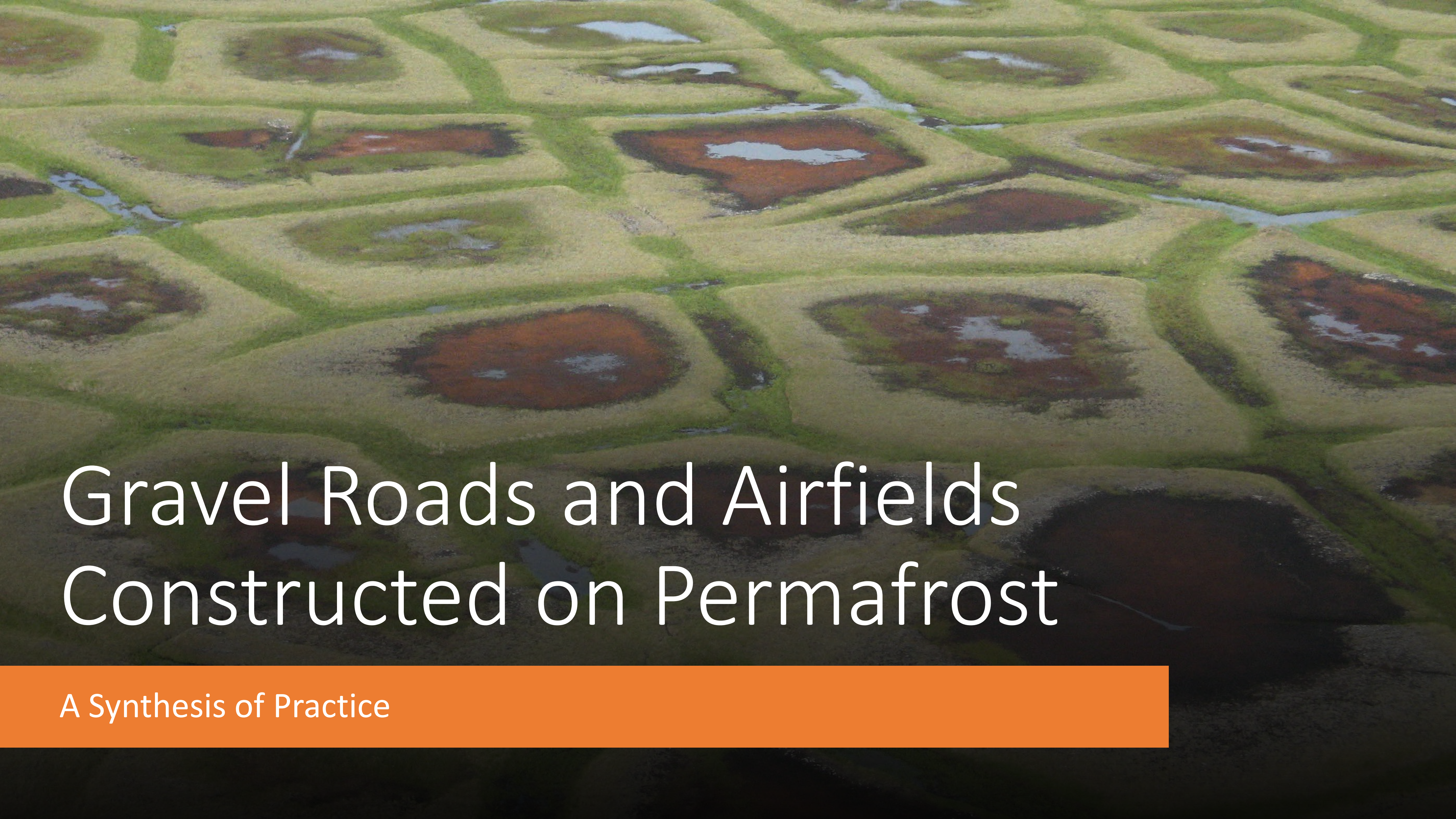
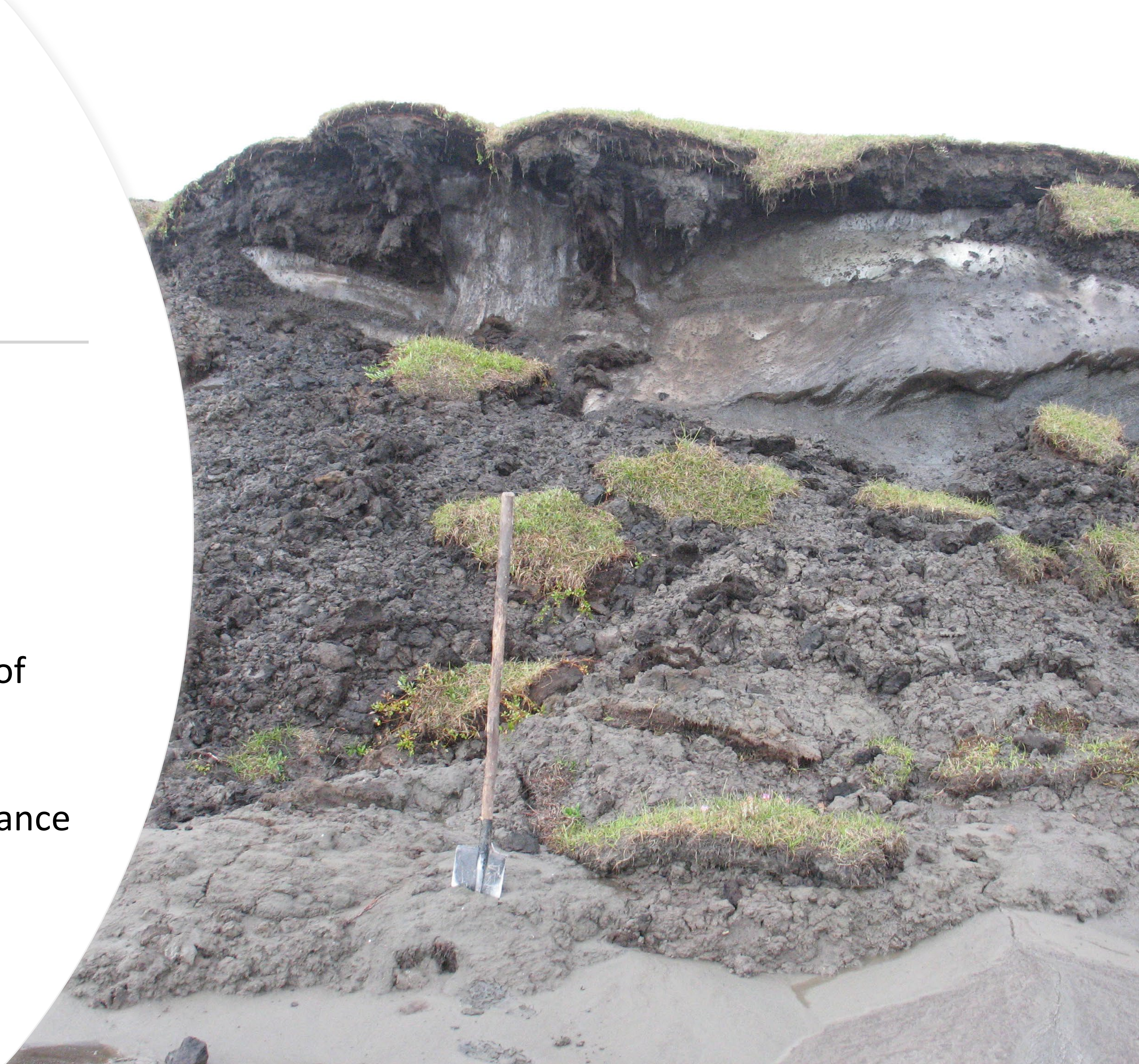


Gravel Roads and Airfields Constructed on Permafrost

A Synthesis of Practice

Purpose

- Provide designers, construction staff, & maintenance with a fundamental understanding of permafrost.
- Provide practitioners with a summary of practices.
- Share successes, limitations and pitfalls of those practices.
- Provide designers with information of where, when and who to go to for assistance



What it is not….

- It’s not a detailed manual
- Nor is it a set of guidelines
- It is not a comprehensive body of knowledge

Overview

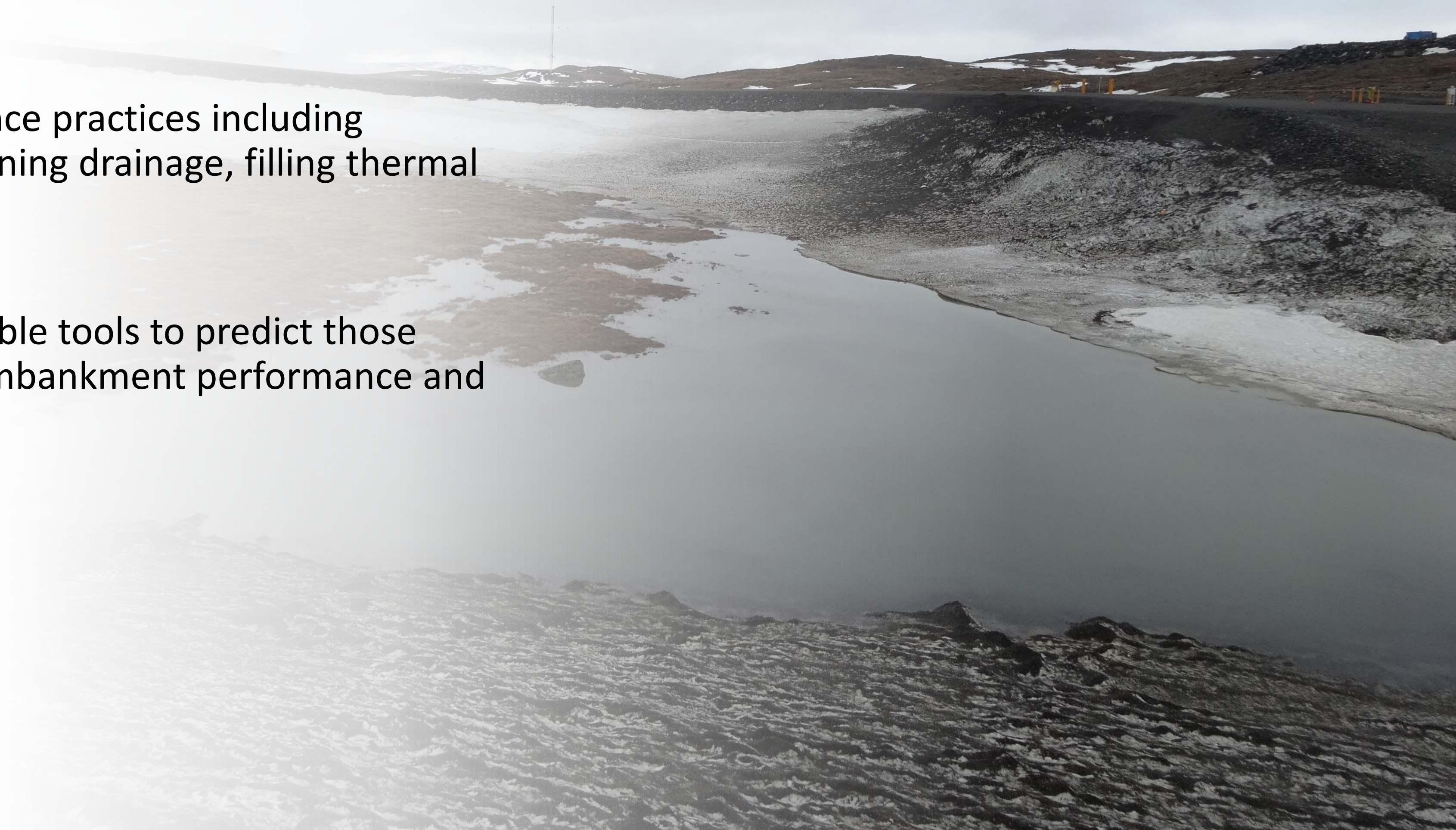
- Introduction
  - Provides brief history and summary of what is contained in the Synthesis
- Description of Permafrost
  - Describes permafrost, its distribution, its properties, how to recognize permafrost terrain and common terminology
- Geotechnical Investigations
  - Provides geotechnical tools available, when and where they are appropriate, and how to use the information provided by the geotechnical reports.
- Thermal Modeling
  - Introduction to thermal modeling, the physical processes involved, methods of approximating thermal impacts of roadway designs, and a summary of pitfalls and complexities that may be encountered.

Chapter Overview

- Design Alternatives
  - Summarizes techniques that have been employed when building roads and airfields on permafrost
- Slope Stability
  - Describes methods of constructing stable slopes on permafrost and techniques to manage water quality coming off those slopes
- Drainage in Permafrost Terrain
  - Discusses the importance of drainages, the pitfalls of improper drainage and the impacts of embankments and thawing permafrost on drainage
- Construction
  - Reinforces the need to follow the design, minimize disturbance, and provide guidance on procedures should unanticipated ice be found.

Overview

- Best Practices in Maintenance
  - Includes guidance on maintenance practices including minimizing disturbance, maintaining drainage, filling thermal cracks
- Climate Change
  - Discusses climate change, available tools to predict those changes, potential impacts of embankment performance and



A Historical Overview

- "A serious detriment to the making of a road in Alaska is the thawing of the ground beneath the moss. It has been the universal experience that whenever the moss is cut into, thawing immediately commences, and the trail which was passable becomes a filthy, slimy mass of mud, roots and broken stone…"
- Chester W. Purington 1895

Dawson City late 1800's

Road design philosophy adopted by Alaska Road Commission in 1950 Naske 1983

- Avoid permafrost whenever possible, locating on south slopes whenever possible
- Avoid wet side hills or slopes with seeping water
- Avoid disturbing moss. Place material over undisturbed moss carefully. Even location parties are required to walk.
- Use corduroy over soft areas (originally proposed by Purington)
- In cut sections, employ staged construction using thaw and cut technique backfilling with porous granular gravel.

Permafrost:
Soil or rock frozen two or more years

- Engineers
  - Ice rich thaw unstable permafrost
  - Ice poor thaw stable permarost
- Scientists
  - Syngenetic: Permafrost formed in concert with deposition of soil layers with time
  - Epigenetic: Permafrost formed by freezing the soil column from top down
  - Yedoma: Syngenetic permafrost that is mostly ice.

Three Things to Know and Understand

- Ice Content
- Soil make-up
- Temperature

These have a major impact on your decisions

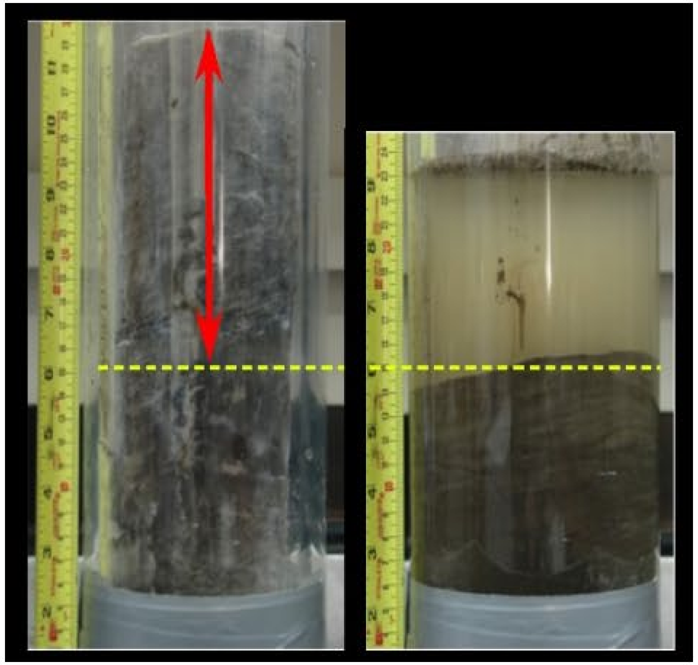
Ice Content

- High ice content
  - Large thaw consolidation
  - Low Bearing capacity
  - Increased differential settlement
  - Lack of slope stability
- Lower ice content
  - Lower thaw consolidation
  - Greater strength
  - Less roughness
  - More Stable Slopes

Ice Content

Two categories

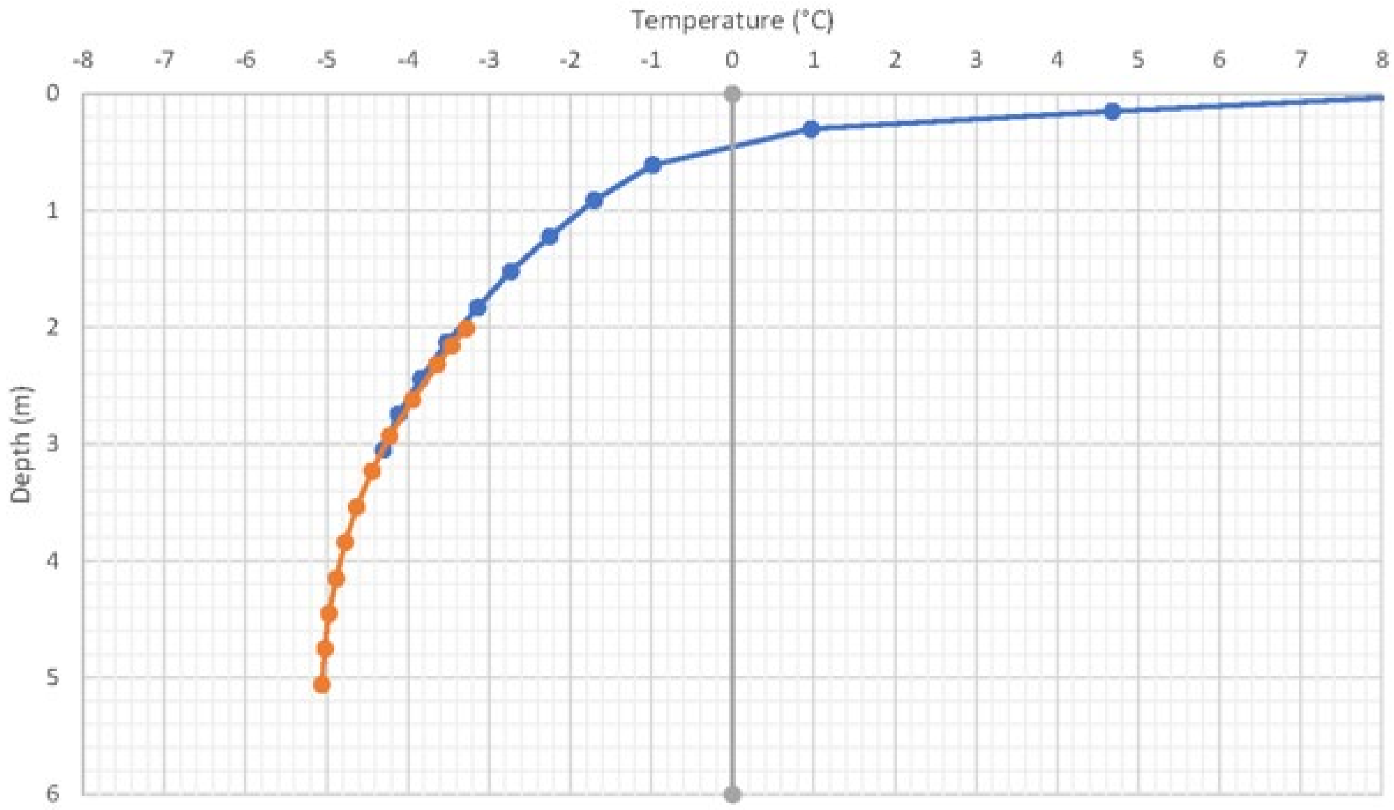
- Thaw-stable
  - Coarse grained sediments and competent rock
  - Little consequence if bearing soils thaw
- Thaw-unstable
  - Fine-grained sediments and decomposed rock
  - Major consequences if bearing soils thaw



Inuvik, NWT

Temperature

- Colder permafrost
  - Takes longer to thaw
  - Lower creep
  - Focus on options to keep frozen
- Warmer permafrost
  - Less temperature buffer for thawing
  - Higher creep rates
  - Likely to thaw when disturbed



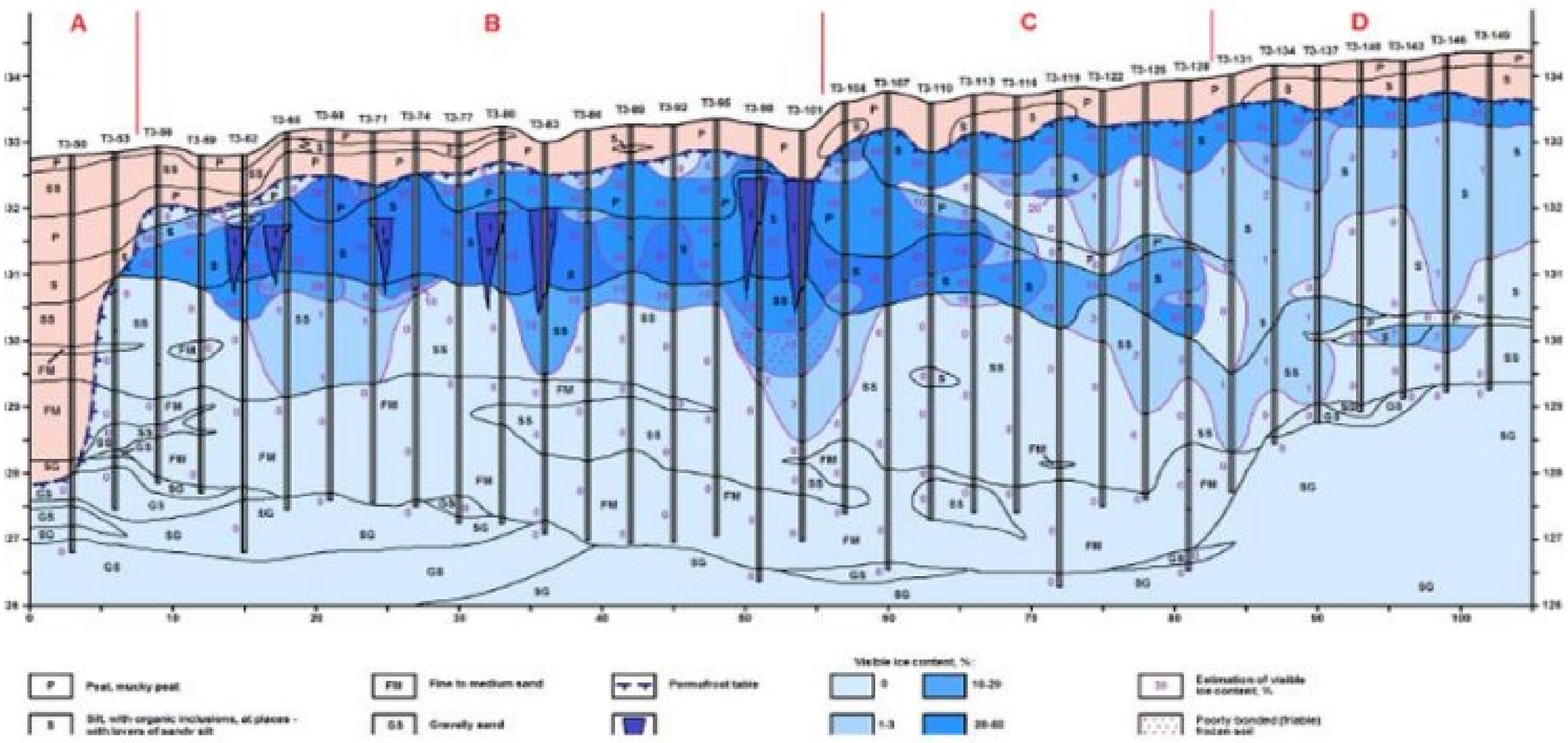
Available designs according to Dr. Eb Rice (UAF)

Only four basic choices

- Keep it frozen
- Thaw it
- Remove and replace
- Accept the consequences of thaw beneath the structure


Questions?

Geotechnical Investigations



Gold Standard - Drilling

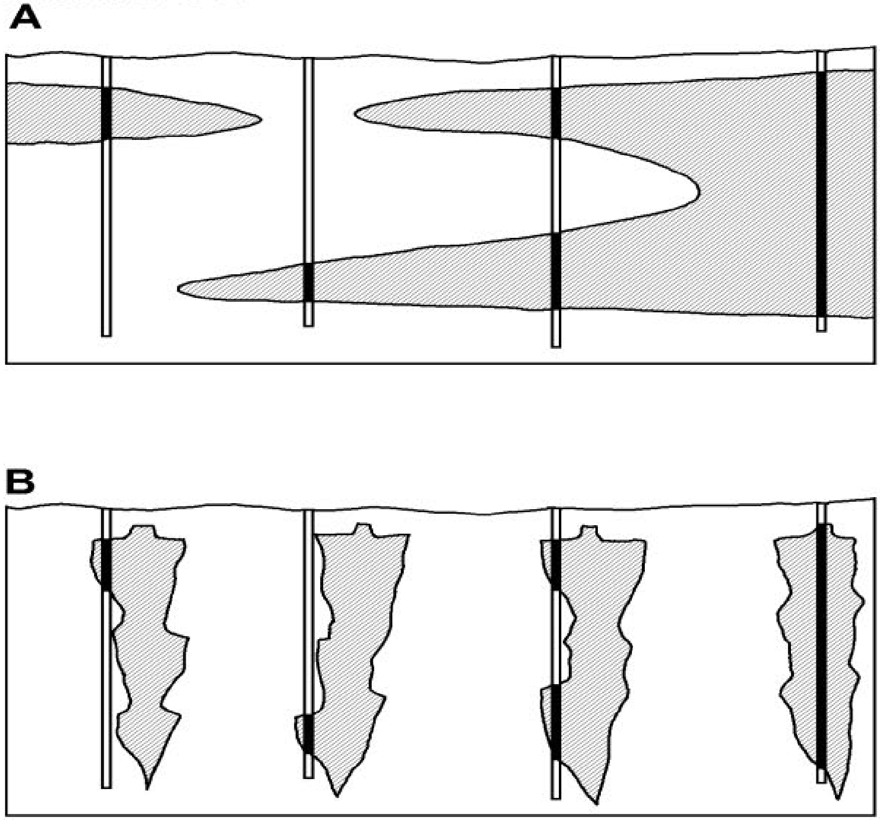
- Drilling
  - Invaluable in-situ info
  - Ice content and bearing capacity
  - New construction – 300 ft BH spacing
  - Reconstruction – BH randomly located
  - Limited information to connect the dots
  - Limited information illustrating thawed vs frozen and ice-rich vs ice-poor boundaries

UNIVERSITY OF ALASKA FAIRBANKS

CRREL

PF Characterization

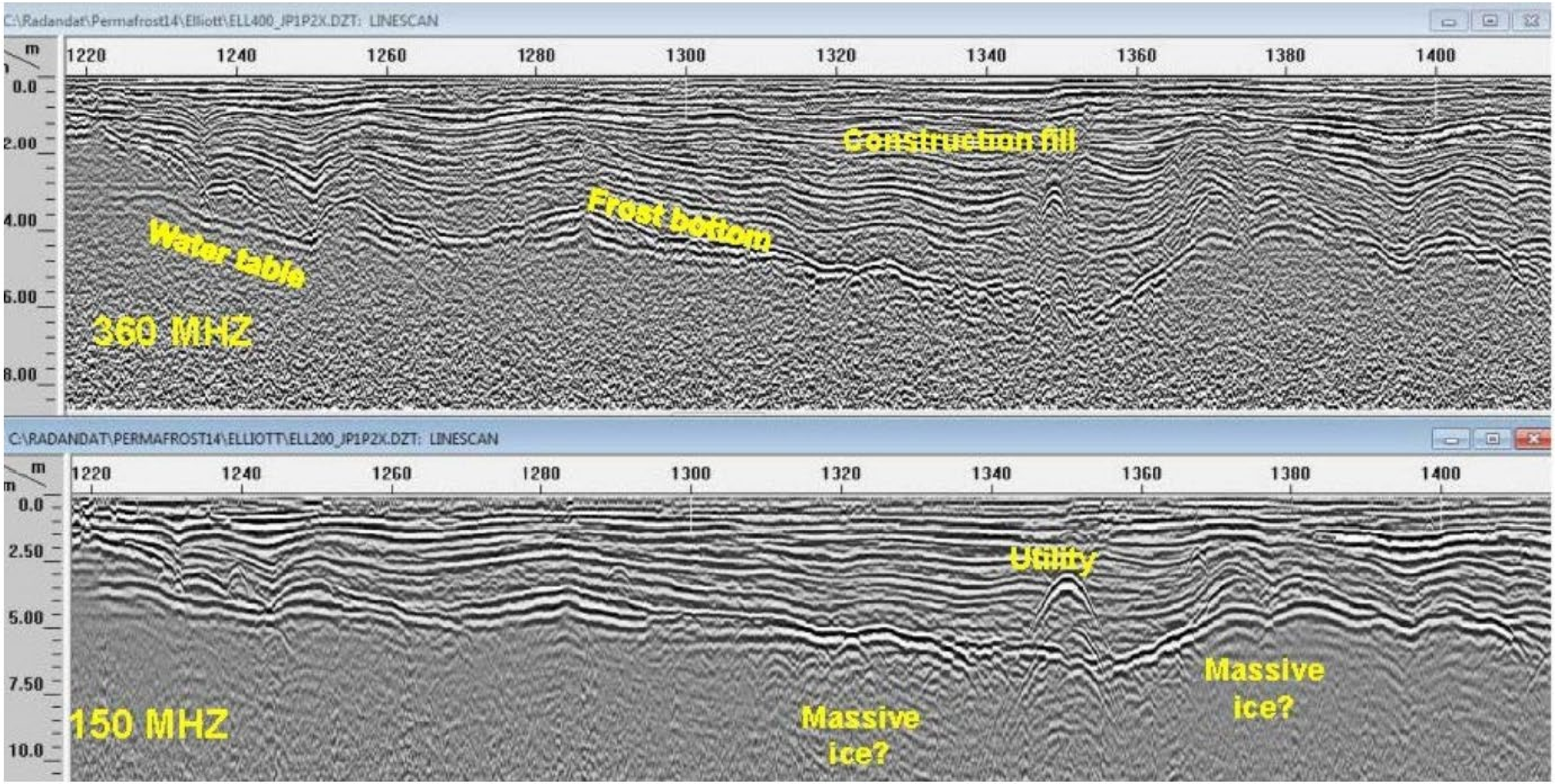
- Majority of geotechnical investigations are evaluated solely on borehole information



Ground Penetrating Radar

- Many commercial systems
  - Defined by antenna frequency
  - Monostatic – one antenna
  - Bi-static – two antennas
  - Low power
  - Complicated setup – complicated processing

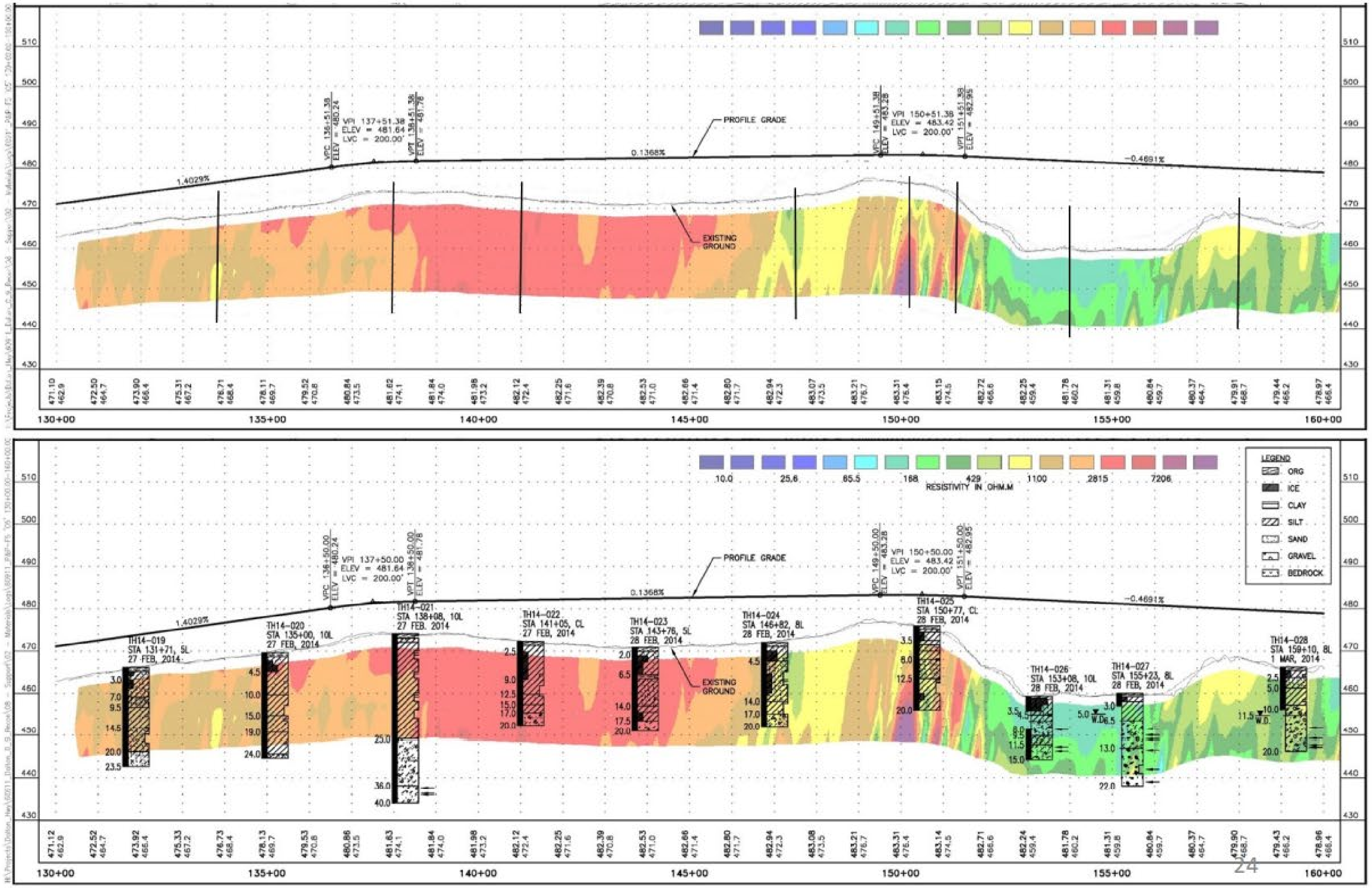
Elliott Highway



Electrical Resistivity

- Galvanic – Electrical Resistivity Tomography (ERT)
  - Electrodes – cables – computer
  - Deep penetration ~150 ft.
  - Fixed length of survey – rollalong
  - Time consuming
- Capacitive Coupled
  - Up to 5 Rx's – 1 Tx - in series
  - Medium penetration ~ 50 ft.
  - Unlimited length of survey
  - Fast collection
  - Relatively simple processing

New Alignment - 0 to 8 Mile Lost Creek




Questions?

Design Alternatives

- Avoid Permafrost
- Managing Permafrost Thawing
- Preserving Permafrost

Which Altnerative?

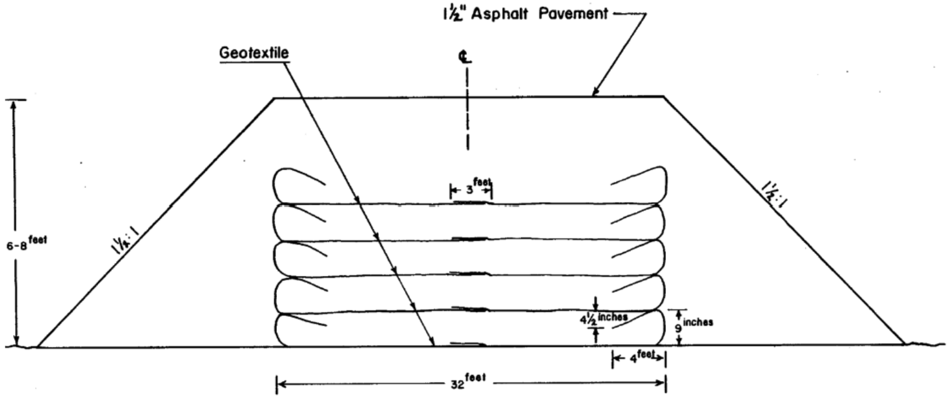
- Seek to avoid permafrost whenever practical.
    - There are often competing requirements such as grades, sight distance etc.
- Managing thaw is generally attractive in warm permafrost or when permafrost is thin. Mean Annual Surface Temperature above freezing.
- Preserve Permafrost in cold permafrost or when Mean Annual Surface Temperature is below freezing.

Acceptance of consequences of thaw

- Impossible to avoid thaw unstable permafrost entirely.
- Not practical to construct preservation features, subcuts or pre-thawing for long distances.
- If rerouting, carefully evaluate in-situ soils.
- Techniques to minimize impacts
  - Minimize disturbance of vegetation.
    - Hand clear for sight distance
  - Minimize disturbance of drainage patterns
  - When possible, minimize disturbance of the embankment especially if it is frozen.

Use of Geosynthetics

- Effective as a separator between fine- and coarse-grained materials.
- Minimizes longitudinal cracking and lateral spreading
- Ineffective in reducing vertical displacement



Prethawing

- Works well for thin warm permafrost
- Must plan two or more years in advance
- Estimate thaw rates carefully
- Measure progress

Shoulder Modifications

- Stabilization (Toe) Berms
  - Work well in cold permafrost
  - Work poorly in warm permafrost
  - Designer must account for snow accumulation. Ensure MAST below freezing
    - Around Fairbanks MAST of sideslopes around 37°F
- Barn Roof Shoulders
  - Allows the barn roof to be cleared of snow
  - Moves thermal cracking out of travelled surface
  - Work well when M&O clears, but this rarely happens due to cost

Techniques for Preserving Permafrost

- Insulation
- Air Convection
- Shading
- Thermosyphons
- Winter Construction

Insulation

Extruded

- Advantages
  - Absorbs less water
  - Less sensitive to water content
  - Higher R-value over time
- Disadvantage
  - Higher Cost

Expanded

- Advantages
  - Less Costly
  - Made in Alaska
- Disadvantages
  - Absorbs more water
  - More sensitive to water
  - About 25% lower R-value over time

Consider using in-service R-values instead of intimal R-values for your design..

Where do you put the insulation?

- Just as you would not put both hot and cold foods in your cooler, neither should you put both hot and cold soil beneath the insulation.
- Summer construction
  - Place insulation near insulation
  - Don’t leave permafrost exposed more than a few hours
  - If possible, construct in late spring or late fall.
- Winter construction
  - Place high in the embankment but no closer than 36 inches of the surface
  - If possible, let soil beneath insulation freeze

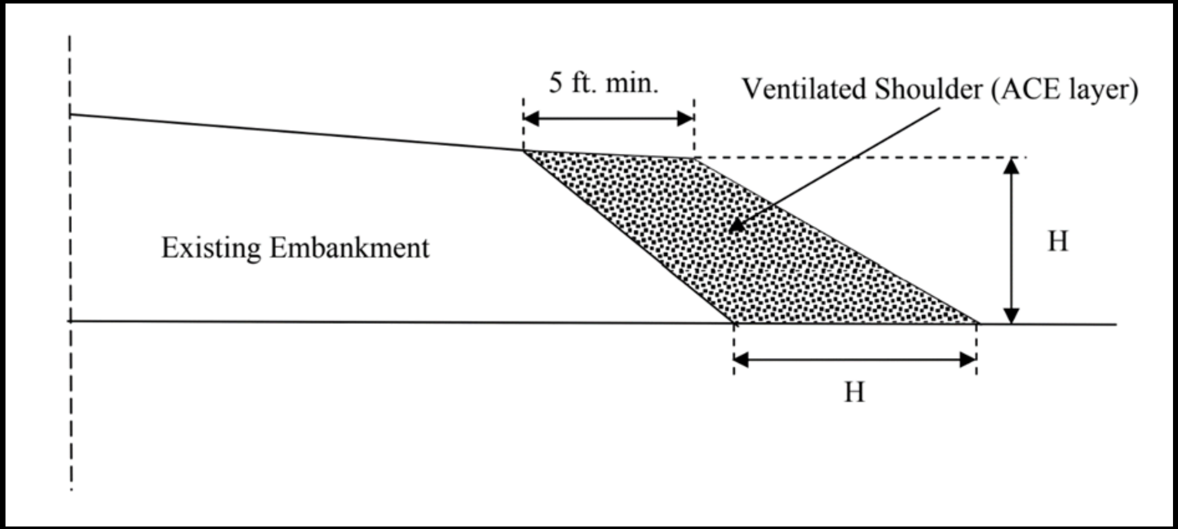
Minimize the exposure of permafrost to heat.

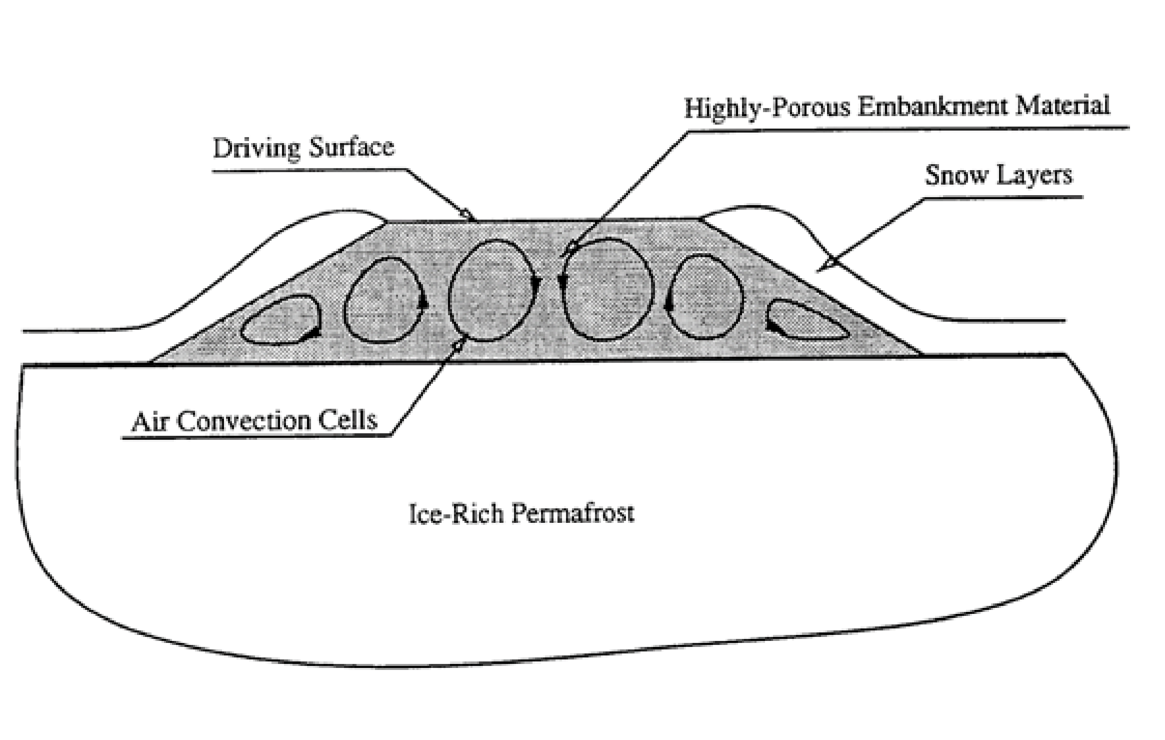
Use of Air Convection (The most effective systems)

- Air Convection Embankments
- Air Convection Culverts
- Heat Drains

Air Convection Embankments

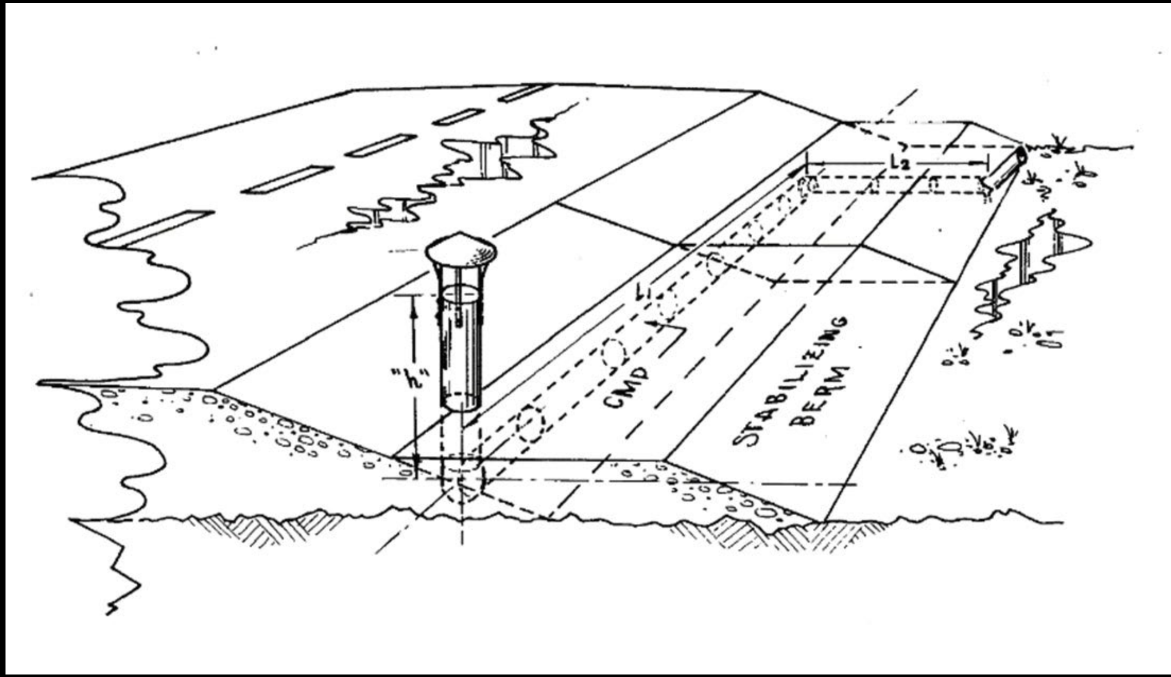
- Proven to be the most effective in preserving permafrost.
- Often expensive due to the cost of rock
- Ventilated shoulders may be affected by wind
- Ventilated shoulder can be uses as retrofit





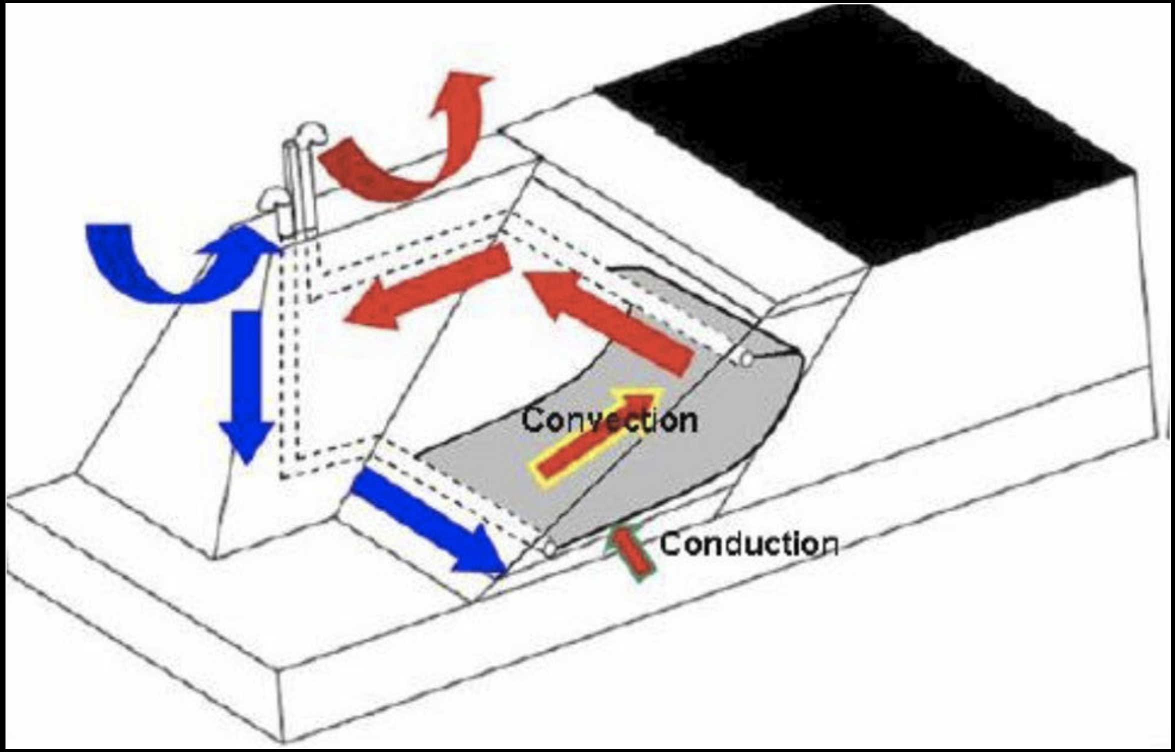
Air Convection culverts

- Works similar to ventilated shoulder
- Works well for protecting sideslopes and embankment shoulders
- Relatively inexpensive
- Must be placed high enough to keep out of water
- Consider closing in the summer months especially in windy areas



Heat Drains

- Developed by Guy Dore'
- Uses geosynthetic layers with air gaps.
- Relatively inexpensive
- Used primarily to side slopes
- Similar to air ducts in performance

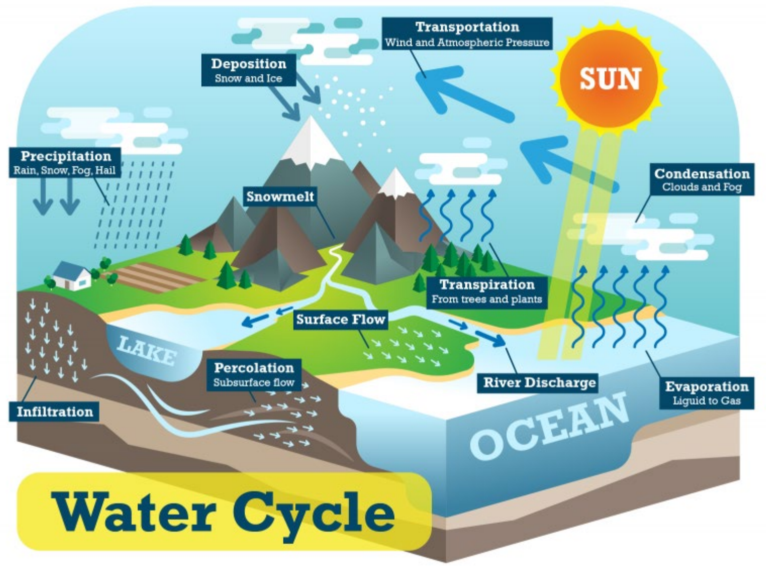


Shading

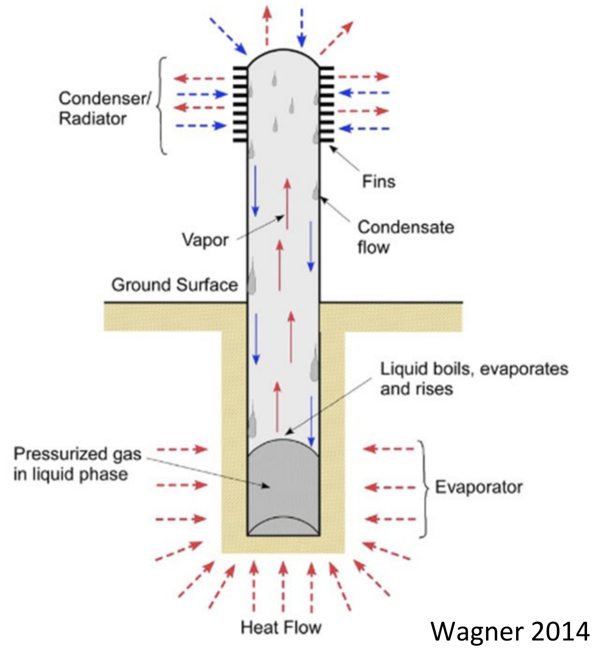
- Simple in concept
- Snow Sheds are the most common implementation
- Reduces surface temperature in both summer and winter.
- Sideslope MAST reduced from 39 to 28ºF.
- Alaska DOT&PF requires guardrail since they fall within the clear zone.

Thermosyphons

- Developed by Erv Long in 1956; First used in 1960
- Uses the same cycle we see in nature
- Passive
- Only work in the winter
- Effective, but expensive



Letstalkscience.ca



Wagner 2014

Winter Construction

- Allow grade to freeze and place frozen material
  - Poor compaction
  - Ensure frozen material has low moisture content
  - Best in lower levels of embankment where thawing is unlikely
- Place material in thawed condition and allow to freeze before next lift
  - Effective, but more expensive.
  - Thawed material may be difficult to obtain in many areas
- Place frozen material in the lower levels and continue conventical construction in summer
  - Protects permafrost and reduces costs

Summary

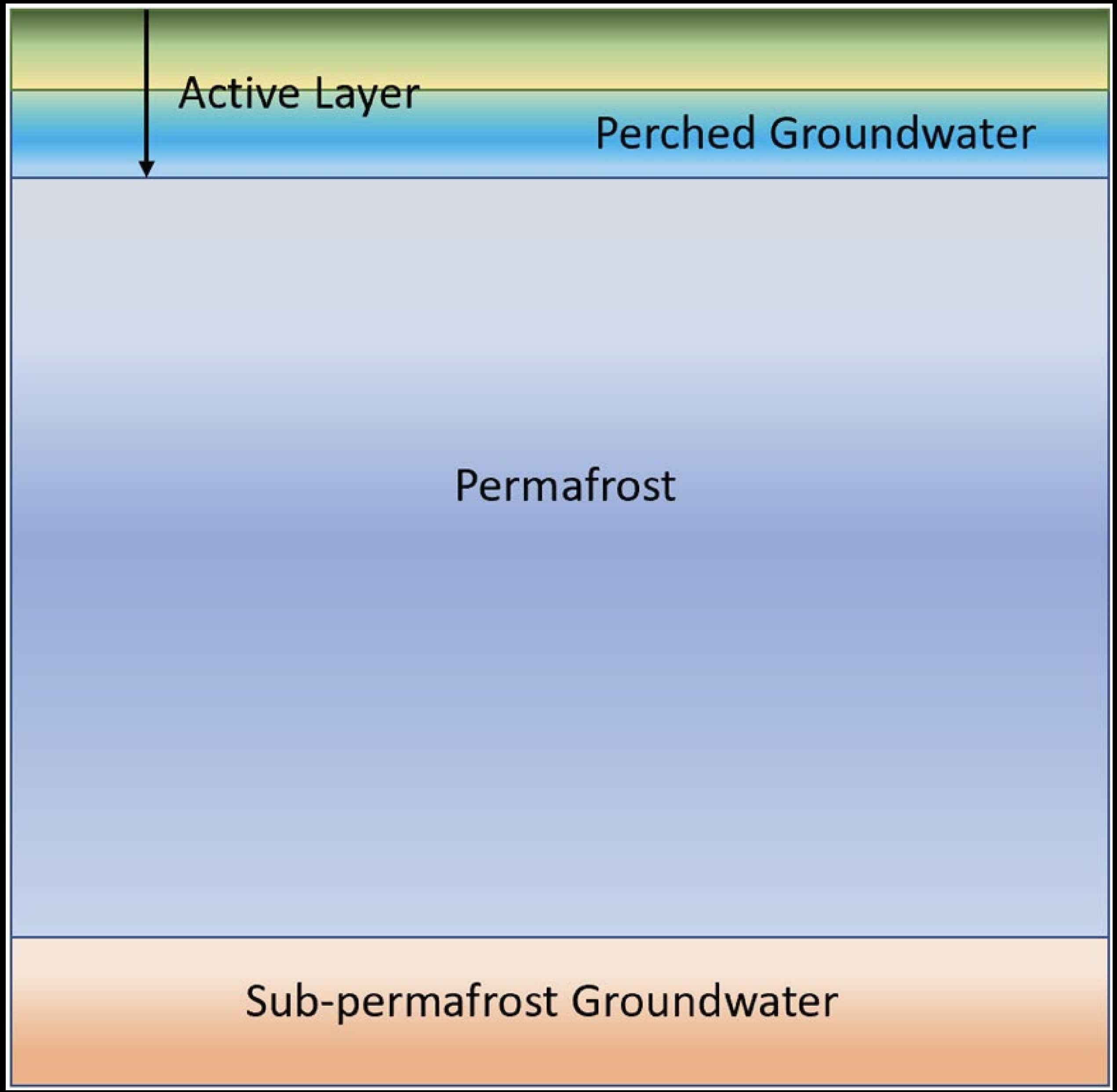
- First chose approach
  - Avoid
  - Keep frozen
  - Thaw
  - Accept consequences
- Current technologies address localized problem
- No technique fits all situations
- All are expensive
- Choose carefully

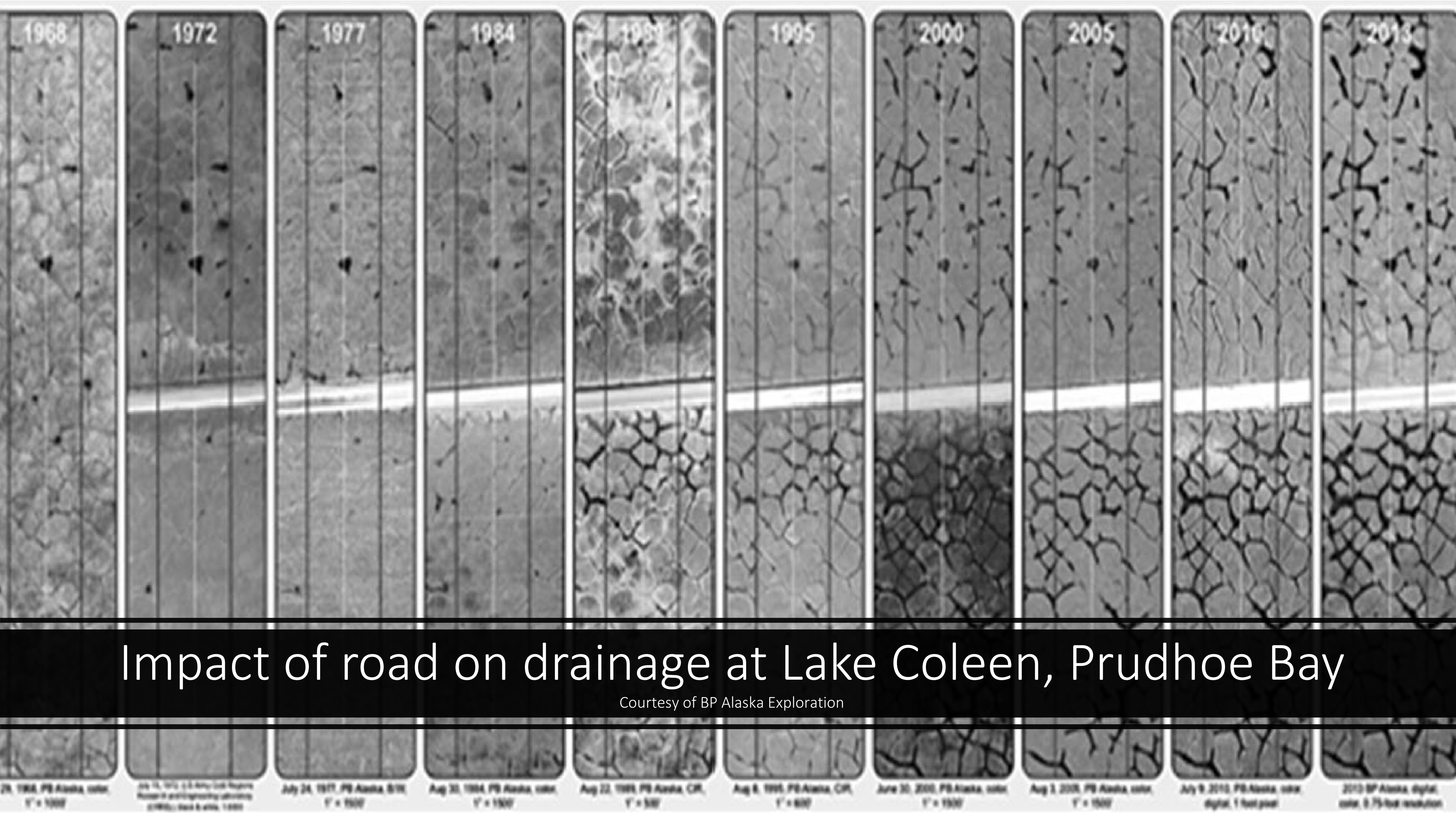

Questions?

Chapter 7 Drainage in Permafrost Terrain

The fastest way to damage permafrost terrain is to change the drainage patterns no matter how small the change.

As noted by the Alaska Road Commission, drainage in permafrost requires careful inspection of the terrain including water movement in the active layer. (1950)





Impact of road on drainage at Lake Coleen, Prudhoe Bay

Courtesy of BP Alaska Exploration

Water ponding in thermokarst along Parks Highway

Damage to inlet due to thermokarst

Use of extended outlet to move thermokarsts away from roadway


Use of riprap to protect inlet

Use of insulation under culverts

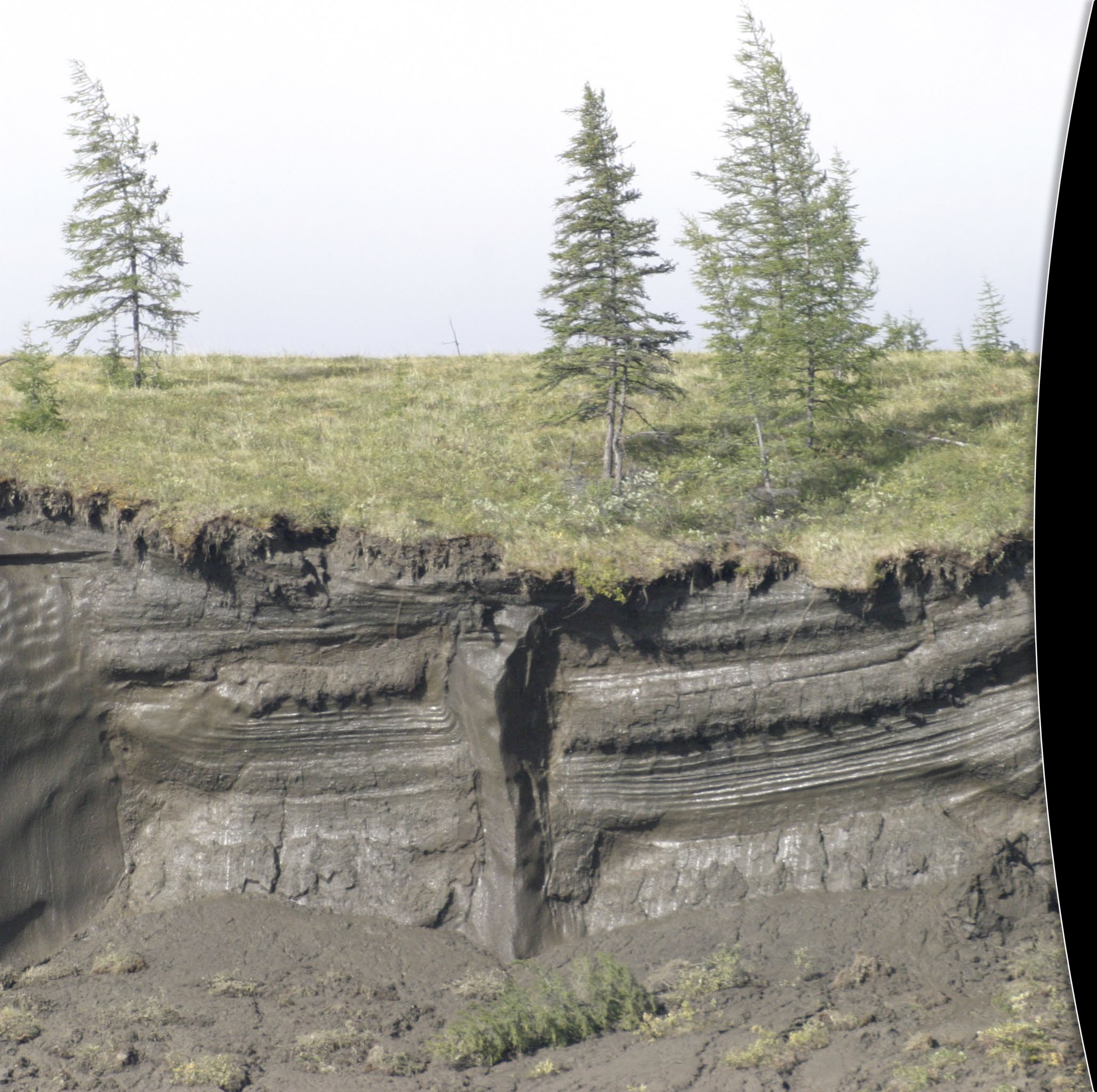
- If the there is an established channel, a talik already exists and insulation will be of no value.
- If the water flows only during spring, insulation may be of some value.
- If the water exists only in the active layer, insulation will likely be of value.

Other thoughts

- When the embankment allows use at least one size larger culvert than required to allow for thaw settlement.
- Use a heavy gauge culvert.
- If a spiral culvert is use weld the J-seam for strength.
- Consider using multiplate for larger culverts.
- Alter channel alignment only as a last resort.

Construction
&
Maintenance

Small mistakes, big consequences; consequences that cannot be undone.



Minimize disturbance outside the prism

Simply clearing the trees over ice rich permafrost can increase thaw consolidation by 5.9 feet over 5 years. (Linell, 1973)

Clearing the vegetation result in 22 ft of thaw.

Enforcement of permits

- Everyone including equipment operators must know the provisions of permits and regulations that affect their work.
- Discuss permits and regulations before beginning any work.

Managing unforeseen ice

- In general stop work and contact the regional Materials Engineer (see specification 108-106)
- Work with the Materials Engineer and the Contractor
  - To stabilize the situation
  - Identify the extent of the ice
  - Work to develop a plan of action (a change order will likely be required)
  - Execute the plan

Monitor drainage patterns for M&O

- Work with regional Hydrologist for any changes other than moving a culvert to account for terrain.
- As thermokarst ponds form action may be necessary to correct the draingage.
- Ensure culverts are working correctly. Clean or make repairs as necessary.

Filling longitudinal cracks and thermokarsts

- Avoid sands and pea gravel allow for rapid filling
  - Water flows easily accelerating additional that
  - Settle in voids rapidly
  - Performance sort lived
- Fine grained material gives better performance.
  - Reduces advection due to water
  - Can use as a slurry to aid in flow. (keep water content to a minimum)

Winter Construction

- Know the plans and specifications. If you don't understand why, contact the designer
- The cost of winter construction is high due to increased time requirements
- Know that contractors will likely complain

Roadway levelling

- Mill or break up surface before beginning. This will reduce the amount of material required.
- Level and compact the road to make it smooth. No need to return to original grade unless sight distance is compromised.

Summary

- Minimize disturbance. Simply clearing trees can cause 15 ft of thaw in 5 years.
- Be careful with drainage
- In case of problems ask for input
- Small mistakes can result in big consequences

Questions?