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SUSTAINABLE WINTER SERVICE FOR ROAD USERS

Reducing Maintenance Requirements on Permafrost-Affected Highways: Permafrost Test Sections Along the Alaska Highway, Yukon

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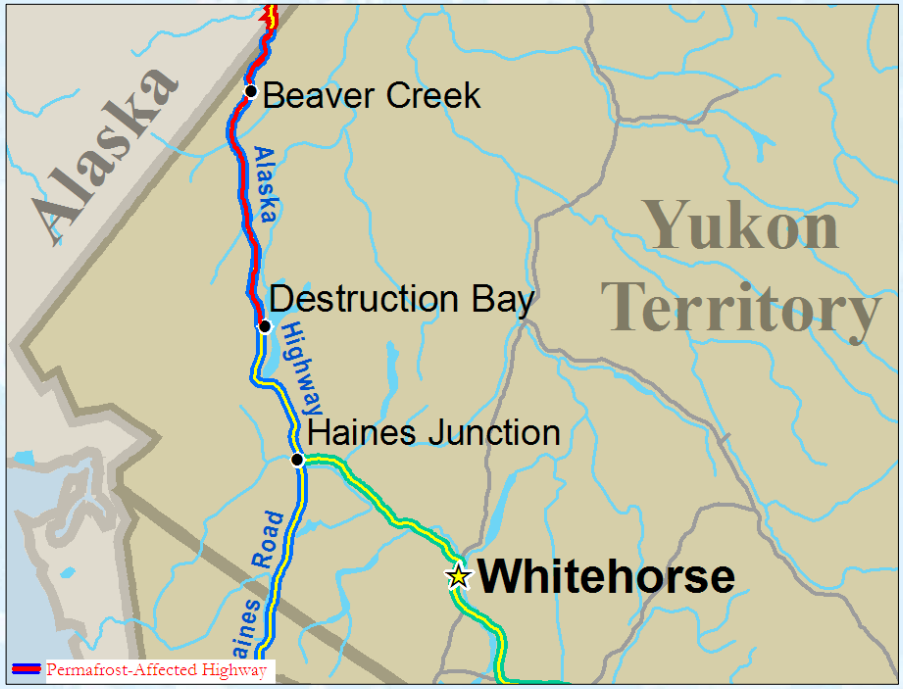
Overview

- North Alaska Highway built on warm, ice-rich permafrost (220 kms)
- Permafrost is thawing
  - Maintaining service level
  - Climate change
  - Adaptation challenges
- Research project near Beaver Creek, Yukon
  - Testing techniques to stop/slow thawing of permafrost

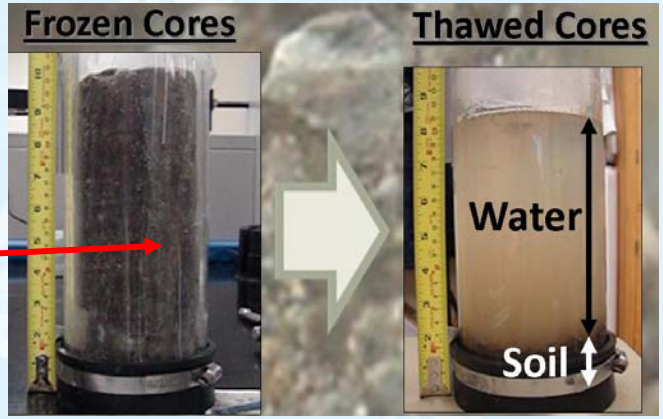


Southwest Yukon

Ice Rich Permafrost

Ice Wedge in Highway Sub-grade

Cores from Beaver Creek Test Site

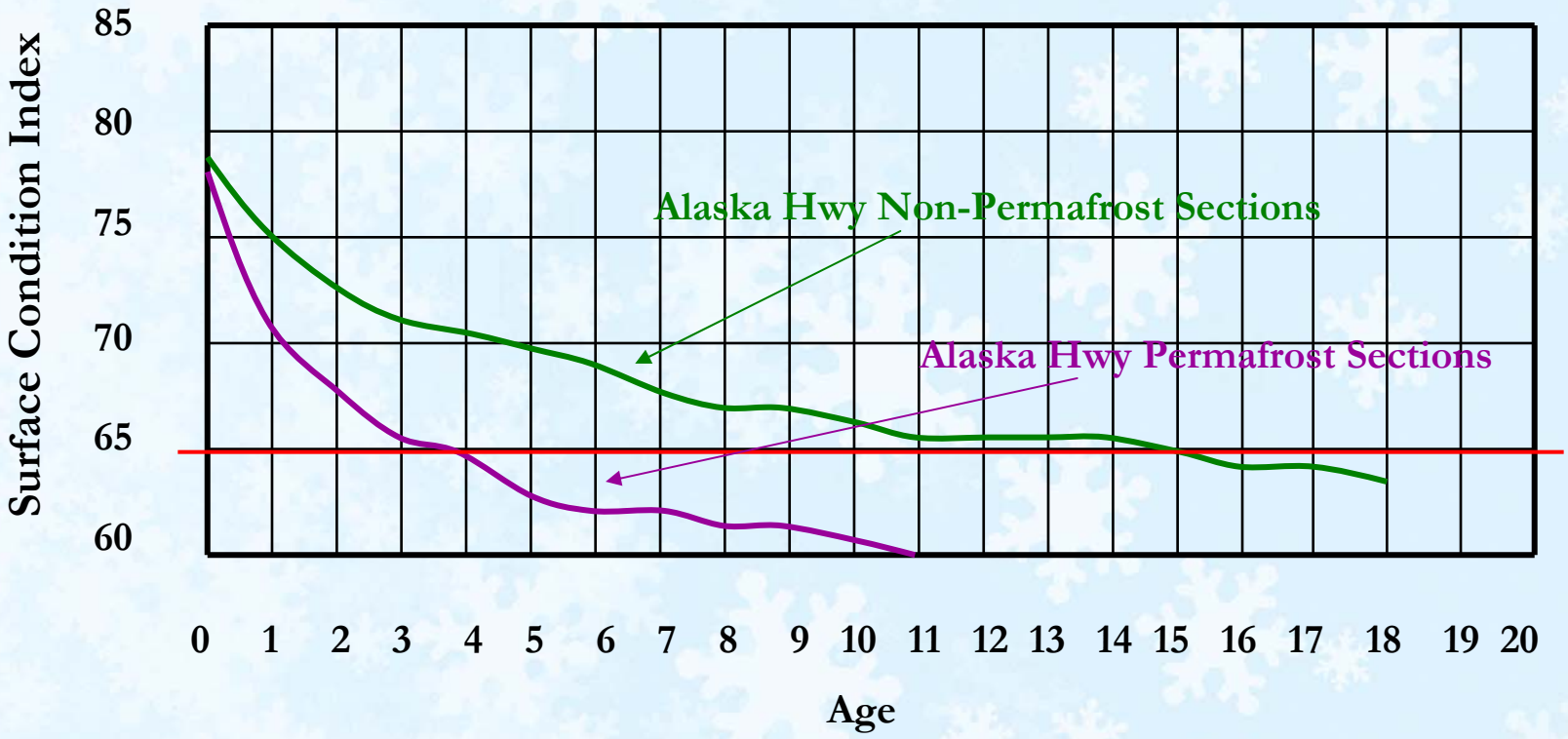


Problems Caused by Melting Permafrost

Cracking of Road Embankment

Severe Differential Settlement

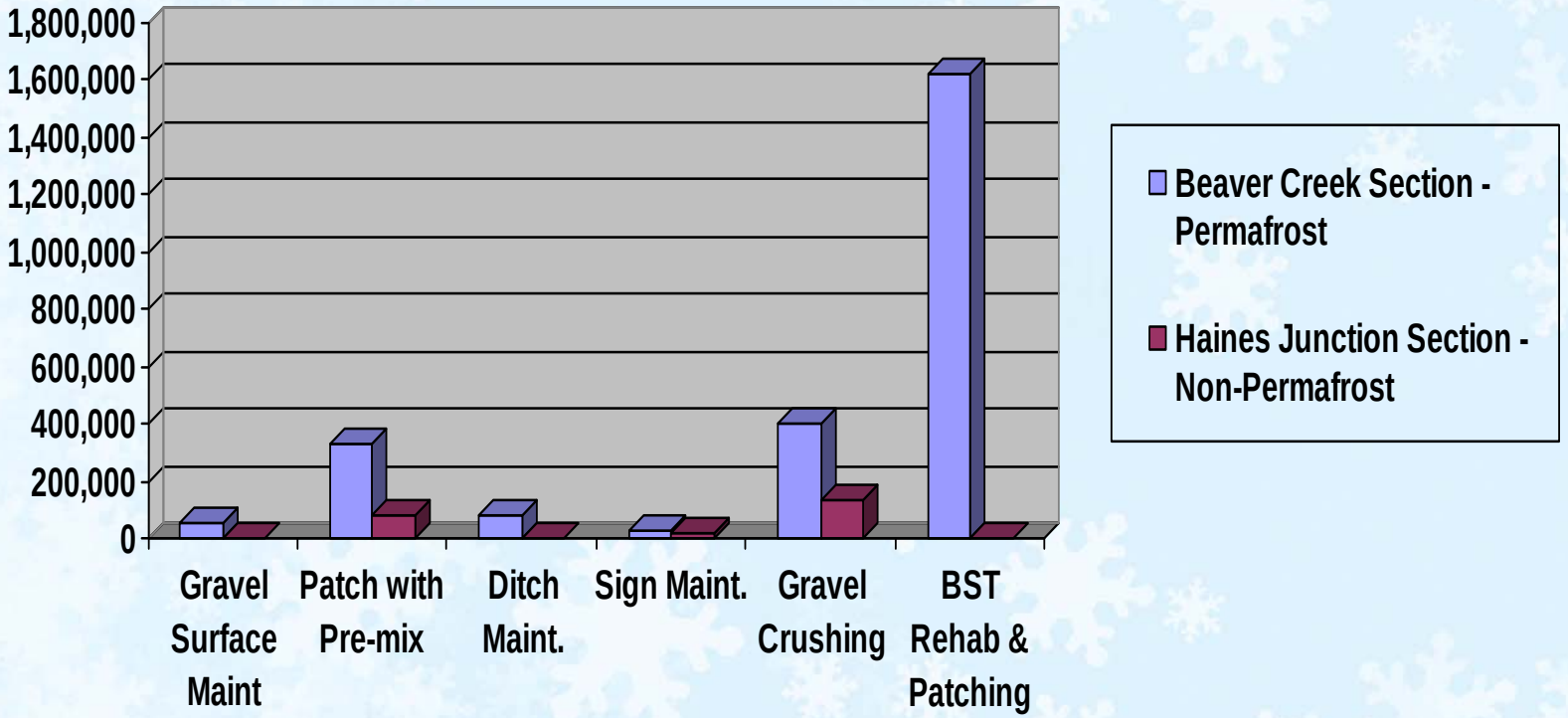
Road Surface Performance
Permafrost Vs Non-permafrost



The service life for the same pavement structure is:

- between 3 and 4 years over an ice rich permafrost sub-grade
- compared to 12+ years over a non-permafrost sub-grade

Maintenance Costs
Permafrost Vs Non-Permafrost



- Additional maintenance / rehab cost in the permafrost section is $22,000 / km / year
- Maintenance / rehab costs in the permafrost section are approx 8 times as much as the non-permafrost section

Strategy

- **Find ways to keep the permafrost frozen**
  - Air Convection Embankments (ACE)
  - Heat Drain
  - Air Convection Ducts
  - Light Coloured Surface

Beaver Creek Test Site

- **Develop adaptive maintenance procedures**
  - Side slope snow removal
  - Alternatives to Aggregate quarrying (e.g.windrow crusher)
  - More efficient surface repairs

Side slope snow removal

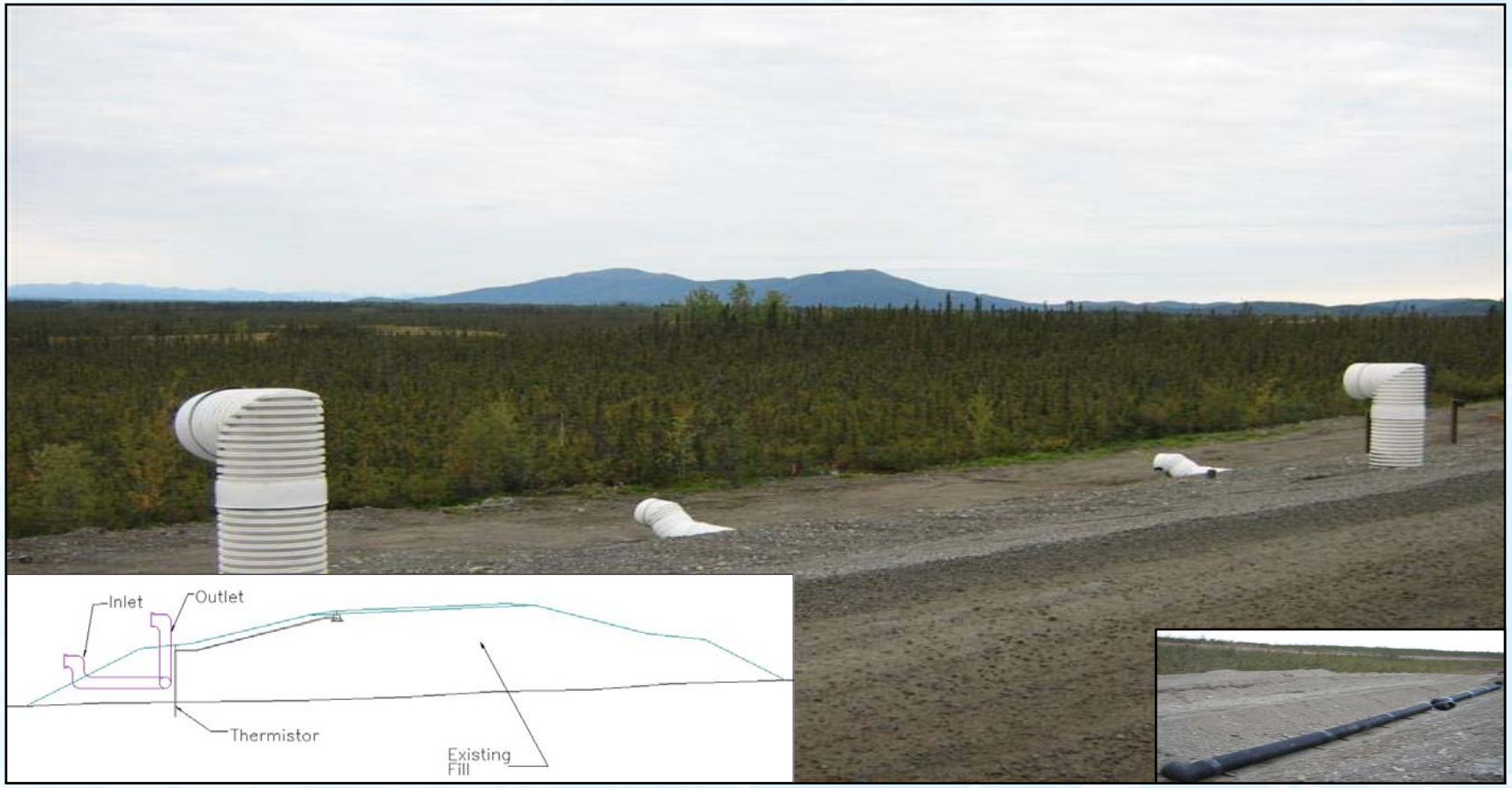
Air Convection Embankment (ACE)

- ❖Straightforward construction
- ❖Requires suitable rock source
- ❖High cost
- ❖Thermal effectiveness is promising based on preliminary data from Test Site

Heat Drain

- Difficult to construct – very labour intensive
- Robustness is a potential issue
- High cost
- Thermal effectiveness less than ACE based on preliminary data from Test Site

Air Convection Ducts



- Reasonably easy to construct
- Water infiltration an issue
- Relatively high cost
- Thermal effectiveness less than ACE based on preliminary data from Test Site

Light Coloured Surface

- Routine construction procedure for maintenance forces
- Requires a suitable source of light coloured aggregate
- Cost is within reason
- Thermal effectiveness is promising based on preliminary data from Test Site

Snow Sheds

- Feasible to install as a retrofit
- High construction and maintenance cost
- Potential collision hazard
- Thermal effectiveness is promising based on testing in Alaska

Cost Analysis

Description	Design/ Geotech Cost (50m)	Construction Cost (50m)	Operational Cost over Lifespan (per km, 5% infl/yr)	Lifespan (yrs)	Large Scale Project Savings	Cost per year per km
ACE – full embankment	$ 13,000	$ 592,000		50	20%	$ 190,000
Heat Drains – full embankment	$ 21,000	$ 284,000		10	10%	$ 513,000
ACE – slopes, covered	$ 21,000	$ 390,000		50	20%	$ 125,000
Heat Drains – slopes	$ 13,000	$ 136,000		10	10%	$ 245,000
Longitudinal culverts	$ 26,000	$ 222,000		35	5%	$ 121,000
Heat drains – (slopes) with insulation	$ 15,000	$ 215,000		10	10%	$ 389,000
ACE – slopes, uncovered	$ 9,000	$ 288,000		50	20%	$ 92,000
Snow Clearing	$ 4,000	$ 6,000	$2,073,000	50	15%	$ 44,000
Light-Coloured BST	$ 9,000	$ 25,000		10	0%	$ 51,000

- Based on records from Beaver Creek Test Site Construction
- Broad assumptions on lifespan
- Order of magnitude only

Cost Comparison

Based on the cost analysis, mitigation techniques rank as follows:

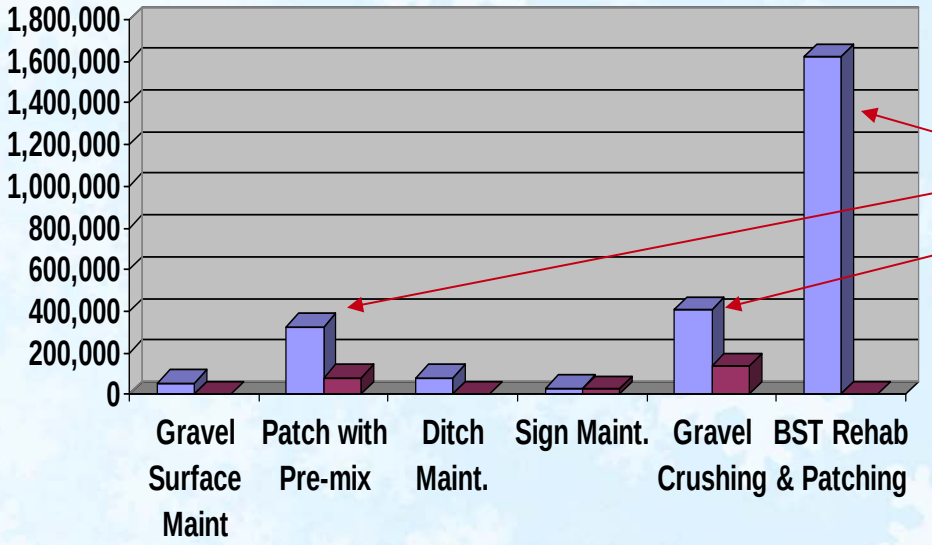
		$ / km / year
1.	Side slope snow clearing	44,000
2.	Light-coloured BST surface	51,000
3.	ACE – slopes, uncovered	92,000
4.	Air convection ducts	121,000
5.	ACE – slopes, covered	125,000
6.	ACE – full embankment	190,000
7.	Heat Drains – slopes	245,000
8.	Heat Drains (slopes) with insulation	389,000
9.	Heat Drains – full embankment	513,000

Compared to current additional maintenance costs 22,000 *

The more expensive mitigation techniques will likely be localized to severe problem areas rather than large scale application

* Its important to note that despite current high maintenance costs the highway is unsatisfactory from a user perspective

Adapting Maintenance Procedures



High cost maintenance activities

- Rehabilitating profile and surface
- Patching with pre-mix
- Producing aggregates

Alternative procedures under consideration include

- spray patching instead of pre-mix
- synthetic binders instead of asphalt cement
- re-processing existing embankment materials instead of crushing new aggregates

Conclusions

- Effectiveness, practicality, and cost of maintenance techniques are key considerations for highway owners
- Implementation of adaptive techniques will be contingent on findings from the Beaver Creek Test Site demonstrating whether they can considerably increase the performance of the highway and decrease the costs of permafrost-related maintenance.
- Specialized maintenance techniques such as regular snow clearing from side slopes and more efficient repair and rehabilitation procedures may be more practical than some of the other mitigation measures being tested.
- It is likely that the problems created by permafrost thawing underneath highways will be solved through a combination of non-traditional mitigation techniques and novel, advanced maintenance practices.

Thank You

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