



Infrastructure Climate Risk Assessment: Principles and Applications

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Agenda

Activity	Approximate Timing (Minutes)
Introduction and Background	10
Principles of Infrastructure Climate Risk Assessment	15
The PIEVC Engineering Protocol	10
PIEVC Case Studies – Summary Results	20
Closing Remarks	5



What is Engineers Canada?

- National organization for the engineering profession in Canada
- Members are the 12 constituent provincial and territorial associations that regulate the practice of engineering
- Over 160,000 registered professional engineers in Canada
- Facilitates common approaches among the members for professional qualifications, professional practice and ethical conduct
- Accredits all undergraduate engineering programs in Canada on behalf of the 12 members
- National and international voice of the profession



Engineers Canada Climate Change Impacts and Adaptation Action Plan

- Communication
- Education
- Continuing Professional Development (CPD)
- Guidelines, Codes and Standards
- Networking of Scientists and Engineers
- Funding arrangements



Civil Infrastructure - Overview

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

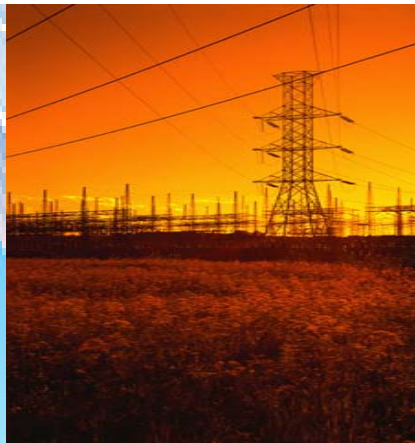
Water, Waste, & Storm water networks

Industrial structures

Communications networks

Landfills and waste depots

Culture and recreational facilities





Climate change impacts on infrastructure

- Direct impacts:
 - Changes in seasonality and type of precipitation
 - Intensity of precipitation
 - More coastal and river flooding
 - Sea level rise
 - More freeze-thaw cycles
 - Melting permafrost

Indirect impacts:

- Changes to peak energy demand
- More frequent and severe water shortages
- Reduced service levels or product quantity/quality
- Critical failures





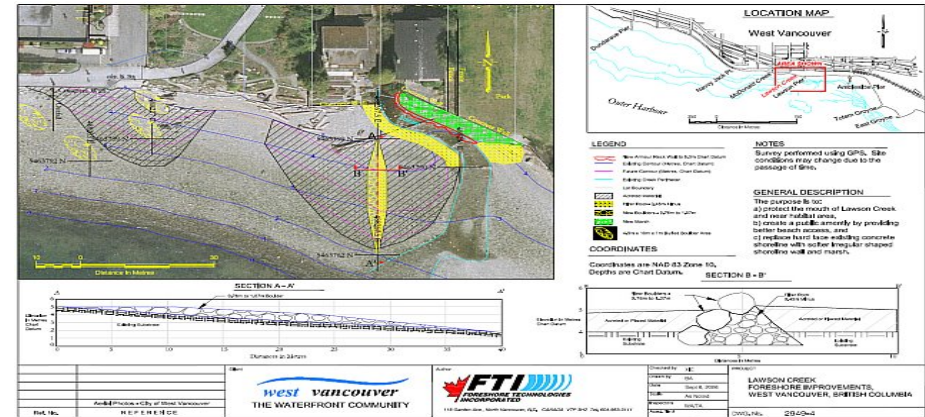
Implications for Infrastructure Codes and Standards

- Codes and standards rely on climate information to determine design loads
- Historical climate values are no longer reliable predictors of future climate conditions
- Future-looking, site-specific climate data is needed to upgrade codes and standards
- Many codes and standards still use historical data
- Environment Canada starting to address issues and current shortfalls in climate data but much more work is required



Challenges facing infrastructure professionals

- Inadequate data on localized climate future-states
- Detail and resolution of data insufficient for local use
- Design codes and standards may be less applicable going forward
- Procurement & contracting policies
- Increasing affluence (North America)
- Infrastructure turnover and age
- Consumer behaviour





Guiding Principles

- The climate is changing
- Climate change threatens the ability of engineers to safely and effectively design infrastructure to meet the needs of Canadians
 - Calls into question current rules and design standards
 - Design, operation and maintenance practices must adapt
- Climate change engineering vulnerability assessment is one tool to aid in the adaptation process



Public Infrastructure

“Those facilities, networks and assets operated for the collective public benefit including the health, safety, cultural or economic well-being of Canadians, whether operated by government and/or non-government agencies”.



Engineering Vulnerability

“The shortfall in the ability of public infrastructure to absorb the negative effects, and benefit from the positive effects, of changes in the climate conditions used to design and operate infrastructure.”

Vulnerability is a function of:

- Character, magnitude and rate of change in the climatic conditions to which infrastructure is predicted to be exposed;
- Sensitivities of infrastructure to the changes, in terms of positive or negative consequences of changes in applicable climatic conditions; and
- Built-in capacity of infrastructure to absorb any net negative consequences from the predicted changes in climatic conditions.
- Vulnerability assessment will, therefore, require assessment of all three elements above.



PRINCIPLES OF INFRASTRUCTURE CLIMATE RISK ASSESSMENT



Three Things That Engineers Believe

- The past predicts the future
- Scientific principles always apply
 - Thermodynamic laws don't change
 - Newtonian physics is constant
- Problems can be solved with logical reasoning
 - The physical world is not irrational
 - Observed phenomena can be explained

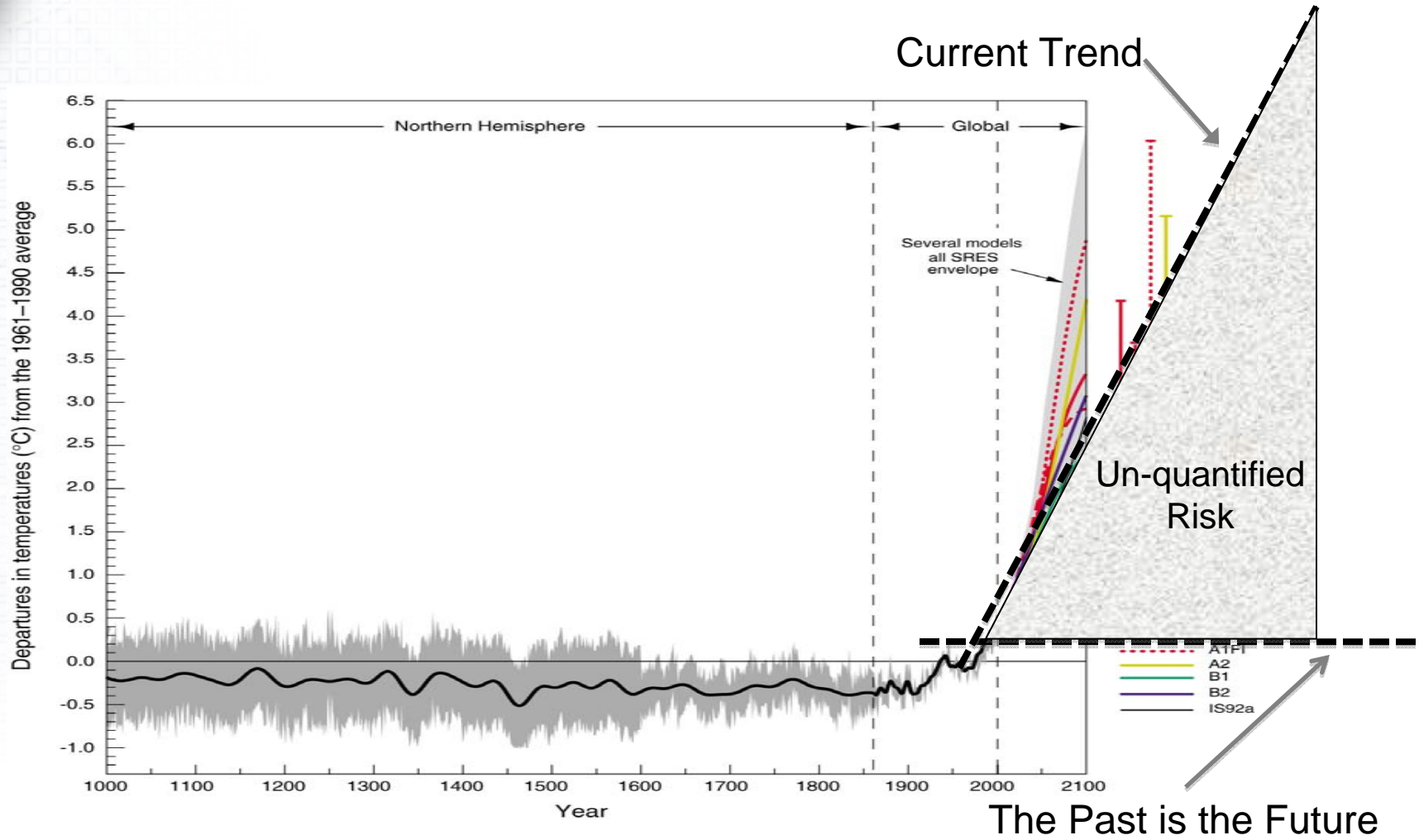


However ...

- The past IS NOT the future
- Scientific principles must be applied in the proper context
- Solving problems using logic only works when our assumptions are correct

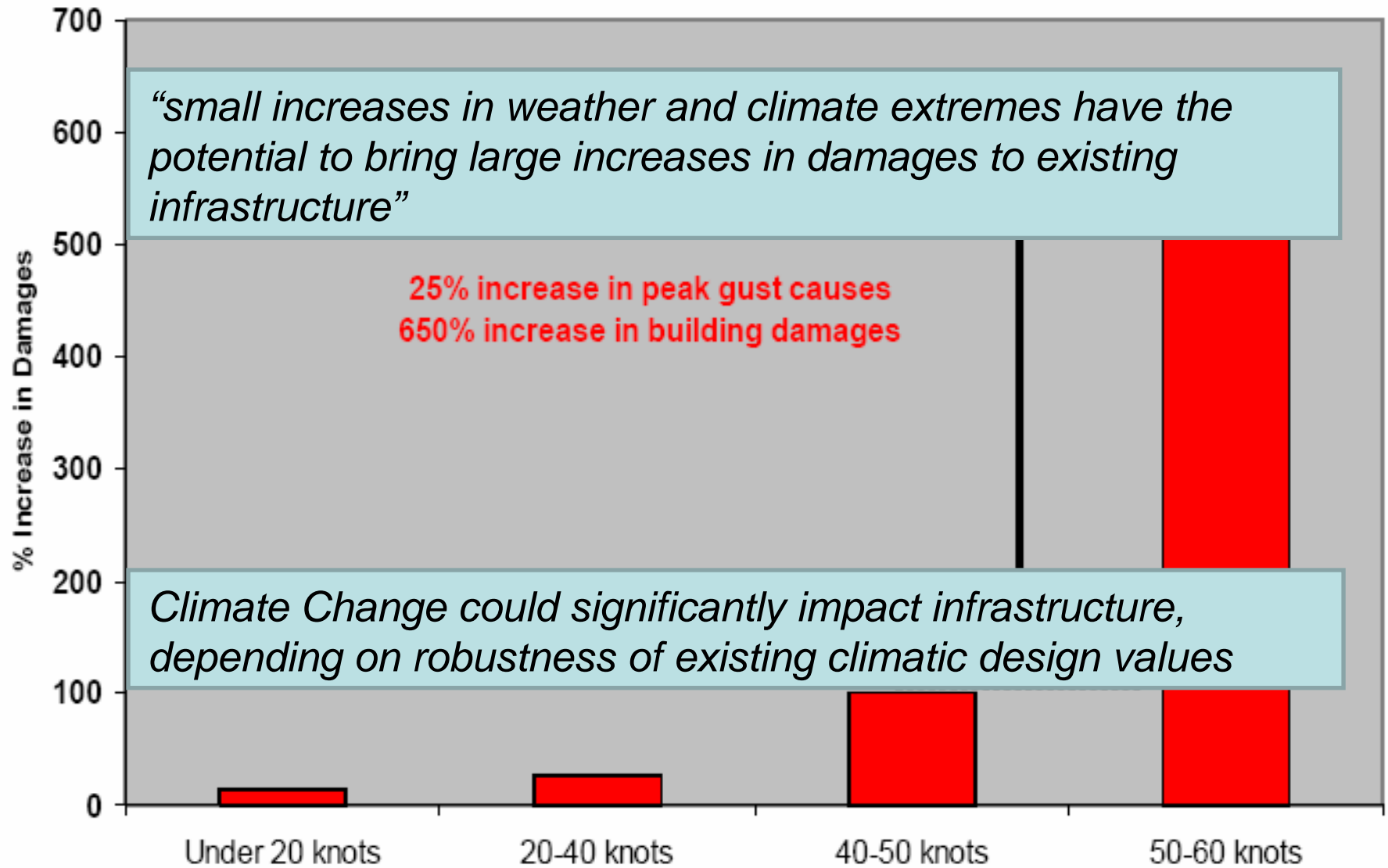


The Past IS NOT the Future





Small Increases = Escalating Infrastructure Damage



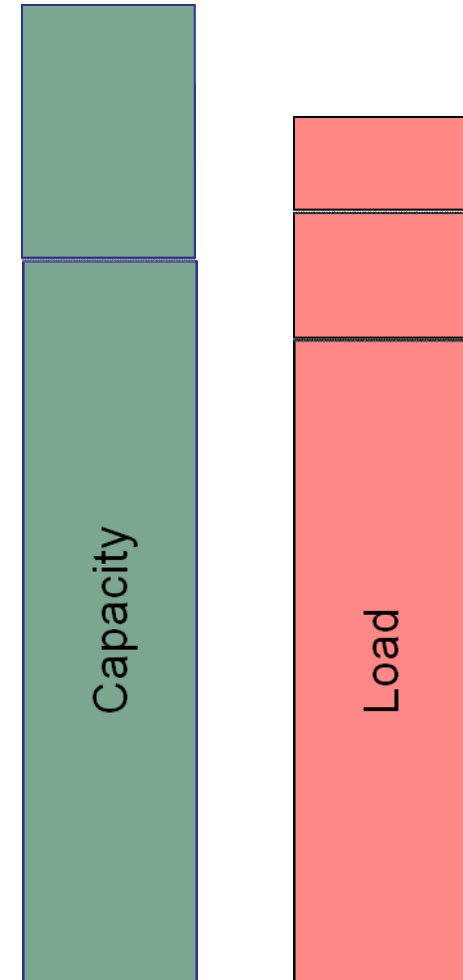


How do Small Changes Lead to Catastrophic Failure?????



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

- Design Load
- Change of use over time
 - For example – population growth
- Severe climate event





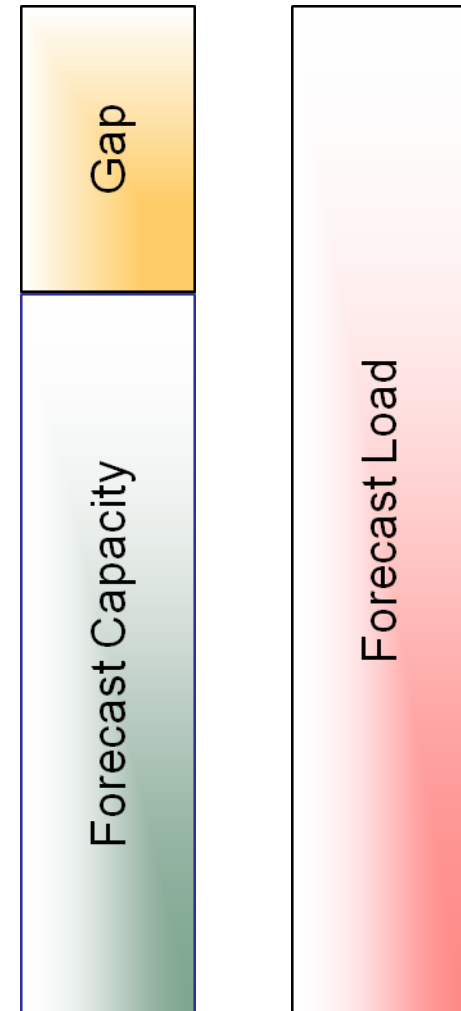
Some Observations

- A small change can have a dramatic impact
- Design safety margins may not last through the full operational life of an infrastructure system
 - Margins may be consumed by day-to-day uses/activities
- Failure often arises from a combination of events
 - Many of which we do not normally monitor
- Climate change can affect both the load and capacity of a structure
- Smaller measures can mitigate risk if we act early
 - Changes in maintenance practice
 - Measuring and monitoring



What is Vulnerability???

Vulnerability



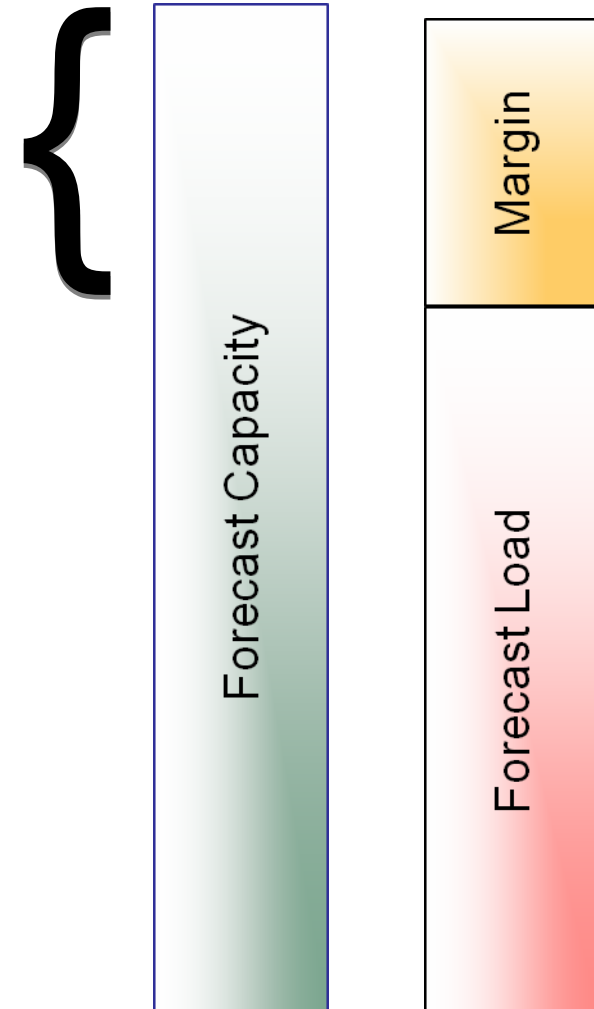
- Engineering design forecasts both the load and capacity of a structure
- If we predict a gap between forecast capacity and forecast load we identify a potential future failure condition
- Such a gap is called an “engineering vulnerability”



What is Resiliency???

Resiliency

- If we can predict a safety margin between forecast capacity and forecast load we identify a potential future non-failure condition
- Such a margin is called “engineering resiliency”





How can we assess vulnerability / resiliency?

- The PIEVC Protocol leads practitioners through a formal, documented, process to identify vulnerabilities and resiliency
- Applies standard risk assessment processes to this new concern



More Observations

- Vulnerability assessment is predictive
- We are contemplating POTENTIAL failure modes based on forecast information
- But how much confidence do we have in the prediction?
- In order to effectively address the issue we need to assess:
 - The likelihood of the event
 - The level of service disruption
- Without this assessment there is insufficient context to properly manage the issue

⇒ **RISK ASSESSMENT**



No Need to Discard the Past

- The past can be used to forecast the future when:
 - Based on an accurate understanding of the historical record
 - Appropriate application of scientific analysis
 - Assumptions that have been verified with real world observations and experience
- Simply extending the historic record foreword does not forecast future events:
 - Simplistic
 - Risky
- New tools are needed to quantify and manage the risk



Quantifying the Risk

- Risk assessment tools and techniques help us quantify risk
- The PIEVC Engineering Protocol is one such tool
- But what do we mean by RISK?



Defining Risk

Risk (R) is defined as the product of the probability (P) of an event and the severity (S) of that event – *should it occur*.

$$R = P \times S$$



Defining Risk

- Since risk is the combined effect of probability and severity **both** elements must be considered
 - Very low likelihood and high severity can still be a serious risk
 - Very high likelihood and low severity may be a very low risk
- Most people have an intuitive understanding of risk but need guidance to sort out and assess the relative significance of:
 - Likelihood
 - Severity
- The protocol guides practitioners through the process of assessing both probability and severity in a rigorous manner



THE PIEVC ENGINEERING VULNERABILITY ASSESSMENT PROTOCOL



Climate Change Risk Mitigation through Adaptation

SEVERITY		PROBABILITY							
		negligible or not applicable	improbable 1:1 000 000	remote 1:100 000	occasional 1:10 000	moderate 1:1 000	probable 1:100	frequent 1:10	continuous 1:1
7	Catastrophic 0.800	0	7	14	21	28	35	42	49
6	Hazardous 0.400	0	5	10	15	20	25	30	35
5	Serious 0.200	0	4	8	12	16	20	24	28
4	Major 0.100	0	3	6	9	12	15	18	21
3	Moderate 0.050	0	2	4	6	8	10	12	14
2	Minor 0.025	0	1	2	3	4	5	6	7
1	Measurable 0.0125	0	0	0	0	0	0	0	0
0	No Effect	0	0	0	0	0	0	0	0

Climate Change (indicated by a large grey arrow pointing from left to right across the table)

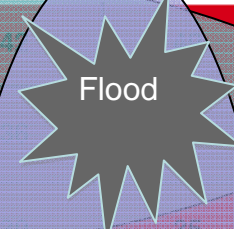
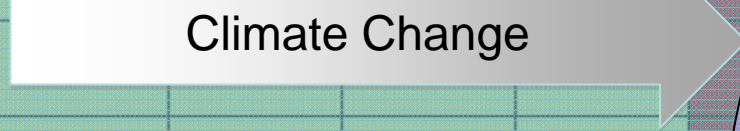
Adaptation (indicated by a large grey arrow pointing from right to left across the table)

Flood (indicated by starburst icons in the top-left, top-right, and bottom-right corners of the table)



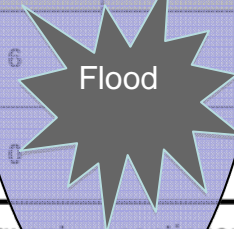
Vulnerability Assessment and Risk Mitigation

SEVERITY		PROBABILITY							
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Engineering
Vulnerability
Assessment

Risk
Mitigation





PIEVC Engineering Protocol

- Five step evaluation process
- A tool derived from standard risk management methodologies tailored to climate change vulnerability
- Data quality and availability assessed throughout
- Applied to vulnerability assessment of eight infrastructure case studies across Canada
- The protocol is a useful tool in the hands of a qualified professional



When Resources are Limited

- Not every application of the Protocol has all an ideal set of resources
 - Data
 - Computer models
 - Technical expertise
- This need not deter infrastructure owners from completing an assessment
- The Protocol identifies which questions to ask
 - Does not dictate the method that practitioners “should” use to answer those questions



Resources are Always Limited

- There are usually gaps
- Models may not cover the region being assessed
- Meteorological data may not have been collected
- Operational records may not exist
- Staff turnover
 - Experience gap
 - Corporate memory lapse



Filling the Gaps

- Engineering Vulnerability Assessment is a multidisciplinary activity
 - Team structure is a critical element of filling the gaps
- Must have:
 - Expertise in risk/vulnerability assessment
 - Directly relevant engineering knowledge of the infrastructure
 - Climatic and meteorological expertise relevant to the region
 - Operational experience
 - Hands-on management knowledge of the infrastructure
 - Local knowledge



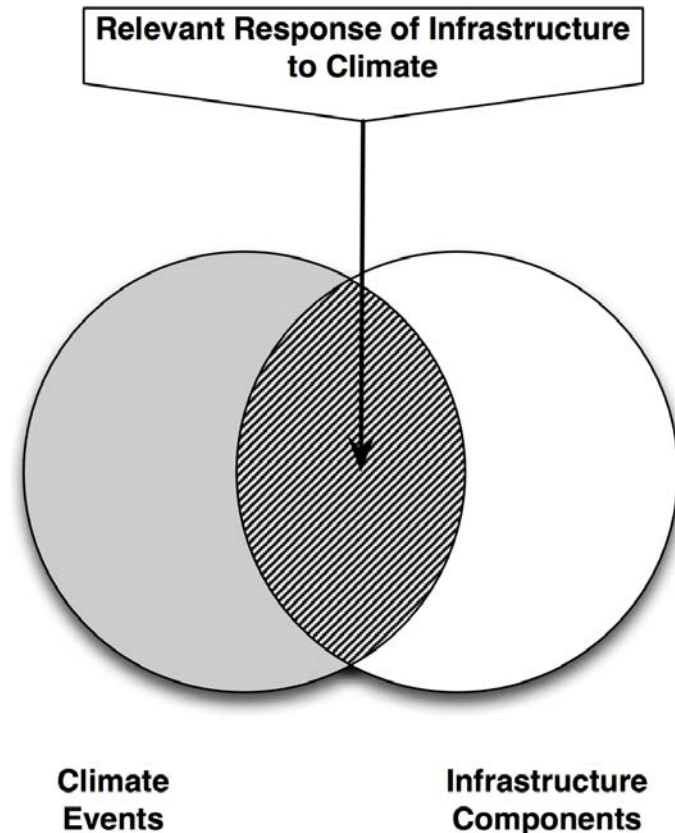
The Importance of Local Knowledge

Local knowledge, filtered through the expertise of the assessment team, can often compensate for data gaps and provide a basis for professional judgment of the vulnerability of the infrastructure.



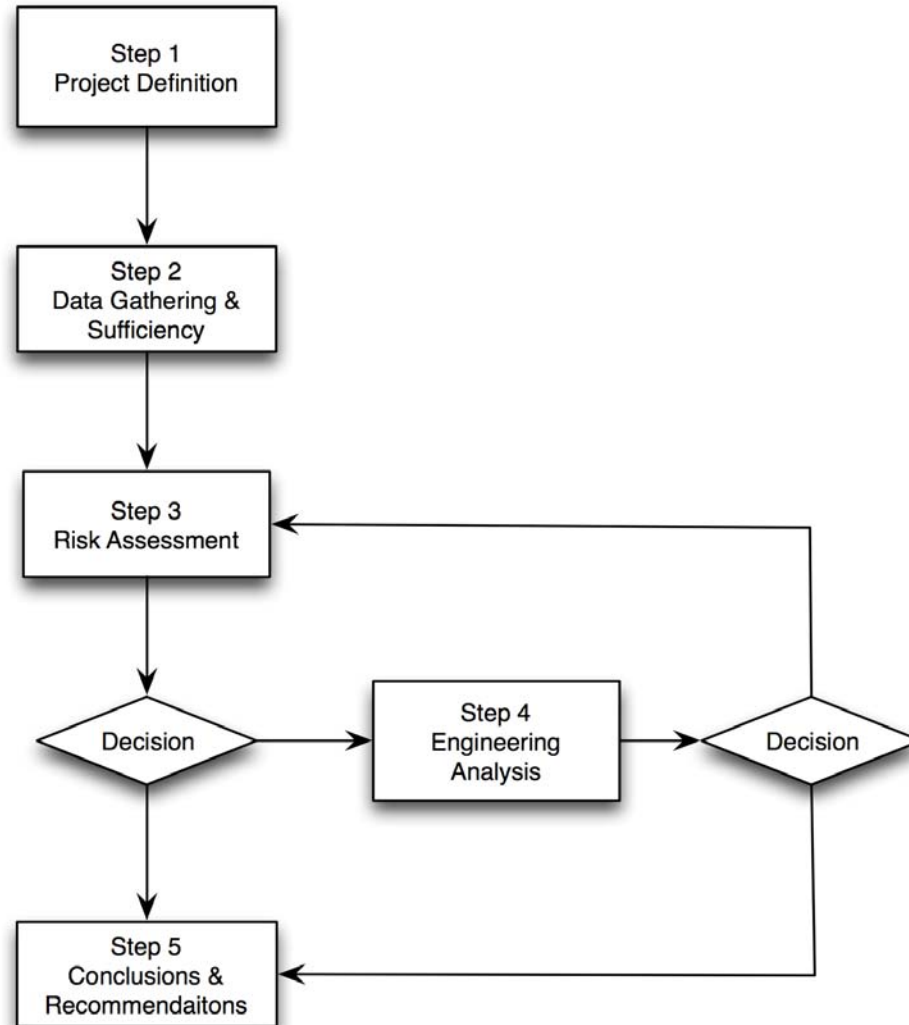
PIEVC Protocol Principles

- The PIEVC Protocol is a step by step process to assess impacts of climate change on infrastructure
- Goal:
 - Assist infrastructure owners and operators to effectively incorporate climate change adaptation into design, development and decision-making





A Five Step Process





PIEVC CASE STUDIES





Public Infrastructure Engineering Vulnerability Committee (PIEVC)

- **Oversee a national engineering assessment of the vulnerability of public infrastructure to climate change in Canada**
- **Facilitate the development of best engineering practices that adapt to climate change impacts**
- **Recommend reviews of infrastructure codes and standards**
- **Partnership between Engineers Canada and Natural Resources Canada**



PIEVC Membership

- **Engineers Canada**
- **NRCan**
- **Transport Canada**
- **Environment Canada**
- **Infrastructure Canada**
- **Public Works and Government Services Canada**
- **National Research Council**
- **Alberta Infrastructure and Transportation**
- **NWT Department of Public Works and Services**
- **Government of Newfoundland and Labrador**
- **Institute of Catastrophic Loss Reduction**
- **Canadian Standards Association**
- **Federation of Canadian Municipalities**
- **Municipality of Portage la Prairie**
- **City of Toronto**
- **City of Delta, BC**
- **City of Calgary**
- **Ontario Ministry of Energy and Infrastructure**
- **Ouranos**



Infrastructure Categories

- **Buildings**
- **Roads and Associated Structures**



- **Water Resources (water supply and water management structures)**
- **Stormwater and Wastewater Systems**



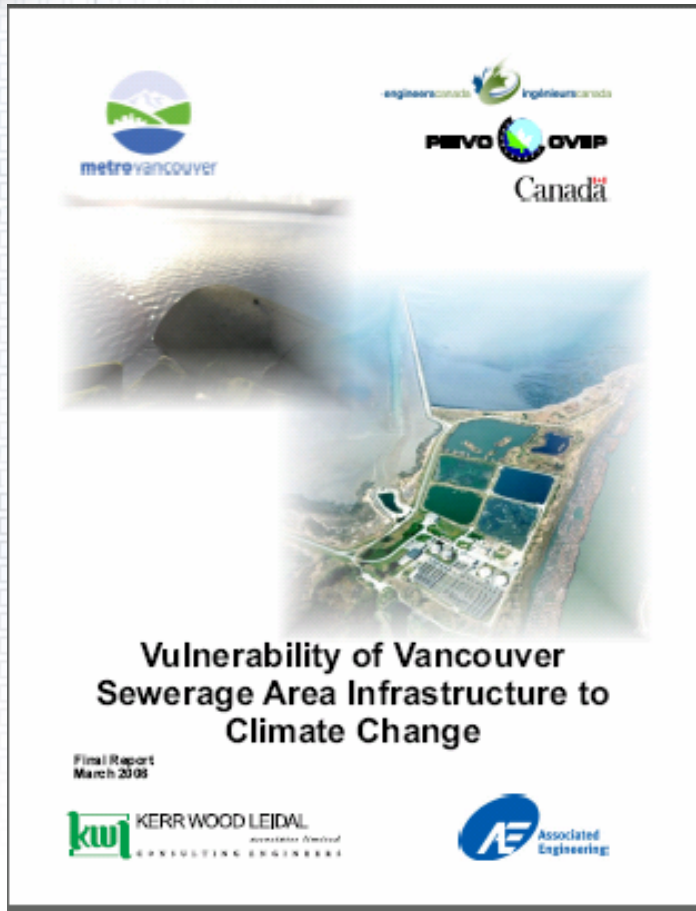
Phase II Case Studies

- Water resources systems
- Storm & waste water systems
- Roads & bridges
- Buildings



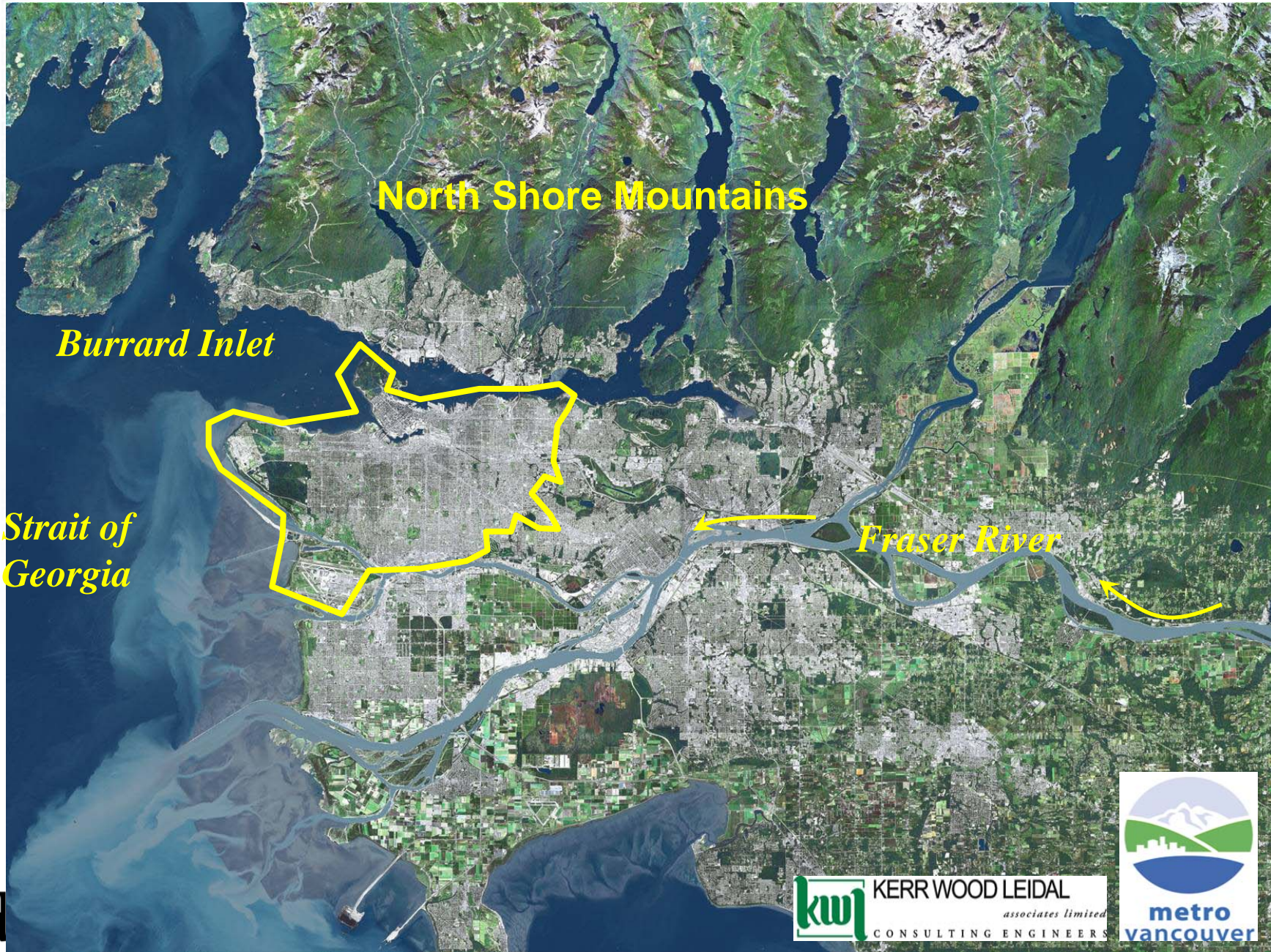


Metro Vancouver: Vancouver Sewerage Area Case Study





Metro Vancouver – Vancouver Sewerage Area



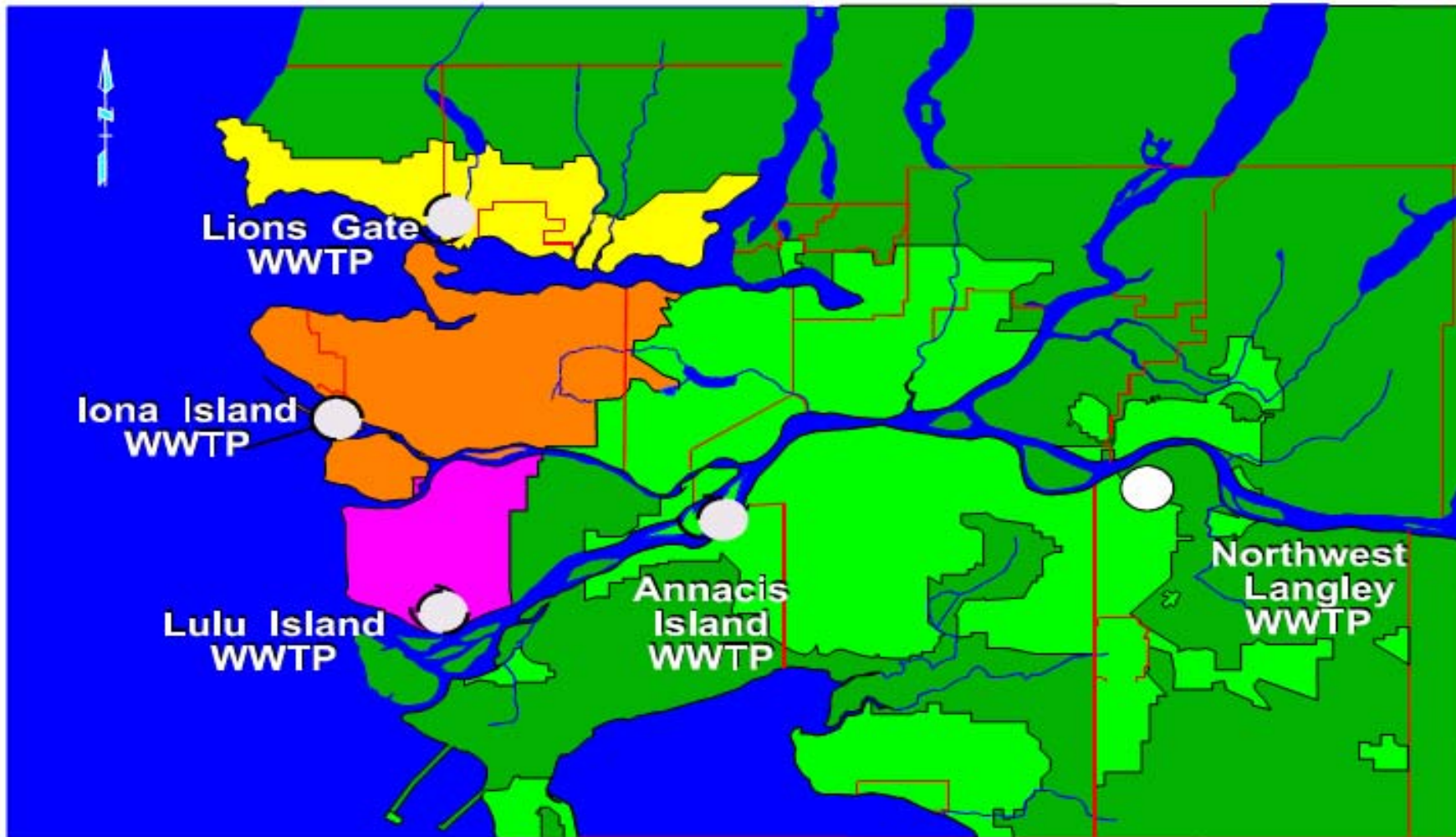
Canada





Metro Vancouver sewerage system

- Maintains and operates major interceptor sewers and five treatment plants





Metro Vancouver – Vancouver Sewerage Area

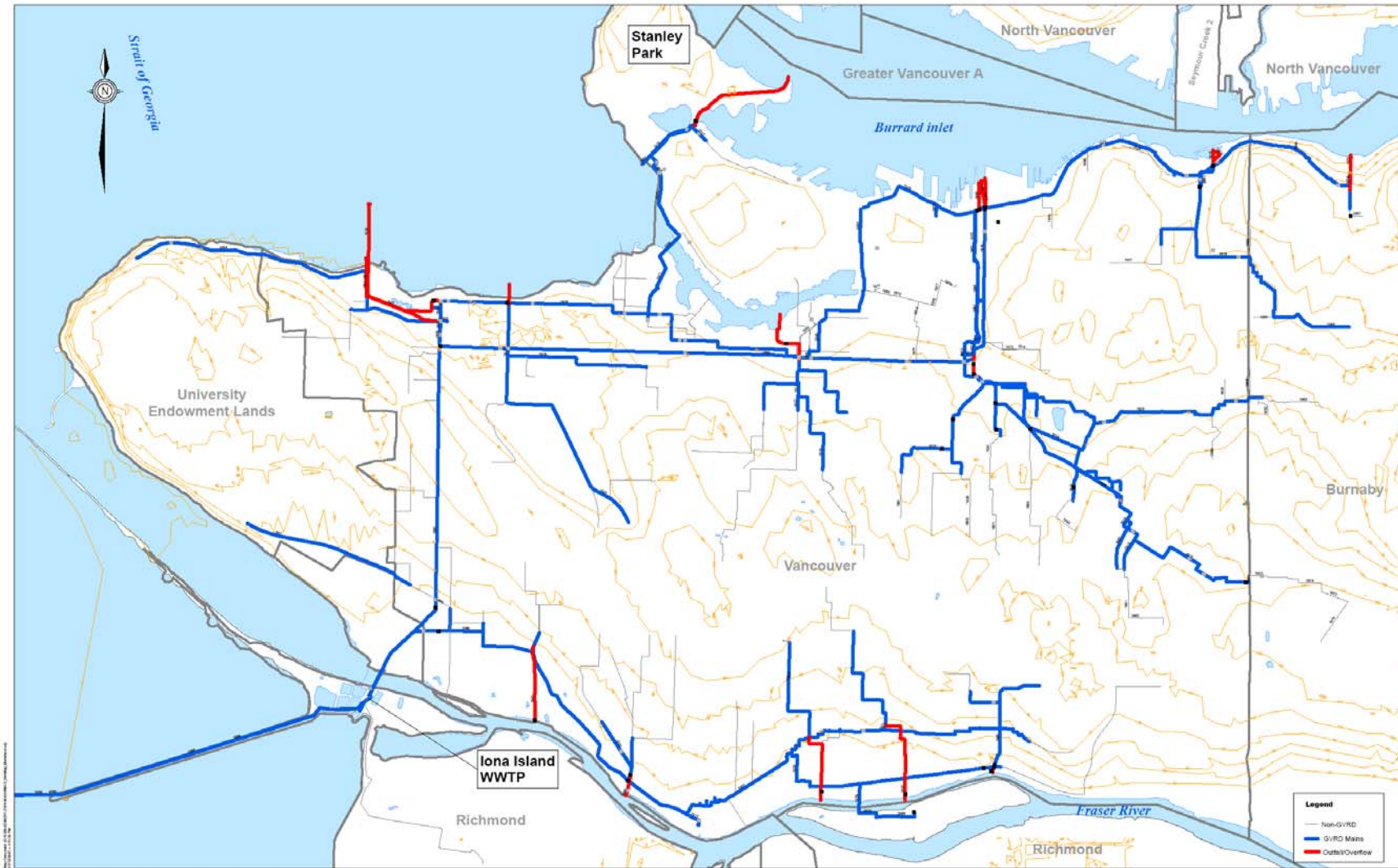


Iona Island waste water treatment plant

- predominantly combined (storm/sanitary) sewers
- collection system
- mechanical system
- discharge system
- 25 – 100 yr design life



Regional collection system





Vancouver Sewarage - Conclusions

- Key vulnerabilities
- Combined sewer overflows (CSO)
 - Intense rain, annual rain
- WWTP
 - Flooding - combined effects of storm surge, sea level rise and subsidence
 - Saltwater intrusion
 - Process unit redundancy
 - Standby power
- Effluent disposal – outfall/jetty structure

Canada Storm surge, wind/wave effects



Vancouver Sewerage – Recommendations

- Next phase of treatment upgrading
 - Design secondary treatment to accommodate sea level rise and storm surge
- Sewer Separation
 - Confirm timelines and commitments
- Identify stand-by power requirements
- Assess potential for WWTP flooding

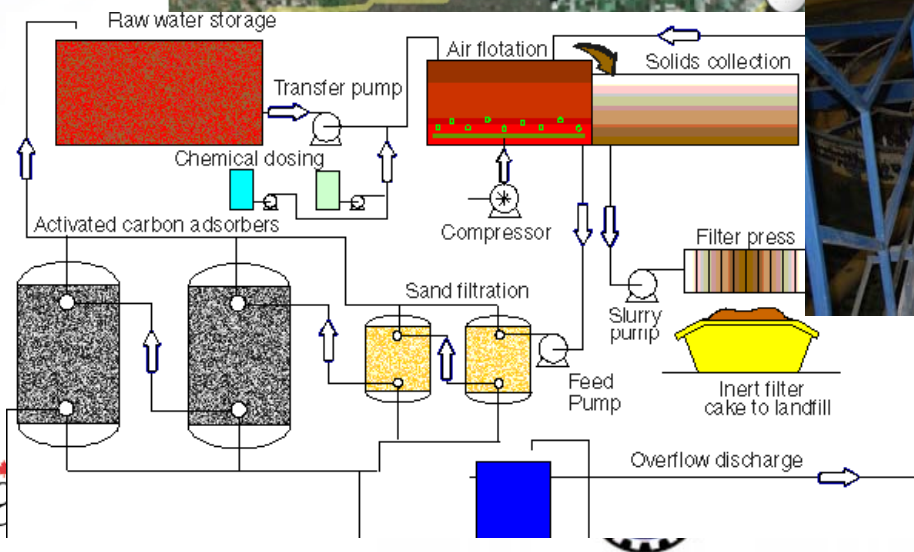


Vancouver Sewerage – Recommendations

- Review and update the Liquid Waste Management Plan
 - Review regional design standards
 - Consider policies and commitments to set targets for climate change adaptation
 - Reaffirm commitments to green infrastructure
 - Review how to incorporate climate change into new designs (IDF curves)



Portage la Prairie - Drinking Water Treatment Facility





Portage la Prairie - Drinking Water Treatment Facility

Vulnerabilities

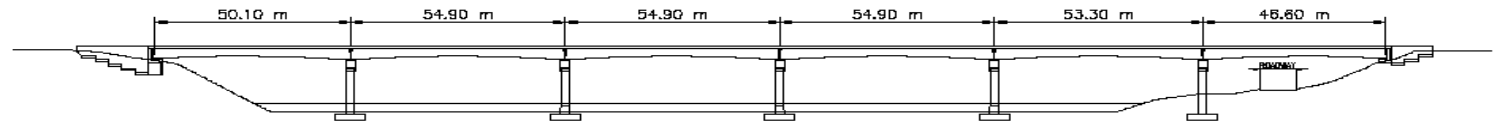
<i>Climate Effect</i>	<i>Infrastructure Component</i>
Floods, ice jams, ice build up	Control dam structure
Floods, ice jams, ice build up, intense rain	Intake well & pump
Drought	Water source
Ice storms, hail, intense rain, tornadoes	Power supply, communications, operations staff

Recommendations

- Improve emergency preparedness for extreme events
- Improve flood protection
- Planned infrastructure improvements to account for climate change



Edmonton – Quesnell Bridge



Design high water level : 1915 flood





Edmonton – Quesnell Bridge

Vulnerabilities

<i>Climate Effect</i>	<i>Infrastructure Component</i>
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



Ottawa - Buildings





Ottawa - Buildings

Vulnerabilities

<i>Climate Effect</i>	<i>Infrastructure Component</i>
Rainfall / humidity	Building envelope
Freeze-thaw cycles	Deterioration of building materials, especially roof membrane, concrete and masonry
Temperature / humidity extremes	HVAC systems ability to maintain an acceptable indoor environment
Snow load / wind / combo changes	Structural (e.g. roof)

Recommendations

- Historical or culturally valuable buildings may need a longer time horizon
- Identify stand by power requirements
- Further assessment of buildings located on permafrost



National Engineering Vulnerability Assessment Project – Phase III

- PIEVC Engineering Protocol enhancements
- More case studies (12 to 15) across Canada in the four infrastructure categories and develop a knowledge library
- Communications and outreach program with the engineering community, governments, other professional and industry associations in Canada and internationally
- Training workshops for engineers and geoscientists and other professionals
- Recommendations on reviews of infrastructure codes, standards and engineering practices
- Complete by October 31, 2011



PIEVC Case Study Process

- Owner signs license agreement with Engineers Canada to use Protocol
- Financial and administrative details handled through a Memorandum of Agreement
- Project advisory committee through the PIEVC Secretariat
- Case studies take about 6 -8 months to complete
- Cost - 60-80K depending on scope of infrastructure being assessed



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 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



Adaptation issues at the municipal and provincial level

- Low levels of awareness
- Gap between science and local planning
- Available tools/initiatives have focused on mitigation through GHG reduction, not adaptation
- Uncertainties affect willingness to take action
- Few examples of comprehensive adaptation strategies and tools
- Competing priorities and no sense of urgency



The Question

What would be an ideal framework for adapting our infrastructure to account for the changing climate?



The Ideal Adaption Framework

- **People**
 - Engineers, planners and other professionals, policy-makers, politicians and the public
- **Tools**
 - Vulnerability and risk assessment
 - Codes and standards
 - Climate change models and projections
 - Insurance, by-laws, regulations, land-use planning
 - Economic and social impact analysis
 - Risk management
- **Processes**
 - Political, social, outreach, education



Questions



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