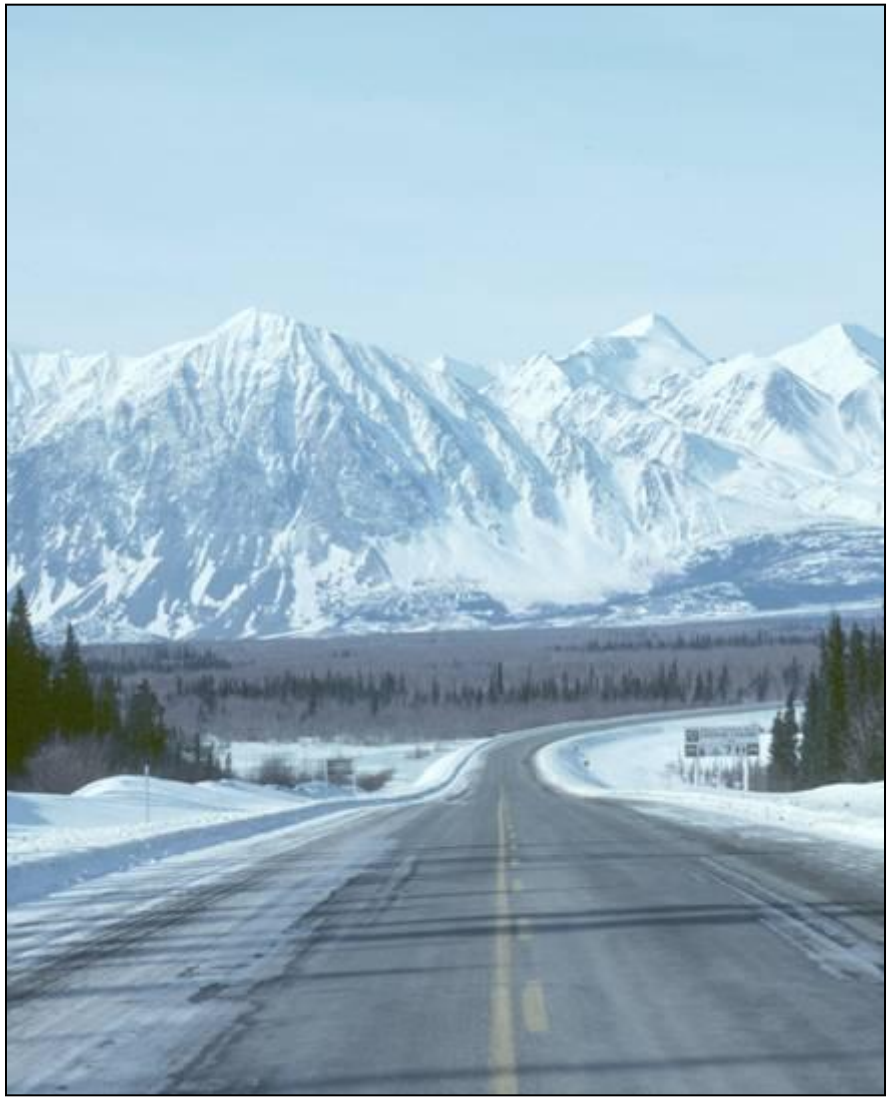

Stabilizing Highways Over Degrading Permafrost Yukon, Canada

Presented by: Paul Murchison

Northern Transportation Conference 2011:

Circumpolar Challenges and Opportunities

Anchorage Alaska

September 18-20, 2011

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Outline

- Yukon Highway Infrastructure
- Infrastructure Maintenance Issues
- Yukon Climate Trends and Scenarios
- Mitigation Measures/Permafrost Protection (Permafrost Test Site)
- Results of Data Analysis, Permafrost Test Site

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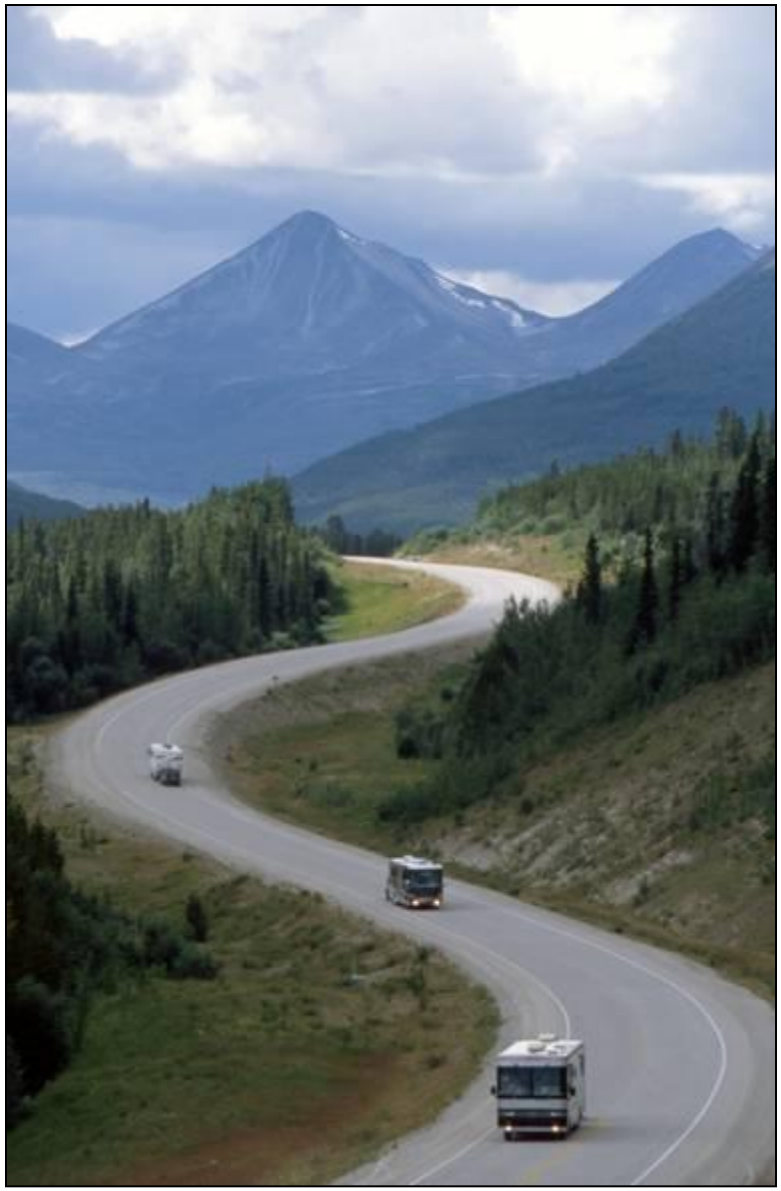
Yukon Highway Infrastructure



- Area 483,450 km^2
- Population ~35,000
- 4,808 km of maintained highway
  - Asphalt pavement 310 km;
  - BST 1,930 km;
  - Gravel 2,568 km; and
  - 28 bridges.
- About 25% of the highway infrastructure is underlain by permafrost.

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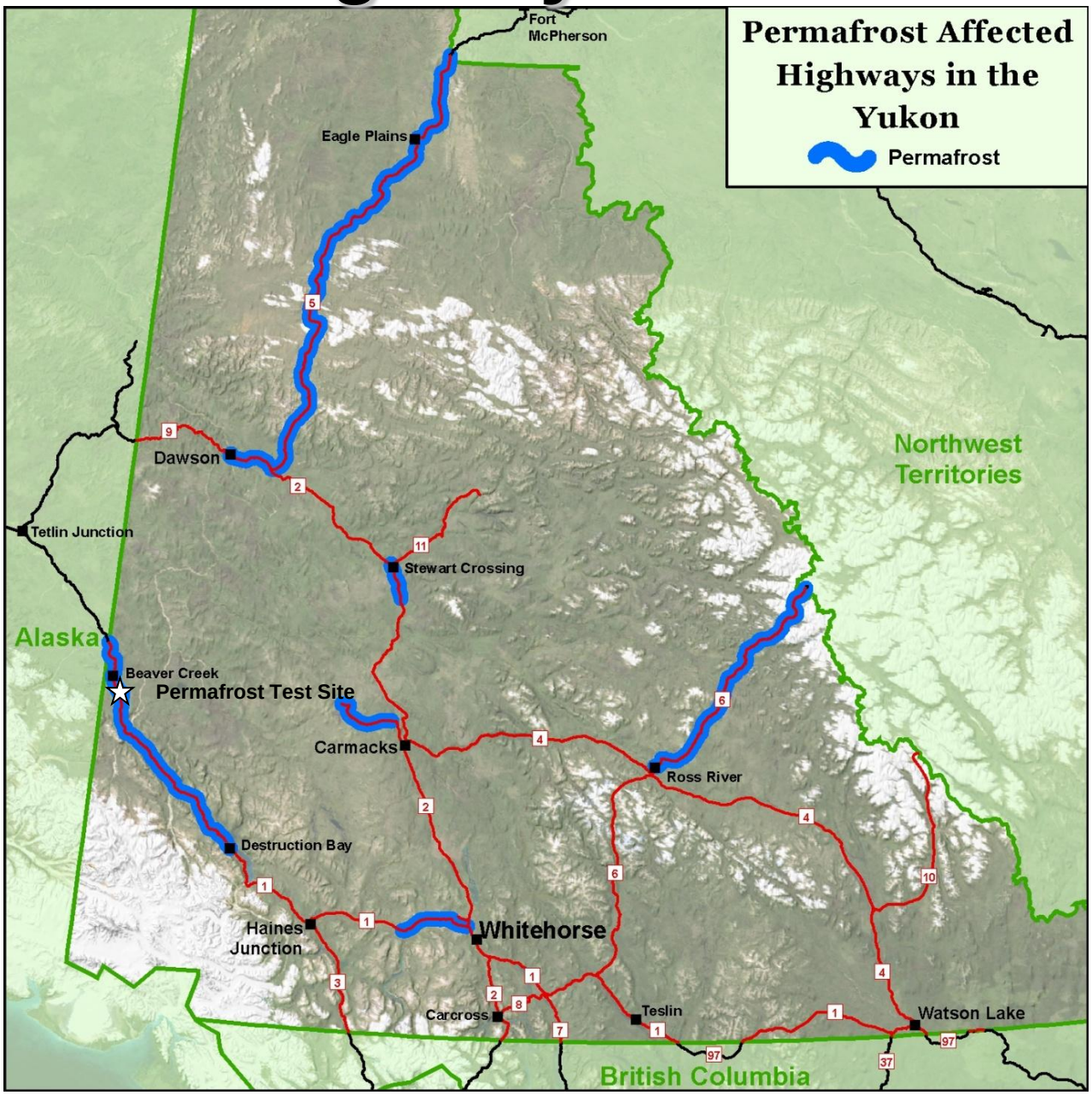
Yukon Highway Infrastructure



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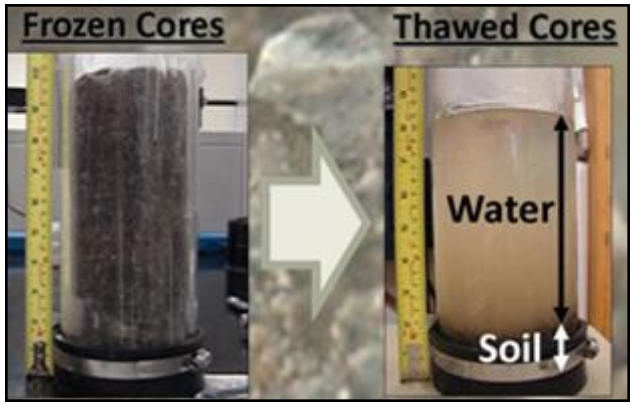
Infrastructure Maintenance Issues

Warm, thaw sensitive permafrost = problems



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Infrastructure Maintenance Issues

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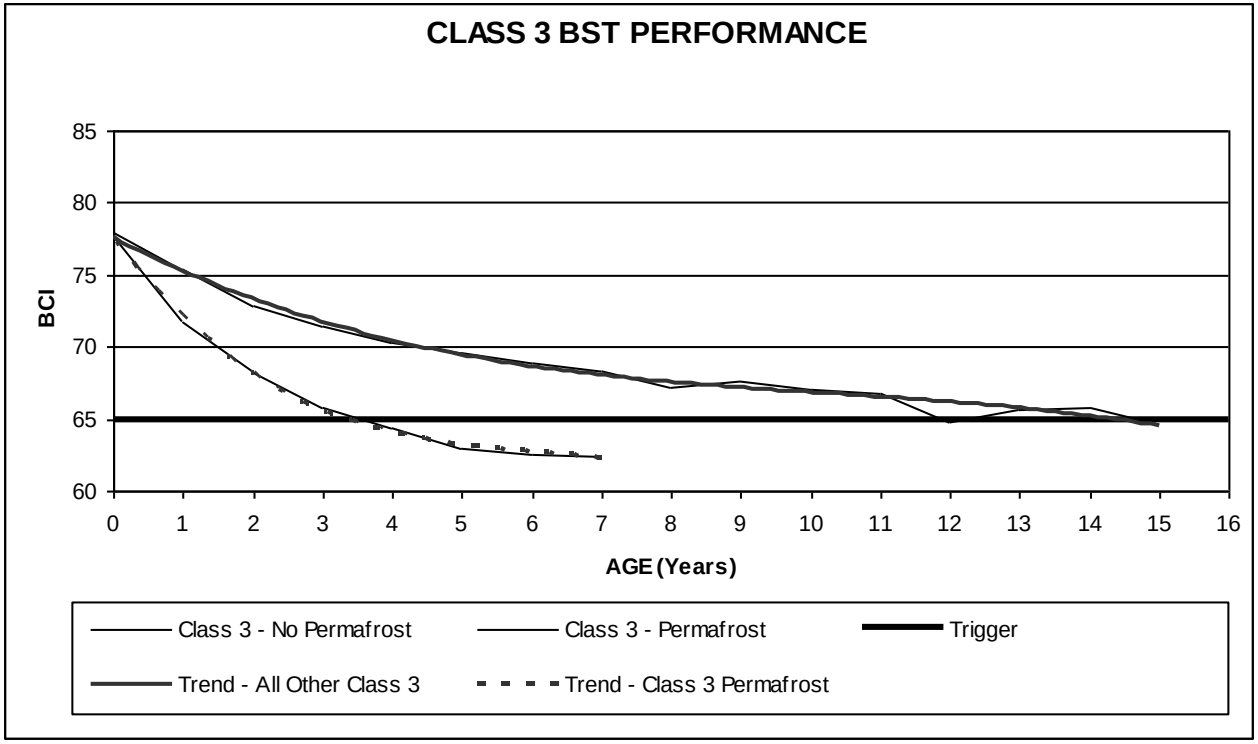
Infrastructure Maintenance Issues



- Additional maintenance / rehabilitation cost in the permafrost section is up to $22,000 / km / year
- Maintenance / rehabilitation costs in permafrost sections are approximately 8 times as much as non-permafrost sections

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Infrastructure Maintenance Issues

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Infrastructure Maintenance Issues

Permafrost deterioration is expected to continue and possibly accelerate based on observed and predicted warming trends

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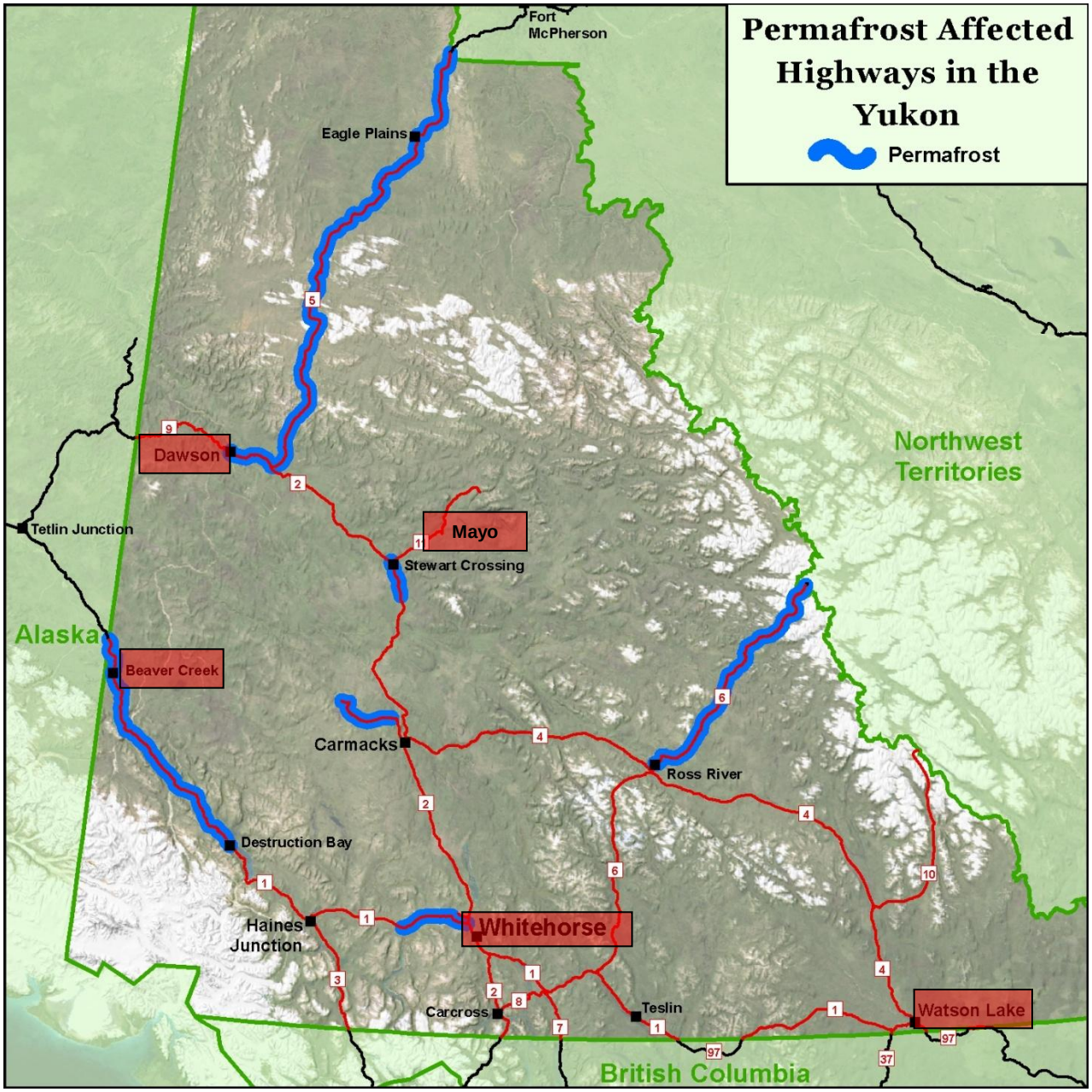
Yukon Climate Trends



Evidence of a warming trend from observations in:

- Dawson City
- Mayo
- Watson Lake
- Whitehorse
- Beaver Creek

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Yukon Climate Trends

Dawson City Climate Trends	Rate of Change
Mean Daily Minimum in Winter (°C)	0.62 °C/ decade
Mean Daily Maximum in Summer (°C)	0.38 °C/ decade
Mean Annual Temperature (°C)	0.24 °C/ decade
Days Below -40°C	-3.9 days/decade
Frost Free Days	7.4 days/decade

Data Source: Environment Canada

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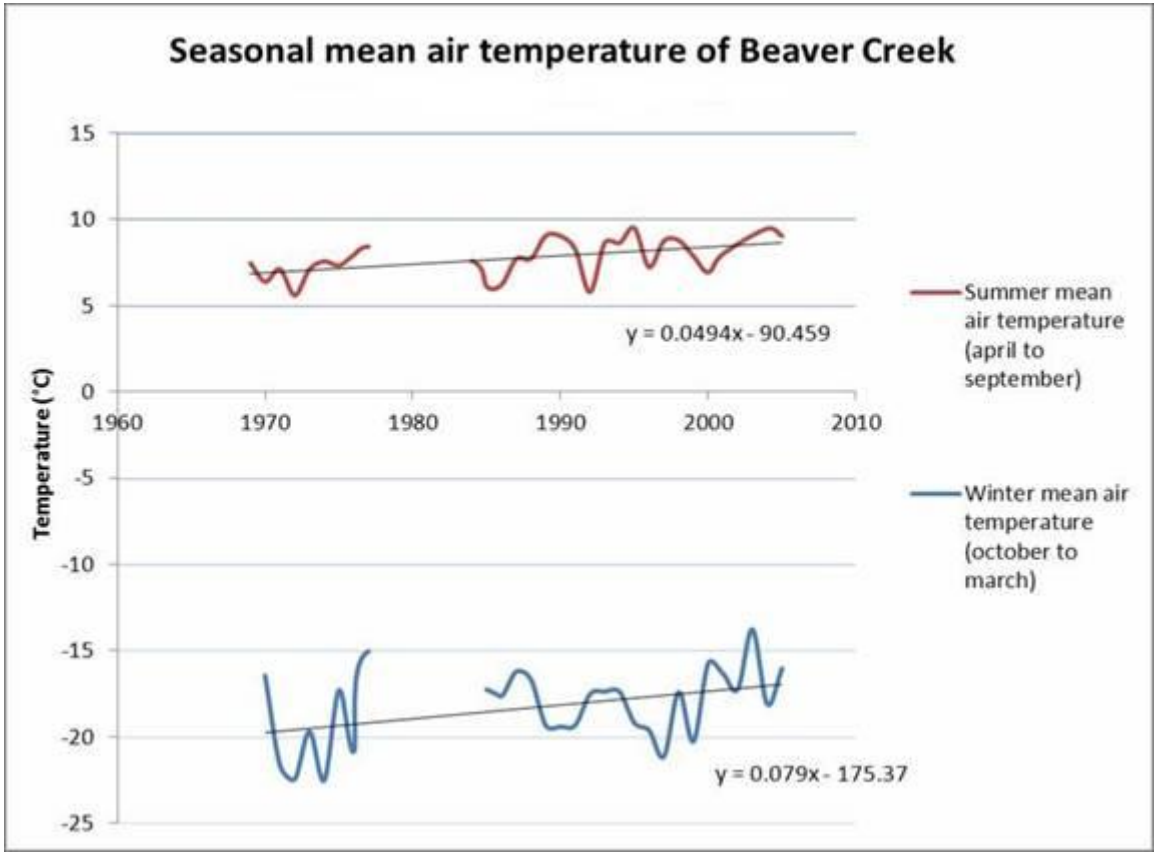
Yukon Climate Trends



Data Source: Environment Canada

- Observed mean winter air temperatures rate of change is 1.6 times greater than mean summer air temperatures.
- Mean annual air temperatures increasing at 0.6ºC per decade (1969 and 2006).

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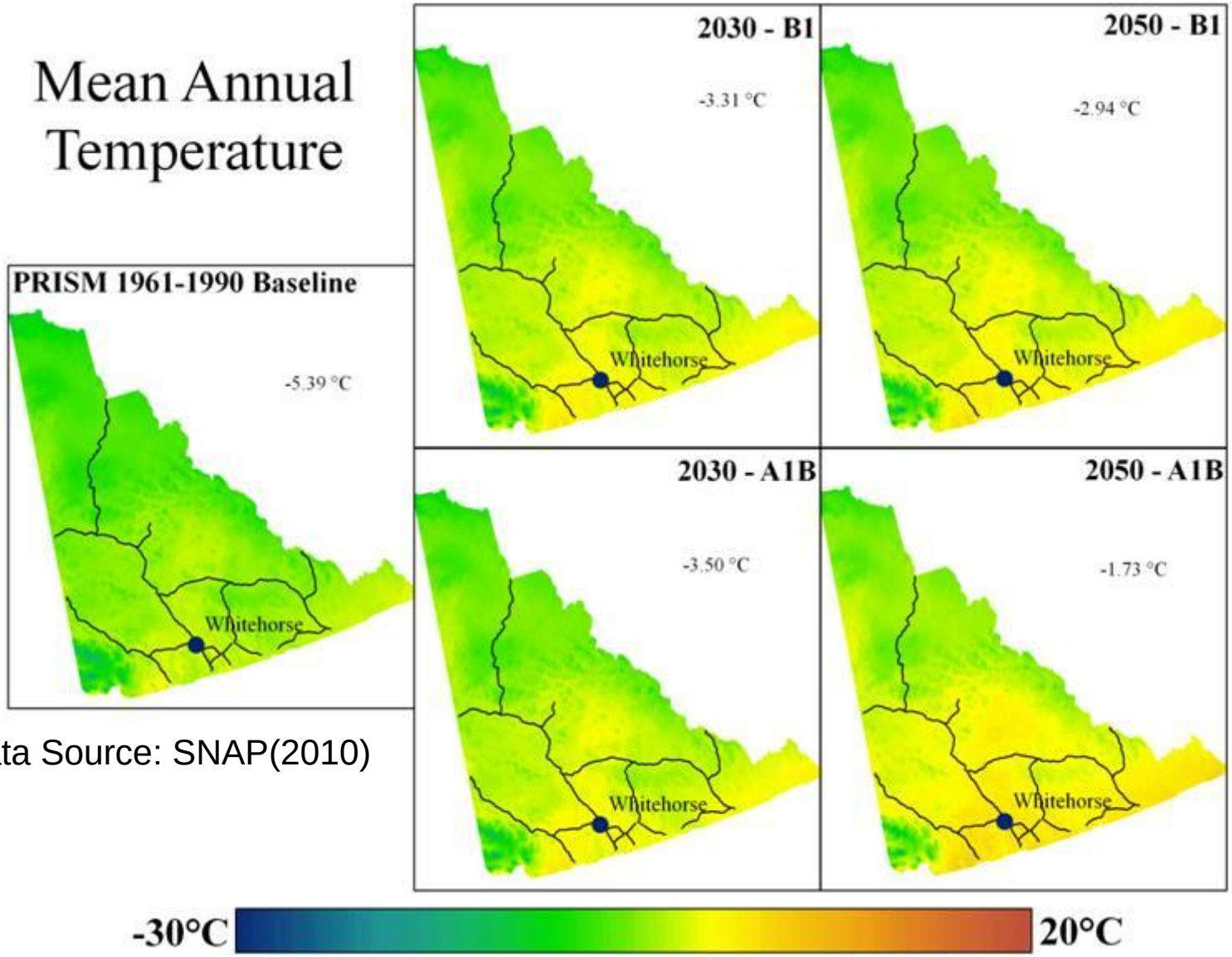
Yukon Climate Scenarios



Data Source: SNAP(2010)

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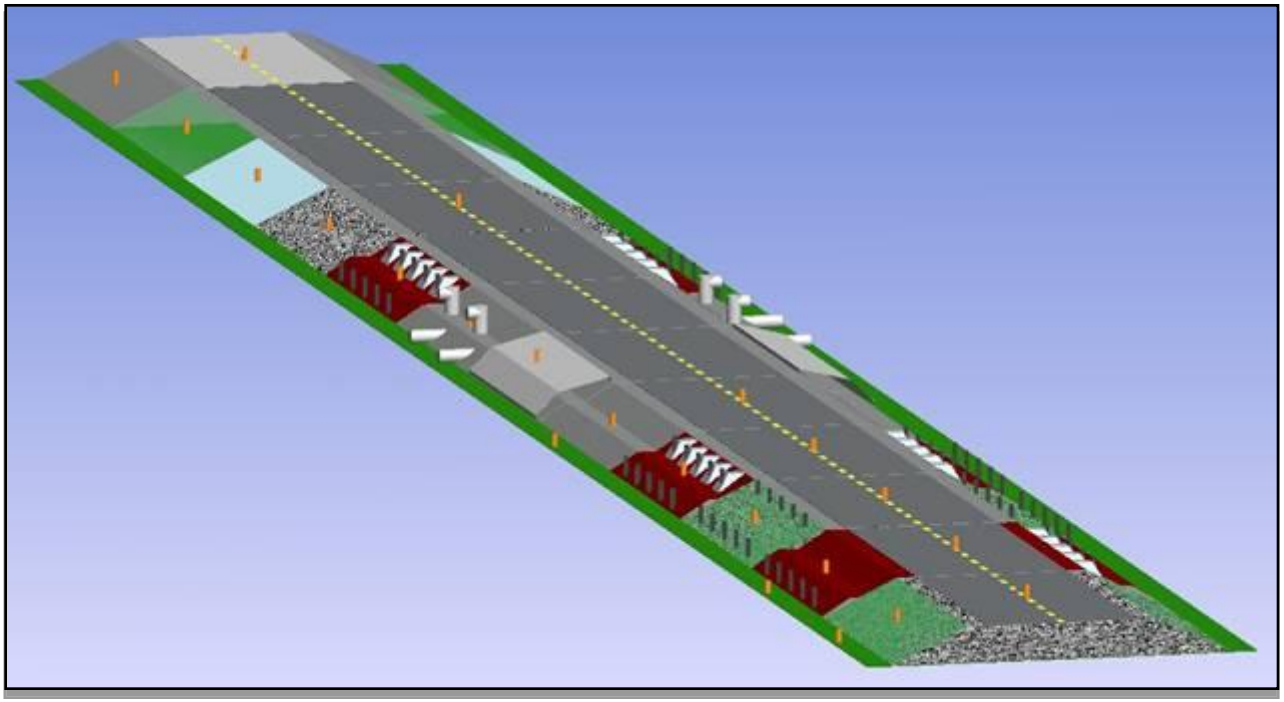
Permafrost Test Section – Alaska Highway



- Twelve instrumented test sections.
- The test site is heavily instrumented over 300 thermisters, 150 surface temperature loggers, heat flux plates, groundwater sensors and weather monitoring equipment (air temperature, snow depth, wind speed and direction).
- Temperatures are recorded hourly and transmitted by satellite every four hours to the GOY SCADA (Supervisory Control and Data Acquisition) server in Whitehorse.

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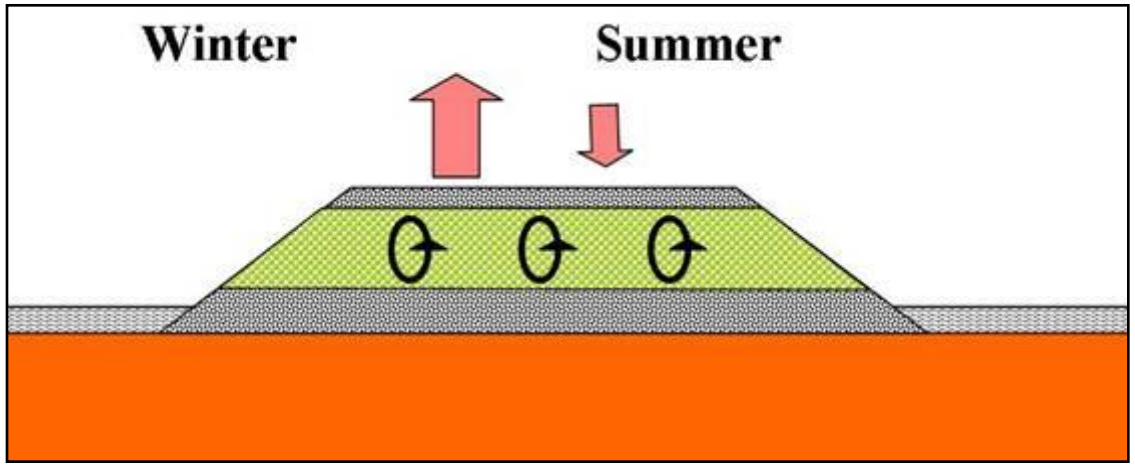
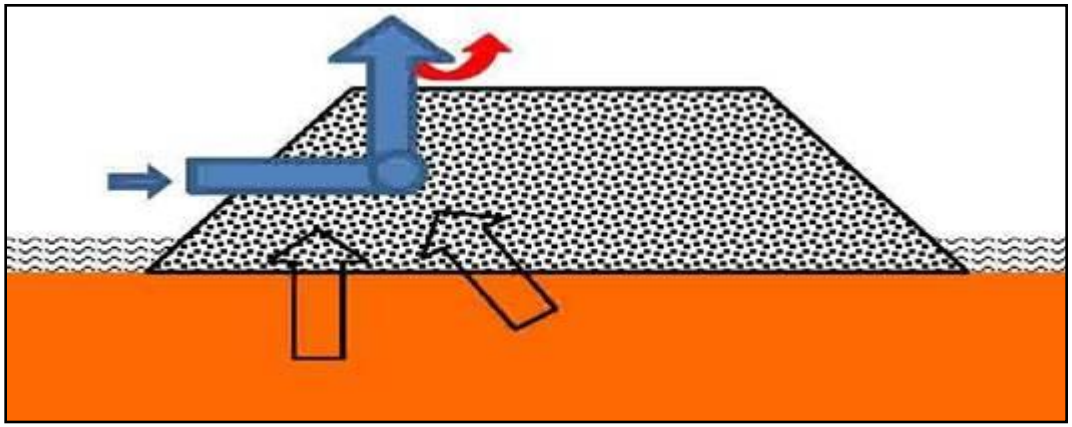
Air Convection Embankment (ACE)

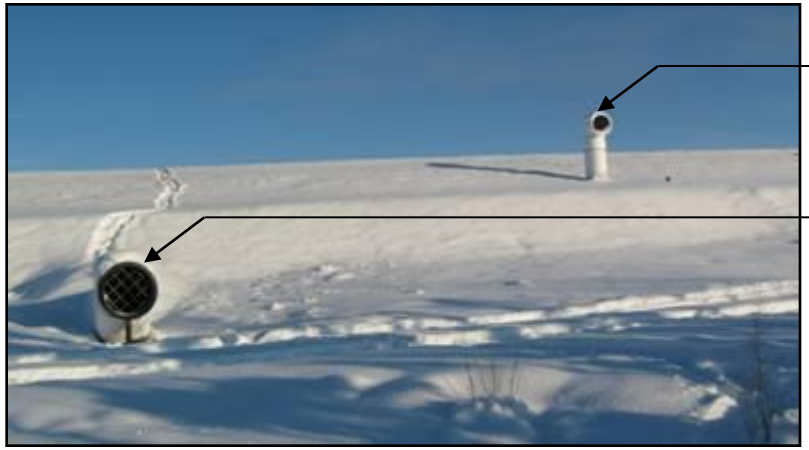


- Constructed using 150 mm to 300 mm, crushed, rock to form interconnected, convective cells in the embankment.
  - Winter – air cooled in the upper voids travels down into the embankment displacing warm air which rises and exits from the embankment.
  - Summer – the rock insulates the ground and reduces warming by keeping warm air near the surface and cool air at the base of the ACE.

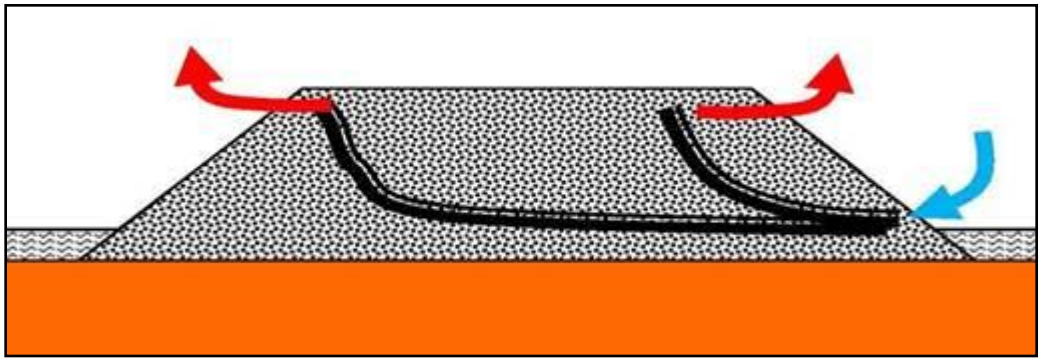
Longitudinal Culverts



- Heat extraction by natural convection.
  - Winter, cold air is drawn into the embankment at the inlet and warmed air exits at the outlet.
  - Summer, inlet and outlet are blocked to minimize warm air input.



Heat Drains



- Heat extraction by natural convection induced in a geocomposite layer
- Applications on embankment slope and across full embankment width

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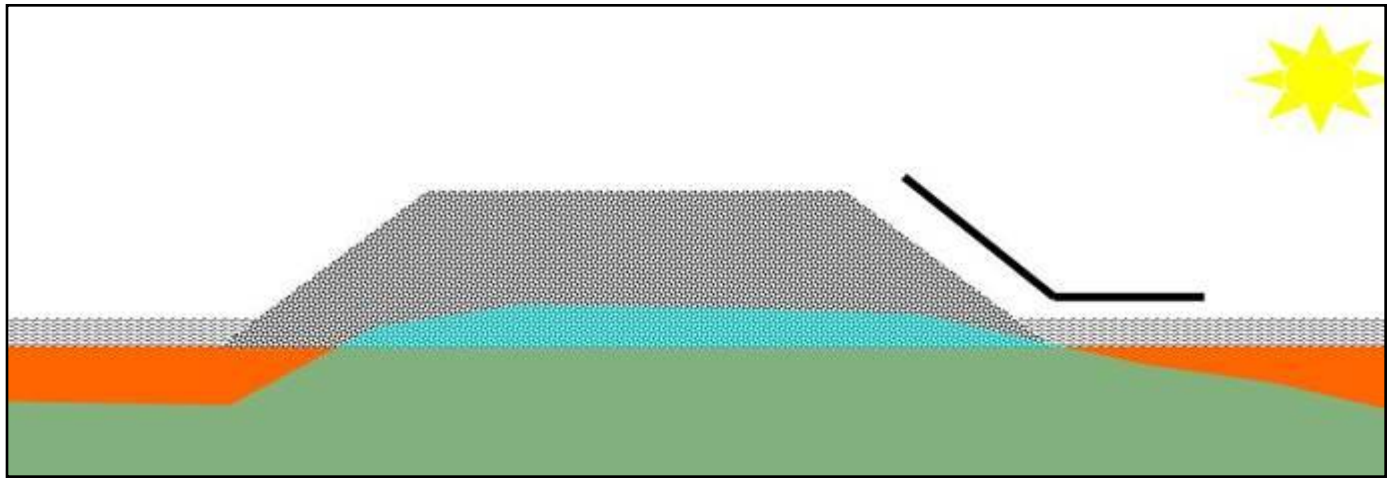
Sun/Snow Shed



- Winter – promote air circulation and protect embankment slopes from snow insulation.
- Summer – Reflects solar radiation and drastically reduces drastically the effect on exposed slopes

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High Albedo Surfacing

- Light-coloured aggregate BST reflects solar radiation resulting decreasing heat transfer into the embankment.

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Grass Covered Embankment

Affects of vegetation on permafrost underlying embankment slope

Snow Clearing

Clearing the snow from the side slopes during winter to minimize the insulating effect

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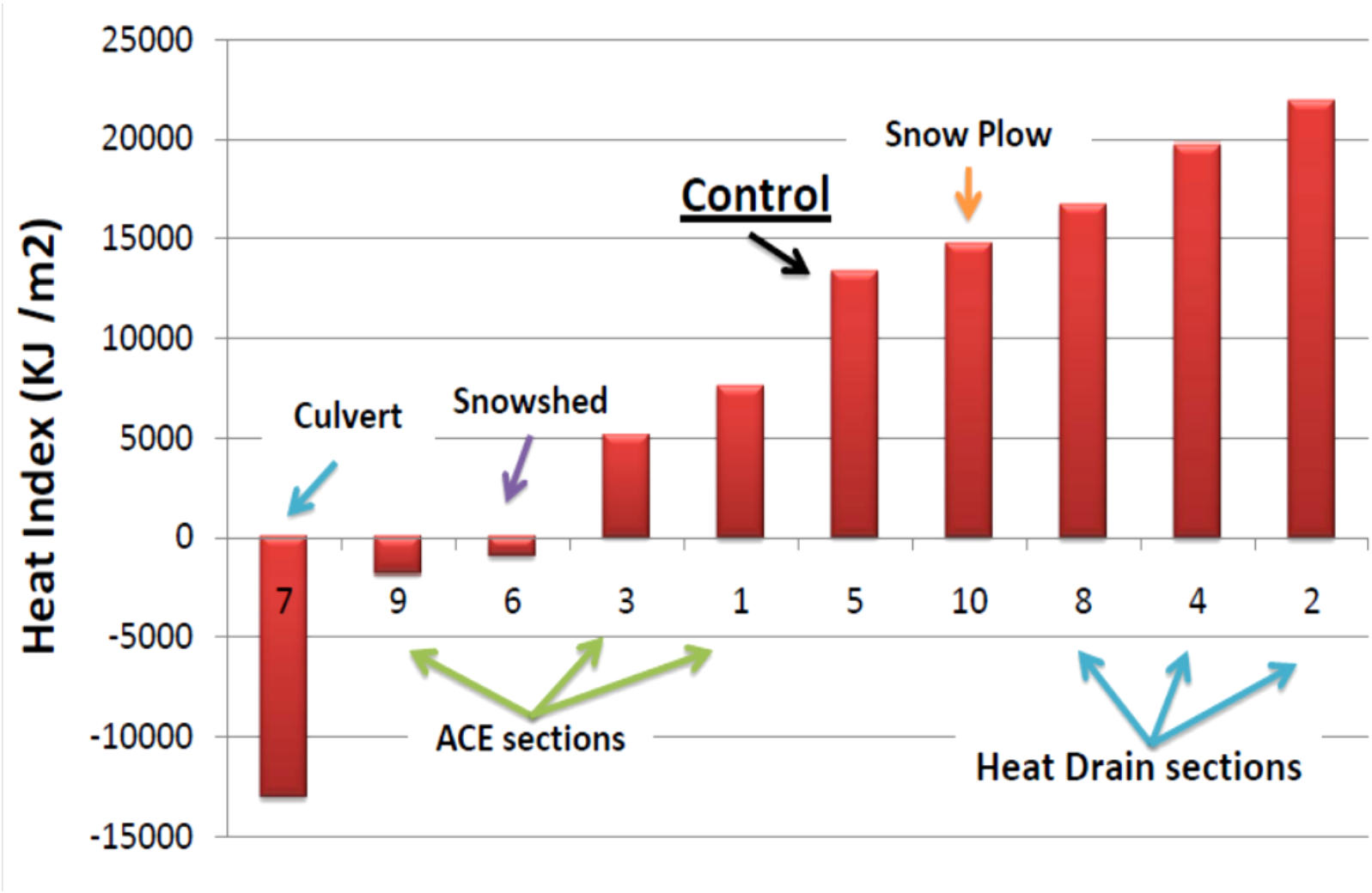
Data Analysis Results



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Summary

- Roads constructed on permafrost (especially warm, thaw sensitive permafrost) tend to deform due to permafrost degradation.
- Climate warming trends may be accelerating this degradation.
- Stable highway sections may be destabilized in the future.
- Permafrost protection techniques may prevent permafrost thaw resulting from thermal regime changes due to:
  - highway construction and/or
  - warmer air temperatures

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Thank you

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