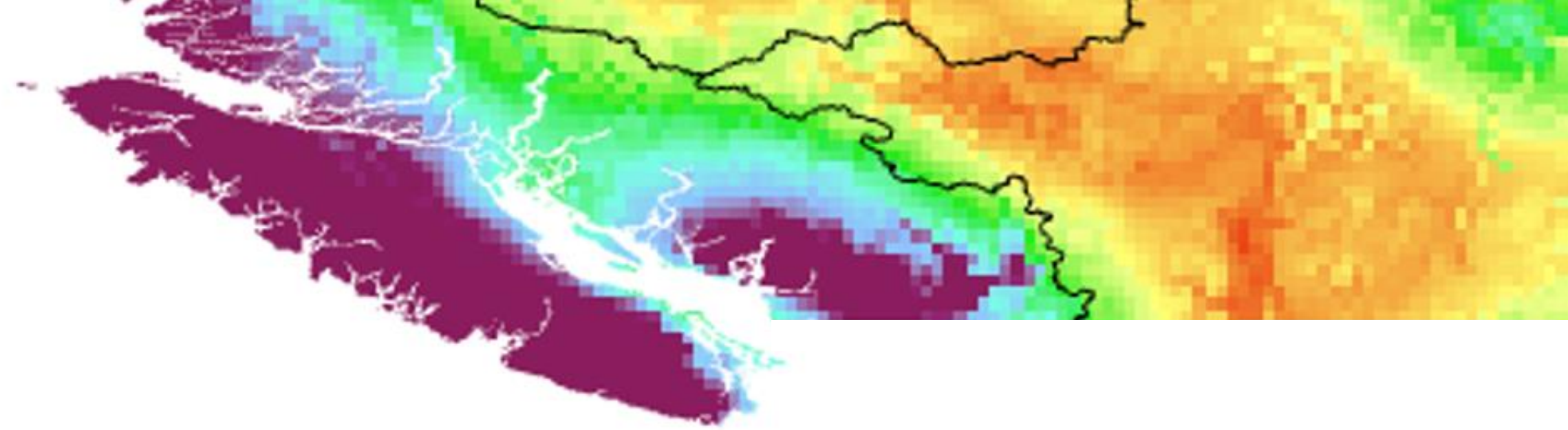

Climate Change Impacts to BC Resource Roads: Update on Research

Matt Kurowski P.Eng., M.Sc. – Research Engineer, Transportation and Infrastructure

FPInnovations

Dec 14, 2021

BRITISH COLUMBIA

Ministry of Forests, Lands, Natural Resource Operations and Rural Development

PACIFIC CLIMATE IMPACTS CONSORTIUM

climate change assessments team

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- Francis Bober, EIT

Poll: slido.com (fpi is event code)

Outline

- **1. Background**
  - **Poll:** applying climate change in professional practice
  - **Basics:** central climate change language and ideas
- **2. Progression of climate change impact assessment methods**
  - **FSR-scale:** (3 BC locations) – risk methods, extensive workshops
  - **District-scale:** (Eastern Canada) – simpler risk methods, workshops
  - **Province-scale:** (BC) – regional vulnerability methods, short workshops
- **3. BC regional assessments**
  - **Overview:** method and results from workshops, climate data summaries
  - **Tool development:** purpose and components
- **4. Discussion** (~20 min)
  - **Feedback:** poll, questions, comments, ideas…

Poll: slido.com (fpi is event code)

Poll: check-in on professional practices

Poll: slido.com
event code: fpi

1. Background

Basics: climate change terms

1. Standard projection reporting: 2030s, 2050s, 2080s

- 2010-2039 (or 2030s)
- 2040-2069 (or 2050s)
- 2070-2099 (or 2080s)

Poll: slido.com (fpi is event code)

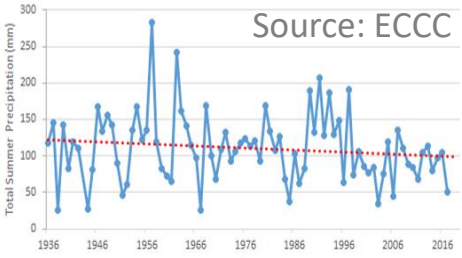
Basics: climate change terms

1. Standard projection reporting: 2030s, 2050s, 2080s

2. Types of climate change impacts: averages and extremes

1. Changes in <u>average conditions</u> over long time
   - Eg: average rainfall total per year

2. Changes in <u>extreme events'</u> intensity and frequency
   - Eg: number of heavy rain days



Both are linked

Poll: slido.com (fpi is event code)

For more information visit climatedata.ca

Basics: climate change terms

1. **Standard projection reporting: 2030s, 2050s, 2080s**
2. **Types of climate change impacts: averages and extremes**
3. **Quantification of climate change: climate indices**

- Statistical summaries of climate, for example:
  - maximum consecutive days with no rain
  - daily maximum precipitation
  - average number of days/year that reach 20 degrees
  - 5-day daily antecedent rain >15mm
  - 1 in 10-year extreme rainfall amount within 48 hours……

Poll: slido.com (fpi is event code)

Basics: climate change terms

1. **Standard projection reporting: 2030s, 2050s, 2080s**
2. **Types of climate change impacts: averages and extremes**
3. **Quantification of climate change: climate indices**

- Can be on the spectrum of specific to general:
  - 3-day rainfall of at least 10mm, followed by day with freezing temperatures
  - 3-day sustained rainfall with each day at least 40mm
  - 1-day extreme rainfall
  - monthly average rainfall

Poll: slido.com (fpi is event code)

Basics: climate change terms

1. **Standard projection reporting: 2030s, 2050s, 2080s**
2. **Types of climate change impacts: averages and extremes**
3. **Quantification of climate change: climate indices**

- Different levels of certainty
  - The higher temporal resolution of the event → more uncertain
  - Extremes compared to averages → more uncertain
  - Those that mix more than 1 variable → more uncertain

Poll: slido.com (fpi is event code)

Poll: check-in

Poll: slido.com
event code: fpi

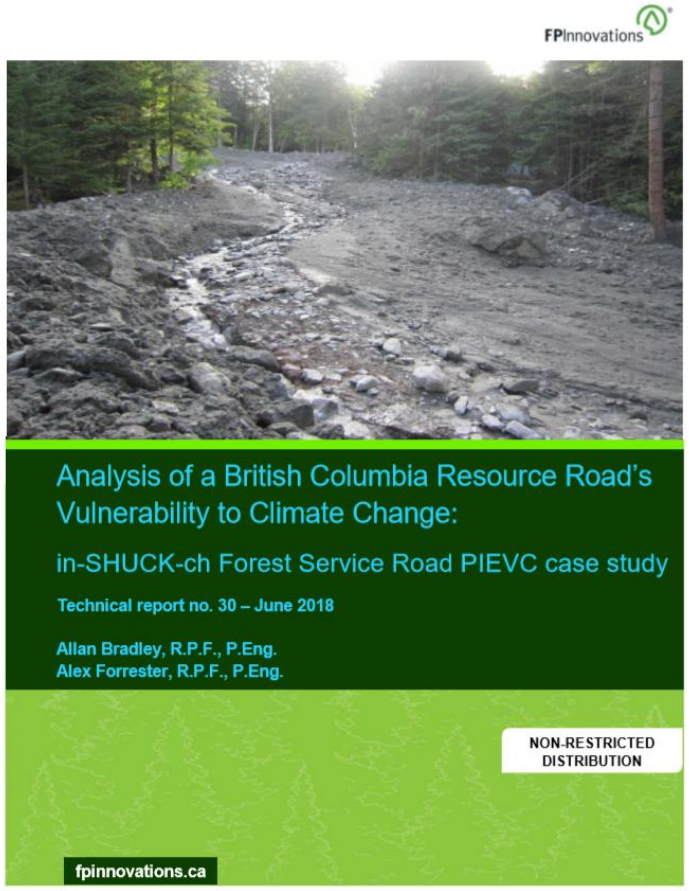
?

2. Progression of climate change impact assessment methods

FSR-scale: 2016-19

2015-16

- Applied the **PIEVC** protocol to In-SHUCK-ch FSR



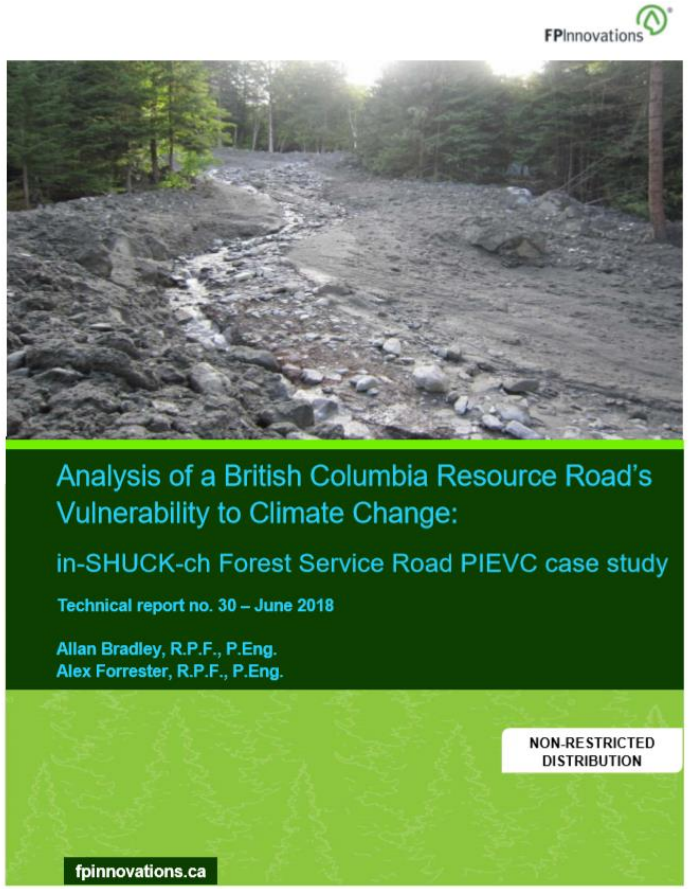
Public Infrastructure Engineering Vulnerability Committee Protocol

- Built upon ISO 31000 risk management process that is specific to infrastructure
- Requires intensive workshop to consider each interaction between climate events and infrastructure elements
- Uses **PROBABILITY** (of a climate event likelihood) and **SEVERITY** (consequence)
- **PROBABILITY x SEVERITY = RISK**

FSR-scale: 2016-19

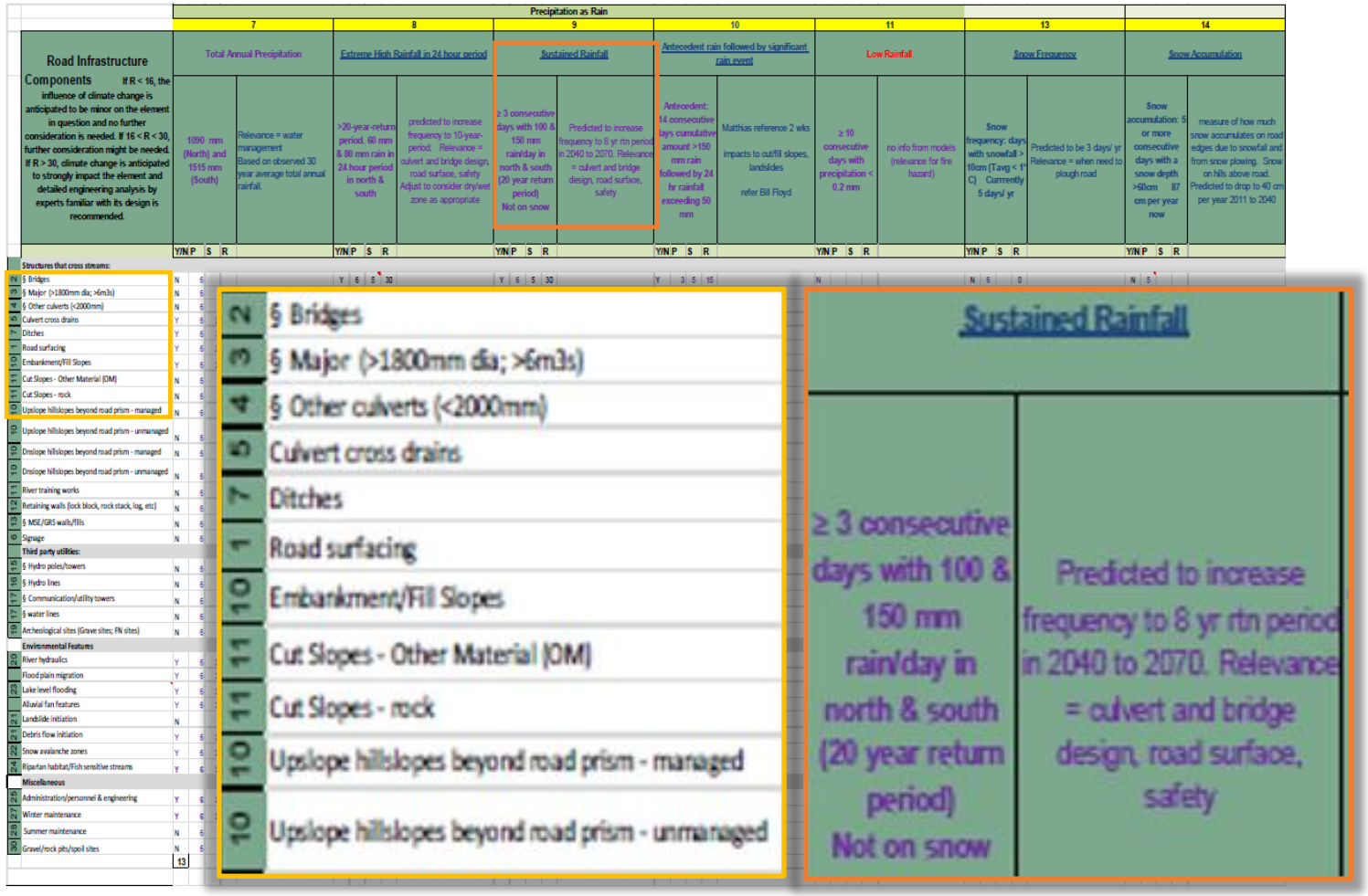
2015-16

- Applied the **PIEVC** protocol to In-SHUCK-ch FSR



Climate indices

Resource road elements



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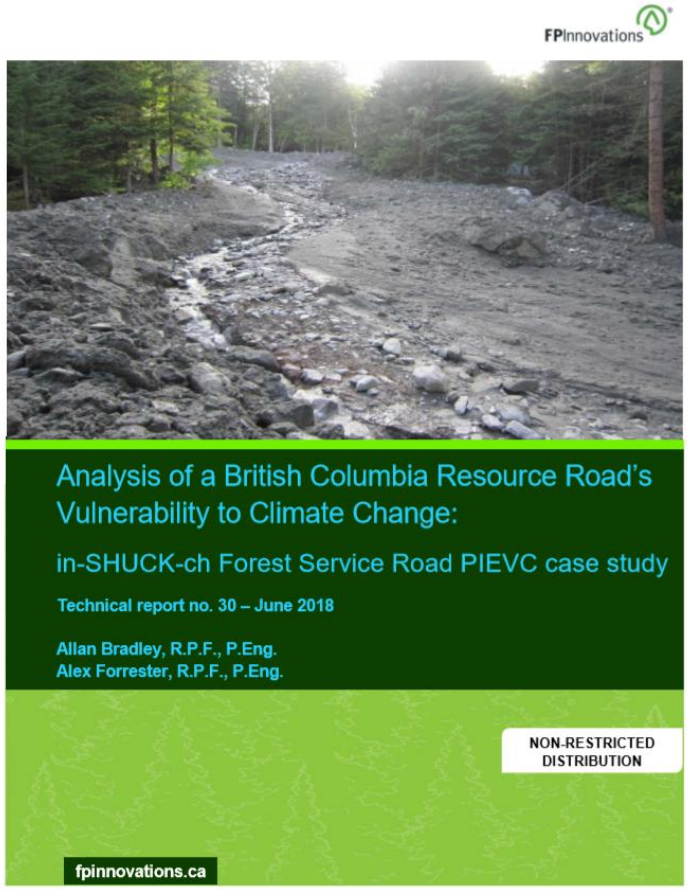
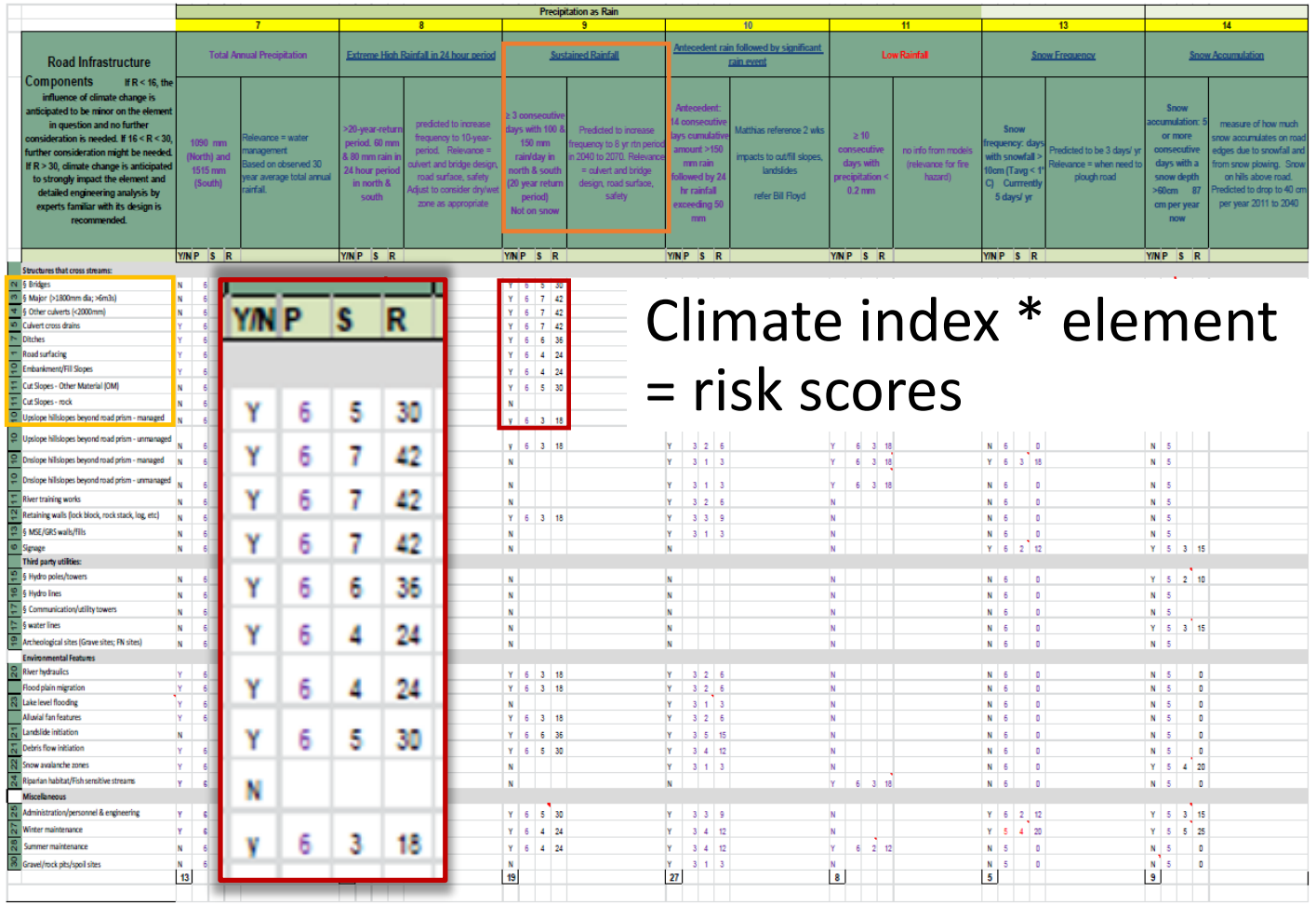


Climate indices

Resource road elements

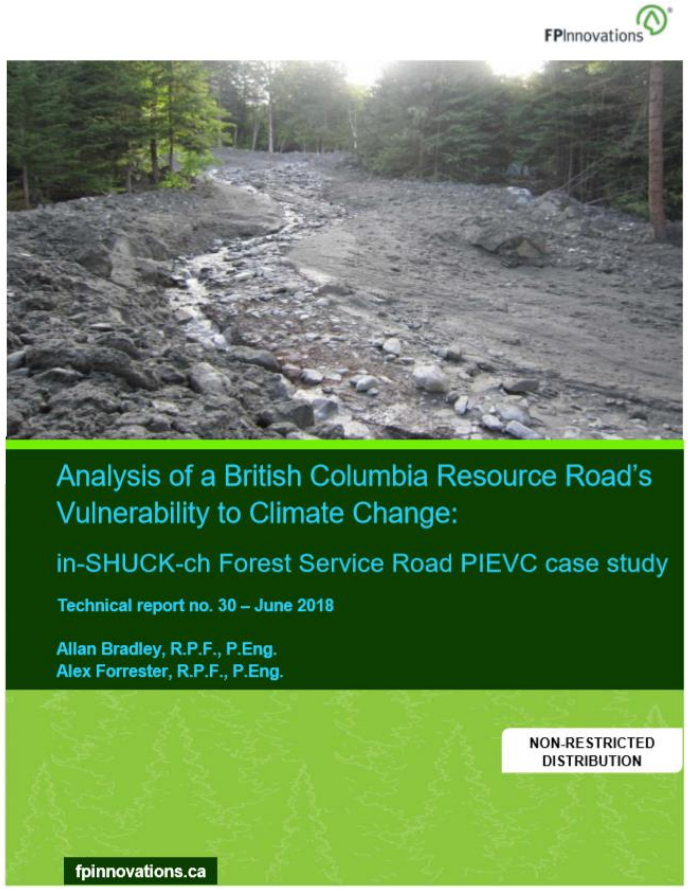


Climate index * element = risk scores

FSR-scale: 2016-19

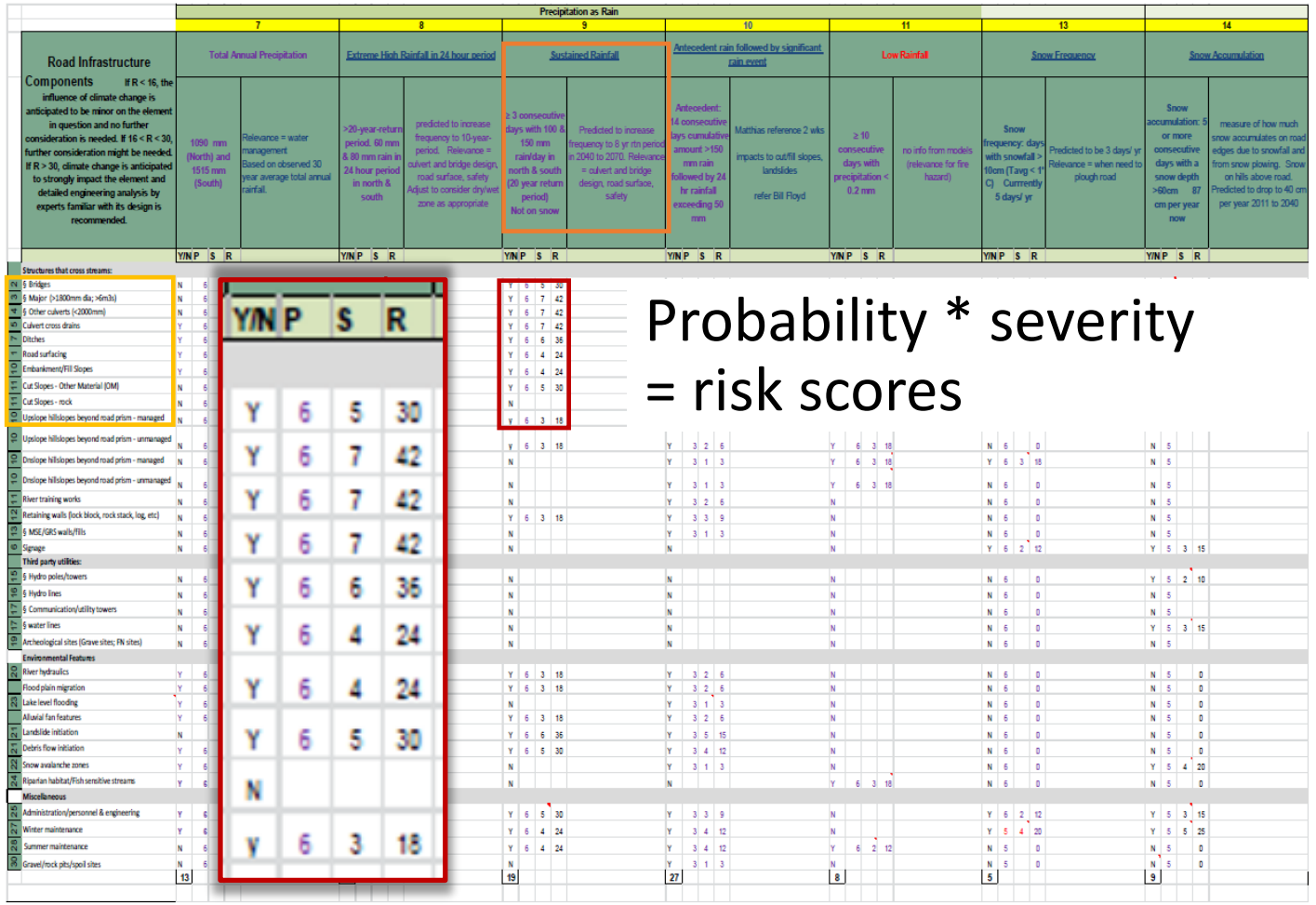
2015-16

- Applied the **PIEVC** protocol to In-SHUCK-ch FSR



Probability

Severity



Probability * severity = risk scores

FSR-scale: 2016-19

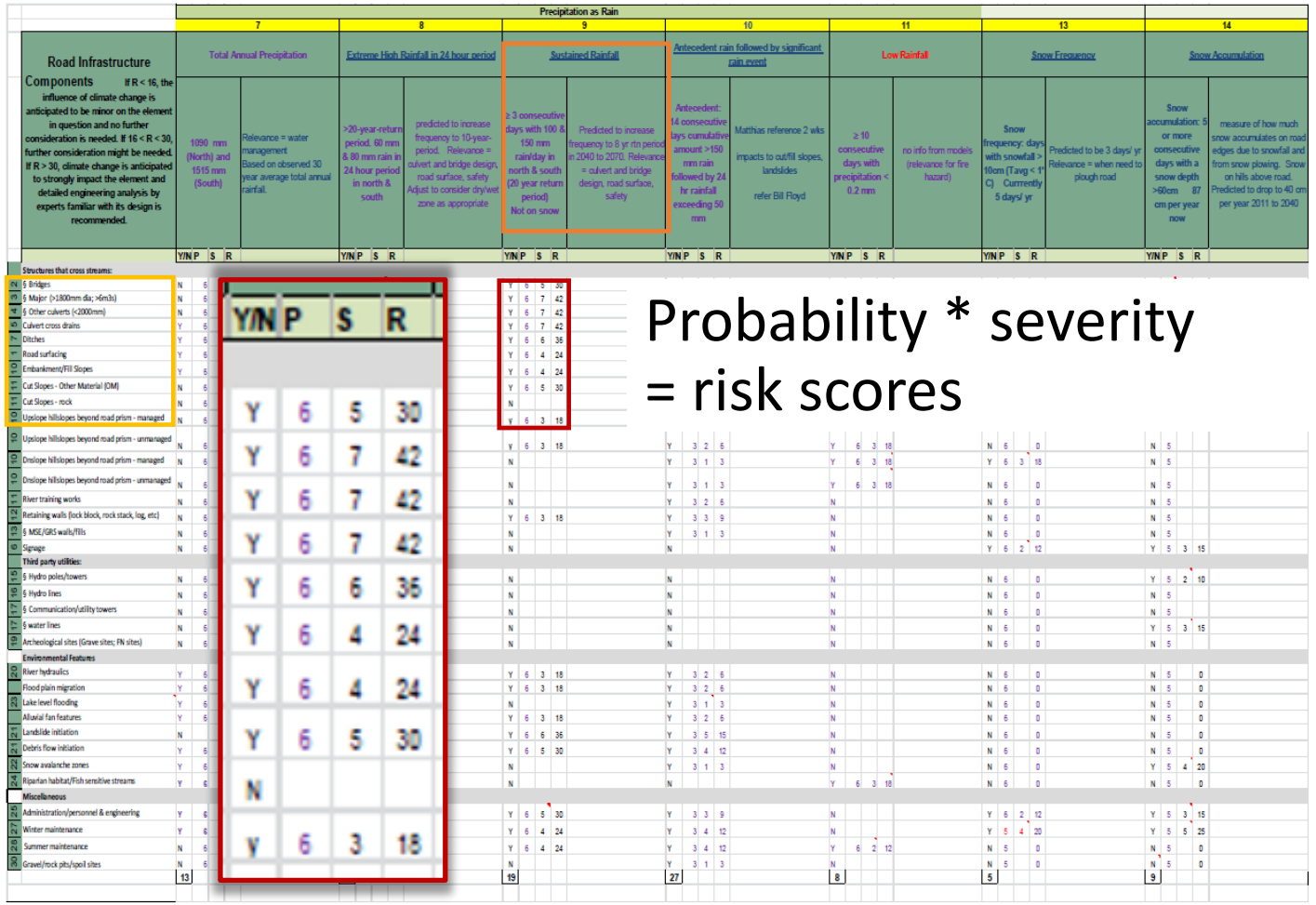
2015-16

- Applied the **PIEVC** protocol to In-SHUCK-ch FSR

Score	Probability	
	Method A	Method B
0	Negligible Not applicable	< 0.1 % < 1 in 1,000
1	Highly unlikely Improbable	1 % 1 in 100
2	Remotely possible	5 % 1 in 20
3	Possible Occasional	10 % 1 in 10
4	Somewhat likely Normal	20 % 1 in 5
5	Likely Frequent	40 % 1 in 2.5
6	Probable Very frequent	70 % 1 in 1.4
7	Highly probable	> 99 %

Probability

Severity



Probability * severity = risk scores

FSR-scale: 2016-19

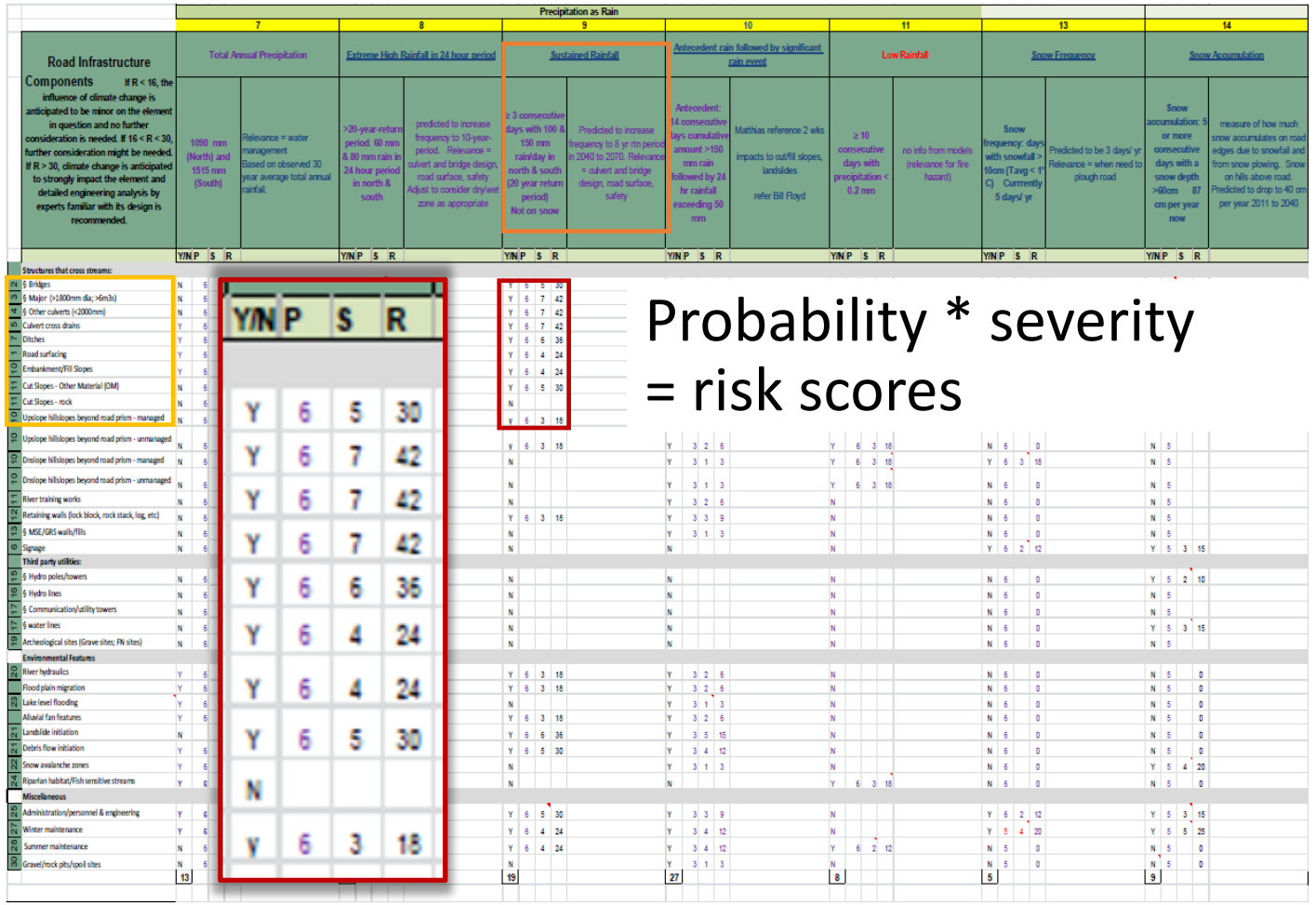
2015-16

- Applied the **PIEVC** protocol to In-SHUCK-ch FSR

Score	Severity of consequences and effects	
	Method D	Method E
0	No effect	Negligible Not applicable
1	Measurable	Very Low Some measurable change
2	Minor	Low Slight loss of serviceability
3	Moderate	Moderate loss of serviceability
4	Major	Major loss of serviceability Some loss of capacity
5	Serious	Loss of capacity Some loss of function
6	Hazardous	Major Loss of function
7	Catastrophic	Extreme Loss of asset

Probability

Severity



Probability * severity = risk scores

FSR-scale: 2016-19

2017-18

- Simplified approach for Tum Tum FSR

Climate indices

Resource road elements

Table 10. Summary of risk scores for baseline (B = 2011 to 2040) and future (F = 2041 to 2070) periods

Infrastructure components	Drought		Daily temp. variation		Freeze/ thaw		Cold spells		Spring thaw		Extreme rainfall		Sustained rainfall		Ante. rain		Rapid snow melt		Ice / ice jams		Snow freq.		Snow accum.	
Baseline / Future	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F
Road prism																								
Road surface	12	12	5	5	7	7	5	5	28	28	12	15	9	12	18	18	6	6	6	6	10	10	14	12
Cut fill and slope	6	6	5	5	7	7	5	5	7	7	12	15	9	12	18	18	6	6	0	0	10	10	14	12
Ditches	0	0	5	5	21	21	5	5	7	7	12	15	9	12	18	18	12	12	4	4	5	5	7	6
Catch basins	0	0	5	5	14	14	15	15	7	7	8	10	6	8	12	12	12	12	0	0	5	5	7	6
Cross drains																								
Stream crossings																								
Major culverts																								
Other culverts																								
Bridges																								
Upslope/downslope beyond road prism																								
Managed																								
Unmanaged																								
Operational considerations																								
Commercial access																								
Emergency response	18	18	0	0	14	14	5	5	7	7	20	25	15	20	30	30	6	6	6	6	5	5	7	6
Winter maintenance	N	N	0	0	21	21	15	15	7	7	N	N	N	N	N	N	12	12	6	6	10	10	14	12
Summer maintenance	12	12	0	0	N	N	N	N	N	N	12	15	9	12	18	18	N	N	N	N	N	N	N	N
Personnel	18	18	0	0	14	14	0	0	0	0	12	15	9	12	18	18	6	6	6	6	5	5	7	6

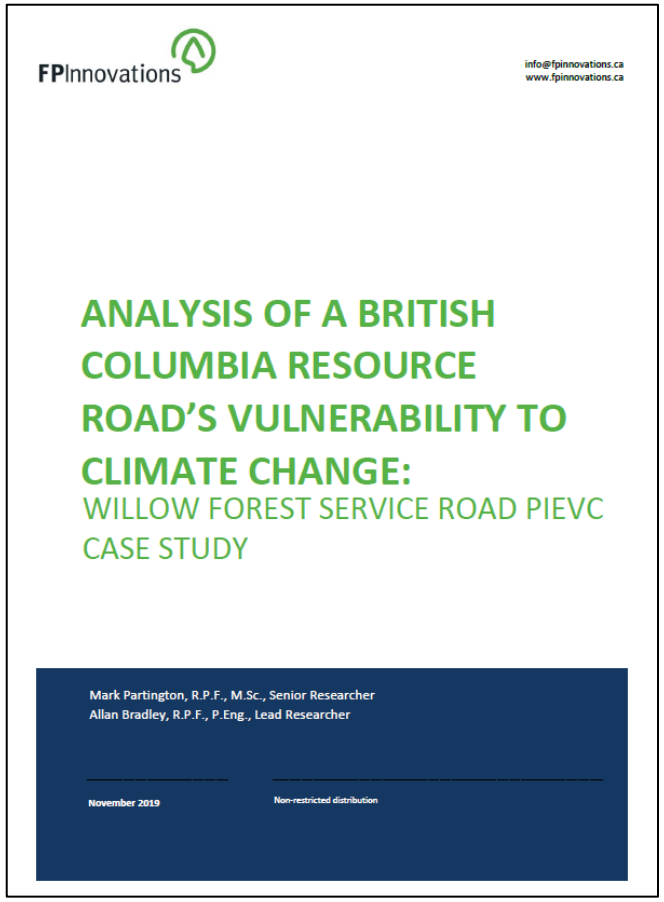
1. A risk score of "N" indicates that the infrastructure component was not assessed for risk to the corresponding climate factor.

Threshold	Risk range	Response
Low	< 13	No action required
Low-Medium	13 - 25	Remedial actions may be required
High-Medium	26 - 36	Remedial actions may be required
High	>36	Immediate action required

FSR-scale: 2016-19

2018-19

- Simplified again for Willow FSR



Climate indices

Resource Road Elements

Table 10. Summary of risk scores for baseline (B = 2011 to 2040) and future (F = 2041 to 2070) periods.

Infrastructure components	Drought		Extreme high rainfall in 24 hr period		High rainfall in 24 hr period		Sustained rainfall		Antecedent rain followed by significant rain event		Freeze-thaw cycling		Freeze / thaw 2		Spring thaw		Rain on snow		Rapid snow melt		Snow frequency	
Baseline / Future	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F	B	F
Road features																						
Road prism	6	6	12	15	4	6	6	9	5	5	21	21	24	36	42	42	20	25	10	10	3	2
Cut fill and slope	4	4	12	15	4	6	6	9	5	5	14	14	8	12	7	7	20	25	10	10	3	2
Ditches	0	0	16	20	6	9	6	9	5	5	35	35	12	18	7	7	24	30	12	12	3	2
Cross drains	2	2	16	20	4	6	6	9	5	5	35	35	20	30	7	7	24	30	12	12	3	2
Stream crossings																						
Major culverts >2.0m	2	2	8	10	2	3	4	6	3	3	7	7	4	6	7	7	8	10	4	4	3	2
Other culverts <2.0m	2	2	16	20	4	6	8	12	5	5	28	28	12	18	7	7	20	25	10	10	3	2
Bridges	12	12	8	10	2	3	4	6	3	3	7	7	4	6	7	7	8	10	4	4	3	2
Operational considerations																						
Commercial, recreational, residential access	8	8	12	15	2	3	6	9	5	5	42	42	24	36	35	35	20	25	10	6	9	6
Emergency response	12	12	12	15	2	3	6	9	5	5	28	28	24	36	35	35	20	25	10	10	9	6
Winter maintenance & construction	na	na	na	na	na	na	na	na	na	na	21	21	24	36	28	28	24	30	12	12	9	6
Summer maintenance & construction	12	12	12	15	2	3	6	9	5	5	na	na	na	na	na	na	na	na	na	na	na	na
Safety	10	10	8	10	4	6	6	9	5	5	35	35	24	36	28	35	24	30	12	12	12	8

District-scale: 2020

Latest simplified risk assessment:

1. Identify infrastructure elements

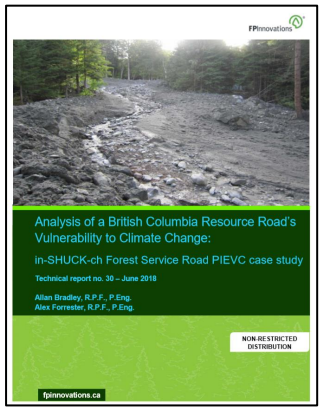
Used FSR experience to simplify selection of elements for a road network

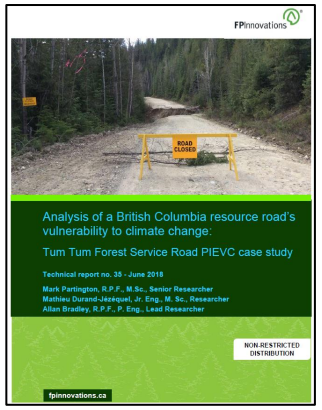
2. Identify climate indices

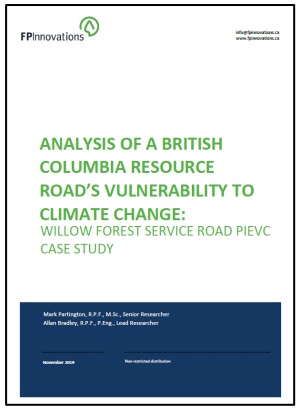
Used FSR experience to simplify climate index selection + public climate projection data to get percent change, estimate probabilities

3. Determine risks and vulnerabilities

Used FSR experience to simplify ranking system + streamlined workshops to assign severities







Many publicly accessible climate projection data now available through various web interfaces/applications

Severity \ Probability	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

District-scale: 2020

Latest simplified risk assessment:

1. Identify infrastructure elements
2. Identify climate indices
3. Determine risks and vulnerabilities

Resource road elements

Climate indices

Climate Vulnerability Event	Infrastructure elements and considerations													
	Road prism (surface/subgrade)		Water control structures		Water crossings - Culverts		Water crossings - Bridges		Maintenance & construction (Summer)		Maintenance (Winter)		Roads in high value areas	
	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future
Sustained rainfall	4	6	6	12	4	6	4	6	4	6	N/A	N/A	6	9
High Rainfall	8	8	12	12	8	8	8	8	8	8	N/A	N/A	12	12
Extreme high rainfall	6	12	8	16	8	16	4	8	6	12	N/A	N/A	8	16
Rain on snow (winter)	6	10	12	20	6	10	6	10	N/A	N/A	9	15	6	10
Freeze thaw days (winter)	12	16	9	12	9	12	6	8	N/A	N/A	12	16	6	8
Rapid snow melt (spring)	8	12	8	12	6	9	8	12	N/A	N/A	8	12	8	12
Freeze thaw days (spring)	12	20	6	10	6	10	6	10	N/A	N/A	9	15	6	10
Drought / extended dry days (summer)	9	15	3	5	3	5	3	5	9	15	N/A	N/A	3	10

Provincial-scale: 2020-21

recent climate vulnerability assessment

- Need: economical assessment for entire BC

Surveyed professionals in region about climate vulnerabilities beforehand, then reviewed results/discussed in workshops

Used public climate tools, experience from 3 FSRs as a starting point, along with expertise from PCIC

Presented climate index projections with survey results about historic observations to help interpretation during workshops

1. Identify vulnerable forest operations activities

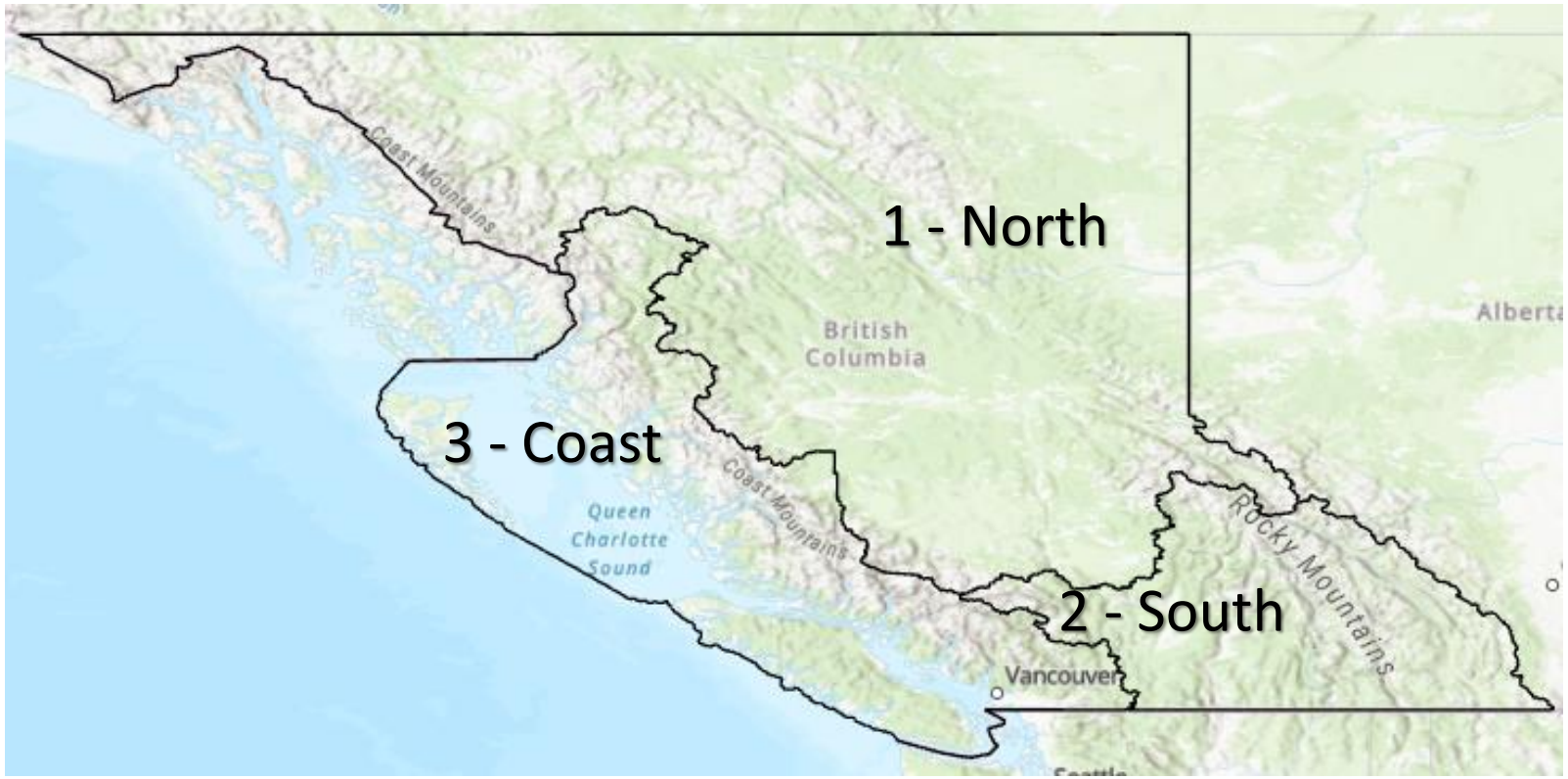
2. Identify and calculate climate indices that affect these activities

3. Interpret how changes to the climate indices may inform adaptation

3. BC regional assessments

Overview: BC regional assessments - method

- Three workshops: 6-10 participants (private & government forestry professionals)
- Participants received surveys prior to a 2 h workshop asking about past climate vulnerabilities of forest operations



Overview: BC regional assessments - method

Surveys re: forest operations activities previously vulnerable to climate events

Harvesting and Silviculture

1. Shutdown/disruption – due to dry conditions
2. Shutdown/disruption – due to rain
3. Shutdown/disruption – frequency – due to milder winters
4. Spring shutdown start date (earlier =decrease)
5. Safety concerns
6. Planting failures
7. Planting season – length
8. Planting season – start
9. Need to perform salvage operations
10. Slash pile burning – scheduling window
11. Herbicide spray – scheduling window
12. Herbicide spray – start
13. Challenges in meeting soil disturbance requirements
14. Overall harvesting and silviculture activity costs

Roads and Infrastructure

1. Shutdown/disruption – due to dry conditions
2. Shutdown/disruption – due to rain
3. Shutdown/disruption – due to milder winters
4. Spring shutdown start date (earlier =decrease)
5. Safety concerns
6. Shutdowns/disruption frequency – due to landslides/mass wasting
7. Road washouts and repairs
8. Water crossing structure maintenance or replacement
9. Bridge scouring / embankment erosion
10. Usability of winter roads
11. Summer road maintenance
12. Winter road maintenance
13. Overall road and infrastructure costs

Transportation

1. Shutdown/disruption – due to dry conditions
2. Shutdown/disruption – due to rain
3. Shutdown/disruption – due to milder winters
4. Spring shutdown start date (earlier =decrease)
5. Safety concerns
6. Transportation scheduling challenges
7. Vehicle traction challenges /getting stuck
8. Overall transport costs

1. Identify vulnerable forest operations activities

2. Identify and calculate climate indices that affect these activities

3. Interpret how changes to the climate indices may inform adaptation

substantial decrease | decrease | no change | increase | substantial increase | not sure

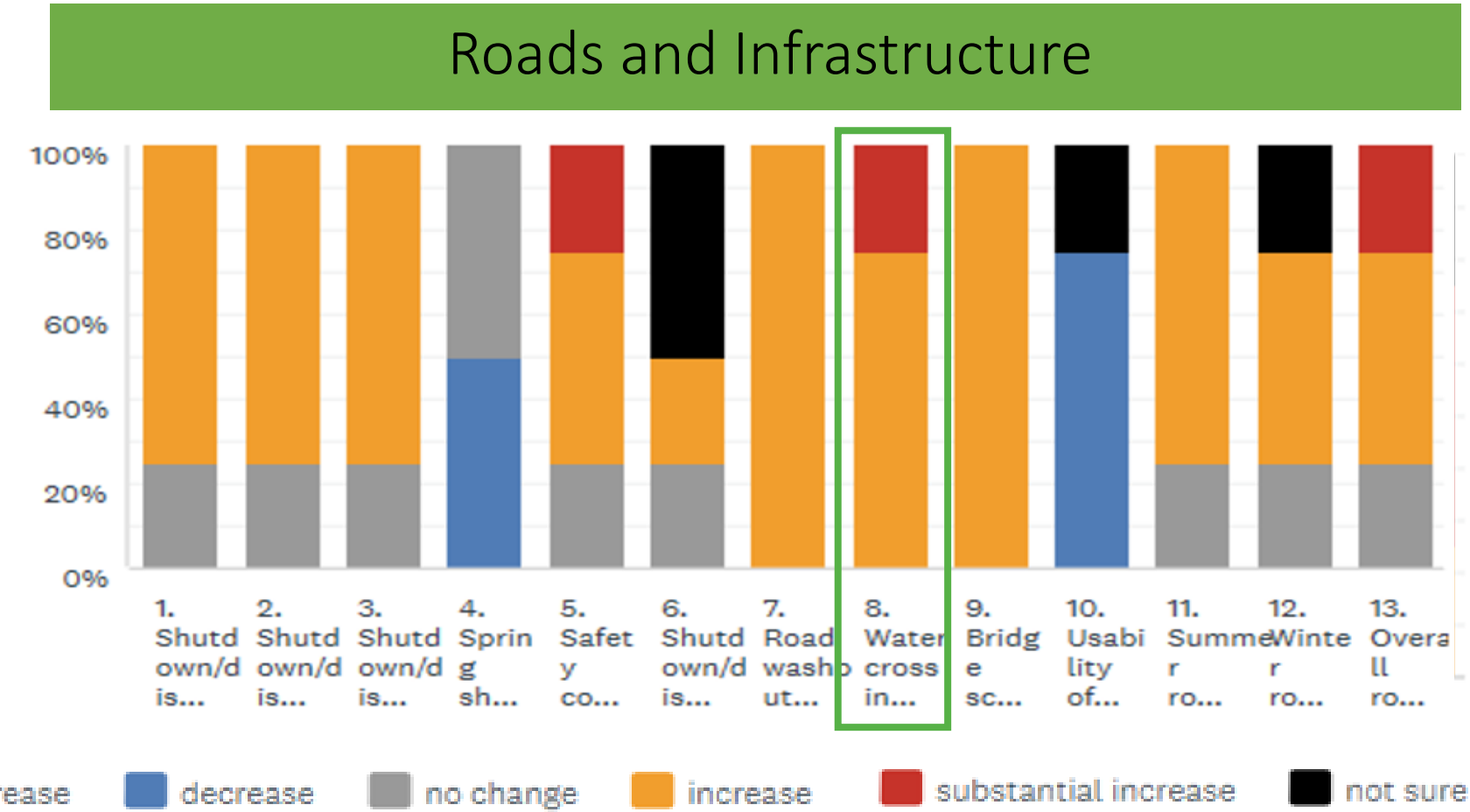
Overview: BC regional assessments - method

Surveys re: forest operations activities previously vulnerable to climate events

"In your experience, how has climate change affected the vulnerabilities of the following forest ops activities? (past 10-15 years)"

8. Water crossing structure maintenance or replacement

Example from southern BC region



1. Identify vulnerable forest operations activities

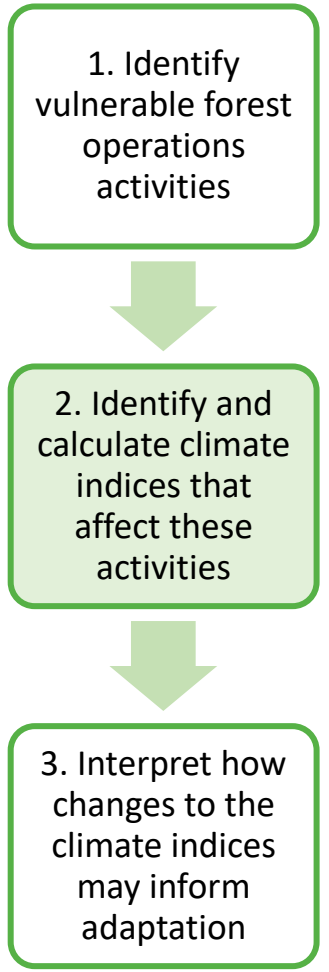
2. Identify and calculate climate indices that affect these activities

3. Interpret how changes to the climate indices may inform adaptation

Overview: BC regional assessments - method

Climate vulnerability	Climate index available (proxy)
1. Drought	Max. daily temp (Summer)
2. Spring Thaw	Freezing degree-days (Winter)
3. Freeze/Thaw cycling	Freeze-thaw days (Year)
4. Short intense storms	20-year return period daily precipitation
5. Sustained rainfall	Max 1-day storm (Year)
6. Snowfall	Precipitation as snow (Winter)

- Experience from FSR assessments
- Literature review: other work in fields related to forestry
- Consultations with climate experts: how well do available climate indices work as proxies?
- How does each of these climate vulnerabilities affect activities from step 1?



Overview: BC regional assessments - method

Climate vulnerability	Climate index available (proxy)	West Coast		South Coast	
1. Drought	Max. daily temp (Summer)	16.9	18 % 20 %	18.2	29 % 33 %
2. Spring Thaw	Freezing degree-days (Winter)	202	-43 % -64 %	351	-42 % -66 %
3. Freeze/Thaw cycling	Freeze-thaw days (Year)	74	-39 % -28 %	98	-29 % -32 %
4. Short intense storms	20-year return period daily precipitation	91	15 % 25 %	69	14 % 26 %
5. Sustained rainfall	Max 1-day storm (Year)	61	23 % 35 %	47	19 % 36 %
6. Snowfall	Precipitation as snow (Winter)	?	-55 % -65 %	?	-42 % -53 %

Baseline value (1971-2000) % change from baseline:
2040-2069
2070-2099

- Data sources:
  PCIC Climate Explorer (#1,2,4,5)
  Climatedata.ca (#3)
  & Plan2Adapt (#6)

1. Identify vulnerable forest operations activities

2. Identify and calculate climate indices that affect these activities

3. Interpret how changes to the climate indices may inform adaptation

Overview: BC regional assessments - method

Climate vulnerability	Climate index available (proxy)	West Coast		South Coast	
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Baseline value (1971-2000) % change from baseline:
2040-2069
2070-2099

Error sources:

- Historic values
- Baseline selection
- Ensemble variance
- Spatial error
- Temporal error

Link to activities:

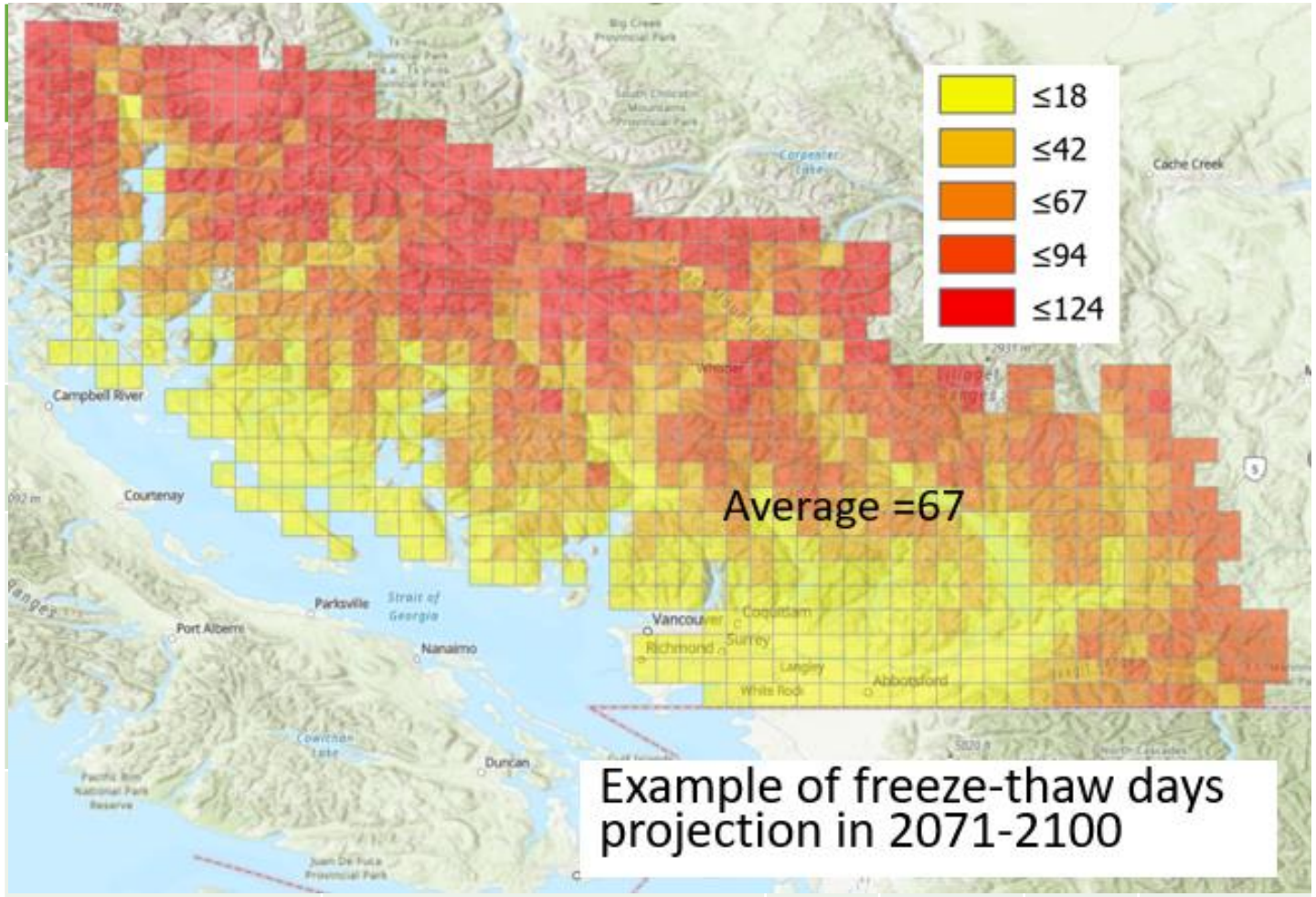
- A need to think of past in new terms

1. Identify vulnerable forest operations activities

2. Identify and calculate climate indices that affect these activities

3. Interpret how changes to the climate indices may inform adaptation

Overview: BC regional assessments - method



Baseline value (1971-2000) % change from baseline:
2040-2069
2070-2099

Error sources:

- Historic values
- Baseline selection
- Ensemble variance
- Spatial error
- Temporal error

Link to activities:

- A need to think of past in new terms

1. Identify vulnerable forest operations activities

2. Identify and calculate climate indices that affect these activities

3. Interpret how changes to the climate indices may inform adaptation

Overview: BC regional assessments - results

1. Identify vulnerable forest operations activities

2. Identify and calculate climate indices that affect these activities

3. Interpret how changes to the climate indices may inform adaptation

Overview: BC regional assessments - results

North – a sample of observations on past climate interactions with resource roads
Winter roads tough to establish
Culverts being blocked by ice build-up due to rain on snow events, mid-winter thaws and fluctuations in transition from winter to spring
Decrease in frost in the ground in the northeast possibly as a result of more moisture in the fall.
Snow insulates the from frost penetration observed (Freeze-up used to occur by end of October)
The spring break-up period appears to be longer.
Road bans coming off later. MOTI. With fire watch.
More maintenance, more failures observed old FSRs and to a lesser degree, new FSRs; more saturated road conditions especially in mountainous areas
More rain occurring in January, creating unsafe road conditions with icy roads.
Lots of unpredictability to forest operations planning due to so many variables.
Safety concerns increasing due freeze-thaw and winter rain events. Icy roads more common with thaw occurring on top of the ice. More rutted roads being created.
Costs have increased due to building roads out of mud/Not a lot of good road builders in tough wet ground

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Overview: BC regional assessments - results

Climate vulnerability event
1. Drought risk
2. Spring Thaw
3. Freeze/Thaw action
4. Short intense storms
5. Sustained rainfall
6. Snowfall

Many-to-many relationship

Roads and Infrastructure vulnerabilities
1. Shutdown/disruption – due to dry conditions
2. Shutdown/disruption – due to rain
3. Shutdown/disruption – due to milder winters
4. Spring shutdown start date (earlier =decrease)
5. Safety concerns
6. Shutdowns/disruption frequency – landslides
7. Road washouts and repairs
8. Water crossing structure maintenance or replacement
9. Bridge scouring / embankment erosion
10. Usability of winter roads
11. Summer road maintenance
12. Winter road maintenance
13. Overall road and infrastructure costs

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Overview: BC regional assessments - results

Climate vulnerability	South Coast	
1. Drought	18.2	29 % 33 %
2. Spring Thaw	351	-42 % -66 %
3. Freeze/Thaw cycling	98	-29 % -32 %
4. Short intense storms	69	14 % 26 %
5. Sustained rainfall	47	19 % 36 %
6. Snowfall	?	-42 % -53 %

Many-to-many relationship

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Roads and Infrastructure vulnerabilities

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Observation:

All workshops requested historical trends for each climate vulnerability to help interpret meaning of % change

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Overview: BC regional assessments - results

North – a sample of climate change adaptations /need for adaptations
Washouts/deteriorating conditions require more machine movements for suitable work; more mobilization/demobilization for grinders
Road and infrastructure maintenance and repairs have been reactive to events for the most part
Increased efforts to steam culverts out during spring breakup (more now than 20 years ago)
There have been upgrades on older roads as an adaptation measure
Starting to use rig mats in very saturated roads (many blocks accessed by rig mats)

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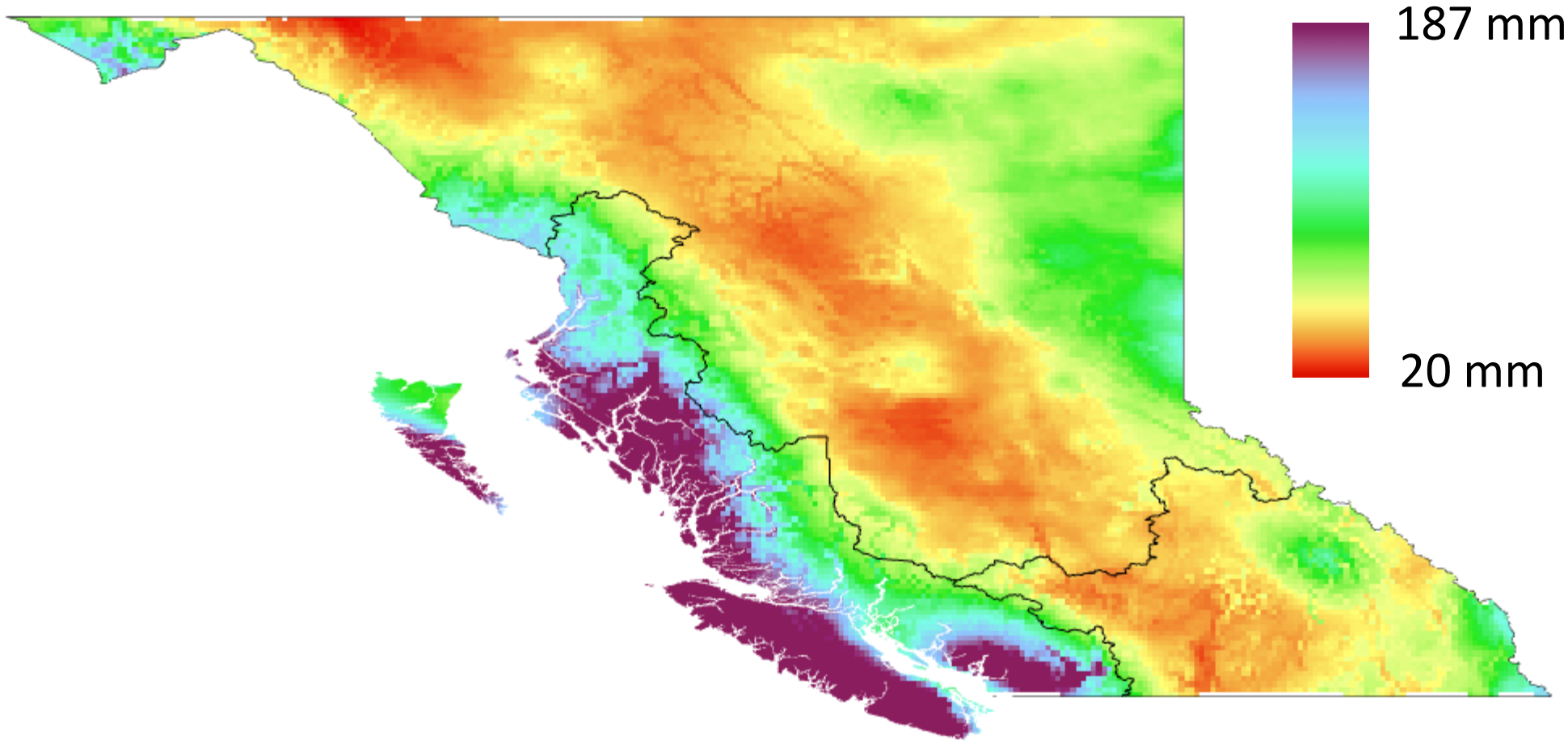
Tool development: how it all applies

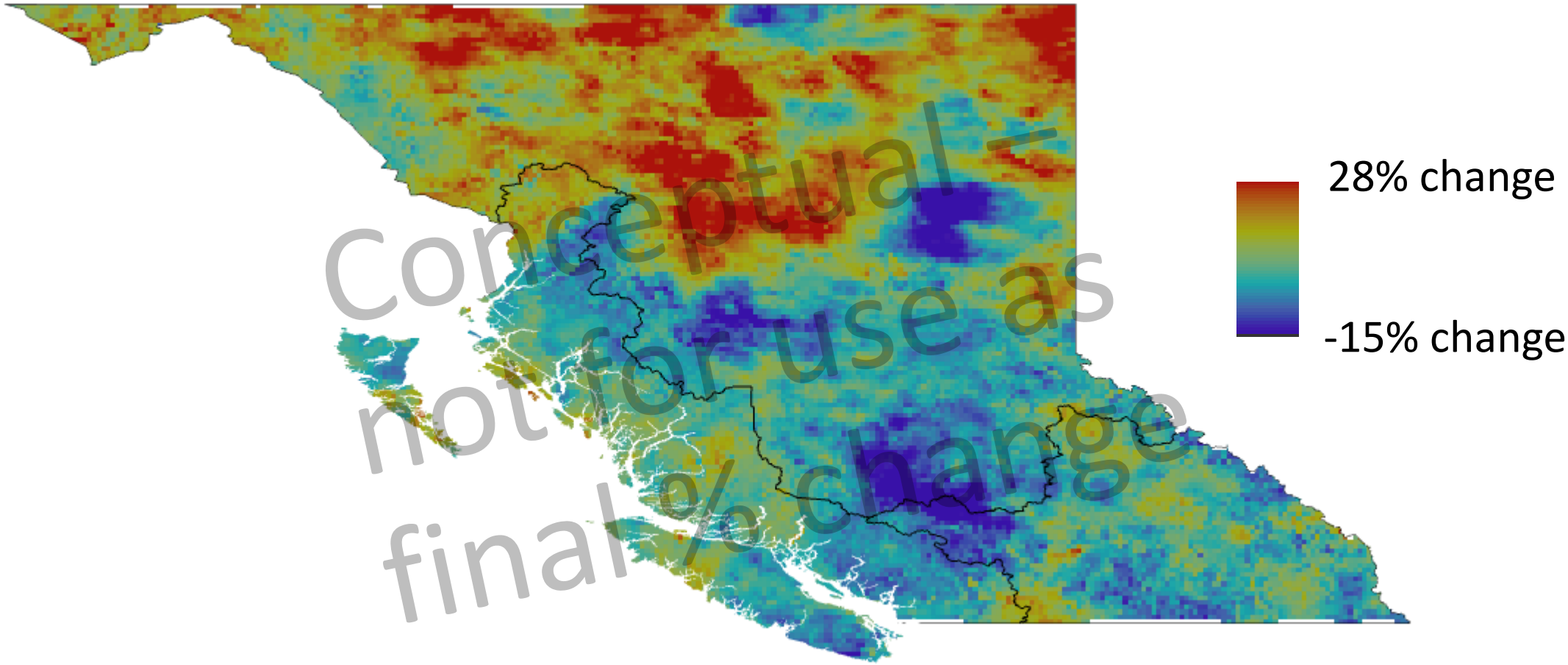
- A story map will summarize the 6 climate vulnerabilities in regions by:
  - Showing maps/values for each through cartography/interaction
    - Including options to summarize different options for RCPs, future periods, and percentiles
  - Explaining the limitations and characteristics of each climate index
    - Final proxy climate indices will be defined with PCIC input
  - Summarizing trends for forest operations vulnerabilities identified in workshops
    - To highlight relevant/different forest operations between regions (local knowledge/experience)
  - Including historic trend information
    - In response to workshop feedback; PCIC will prepare the data
- Data availability:
  - Downloading the data will be an option
    - All raster climate projections files from PCIC post-processed into shp file with all change calculations in the attributes

Tool development: how it all applies



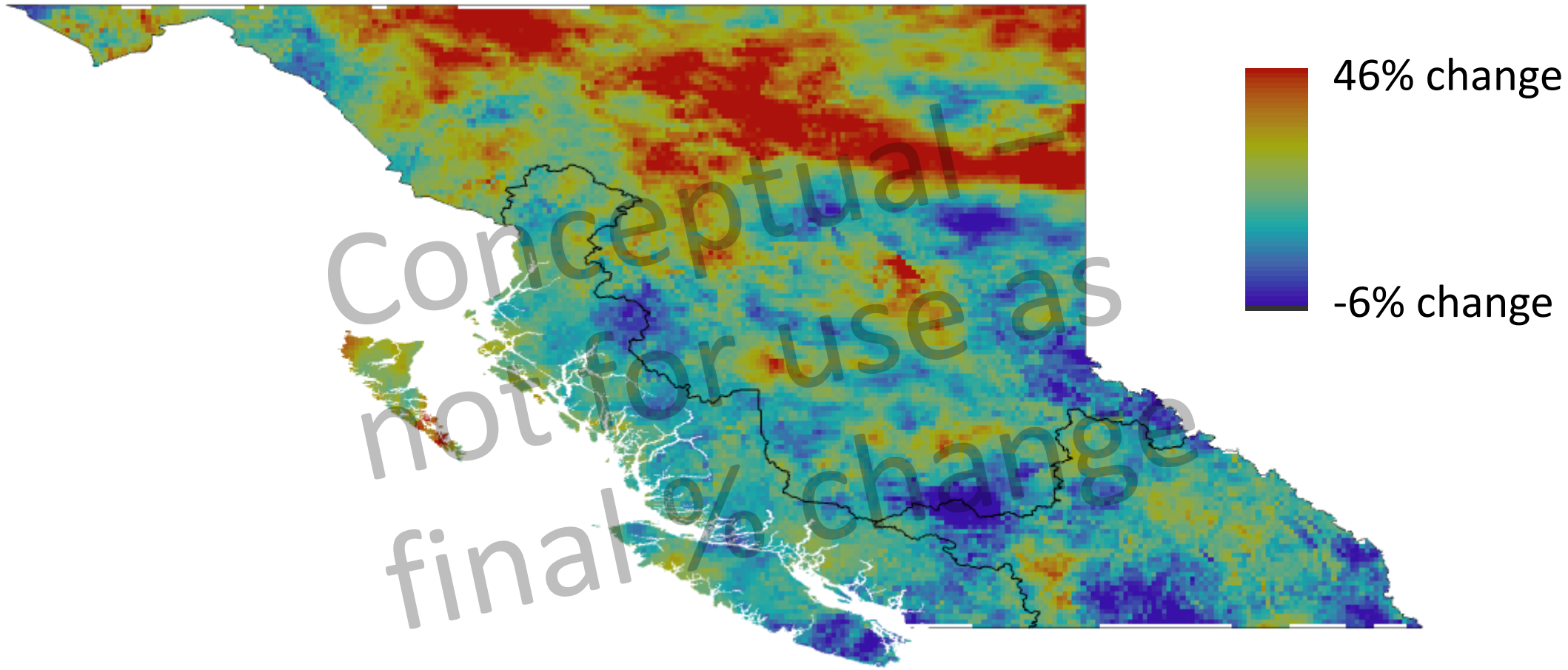
20-year return period daily storm (mm) baseline (1971-200)

Tool development: how it all applies



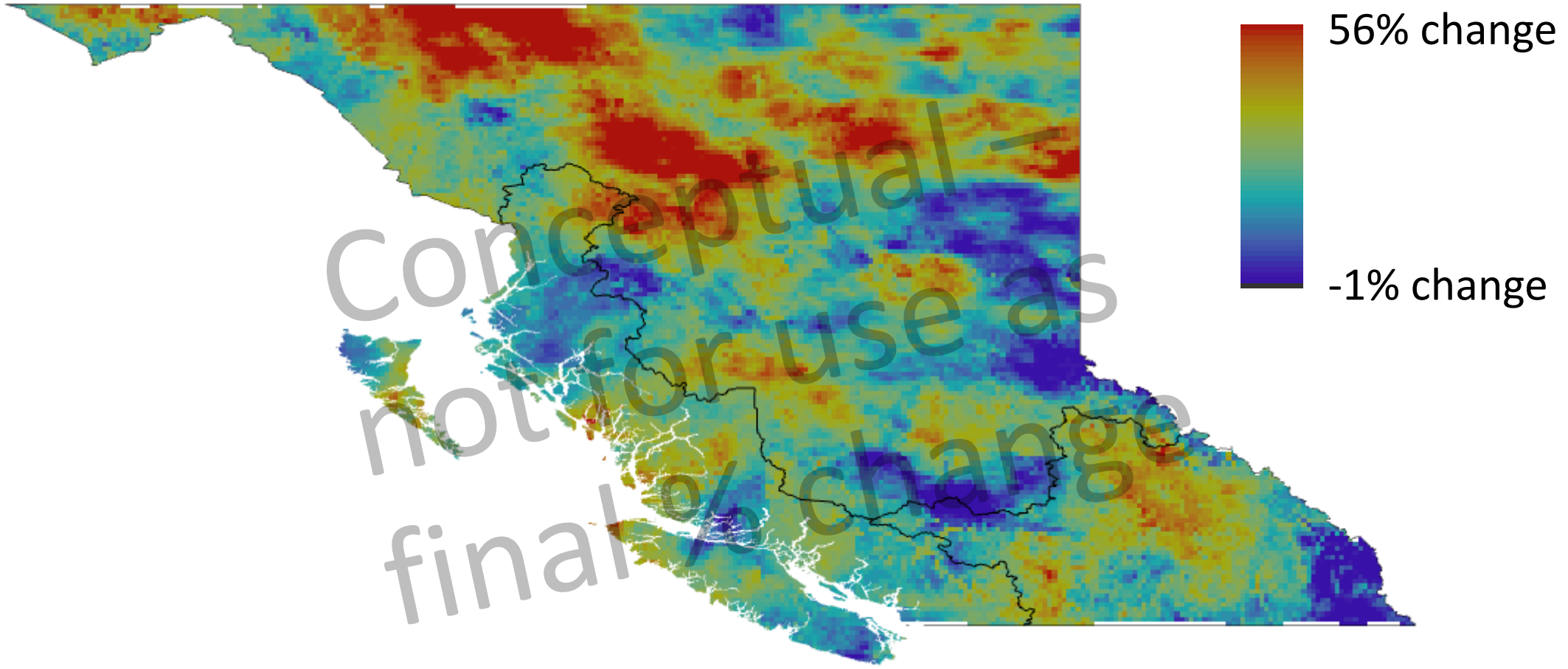
20-year return period daily storm – RCP 8.5 **2030s** p50 (% change from baseline)

Tool development: how it all applies



20-year return period daily storm – RCP 8.5 **2050s** p50 (% change from baseline)

Tool development: how it all applies



20-year return period daily storm – RCP 8.5 **2080s** p50 (% change from baseline)

Tool development: how it all applies

- Example conclusions that could come from vulnerability assessment
  - Importance of road maintenance/implementing practices/budgets
  - Reviewing culvert sizing requirements to projected peak flows
  - Adapting transportation to spring thaws/weight restriction periods
  - Decision-making about road seasoning and seasonal access
  - Better estimates for lifecycle costs
- Ongoing related research at FPInnovations - adaptation
  - Optimizing adaptation solutions for climate change
  - Current experiments on techniques to
    - 1) keep a road frozen 2) keep road dry during spring

4. Discussion

Poll 2: check-in after presentation

Poll: slido.com
event code: fpi

Further reading: resources

- The 3 FSR climate change risk assessments are available at:
  - Climate change adaptation for resource roads - Province of British Columbia (gov.bc.ca)
- Partington, M. (2019). ***Creating climate resilient resource roads: Adapting to climate change***. (InfoNote 1 through 5). Pointe-Claire, Quebec: FPInnovations.
  - Search | Research Library | FPInnovations

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