APPLYING RISK AND VULNERABILITY ASSESSMENTS TO RESOURCE ROADS IN BC

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OBJECTIVES

- Bring awareness to the relationship between roads and climate change
- Define resource road resiliency and adaptation
- Understand the process to identify risks and vulnerabilities to resource roads
- Review the results from three case studies in BC
- Highlight key learnings and future efforts

WHAT IS NEEDED ?

AWARENESS THAT ROAD MANAGEMENT NEEDS TO ADAPT

Photo courtesy: FLNRORD

KNOWLEDGE OF THE CLIMATE EVENTS THAT WILL HAVE THE GREATEST IMPACT

UNDERSTANDING OF PRACTICES THAT CREATE RESILIENT ROAD NETWORKS

UNDERSTANDING ADAPTATION

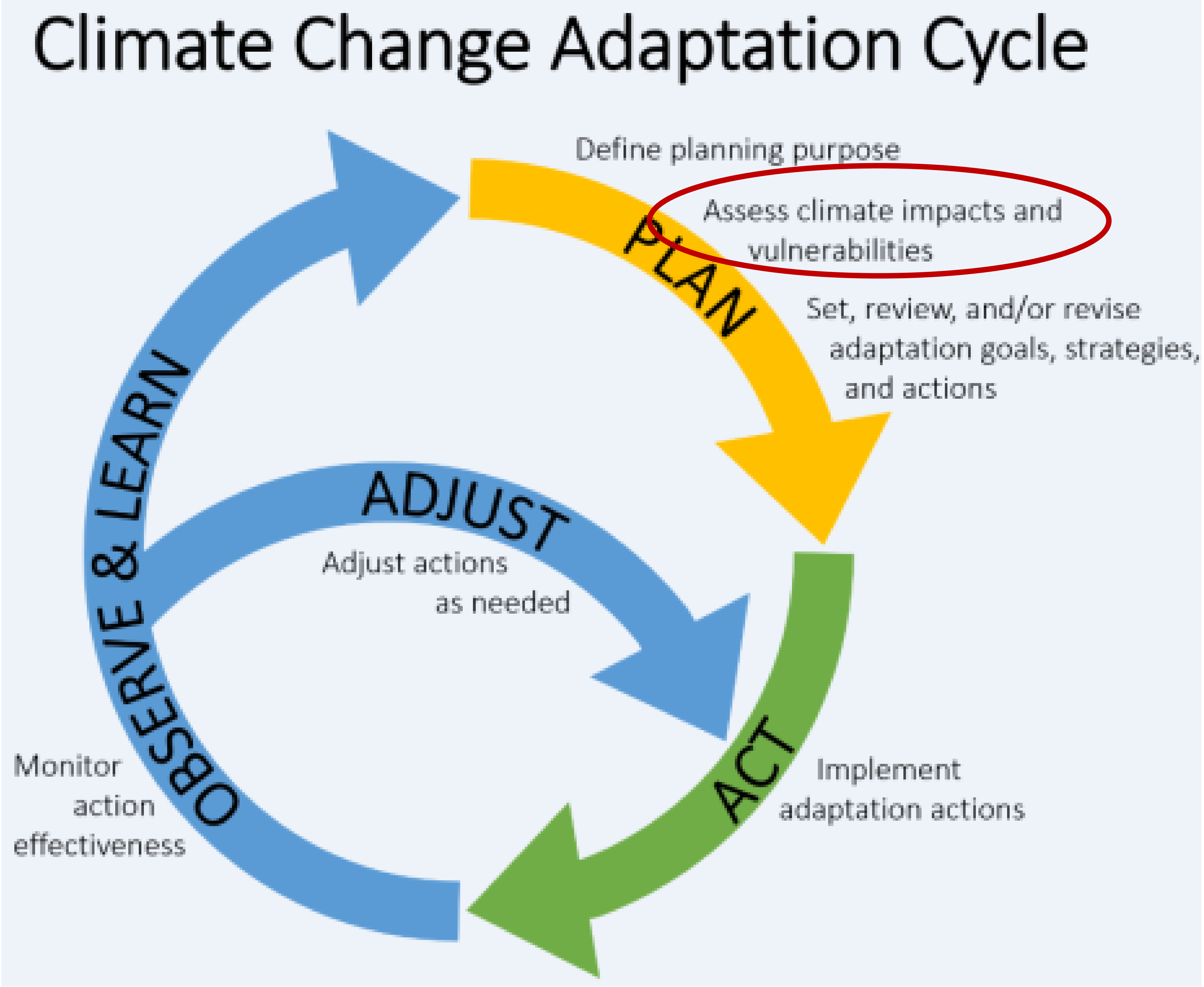
- Refers to **any action** that reduces the negative impact and reduces the vulnerability of the infrastructure to climate change
- Implementing **“soft strategies”** such as robust erosion control practices, or performing ongoing maintenance are examples of easy wins
- Higher impact changes or **“hard strategies”** will require higher capital and long term investments to deal with events such as milder winters

ADAPTATION BUILDS RESILIENCY

- Resiliency is the capacity to withstand disruption and disturbance and to adapt to changing conditions
- The intent :
  - **is not to** create infrastructure that is resistant to all hazards,
  - **is to** create infrastructure with the capacity to respond and adapt to climate change while reducing the severity of damage

IDENTIFYING RISKS AND VULNERABILITIES

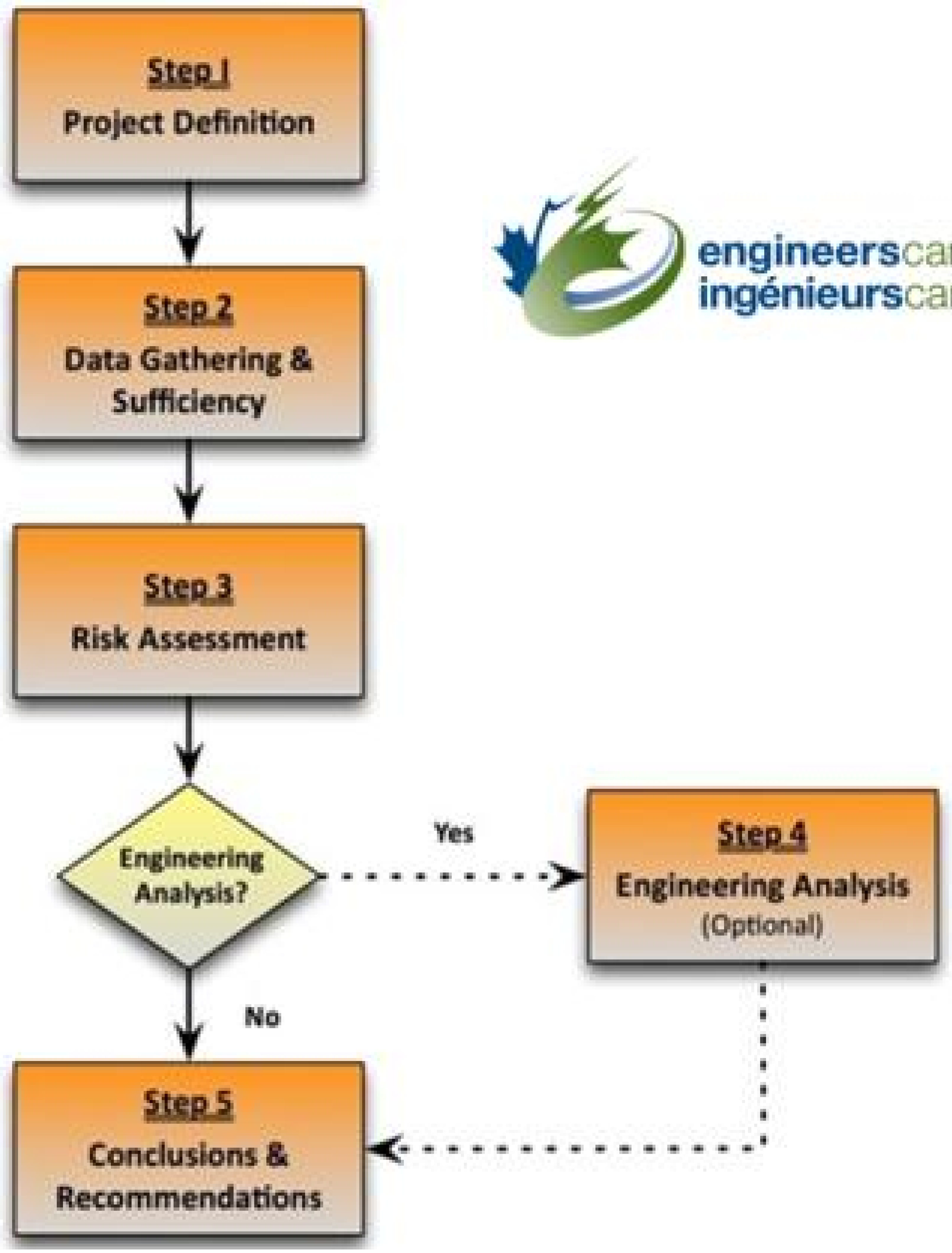
- Identifying risks and vulnerabilities is a critical component of the adaptive management cycle
- May be performed formally as a separate process or imbedded within the management process



Source: https://blackfeetclimatechange.com/our-environment/climate-change-adaptation-plan/

HOW TO ASSESS RISK ?

- The Public Infrastructure Engineering Vulnerability Committee (PIEVC) protocol was developed by Engineers Canada
- Describes a step-by-step methodology of risk assessment for evaluating the impact of a changing climate on infrastructure
- Provides a framework to support effective decision making for infrastructure operation, maintenance, planning and development



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Reproduced from Engineers Canada 2016

HOW TO ASSESS RISK ?

- The PIEVC protocol is designed to assess engineering vulnerability
  - Focus on infrastructure structural and operational features
- The process relies on a team approach and professional judgement
- Emphasis on practical approaches to reducing vulnerability within established schedules and budgetary constraints

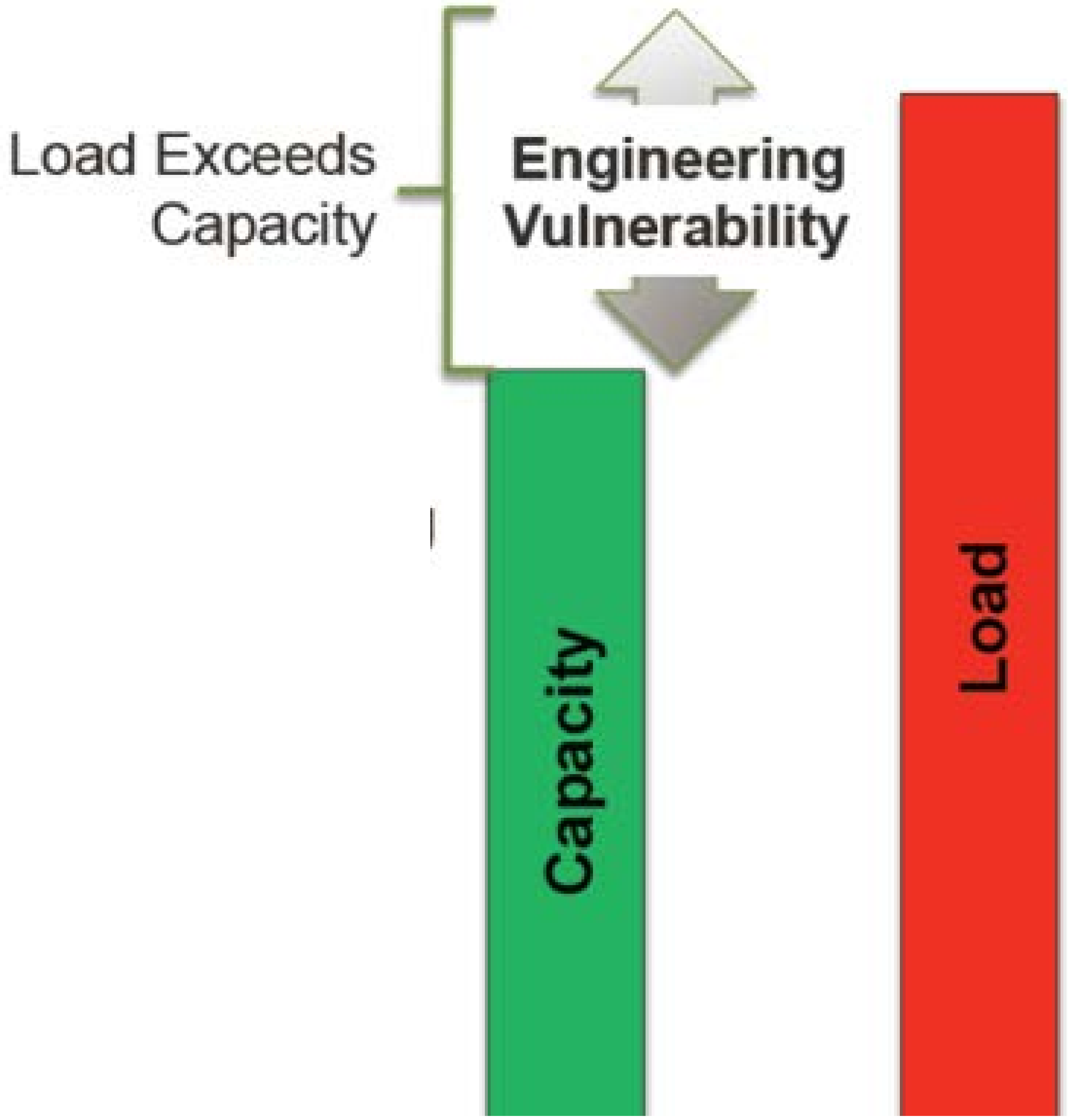

Image: David Lapp Engineers Canada

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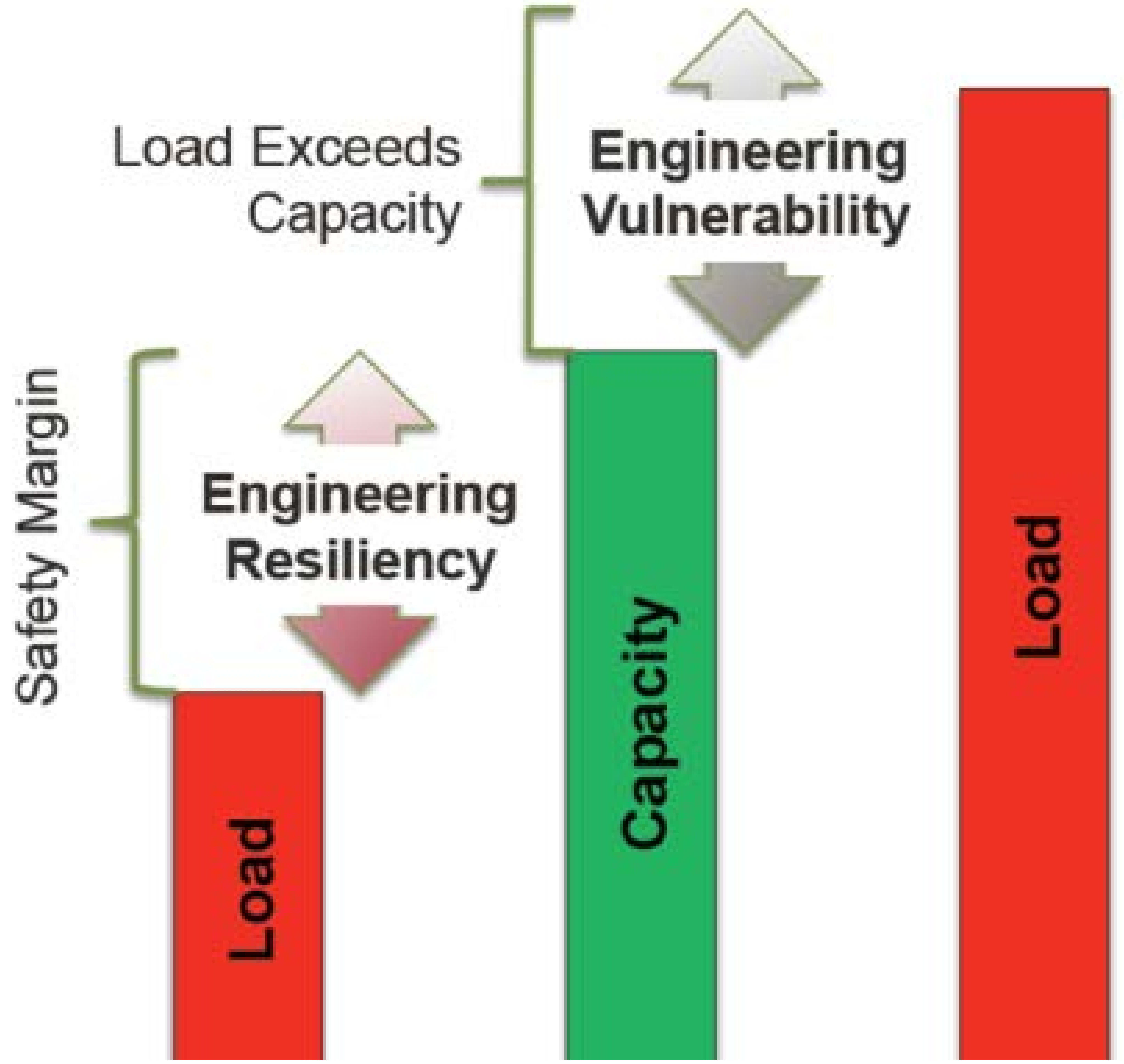

Image: David Lapp Engineers Canada

HOW TO ASSESS RISK ?

- Provides an outcome of risk scores
- These scores can provide an indication of the overall risk of certain infrastructure components to particular climate events
- Results are participant driven:
  - « RESULTS MAY VARY »

Infrastructure Components and Operational Considerations	Extreme High Rainfall in 24 hour period				
	1-day rainfall > 65 mm @ high elevation				High runoff. Culvert and bridge damage or destruction, road surface damage or deterioration, safety
	Y/N	P	S	R	
Road Prism Features					
Road surface	Y	5	3	15	
Cut and fill slope	Y	5	3	15	
Ditches & cross ditches	Y	5	3	15	
Catch basins	Y	5	2	10	
Cross drains	Y	5	5	25	
Stream Crossings					
Major culverts > 1.8 m	Y	5	4	20	
Other culverts < 1.8 m	Y	5	5	25	
Bridges	Y	5	6	30	
Upslope/Downslope beyond road prism					
Managed (Upper Adams Park)	Y	5	3	15	
Unmanaged	Y	5	2	10	
Operational Considerations					
Commercial and recreational access	Y	5	5	25	
Emergency response	Y	5	5	25	
Winter maintenance	N				
Summer maintenance	Y	5	3	15	
Personnel	Y	5	3	15	

FPINNOVATIONS

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APPLYING RISK AND VULNERABILITY ASSESSMENTS TO RESOURCE ROADS IN BC

BACKGROUND

- Investigate a formalized approach to determining risks to Forest Service Road infrastructure from climate change
- Apply the learnings and experience of other BC government ministries (MoTI)
- Support the observations developed through operational field experience
- Provide a process to support budget allocations to create operational resiliency

APPLYING RISK AND VULNERABILITY ASSESSMENTS TO RESOURCE ROADS IN BC

- In-SHUCK-ch Forest Service Road - 2015
  - Facilitated by FLNRORD and MoTI
  - Documented and further analyses by FPInnovations
- Tum Tum Forest Service Road - 2017
  - Facilitated by Nodelcorp Consulting Inc.
  - Documented by FPInnovations
- Willow Forest Service Road - 2018
  - Facilitated and documented by FPInnovations

Photo credit: FLNRORD

IN-SHUCK-CH FOREST SERVICE ROAD

- 70 km length studied
- Mountainous terrain with road located mainly along lake shore and river
- Provides access for industrial usage, resort communities, First Nations, recreation sites
- Recent weather-induced damage included:
    - flooding
    - culvert and bridge washouts
    - debris torrents
    - rock and water falls

INFRASTRUCTURE

Bridges	Signage
Major culverts	Hydro poles/towers
Other culverts	Hydro lines
Culvert cross drains	Communication/utility towers
Ditches	Water lines
Road surfacing	Archeological sites
Embankment/fill slopes	River hydraulics
Cut slopes - soil	Flood plain migration
Cut slopes - rock	Lake level flooding
Upslope hillslopes beyond road prism - managed	Upslope hillslopes beyond road prism - unmanaged
Downslope hillslopes beyond road prism - managed	Downslope hillslopes beyond road prism - unmanaged
Landslide initiation	Snow avalanche zones
Alluvial fan features	Riparian habitat
River training works	Administration/personnel
Retaining walls	Winter maintenance
MSE/GRS walls/fills	Summer maintenance
	Gravel/rock pits/soil sites

IN-SHUCK-CH FOREST SERVICE ROAD

- Infrastructure considered: 34
  - 17 - infrastructure components
  - 5 - third party utilities
  - 8 - environmental features
  - 4 – operational considerations

CLIMATE

High temperature	Snow accumulation
Prolonged dry period	Snow storm/blizzard
Average temperature	Rain/snow/wind
Daily temperature variation	Rain on snow
Freeze/thaw	Hail/sleet
Rock face ice build-up	Rain on frozen ground
Frost and frost penetration	Freezing rain
Total annual precipitation	Visibility(fog)
Extreme high rainfall in 24hr period	High wind combined with rain
Sustained rainfall	Rapid snow melt (not with rain)
Antecedent rain/significant rain event	Snow driven peak flow events
Low rainfall	Ice/ice jams
Snow frequency	Ground freezing

IN-SHUCK-CH FOREST SERVICE ROAD

- Infrastructure considered: 34
    - 17 - infrastructure components
    - 5 - third party utilities
    - 8 - environmental features
    - 4 – operational considerations
- Climate parameters considered: 26
- Total interactions to consider: 334

IN-SHUCK-CH FOREST SERVICE ROAD

- Moving from a snow/rain dominated to a rain dominated system
- General warming expected to result in increased precipitation and higher storm flows
- Increased precipitation as rain in late fall/winter/spring with longer hot and dry periods in summer
- 16% less rain in summer / 6% more in winter
- Mean annual precipitation increase of 8%
- 20 year return period 1day and 5day precipitation events will increase by 16%

IN-SHUCK-CH FOREST SERVICE ROAD

OUTCOMES

- **High risk**
  - Major and minor culverts impacted by ice buildup and obstructions
  - Bridges, minor and major culverts, ditches and cut slopes high risk due to increases in heavy rainfall. Increases in stream peak flows, erosion, obstructions and washouts forecasted.
- **Moderate risk**
  - Road surface maintenance and user safety created by extended prolonged dry periods
  - Winter road surface to increased rutting and potholes due to increased fluctuations in temperature
  - Cut slopes to increased in sloughing and rock falls due to warmer winters and more rainfall

IN-SHUCK-CH FOREST SERVICE ROAD

KEY RECOMMENDATIONS

- Build knowledge and capacity amongst road managers, crews and users
- Investigate improvements to emergency readiness planning
- Review management of road drainage infrastructure and implement an inspection protocol and performance rating
- Increase road maintenance activities and ensure performance levels are met

Photo credit: FLNRORD

TUM TUM FOREST SERVICE ROAD

- 54 km length studied
- Mountainous terrain with road located within a river valley and a provincial park for much of its length
- Provides access for industrial usage, provincial park , recreation sites and private cabins
- Recent weather-induced damage included:
  - culvert and bridge washouts
  - road surface damage

TUM TUM

FOREST SERVICE ROAD

INFRASTRUCTURE

Upslope/downslope beyond road prism - managed	Upslope/downslope beyond road prism - unmanaged
Road surface	Cut/fill slope
Ditches and cross drains	Commercial and recreational access
Catch basins	Emergency response
Cross drains	Winter maintenance
Major culverts	Summer maintenance
Other culverts	Personnel
Bridges	

- Infrastructure considered: 15
  - 8 - infrastructure components
  - 0 - third party utilities
  - 2 - environmental features
  - 5 – operational considerations

TUM TUM

FOREST SERVICE ROAD

CLIMATE

Drought conditions	Antecedent rain/significant rain event
Daily temperature variation	Snow frequency
Freeze/thaw	Snow accumulation
Cold spells	Rapid snow melt (not with rain)
Extreme high rainfall in 24hr period	Ice/ice jams
Sustained rainfall	Spring thaw

- Infrastructure considered: 15
    - 8 - infrastructure components
    - 0 - third party utilities
    - 2 - environmental features
    - 5 – operational considerations
- Climate parameters considered: 12
- Total interactions to consider: 169

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TUM TUM FOREST SERVICE ROAD

- Annual precipitation will increase with reductions in summer and increases in winter
- Warmer winter and summer temperatures forecasted
- Shorter snow season
- Warming projected in all seasons, temperatures increasing by 2-4°C
- 20 year return period 1day and 3day precipitation events will increase by 20-50%

Photo credit: FLNRORD

TUM TUM FOREST SERVICE ROAD

OUTCOMES

- Bridges, small culverts and cross drains = high-medium to certain rain events
- Commercial, recreational and emergency access = high-medium risk
- Water crossing infrastructure = low-medium risks from precipitation events, freeze/thaw
- Access = low-medium risk from drought conditions and freeze/thaw

Risk analysis cumulative results for the 169 infrastructure and climate interactions

RISK PROFILE	BASELINE CLIMATE	FUTURE CLIMATE
Low	71 %	69 %
Low - Medium	25 %	24 %
High - Medium	4 %	7 %
High	0 %	0 %

TUM TUM FOREST SERVICE ROAD

KEY RECOMMENDATIONS

- Major and minor culverts require an inspection protocol and maintenance plan
- A performance rating should be developed for all water crossings
- Review and revise contingency plans to provide medical support, supplies and communication
- Review use of road friendly truck technologies to react to earlier spring thaw periods
- Initiate road maintenance activities to ensure current design capacity and performance is achieved

WILLOW

FOREST SERVICE ROAD

- 92 km length studied
- Gradual terrain with road located within a wide forested valley
- Provides access for industrial usage, provincial park , community and recreation sites
- Recent weather-induced damage included:
    - culvert and bridge washouts
    - road embankment damage
    - icey road surface conditions

WILLOW FOREST SERVICE ROAD

INFRASTRUCTURE

Road prism (surface/subgrade)	Cut and fill slope
Ditches	Cross drains
Major culverts (≥ 2.0 m)	Other culverts (≤ 2.0m)
Bridges	Emergency response
Commercial, recreational, residential access	Winter maintenance and construction
Summer maintenance and construction	Safety
Ditches	Cross drains

- Infrastructure considered: 12
  - 7 - infrastructure components
  - 0 - third party utilities
  - 0 - environmental features
  - 5 – operational considerations

WILLOW FOREST SERVICE ROAD

CLIMATE

Drought conditions	Extreme high rainfall in 24hr period
High rainfall in 24hr 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	Snow accumulation

- Infrastructure considered: 12
  - 7 - infrastructure components
  - 0 - third party utilities
  - 0 - environmental features
  - 5 – operational considerations
- Climate parameters considered: 12
- Total interactions to consider: 132

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WILLOW FOREST SERVICE ROAD

- Warming projected in all seasons with average annual temperature increase of 3°C
- Precipitation in summer will remain the same or slightly decrease
- Winter precipitation increase of 6% and spring/fall increase of 16%
- The 20-year return period annual maximum 1-day and 5-day precipitation are projected to increase by 13%-15%

WILLOW FOREST SERVICE ROAD

OUTCOMES

- Access restrictions = high-medium to high risk due to deteriorating road surface conditions
- Ditches, cross drains, small culverts = high-medium risk from increase of rain on snow events and freeze/thaw cycling
- Operational planning impacted by spring thaw expected to occur 12 days earlier
- Increase in road surface degradation expected due to freeze/thaw cycling, antecedent rain events and earlier spring thaw conditions

***PRELIMINARY* Risk analysis cumulative results for all of the infrastructure component and climate parameter interactions**

RISK PROFILE	BASELINE CLIMATE	FUTURE CLIMATE
Low	59 %	59 %
Low - Medium	29 %	29 %
High - Medium	11 %	11 %
High	1 %	1 %

WILLOW FOREST SERVICE ROAD

KEY RECOMMENDATIONS

- Major and minor culverts require an inspection protocol and maintenance plan
- A performance rating should be developed for all water crossings
- Review and revise contingency plans to provide medical support, supplies and communication
- Implement operational practices, vehicle technologies, road maintenance procedures, road upgrades to address poor road surface conditions
- Implement upgrades and maintenance procedures to ensure ditches, cross drains and small culverts can handle increased winter flows

APPLYING RISK AND VULNERABILITY ASSESSMENTS TO RESOURCE ROADS IN BC

GENERAL LEARNINGS

- Precipitation events and interaction with water crossings and drainage infrastructure is of greatest concern
- Road user safety and emergency access must be strong considerations for roads with both industrial, recreational and community access
- Increased rainfall events in winter and in shoulder seasons will create additional stress to infrastructure and access
- Changes in forest access in winter months and earlier spring thaw periods will have significant impacts on forest operations in the coming decades

APPLYING RISK AND VULNERABILITY ASSESSMENTS TO RESOURCE ROADS IN BC

GENERAL LEARNINGS

- Current road maintenance practices, protocols and budgets are weaknesses
- Poor or complete lack of inventory for majority of infrastructure types impedes the ability to assess risk
- Infrastructure inspections and performance criteria lacking which restricts ability to evaluate current and future performance expectations
- Management of resource roads is focused on high-cost infrastructure while low-cost infrastructure can create high risks to resiliency
- Operational level knowledge is strong but administrative practices to capture this knowledge is weak

“This document should be used to change the present road maintenance BMPs and perhaps legislation to ensure that the road systems are being protected. Most of the maintenance is reactionary at best. There should be a recommendation … of the risks and costs of not doing a better job of maintenance of the road system”

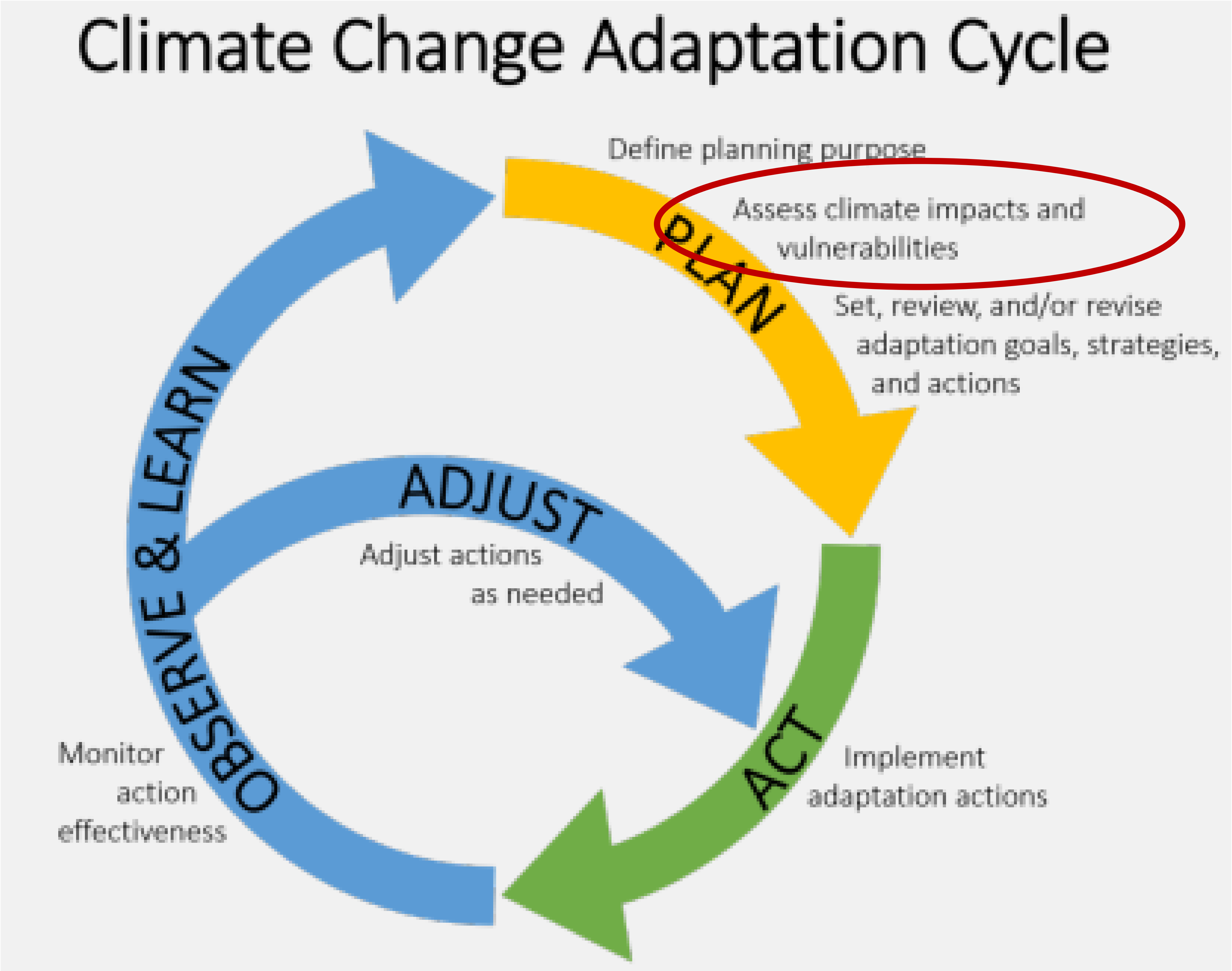
Gene MacInnes, R.P.F., MacInnes and Associates
in-SHUCK-ch FSR analysis participant

APPLYING RISK AND VULNERABILITY ASSESSMENTS TO RESOURCE ROADS IN BC

MOVING FORWARD

- A streamlined approach is required
- Take a higher level view and focus assessments on road networks rather than specific road segments
- Develop list of most common infrastructure components and climate parameters
- Recognize value, understanding and application of performing risk and vulnerability assessments

APPLYING RISK AND VULNERABILITY ASSESSMENTS TO RESOURCE ROADS IN BC



"While risk assessment tends to give good insight, we can focus too narrowly on this one element of a robust risk management process."

Joel Nodelman,
President & CEO, Nodelcorp Consulting Inc.
nodelcorp.com, blog post:
Pulling Together for Climate Resiliency

Source: https://blackfeetclimatechange.com/our-environment/climate-change-adaptation-plan/

FURTHER READING

Bradley, A., & Forrester, A. (2018). ***Analysis of a British Columbia Resource Road's Vulnerability to Climate Change: in-SHUCK-ch Forest Service Roads PIEVC case study*** (Technical Report 30). Pointe-Claire, Quebec: FPInnovations.

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https://fpinnovations.ca/extranet/pages/search.aspx

RESOURCE ROADS – CLIMATE CHANGE TEAM

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