Transport Canada Transports Canada

INCORPORATION OF CLIMATE CONSIDERATIONS: TRANSPORTATION INFRASTRUCTURE DESIGN

Transport Canada Adaptation Webinar Series

Alexa Bradley
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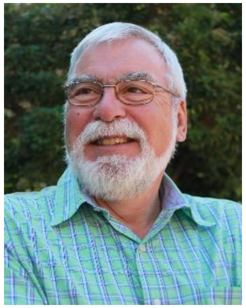


Dirk Nyland
Chief Engineer
British Columbia's Ministry of Transportation and Infrastructure

Allison Kader
Research / Analysis Officer, Transportation Assets Risk Assessment initiative
Transport Canada

Incorporation of Climate Considerations: Transportation Infrastructure Design

Transport Canada Webinar
Dirk Nyland, P.Eng., IRP
Chief Engineer, BCMoTI

March 19, 2019

British Columbia
Ministry of Transportation and Infrastructure

There has been a substantial increase in the intensity of heavy-precipitation events over large parts of the Northern Hemisphere due to greenhouse gases.

(Storms with over 100 millimetres of precipitation in 24 hours.)

Source: Zwiers, Nature, 2011

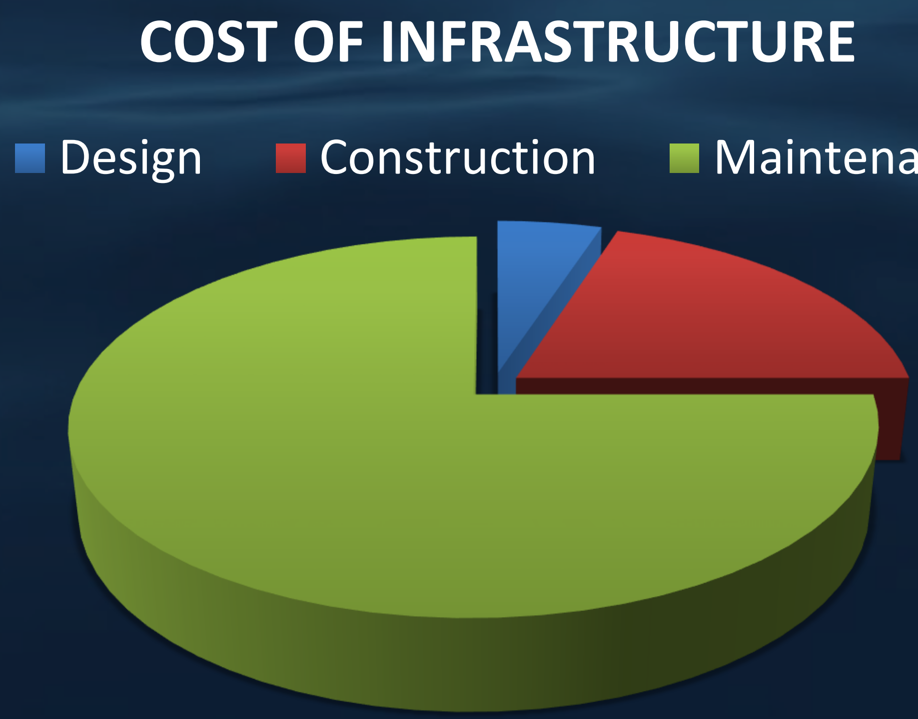
Holberg Road (Vancouver Island, Sept 2010)

Hagensborg (Bella Coola, Sept 2010)

The unavoidable impacts associated with climate change and weather extremes have the potential to adversely affect infrastructure

Planned adaptation can result in lower costs and is often more effective than reactive adaptation. Proactive adaptation measures guide strategic resource allocation and help avoid costly future repairs or replacements

Adaptation in engineering design and practices for resilient, reliable, efficient and effective transportation infrastructure



(resilience = lower maintenance)

Design for **higher temperature and precipitation** over lifecycle of components, i.e. bridges (50-100 years) culverts (75 years), pavement (15-20 years)

Nazko 2018

Revelstoke Hwy 23N 2018

Design for Climate & Weather Extremes

- Extreme rainfall in one or more days (e.g. >76 mm/24 hrs)
- Atmospheric River- Pineapple Express (e.g. >150 mm/24 hrs)
- High Temperature (e.g. number of days over 30°C)
- Temperature variability (e.g. freeze-thaw)
- Sea level rise (e.g. 1m by 2100)

Adaptation Planning Process

Phases	Steps
Preparation	Problem definition
	Stakeholder engagement
Risk review (or Risk mapping)	Risk assessment
	Risk prioritization
Risk Control	Risk mitigation
Monitoring and Evaluation	Monitor, measure and evaluate
Monitoring Review	Program adjustment

Vulnerability or **risk** is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity

Data for Risk Assessment

- Infrastructure Components
- Infrastructure Age
- Availability of Infrastructure Data
- Geotechnical Indicators
- Variety of Terrain
- Traffic Volumes
- Strategic Importance of Route
- Occurrence of Extreme Environmental Events

- Historic Weather Data Available
- Current Weather Data Available
- Expected Climatic Change – Temperature
- Expected Climatic Change – Precipitation
- Climatic Regions
- Sea Level Rise

Infrastructure Components

- Surface asphalt
- Bridges
- Ditches
- Catch basins
- Culverts
- Third-party utilities

Criteria on design standards and limits for infrastructure components to assess risk to climate change and weather extremes

Kootenay Pass 2018

Salmon Arm 2018

Design Criteria - Bridges and Structures

Hydrotechnical Design – Scour	
Current Standards	Maximum instantaneous discharge (Q200) Clearance between design water surface and bridge soffit (i.e. 1.5 m)
Climatic Variables	• Historic streamflow from hydrometric gauges • Historic precipitation from weather stations
Risk Issues	• Changes in streamflow (Q200) • Changes at watershed scale (land use & vegetation) • Changes in channel scale (stability, sediment transport)
Design Adaptation	• Estimate and use future streamflow (Q200) • Structure clearance, size, clear span • Construction quality (riprap) • Debris control • Maintenance for debris and sediment

Design Criteria - Bridges and Structures

Thermal Movement	
Current Standards	Canadian Highway Bridge Design Code
Climatic Variables	Temperature allowance in excess of max and min mean daily temperature
Risk Issues	• Increase in temperature • Temperature extremes • (Note: for general bridge design – risk may be low. Temperature changes may be small relative to accuracy of bridge code values)
Design Adaptation	NRC incorporate projected future temperature maps in code

Design Criteria - Geotechnical

Slope Stability	
Current Standards	Safety factor 1.5
Climatic Variables	Current conditions and moisture changes
Risk Issues	• Increased precipitation • Groundwater changes • Changes in land use and vegetation • Higher flow volumes and velocities
Design Adaptation	Compare recent conditions and future climate projections

Design Criteria - Geotechnical	
Pavement Grade - Asphalt Cement Mix	
Current Standards	Standard Specification 952
Climatic Variables	Pavement Grade values based on historic temperature and use
Risk Issues	Increased temperatures
Design Adaptation	Modify PG rating based on future temperature and use

Organizations require tools and resources to effectively anticipate, plan for, and respond to climate-related risks

ISO 31000 Risk Management - Infrastructure Canada – Climate Lens risk assessment tools:

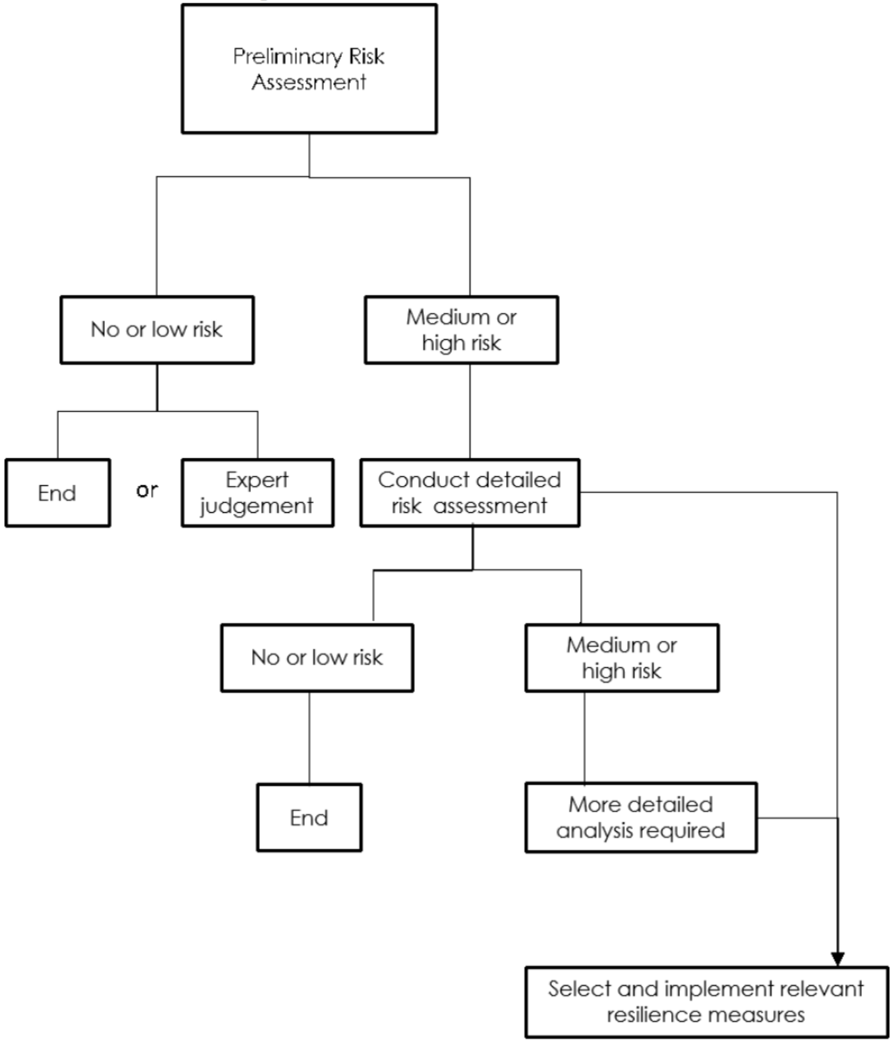
- Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol: https://pievc.ca/
- Envision: https://sustainableinfrastructure.org/envision/
- SuRe - The Standard for Sustainable and Resilient Infrastructure: http://www.gib-foundation.org/sure-standard/

Climate Resilience Assessment

Infrastructure Canada - Climate L

https://www.infrastructure.gc.ca/pub/other-autre/cl-occ-eng.html

Figure 1: Flowchart of Resilience Assessment

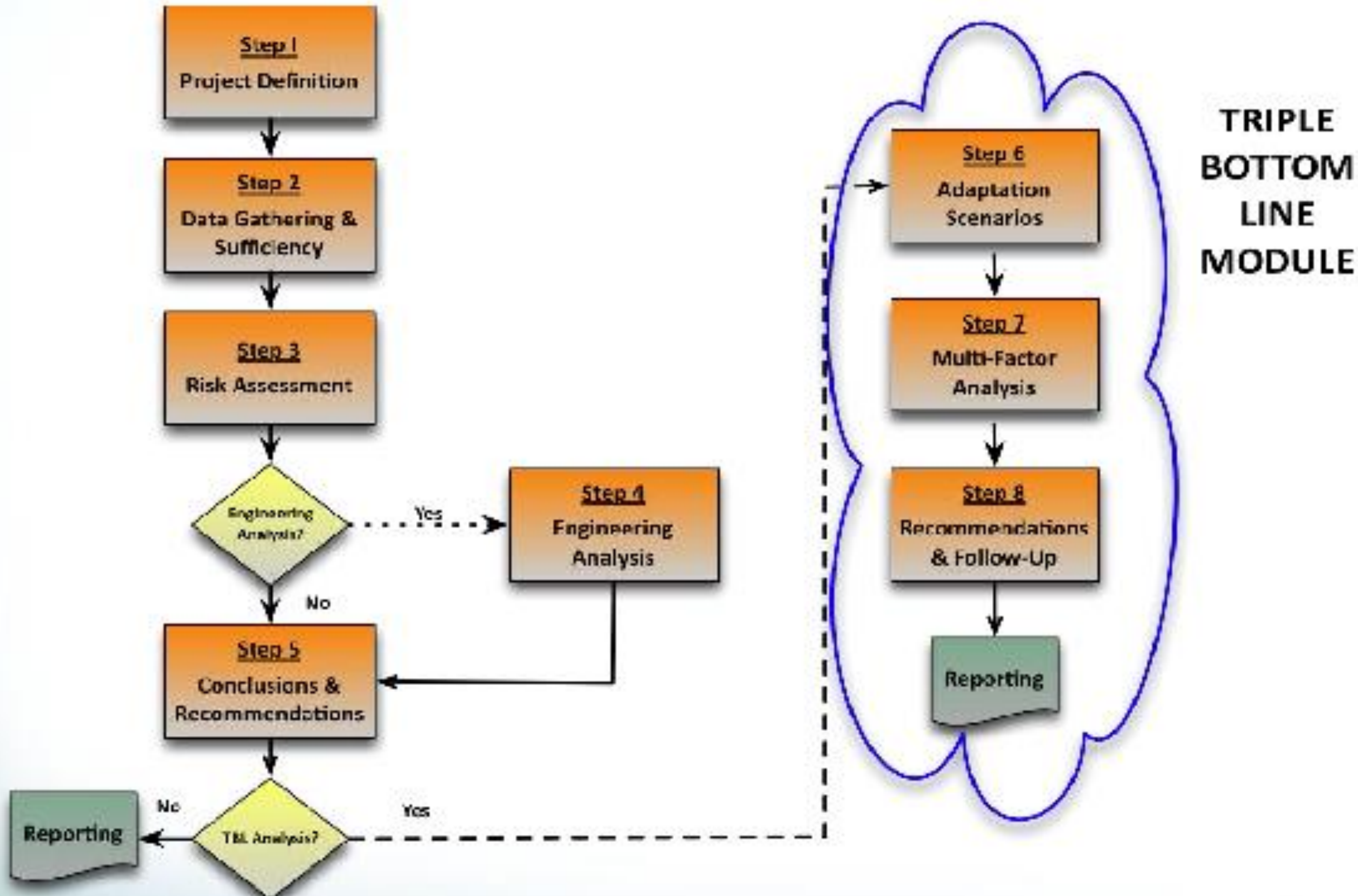


Chief Engineer of BCMoTI involved developing PIEVC tool to assess infrastructure risk to projected climate change and weather extremes. Using multi-disciplinary/stakeholder and local knowledge/experience inputs

Commotion Creek Hwy 97 2016

Peace Region Flooding 2016

PIEVC Steps



Step 1
Project Definition
Step 2
Data Gathering & Sufficiency
Step 3
Risk Assessment
Engineering Analysis?
Yes
Step 4
Engineering Analysis
No
Step 5
Conclusions & Recommendations
Reporting
No
TBL Analysis?
Yes
Step 6
Adaptation Scenarios
Step 7
Multi-Factor Analysis
Step 8
Recommendations & Follow-Up
Reporting
TRIPLE BOTTOM LINE MODULE

Risk Matrix

iclei - Google Search | Infrastructure Canada - Climate L | Professional Practice Guidelines | 2017_MoTI-guidelines-06F-web_

https://www.egbc.ca/getmedia/1ac17fe9-8eaf-41d3-b095-afac3953b8f3/2017_MoTI-guidelines-06F-web_1.pdf.aspx

Figure 4: Sample risk matrix

Severity									
	7	0	7	14	21	28	35	42	49
	6	0	6	12	18	24	30	36	42
	5	0	5	10	15	20	25	30	35
	4	0	4	8	12	16	20	24	28
	3	0	3	6	9	12	15	18	21
	2	0	2	4	6	8	10	12	14
	1	0	1	2	3	4	5	6	7
	0	0	0	0	0	0	0	0	0
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
		Probability							

Special Case	Low Risk	Medium Risk	High Risk

BC Highways are generally resilient to projected climate change except for extreme precipitation events; further research is required for events such as rain on snow, fog and wind, avalanche, landslides, sea level rise, etc.

Yellowhead Hwy

Bitter Creek Bridge, Stewart, Sept 2011

Lessons Learned to Date

- Develop awareness of climate change/extreme weather and implications (primarily water related events)
- Include climate adaptation in organizational practice
- Use multidisciplinary teams for projects
- Use qualified professionals with local knowledge (climate, meteorological, hydrotechnical)
- Adaptation education for professionals, consultants, staff and students

Batnuni Bridge 2018

Narcosli Bridge 2018

Best Practices

- Monitor **data** used in current codes and standards and develop climate resilience specific codes
- Use data and/or professional judgement
- Apply sensitivity analysis
- Understand risks and uncertainties
- Review association guidance

Bella Coola, Sept 2010

- Use information from ensemble of climate models
- Determine best models and data to use

In 2014-15, ACECBC consultants, EGBC, PCIC and BCMoTI partnered in developing a technical circular considering climate adapted design for highway reliability

Grand Forks, May 2018

Technical Circular Requirements

- Design for climate change and weather extremes from model projections
- Vulnerability screening analysis for the design life of structures and components include data sources
- Development of practical and affordable design criteria
- Design Criteria Sheet to summarize climate parameter changes

BC MoTI Design Criteria Sheet for Climate Change Resilience

Highway Infrastructure Design Engineering and Climate Change Resilience

Ministry of Transportation and Infrastructure

Project:	Project No. 12573 Highway 1 at Mountain Highway Interchange
Type of Work:	Interchange Improvement
Location:	Highway 1 at Mountain Highway Interchange, North Vancouver, BC LKI Segment 0515 km 6.18
Discipline	Drainage

Design Component	Design Life or Return Period		Design Criteria + (Units)	Design Value Without Climate Change	Change in Design Value From Future Climate	Design Value Including Climate Change	Comments / Notes / Deviations / Variance
	D.L.	R.P.					
<u>Major Drainage System</u>							
Culverts < 3000 mm	50 yr	100 yr	Flow Rate [m3/s]	18.1	+20%	21.7	
Keith Creek	-	100 yr	Flow Rate [m3/s]	18.1	+20%	21.7	
<u>Minor Drainage System</u>							
Storm Sewer – MoTI	-	25 yr	Intensity [mm/hr]	Varies	+20%	Varies	
Storm Sewer – CNV / DNV	-	10 yr	Intensity [mm/hr]	Varies	+20%	Varies	
Catchbasin - All	-	10 yr	Intensity [mm/hr]	Varies	+20%	Varies	

DRAFT

Explanatory Notes / Discussion:

1. Plan2Adapt Tool (PCIC Website)
   a. Annual Precipitation estimated to increase by ~7% (Mean) ~10.5% (75th Percentile) ~ 17.5% (90th Percentile), for year 2065.
2. APEGBC Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC
   a. If no historical trend is detectable, apply a 10% increase (to year 2100)
   b. If there is a significantly detectable trend, apply a 20 % increase (to year 2100)
3. IDF-CC Tool (Western University / Canadian Water Network)
   a. Ensemble mean estimates approximately a 18% / 18% / 23% increase in rainfall to the year 2065 (assumes RCP 8.5 climate change scenario), for Environment Canada rain gauges North Vancouver Lynn Creek / Vancouver Harbour CS / North Vancouver Sonora Drive.

Recommended by: Engineer of Record:
(Print Name / Provide Seal & Signature) Josh Thiessen

Date: 2016-01-29

Engineering Firm: Associated Engineering (B.C.) Ltd.

Accepted by BC MoTI Consultant Liaison: ______

Deviations and Variances Approved by the Chief Engineer: ______

Program Contact: Dirk Nyland, Chief Engineer BCMoTI

Rev.0

Design Sheet Example

EGBC Practice Guidelines

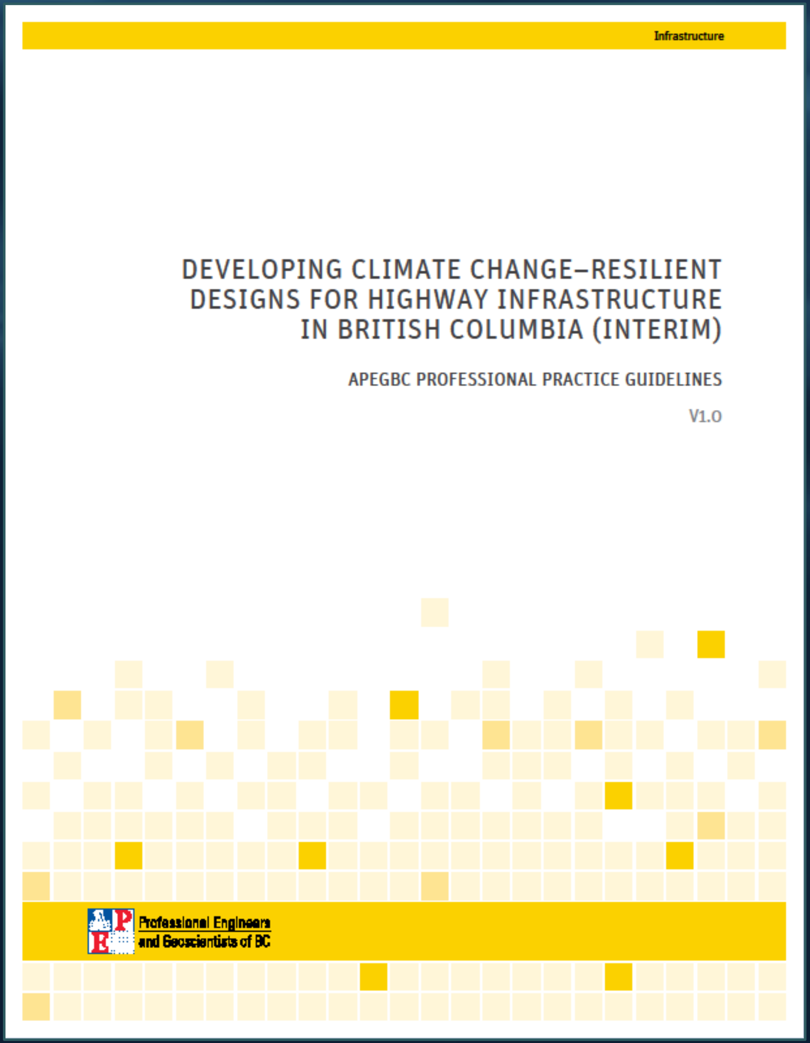
Request for Proposal (2.2.1.1)

Define Highway Infrastructure project (3.2)

Conduct screening-level, climate change risk assessment (3.3)

Identify and incorporate climate adaptation options (3.4)

Documents (3.5)
- Climate change risk assessment
- Hwy resilient design report
- Assurance statement
- BCMoTI Design Criteria Sheet



Infrastructure

DEVELOPING CLIMATE CHANGE–RESILIENT DESIGNS FOR HIGHWAY INFRASTRUCTURE IN BRITISH COLUMBIA (INTERIM)

APEGBC PROFESSIONAL PRACTICE GUIDELINES

V1.0

Professional Engineers and Geoscientists of BC

Adapted Bridge Designs - Flow

Region	Return periods from sheets vary	% ↑ Design Value for Climate Change	Climate Data
NR	100-200yr	+9% to +30%	-MoTI practices -EGBC recommendations* -PCIC regional reports -IDFCC -Consultant Reports
SIR	100-200yr	+10% to +20%	-MoTI practices -EGBC recommendations* -PCIC -Consultant Reports
SCR	200yr	+11% to +15%	-MoE coastal guidelines -EGBC recommendations* -Consultant Reports

Adapted Culvert Designs - Flow

Region	Return periods from sheets vary	% ↑ Design Value for Climate Change	Climate Data
NR	50-200yr	+10% to +25%	- IDFCC - Consultant reports
SIR	25-200yr	+10%	- MoTI - EGBC recommendations* - Consultant Reports
SCR	5-200yr	+3.6% to +25%	- EGBC recommendations* - PCIC - IDFCC - Consultant Reports

Zonnebeke Creek – Culvert Replacement

(Design $1 million / Construction $10 million)

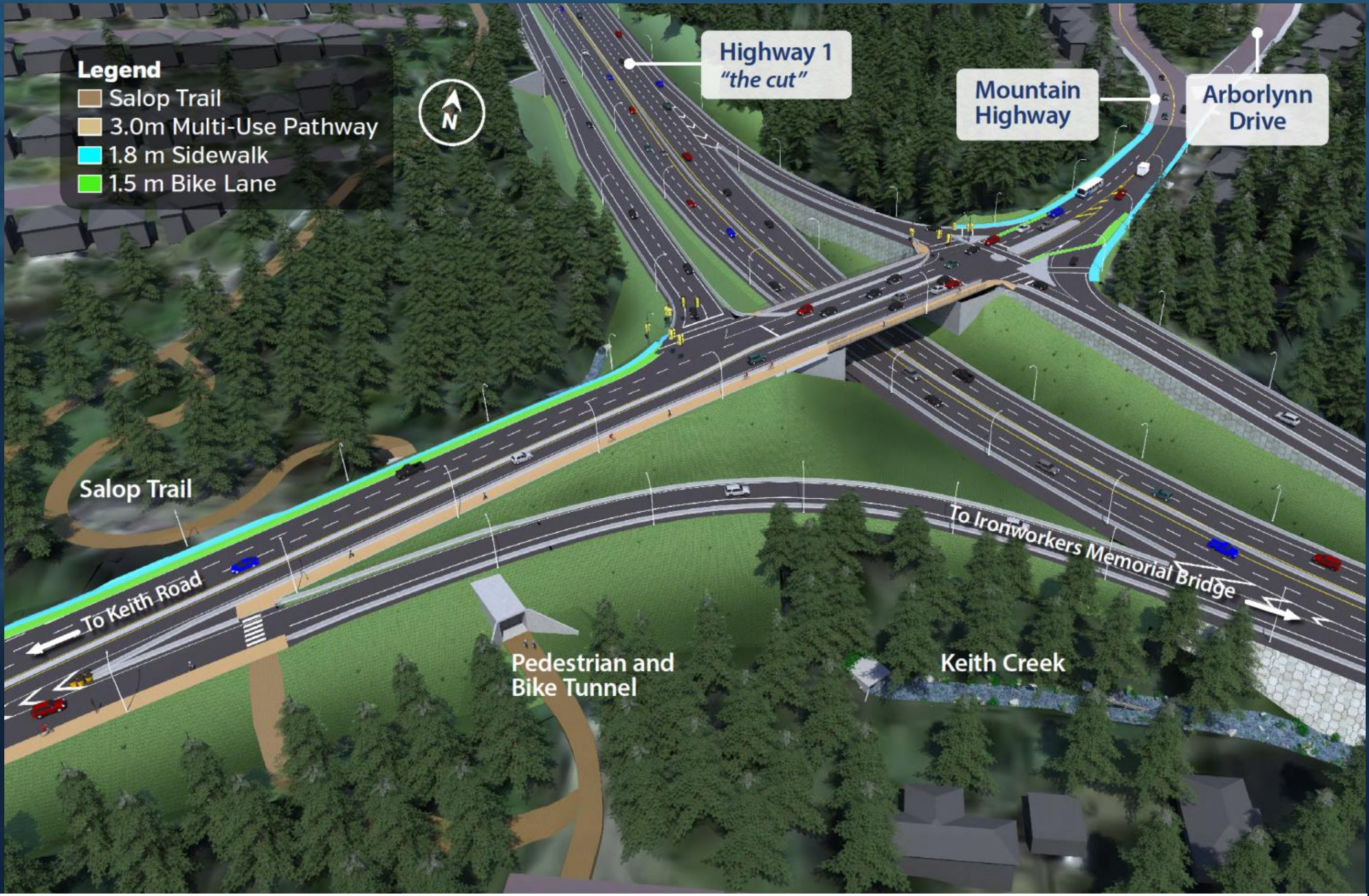
Zonnebeke Creek Culvert Replacement Hwy 29S	Culvert (6,470 mm SPCSP)	Return 200yr	Flow Rate (m^3/s) 61.6	Climate Change +25%	New Flow Rate (M^3/S) 77	NHC IDFCC Report on the 2016 Flood Event and Regional Hydrology – NHC, 2017

McKenzie Interchange

(Critical Sewer Segment 2 of 10)

Admirals-McKenzie Interchange Hwy 1	Critical Sewer Segment #2	Return 200yr	Flow Rate (l/s) 711	Climate Change +18.4%	Flow Rate (l/s) 842	Future IDF curves

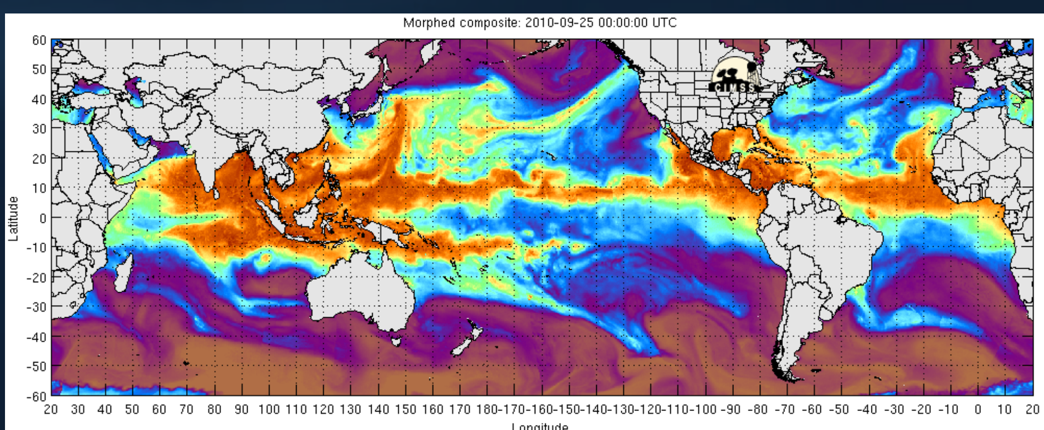
Mtn Hwy Interchange

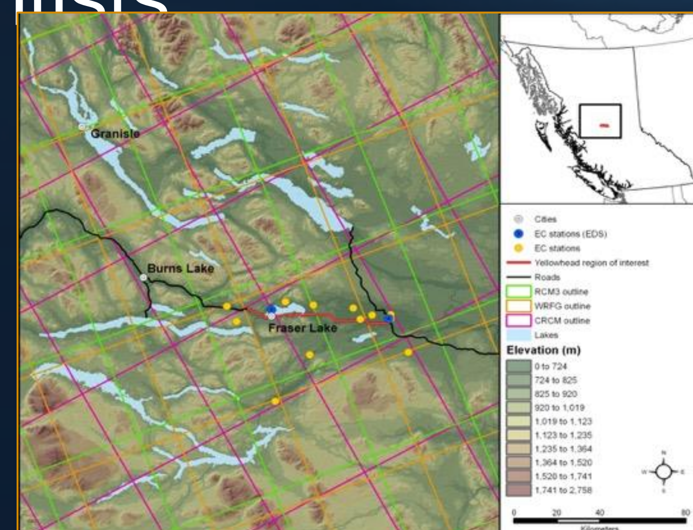


Mountain Hwy Interchange Hwy 1	Major Drainage systems Keith Creek Culverts	Return 100yr (75yr DL)	Flow Rate (m^3/s) 18.1	Climate Change +20%	Flow Rate (M^3/S) 21.7	PCIC (Plan2Adapt 90^{th}% 17.5%↑) APEGBC (10%, 20%↑) IDFCC (18-23%↑)

PCIC Climate Resources

- Plan2Adapt
- *New* Climate Explorer – climate projections
- Downscaled climate data - projections
- Hydrologic model output – projections
- Support from climate scientists





PACIFIC CLIMATE IMPACTS CONSORTIUM

PLAN2ADAPT

PCIC Home | Contact Us

- Summary
- Region & Time
- Temperature
- Precipitation
- Snowfall
- Growing DD
- Heating DD
- Frost-Free Days
- Impacts
- Notes
- References

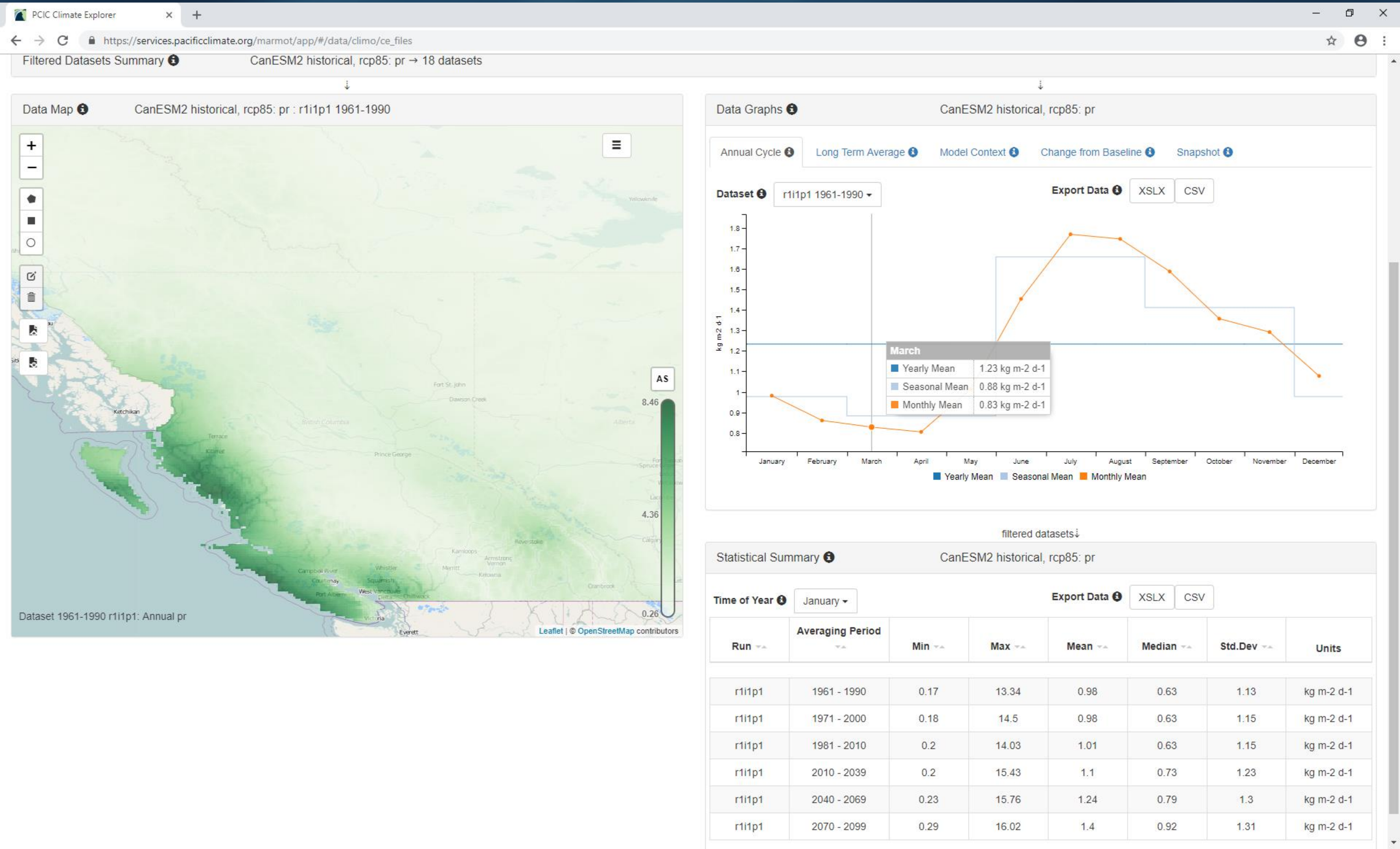
Summary of Climate Change for British Columbia in the 2050s

Climate Variable	Season	Projected Change from 1961-1990 Baseline	
		Ensemble Median	Range (10th to 90th percentile)
Mean Temperature (°C)	Annual	+1.8 °C	+1.3 °C to +2.7 °C
Precipitation (%)	Annual	+6%	+2% to +13%
	Summer	-1%	-8% to +7%
	Winter	+8%	-2% to +15%
Snowfall* (%)	Winter	-10%	-17% to +2%
	Spring	-58%	-71% to -11%
Growing Degree Days* (degree days)	Annual	+283 degree days	+177 to +429 degree days
Heating Degree Days* (degree days)	Annual	-648 degree days	-955 to -454 degree days
Frost-Free Days* (days)	Annual	+20 days	+12 to +29 days

The table above shows projected changes in average (mean) temperature, precipitation and several derived climate variables from the baseline historical period (1961-1990) to the **2050s** for the **British Columbia** region. The ensemble median is a mid-point value, chosen from a PCIC standard set of Global Climate Model (GCM) projections (see the 'Notes' tab for more information). The range values represent the lowest and highest results within the set. Please note that this summary table does not reflect the 'Season' choice made under the 'Region & Time' tab. However, this setting does affect results obtained under each variable tab.

* These values are derived from temperature and precipitation. Please select the appropriate variable tab for more information.

PCIC Climate Explorer
(March release with instructional videos)



BCMoTI Adaptation Site

BCMoTI Adaptation site:
https://www2.gov.bc.ca/gov/content/transportation/transportation-environment/climate-action/adaptation

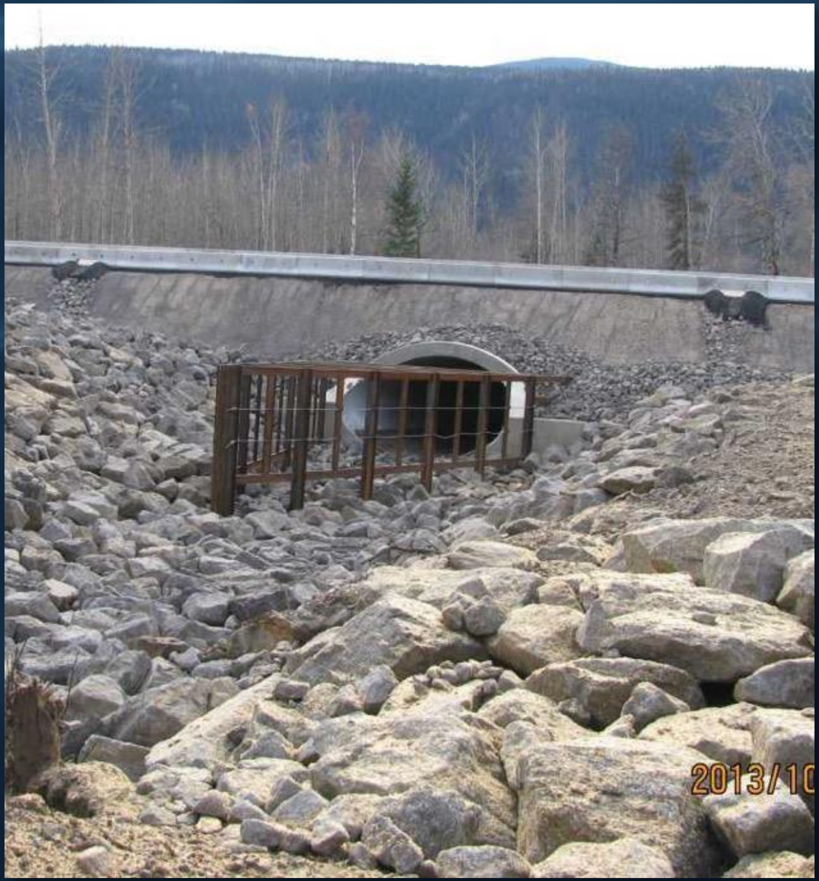
Sportsman Bowl Rd 2018

Old Kamloops Rd Hwy 5A 2018

Recap

Adapt highway infrastructure for resilience to climate change and weather extremes using vulnerability assessment and climate projection tools

Thank you!



Grizzly Creek Culvert
Trash Rack – Flying V (2013)

Transport Canada Transports Canada

Transport Canada's Transportation Assets Risk Assessment Initiative (TARA)

Recommended Practices and Lessons Learned

Presented by: Allison Kader, Research/Analysis Officer with Transport Canada's TARA Team
March 19, 2019

Canada

Presentation Overview

- TARA Initiative
- Examples of Climate Risks
- Climate Risk Assessment
- PIEVC Review Results
- Recommended Practices and Lessons Learned

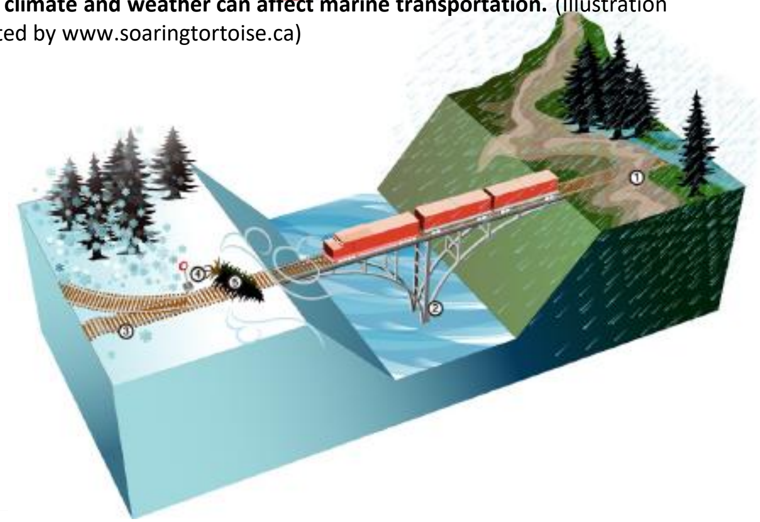
What is the TARA Initiative?

- The TARA initiative was announced following Budget 2017, receiving $16.35 million over five years
- Goal: Better understand climate risks to federally-owned transportation assets and potential adaptation solutions
- Eligible projects
  1. Full climate risk assessment
  2. Subcomponent(s) of a climate risk assessment
  3. Research projects
- $3.7 million in funding approved since 2017
- Grants and Contributions Call for Proposals
  - EN: http://www.tc.gc.ca/en/programs-policies/programs/transportation-assets-risk-assessment-program.html
  - FR: http://www.tc.gc.ca/fr/programmes-politiques/programmes/programme-evaluation-risques-lies-ressources-transport.html

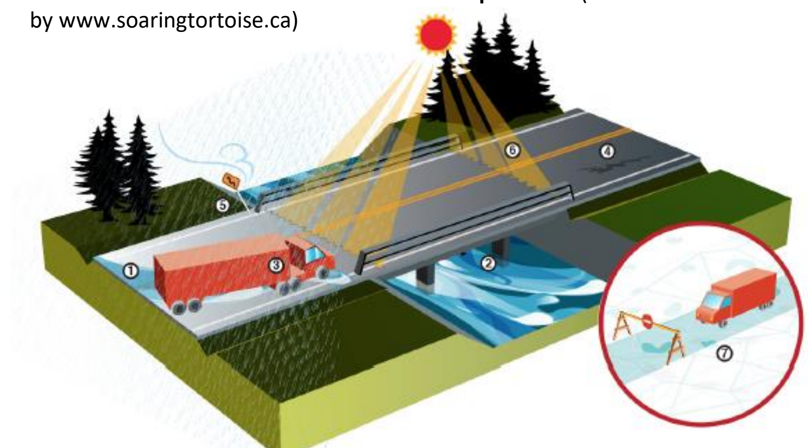
Examples of Climate Risks Affecting the Canadian Transportation System

How climate and weather can affect marine transportation. (Illustration created by www.soaringtortoise.ca)

How climate and weather can affect air transportation (Illustration created by www.soaringtortoise.ca)



How climate and weather can affect rail transportation (Illustration created by www.soaringtortoise.ca)



How climate and weather can affect road transportation (Illustration created by www.soaringtortoise.ca)

What is a Climate Risk Assessment?

- Consideration of the risk associated with the current and future climate impacts
- Follow ISO 31000 Risk Management Standard (i.e. PIEVC protocol)
- Three steps
  1. Risk Identification
  2. Risk Analysis
  3. Risk Evaluation
- Key activities
  - Climate data modelling and forecasting
  - Infrastructure components and climate parameters definition
  - Risk assessment workshop
  - Engineering analysis
  - Recommendations

Why is it Important to Assess Climate Risk?

- A resilient transportation system is critical
- Climate impacts already affecting the Canadian transportation system
- Climate impacts are expected to become more frequent and severe

Who should be involved?

Asset-Specific

- Operational/management
- Technical services
- Environmental services

Specialized Services

- Project Manager
- Climate Specialist
- Engineering Analyst
- Climate Risk Assessment Tool Lead
- Transportation Modal Expert

Asset Owner/Operator's Role

- Provide access to the site and supporting documentation
- Receive deliverables and provide feedback
- Participate in climate risk assessment workshop
  - Representatives from capital planning and operations
- Respond to recommendations

Examples of Approved Projects Assessing Climate Risk

- Climate risk assessment projects
  - Five Transport Canada airports
  - Four Parks Canada highways
  - Confederation Bridge
  - Six Atlantic ferry terminals
  - Toronto Port Authority assets
- Climate risk assessment subcomponent projects
  - Churchill Airport
  - Winnipeg Richardson International Airport
- Research projects
  - National Research Council's development of storm surge and wave activity database and visualization tool for coastal BC

Review of PIEVC Climate Risk Assessments

- Use of publicly available PIEVC climate risk assessment reports
- Focus on the Canadian transportation system
- Establish an understanding of common recommendations

Type of recommendation	Development/update of policies and previous evaluations	Studies and instrumentation	Monitoring	Management and operational changes	Engagement to gather additional information and/or further apply assessment results	Engineering solutions	Vulnerability ranking and criticality parameters
Number of recommendations	35	33	24	6	5	5	2

Recommended Practices and Lessons Learned

Climate Data and Parameters

- Cumulative impacts of climate parameters should be considered
- The lifecycle and management/maintenance plan of the observed asset should be considered when determining climate projection timescales
- There is a need to establish a method at the outset of the assessment to better identify which climate models and RCPs are most appropriate
- Climate data projections would benefit from an additional seasonal analysis as opposed to focusing on yearly projections

Recommended Practices and Lessons Learned

Climate Risk Assessment Tools and Processes

- Most climate risk assessment tools are not decision-making tools
- There is a need to understand what tools and methods exist or can be developed to assess climate risk as part of the normal design process
- Where possible, potential climate change opportunities should be considered along with negative impacts
- Climate risk assessment deliverables and results should be developed in a manner that is clear and easily understood

Thank you!

- For additional information on the TARA initiative, please contact:
    - Donavan Jacobsen, TARA initiative Manager, at donavan.jacobsen@tc.gc.ca, or
    - Allison Kader, Research/Analysis Officer with the TARA initiative, at allison.kader@tc.gc.ca

- Questions on the grants and contributions application process should be directed to: tc.tara-erat.tc@tc.gc.ca

Q & A
(Question and Answer Period)

*Please pose your questions via the chatbox or by hitting *6 to unmute your line*

Thank you for joining us today!

Stay tuned for upcoming webinars!

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