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Cost-effective Strategy for Investigating Permafrost at Remote, Northern Mine Sites

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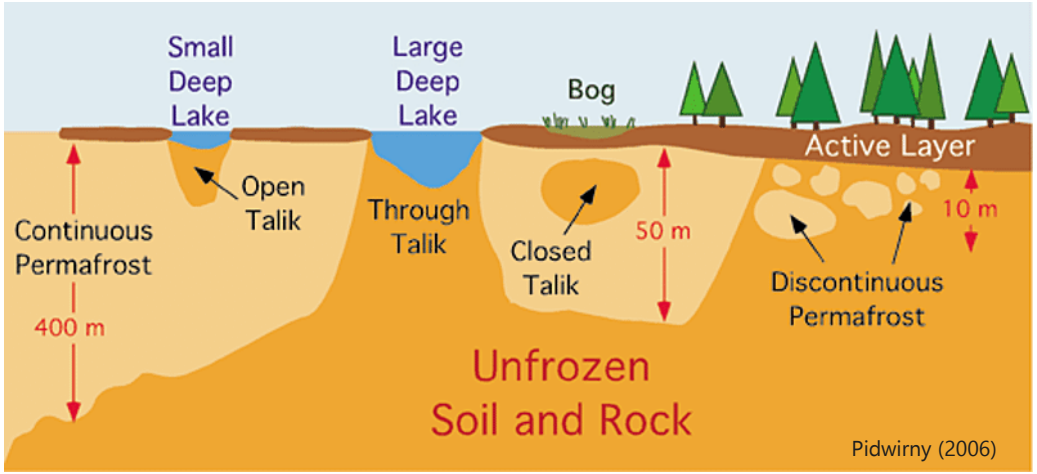
Outline

1. Introduction and Rationale
2. Investigation Strategy
3. Key Takeaways

1. Introduction and Rationale

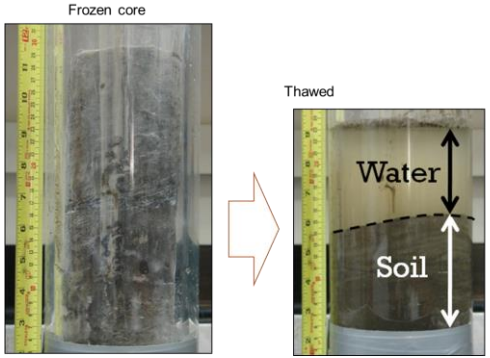
Rationale



- Why do we need a cost-effective strategy?
  - Climate change ➔ permafrost change ➔ mine impacts
  - Remote and challenging terrain
- Want to leave as much $ for exploration, development and operation!

Climate Change Effects on Permafrost

- Warming **air temperatures** ➔ warming/thawing permafrost
- Changes in **precipitation** ➔ altered ground thermal regime and water pathways
- More lightning strikes and **wildfires** ➔ thickening active layer



- Unmitigated disturbance to permafrost from mine infrastructure can compound the effects of climate change

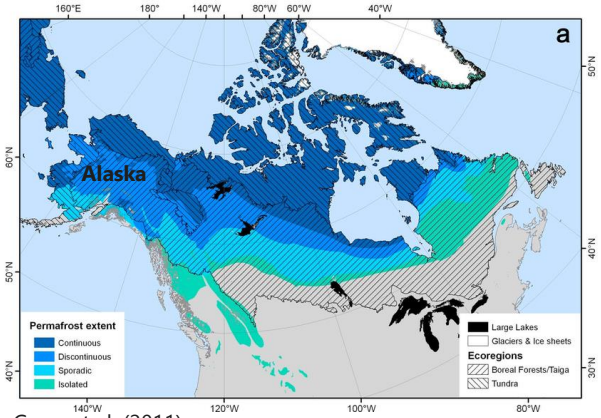
Effects of Thawing Permafrost on Mine Projects

- Change in water
  - Quantity and quality due to permafrost thaw
- Impacts to infrastructure
  - Roads, airstrips, fuel tanks, buildings, dams…
- Containment of mine waste

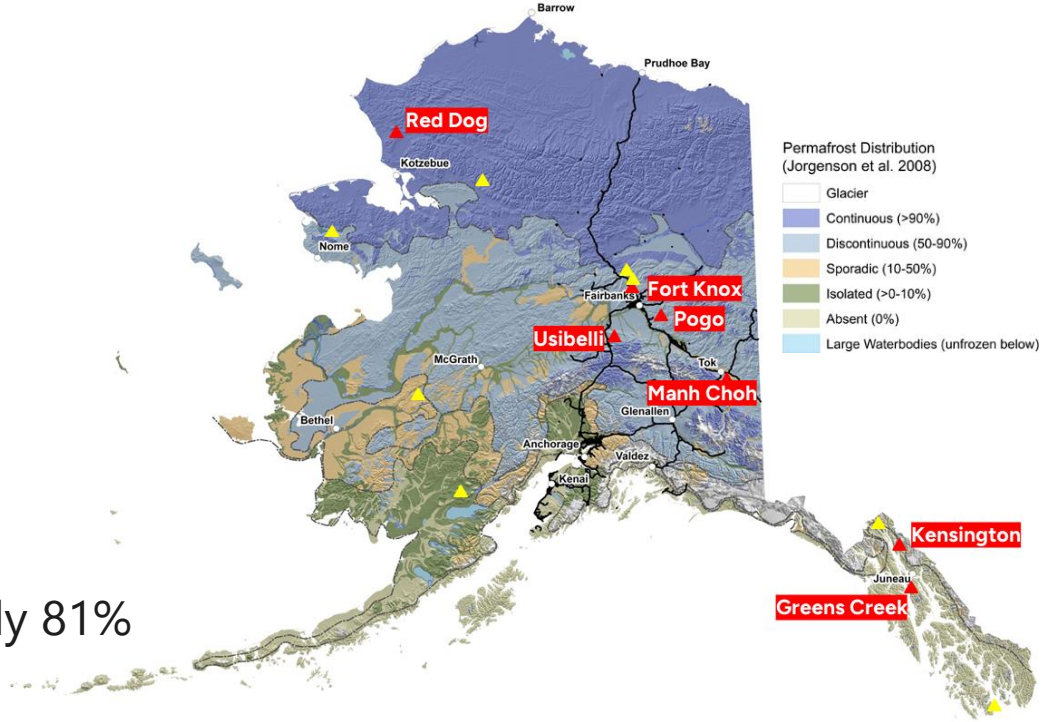
Impacts of impounded water along the Dalton Highway

Run-of-mine backfill forming frozen cap over crown pillar in Nunavut

Permafrost in Alaska

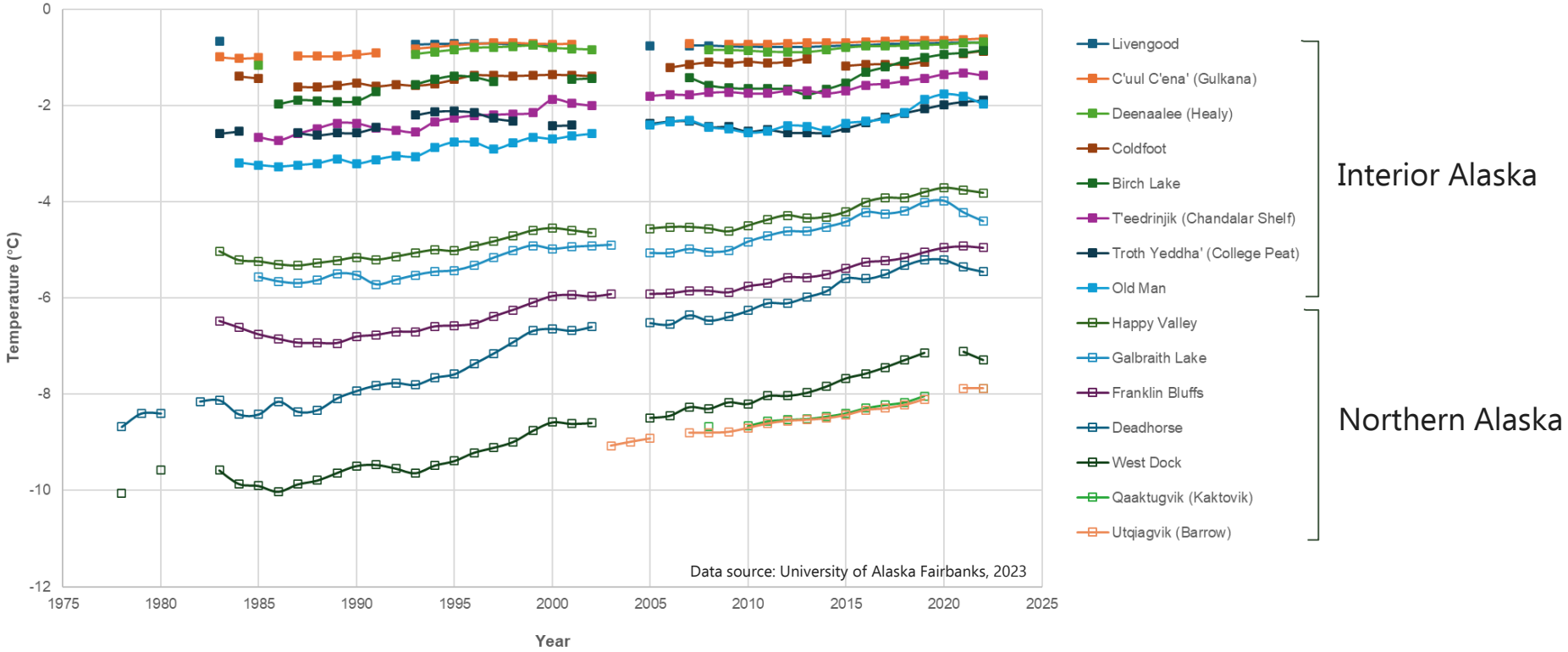


Gross et al. (2011)



- Permafrost underlies approximately 81% of Alaska's land area
- Heterogeneous in composition
- Spatial and temporal response varies

Change in Permafrost Temperature



2. Investigation Strategy

Systematic Investigation of Permafrost

- Stepwise, tailored approach with increasing focus and rigor to minimize up-front costs

1. Desktop review and interpretation

2. Phased field work

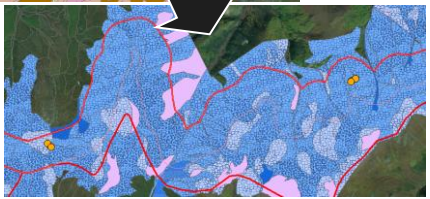
3. Data synthesis and analysis

1. Desktop Review and Interpretation

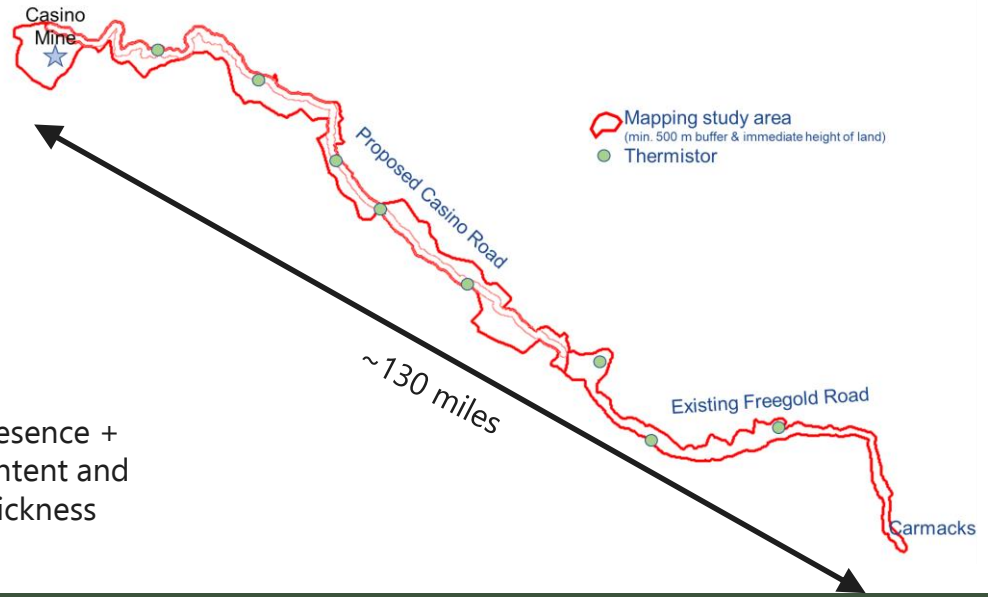
- Compilation and review of any pre-existing information
- Interpretive mapping of permafrost distribution/thaw-sensitivity
- Optimization of field program (e.g., drill sites), for cost savings!

Initial mapping linework

Surficial geology

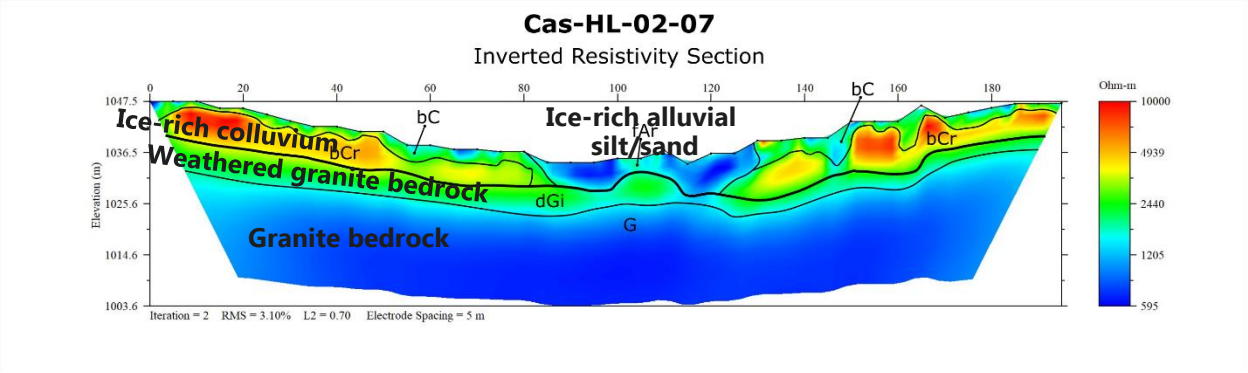


Permafrost presence + relative ice content and active layer thickness



2. Phased Field Work

- ‘Ground truthing’
  - Hand-dug testpits, frost probing, human-portable drill
  - Prioritization of site investigations
- Geophysics?
  - Electrical Resistivity Tomography (ERT)
  - Ground-penetrating Radar (GPR)



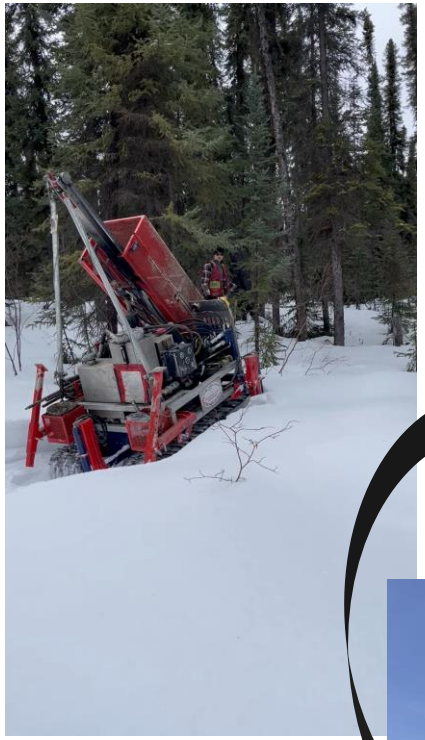
Frost probe

Talon Drill
(core permafrost to ~15 feet)

Pionjar

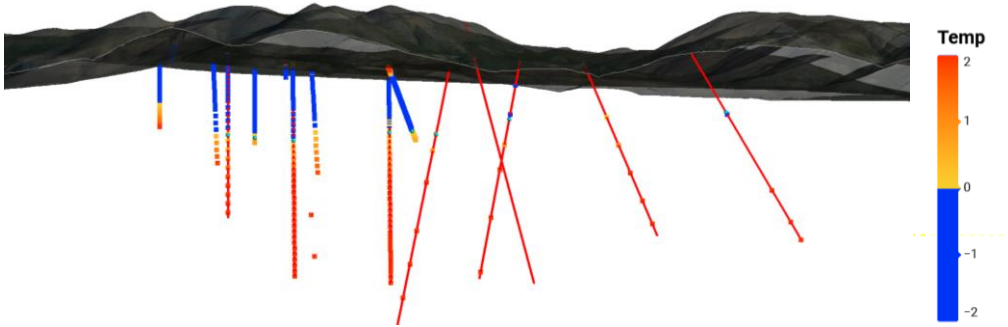
2. Phased Field Work

- Lightweight drills before more conventional rigs
  - Talon / Pionjar
  - ShockAuger
  - Heli-portable sonic



2. Phased Field Work

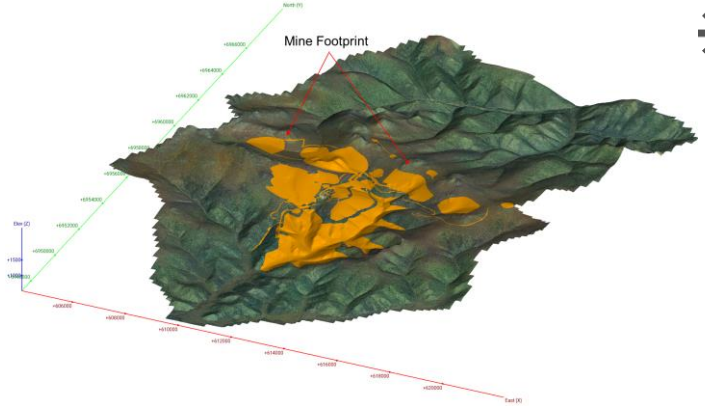
- Thermistors – opportunistic installation in already planned drillholes to save money!
  - Exploration drillholes
  - Geotechnical drillholes
  - Multi-purpose groundwater wells

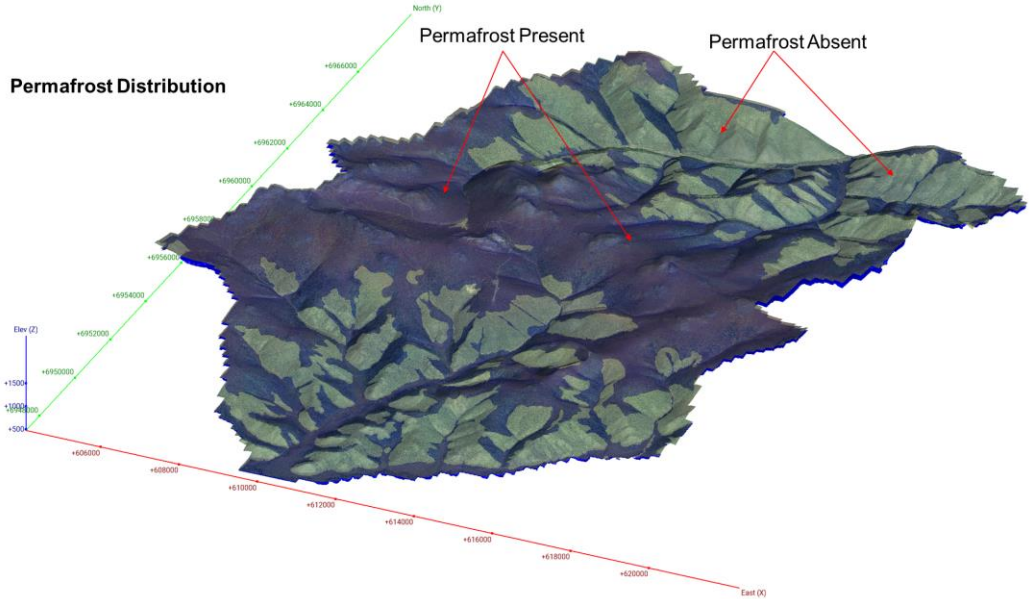


3. Data Synthesis and Analysis

- Data compilation
  - Borehole logs + ground temps + geotech parameters
  - Specialized frozen soil testing (where needed)

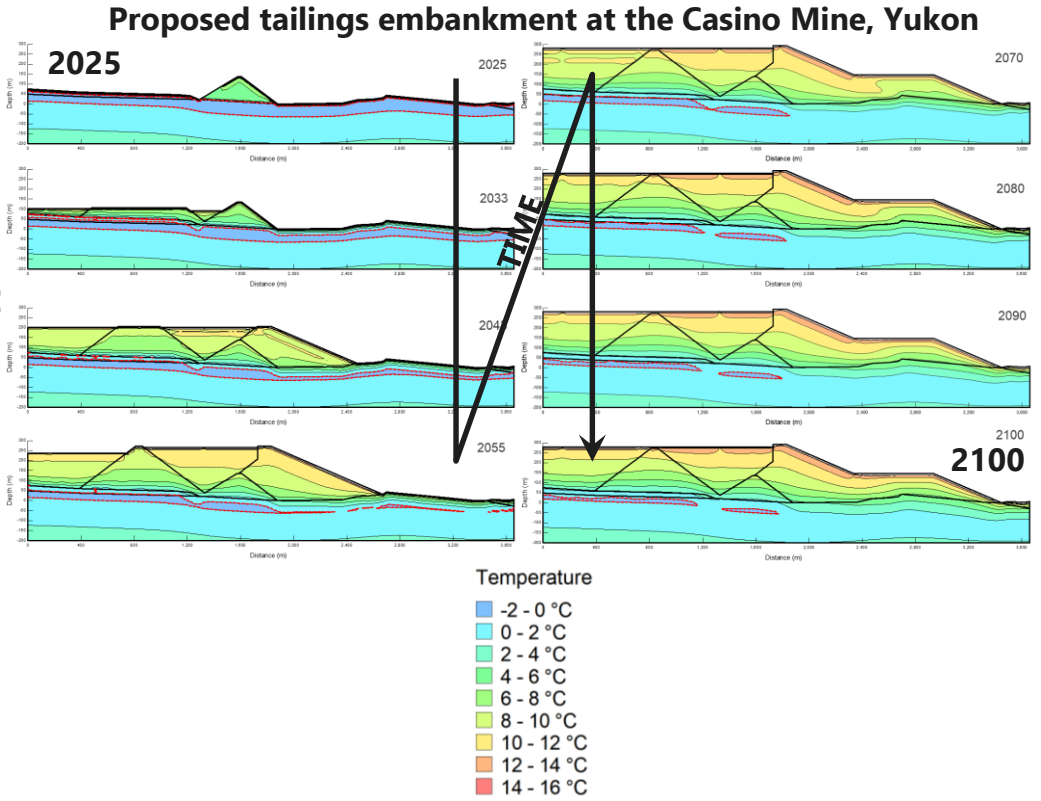
- Early-stage project **planning**
- Impact assessment and **permitting**
- **Groundwater modeling**
- **Infrastructure** design inputs
- **Closure** design (e.g., cover design)





3. Data Synthesis and Analysis

- Thermal modelling
  - Used to **predict change in temperature**, incl. rate of warming and thaw
  - Consideration of climate change, incl. **present and future permafrost** (incl. post-closure)
  - Results can be related back to **ground response**



3. Key Takeaways

Lessons Learned and Recommendations

- **Phase investigations to reduce cost**
  - Lightweight equipment that aligns with early-stage data collection
  - Take advantage of desktop study to narrow focus of assessment and data collection

- **Start temperature monitoring early**
  - Exploit other drillholes for thermistors for obvious cost savings
  - Avoid delays in permitting, design and mitigation

- **Plan (design) for change**
  - Changing climate ➔ changing permafrost conditions ➔ changing considerations and impacts

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