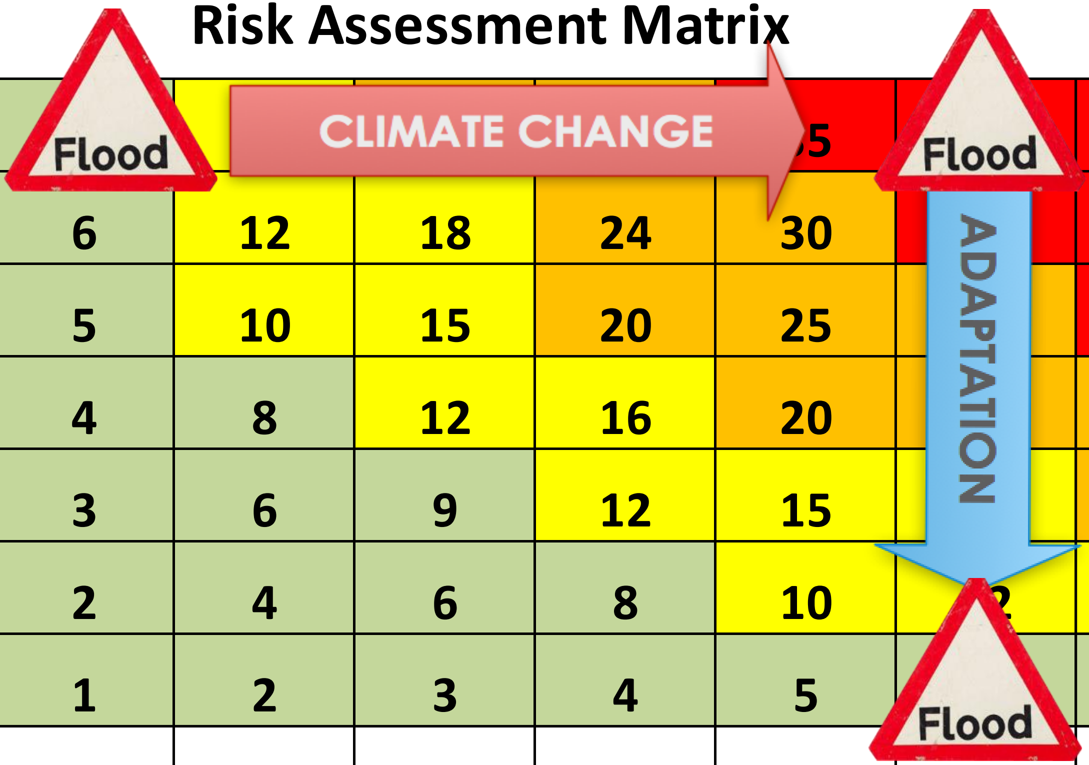


The probability of extreme changes in climate parameters

INCREASES IN MEAN and VARIANCE



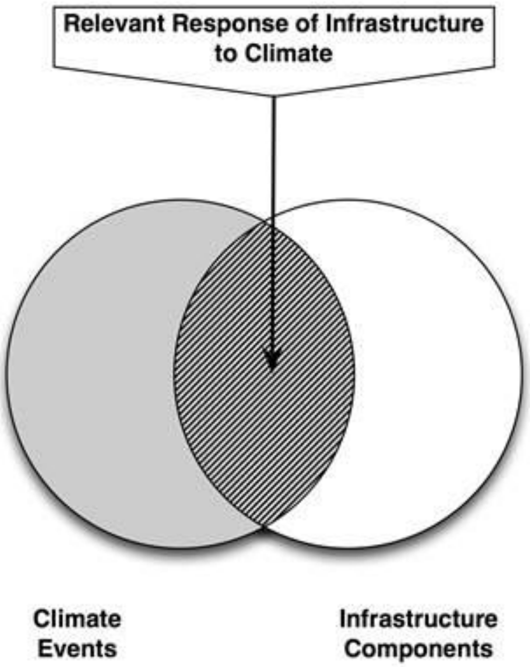
Risk Assessment Matrix



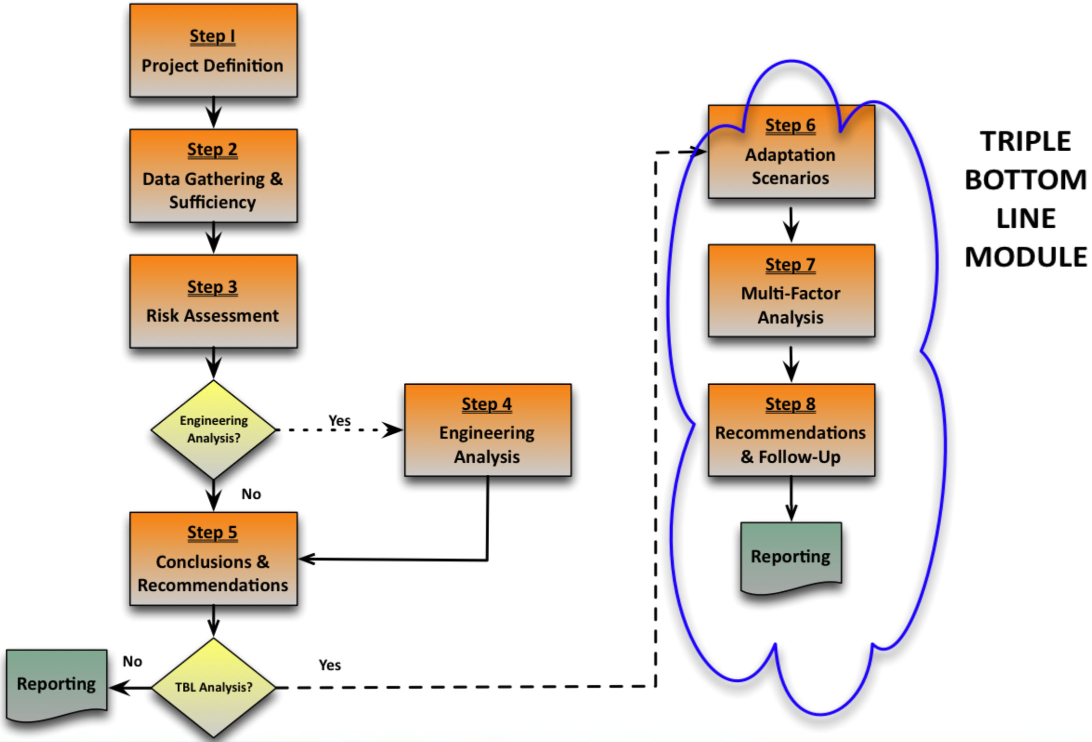
Consequence	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]5	[illegible]	49
	6	6	12	18	24	30	[illegible]	42
	5	5	10	15	20	25	[illegible]	35
	4	4	8	12	16	20	[illegible]	28
	3	3	6	9	12	15	[illegible]	21
	2	2	4	6	8	10	[illegible]2	14
	1	1	2	3	4	5	[illegible]	7
		1	2	3	4	5	6	7
		Probability of Occurrence						

PIEVC Engineering Protocol: a risk screening tool

- Five step evaluation process
- A tool derived from standard risk management methodologies
- Intended for use by qualified engineering professionals
- Requires contributions from those with pertinent local knowledge and experience
- Focused on the principles of vulnerability and resiliency

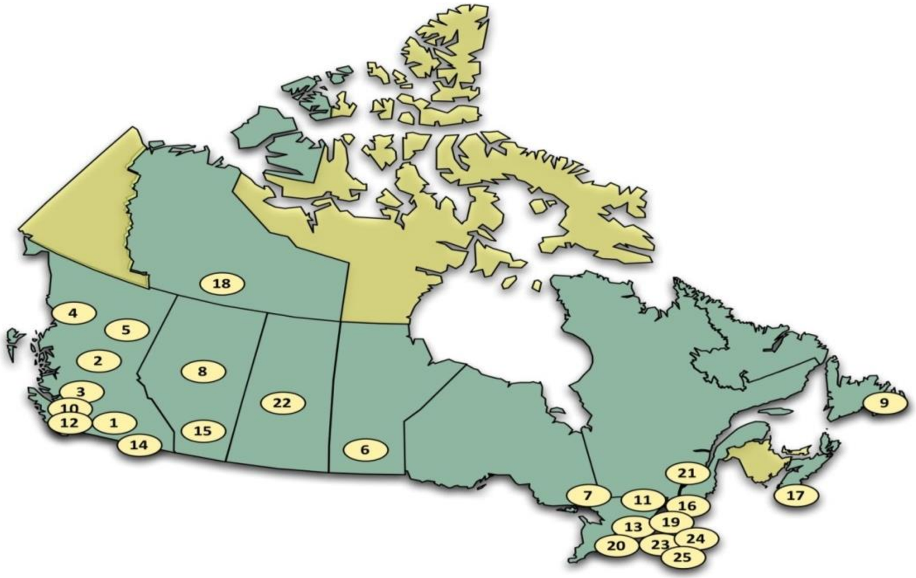


5 Steps plus an Optional TBL Module



45 Projects and Counting …

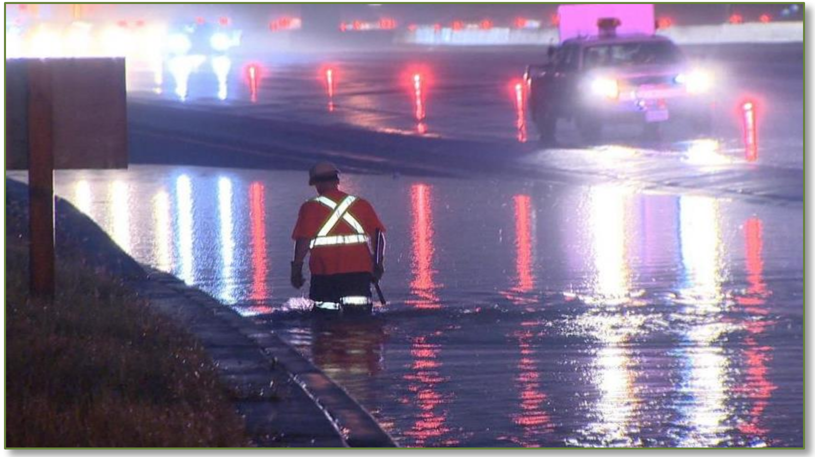
- *Water resources systems*
- *Storm & waste water systems*
- *Roads & bridges*
- *Buildings*
- *Transportation infrastructure*
- *Energy Infrastructure*



Lessons Learned from Infrastructure Climate Risk Assessments

Several common issues:

- **Intensity** – short duration precipitation is almost always a concern
- Infrastructure systems are **almost always vulnerable to interruptions in power supply**
  - Severe weather events can disrupt power supply and have significant impact on the serviceability of your infrastructure
- **Combinations of events can have more impact than discrete events**
  - Rain on snow
  - High snowfall followed by rapid thaw



Highway 404 in Toronto, Ontario July 27, 2014
Image: Global News

Lessons Learned from Infrastructure Climate Risk Assessments

- Meteorological **data used in design can often be very dated**
  - IDF curves based on 1960s precipitation data
- **Regional climate expertise** is always better
  - Climate specialists from distant locations may not be conversant with local weather phenomena
- **Multidisciplinary teams are very important**. Teams should comprise:
  - Fundamental **understanding of risk and risk assessment processes**
  - Directly **relevant engineering knowledge of the infrastructure**
  - **Climatic and meteorological expertise** relevant to the region
  - Hands-on **operation experience** with the infrastructure
  - Hands-on **management knowledge** with infrastructure
  - **Local knowledge** and history

Lessons Learned from Infrastructure Climate Risk Assessments

- Climate change projections should be based on **ensembles of model outputs**
  - There is always a temptation to use only one set of data
- Understanding your **baseline climate is critical**
  - How infrastructure has responded to historical weather events informs judgment on how it will likely respond to future, more extreme, events
- It is important to **monitor and maintain**
  - Good records of weather events
  - The impact they had on your infrastructure
  - How you responded

Benefits of Infrastructure Climate Risk Assessment

- Identify nature and severity of risks to components
- Optimize more detailed engineering analysis
- Quick identification of most obvious vulnerabilities
- Structured, documented and robust approach that 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

Infrastructure Resilience Strategy #2

Adaptation Planning and Implementation for Resilience

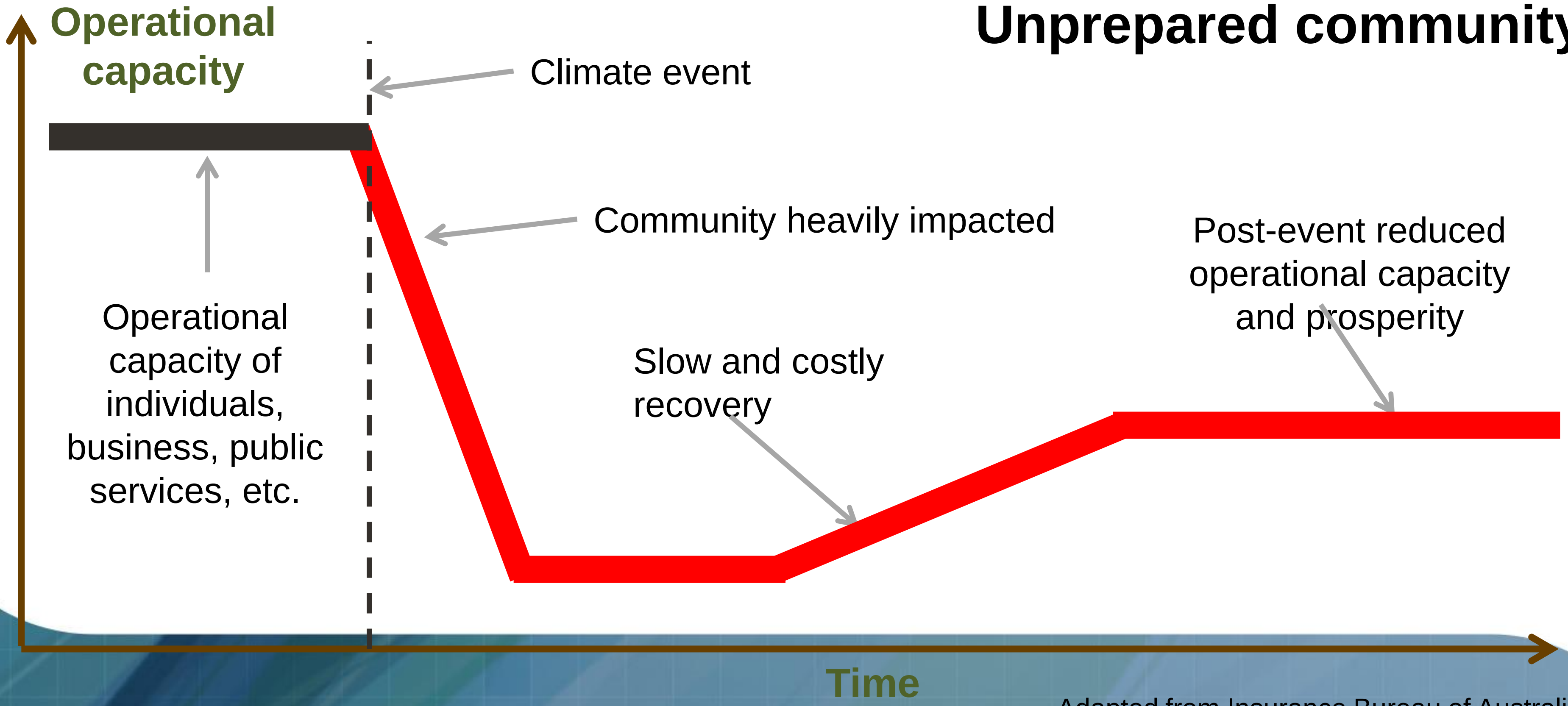
Adaptation options working with *Infrastructure Lifecycle Timeframes*

Structures	Expected Lifecycle
Houses/Buildings	Retrofit/alterations 15-20 yrs Demolition 50-100 yrs
Sewer	Major upgrade 50 yr
Dams/Water Supply	Refurbishment 20-30 yrs Reconstruction 50 yrs
Bridges	Maintenance annually Resurface concrete 20-25 yrs Reconstruction 50-100 yrs

Improves Asset management

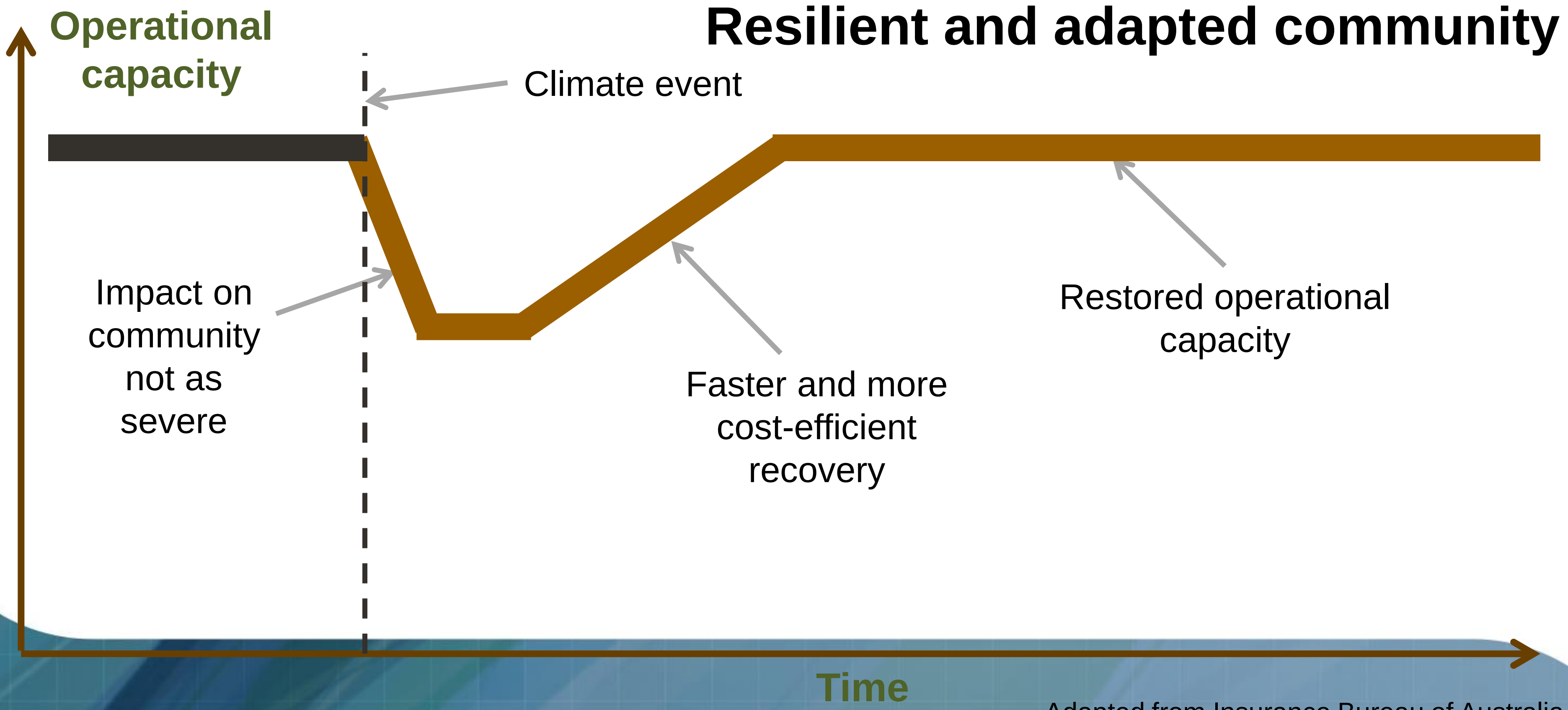
Climate Resilience

Unprepared community



Adapted from Insurance Bureau of Australia

Climate Resilience



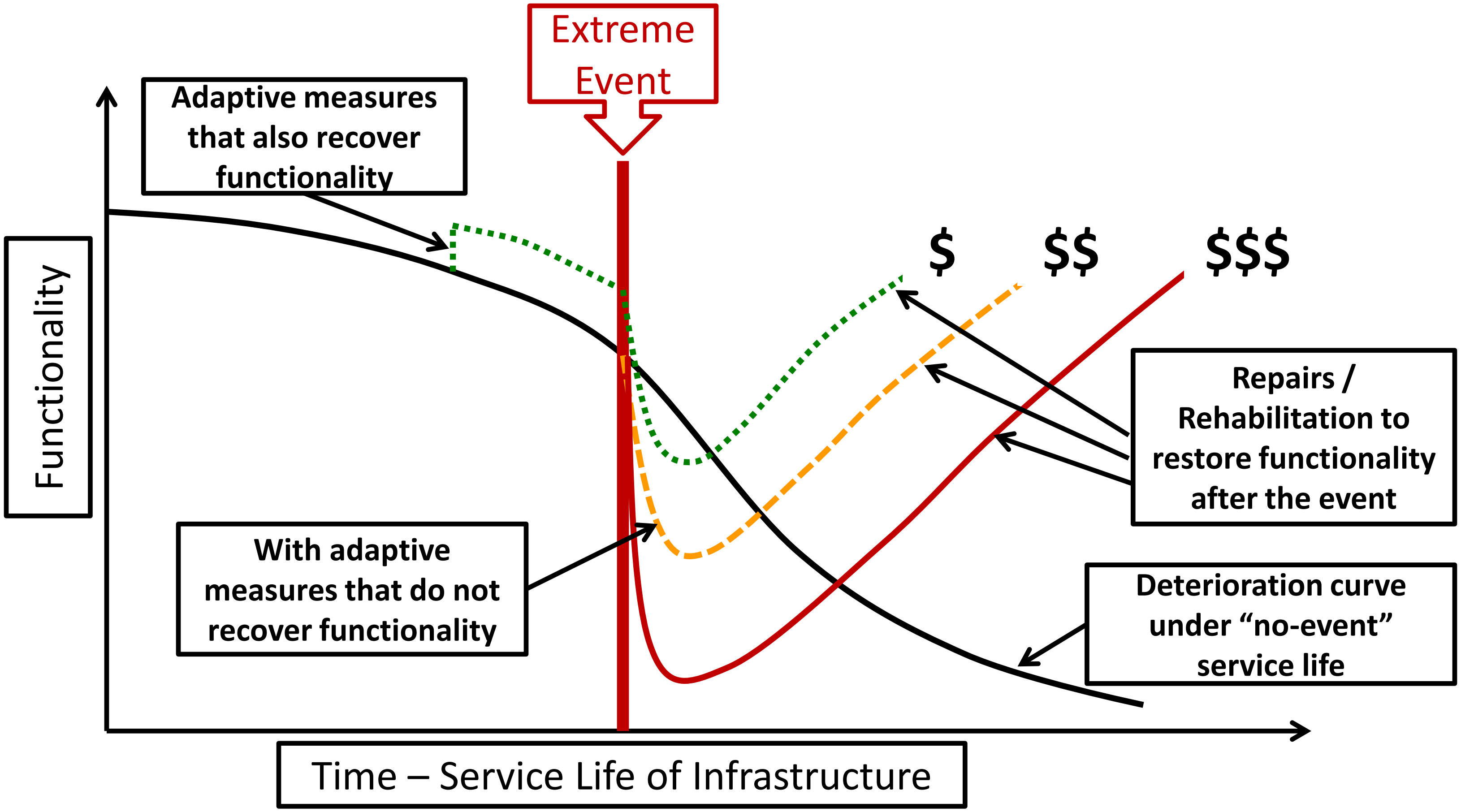
Adapted from Insurance Bureau of Australia

Loss prevention

Adapting Infrastructure to Current and Future Climate Risks and Vulnerabilities

- Gain **climate understanding**
- Understanding **risks and vulnerabilities**
- **Prioritize the risks** (Urgent to Least Urgent)
- **Minimize the risks** (engage Risk Reduction Programs)
- **Evaluate costs and benefits** to reduce risks
- **Communication** to decision-makers

- Combining these key Activities provides key elements of an ***Infrastructure Climate Risk Assessment*** and ***Risk Mitigation Plan***



Adapted from McAllister, T.P. (2013) *Developing Guidelines and Standards for Disaster Resilience of the Built Environment: A Research Needs Assessment*, NIST TN 1795, National Institute of Standards and Technology, Gaithersburg, MD, 20899.

Infrastructure Resilience Strategy #3

Policies, Procurement and Codes, Standards and Related Instruments

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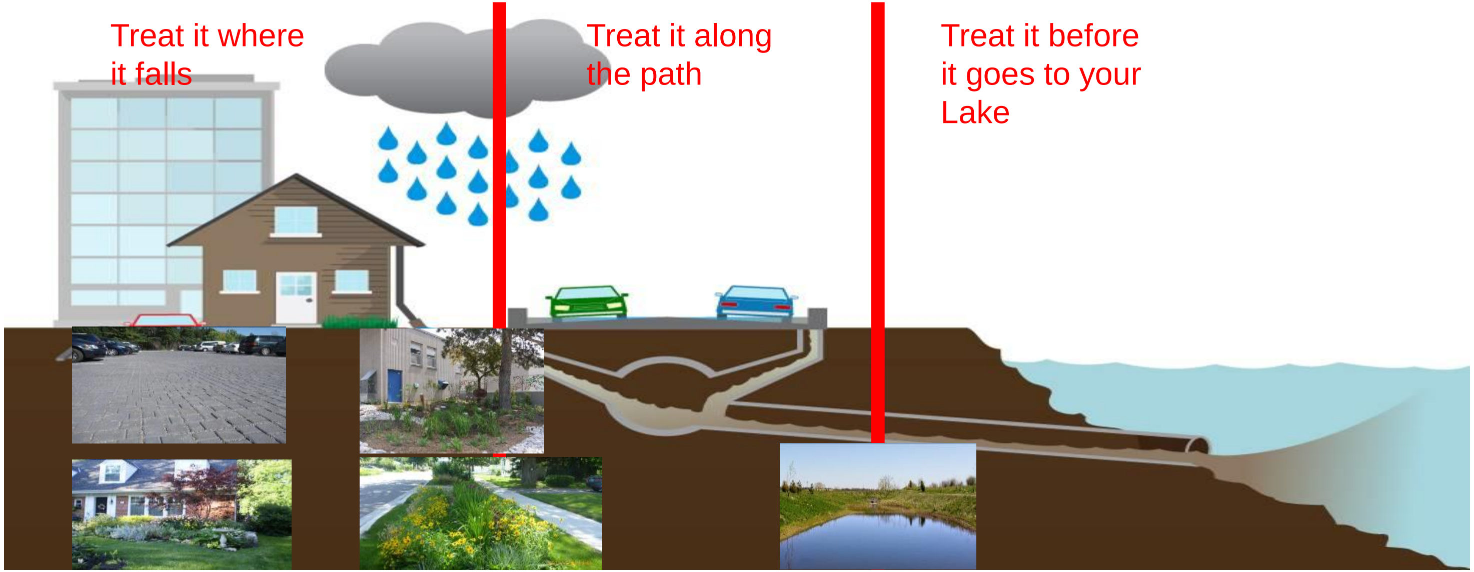
Climate Resilient Community Plan Policy Examples

1. Consider the effects of climate change on water quantity, stormwater, vulnerability to extreme weather events and eco-system changes (City of Castlegar Policies 7.4 and 20.4)
2. Require a stormwater management plan for new development that optimizes water storage capacity on-site and balances pre and post development surface flows and groundwater recharge (CCAC, 2015)
3. Preserve land that is required for current and future flood and stormwater risk management (CCAC, 2015)

Community Plan Policy Examples (cont'd)

4. Adopt low impact development standards for the transportation network including stormwater management techniques such as requiring permeable surfaces for run-off (CCAC 2015)
5. Support the replacement of short span bridges with longer spans, where appropriate to reduce exposure to flood risk.
6. Restrict development in designated hazard land areas, which include steep slopes, floodplains and wildfire interface areas. Consider how future climate projections will change hazard land designations in the future (CCAC, 2015)



Integrated Stormwater Management

(called LID- or Low Impact Development)

Credit Valley Conservation

Increasing Climate Resilience through new and updated Codes and Standards

- Climatic design values very outdated in many codes and standards (*e.g. Highway and Bridge Code*)
- NBCC 2015 added option to include climate change adaptation – given scientific evidence
- Several new Northern CSA standards – snow loads, drainage, permafrost maintenance, thermosyphons, IDFs for Water Practitioners PLUS 4013, Permafrost Foundations PLUS 4011
- Changes to all Codes and Standards based on "**evidence**" – often forensic analyses
- Canada a leader globally in climate change, codes, standard

Infrastructure Resilience Strategy #4

Professional Practice and Capacity-Building

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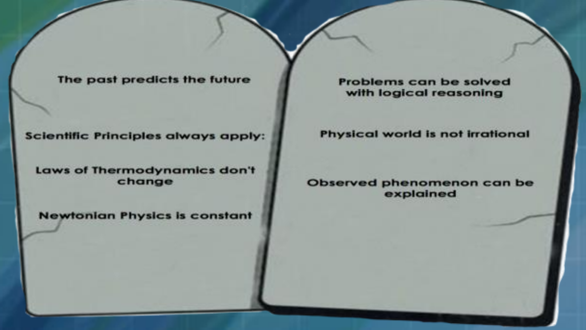
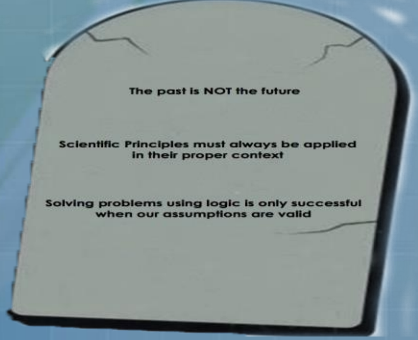


National Guideline



Principles of Climate Change Adaptation for Professional Engineers

June 2014

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Guideline Objective

- The overall intent of this guideline is to **ensure that professional engineers consider the implications of climate change in their professional practice and that they create a clear record of the outcomes of those considerations.**

Professional Engineers
and Geoscientists of BC

Professional Practice Guidelines - Incorporating Climate Resilience in the Design of Public Infrastructure in British Columbia

March 2016

Concluding Remarks

Adaptation Choices for Climate & Weather Resilience

Do nothing – opportunity

Strengthen existing & new designs ***(e.g. enhance safety factors; increase return periods; planned retrofits)***

Current Climate

New approaches & designs ***(e.g. deep water cooling)***

Manage extremes & variability ***(e.g. PIEVC; disaster planning)***

Monitor; Improve science

With Climate Change

IGN (new)

OPERATIONS (existing/new)

Added Resilience; Staged; Flexible

Include future climate (*PIEVC*)

Physical (*Retrofit; Monitor; Maintenance)*

Financial *(insurance; $ reserves)*

… and furthermore

Building infrastructure today without considering future climate impacts is incorporating vulnerabilities that will later cause service disruptions and failures thus increasing costs to government, the private sector and users.

Changing Climate and Uncertainties

- Engineers deal with many types of uncertainty.
- The changing climate is another uncertainty for the design, operation and maintenance of sustainable infrastructure to deliver an acceptable level of service.
- Can’t fix, harden, replace, or climate-proof everything – have to prioritize
- Opportunity costs associated with inaction
- Need to deal with imperfect data (esp. climate) and perpetual uncertainty
- A stitch in time saves four - $1 invested in prevention saves $4 in response

EVENTS DEFINE OUR PROFESSION

THEY CHALLENGE CONVENTION AND DEFINE WHAT IT MEANS TO BE AN ENGINEER

WE HAVE A DUTY OF CARE TO THE PUBLIC

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