

Initial Performance of Sloped Thermosyphons for Stabilization of Massive Ground Ice

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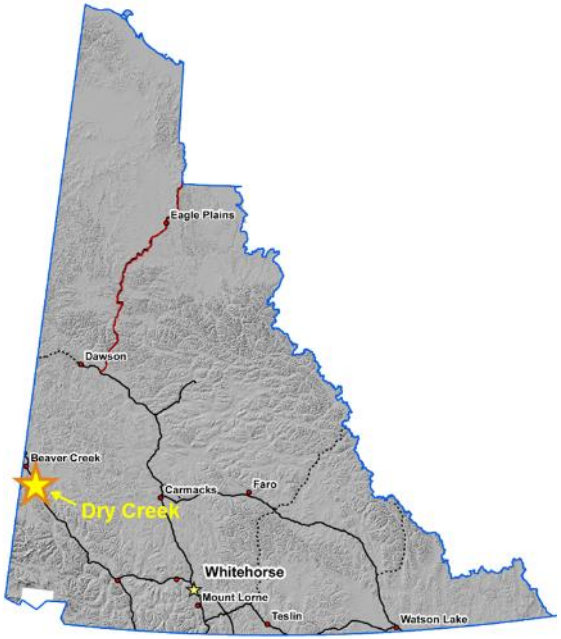
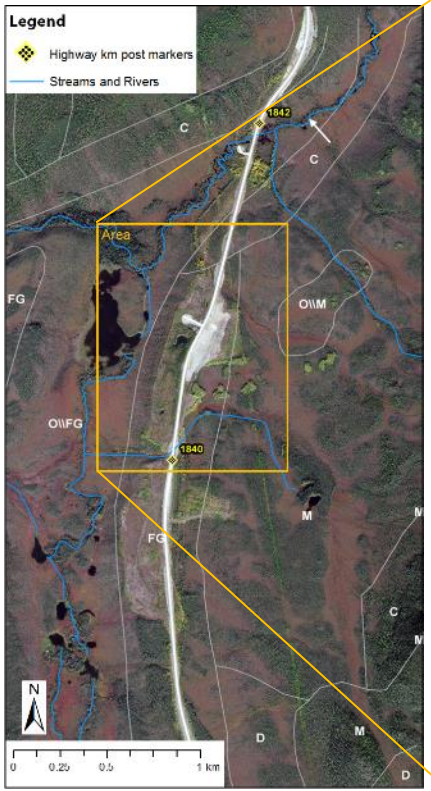
Dry Creek
Highway Test Section

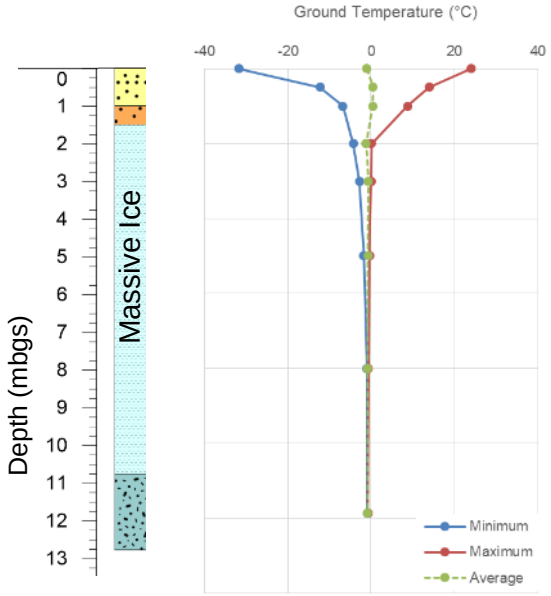


Approximate extent of test section



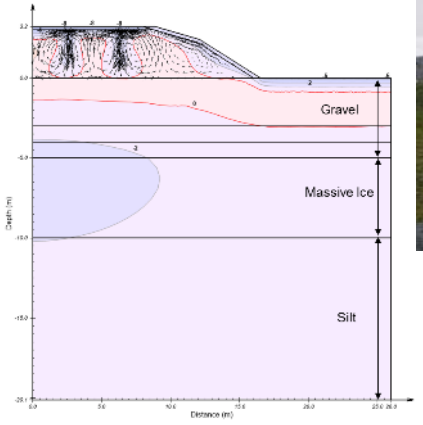
Background

- General stratigraphy
  - Sand and gravel, underlain by silt
  - Massive ground ice > 9 m thick
- Warm permafrost (>-1.0°C) within ROW
- Beneath embankment >-0.5°C with sideslope suprapermafrost talik



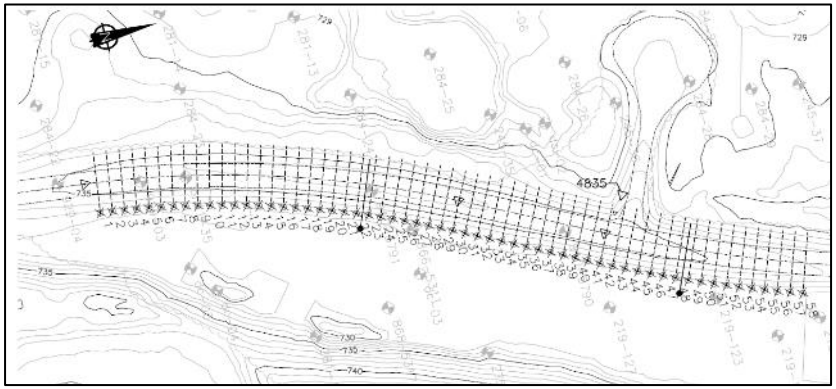
Preliminary Design Options

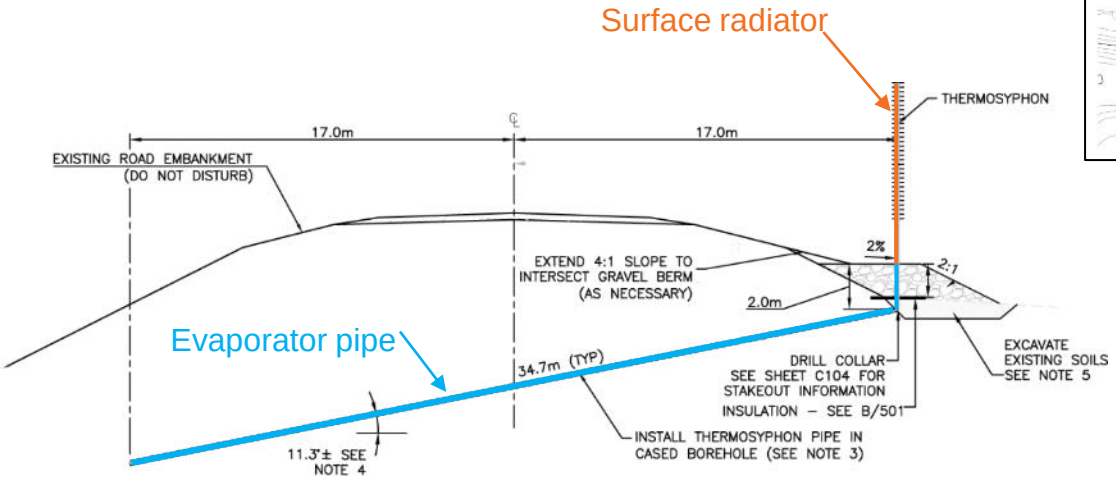
- Two options evaluated during preliminary design stage
- Air convection embankment (full ACE)
  - Reconstruction of embankment required
  - Unknown rock source / costly rock development
  - Marginal ground cooling early-on
  - Potentially less control on thermal performance
- Sloped thermosyphons
  - Existing embankment with minor amount of earthwork
  - Rapid and dependable ground cooling to stability massive ground ice
  - Greater control over thermal performance

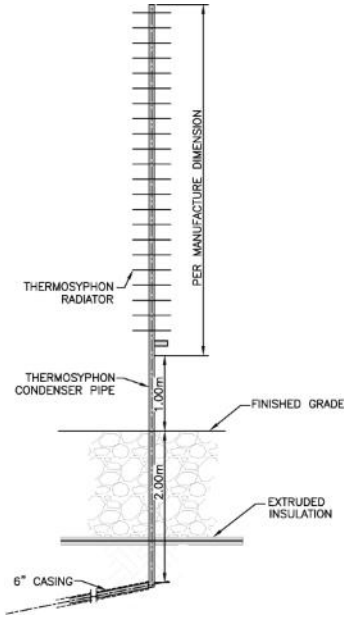


A thermosyphon-based design was predicted to provide more immediate and dependable ground cooling to stabilize the permafrost and massive ground ice with a more predictable project schedule and acceptable costs.

Constructed Section



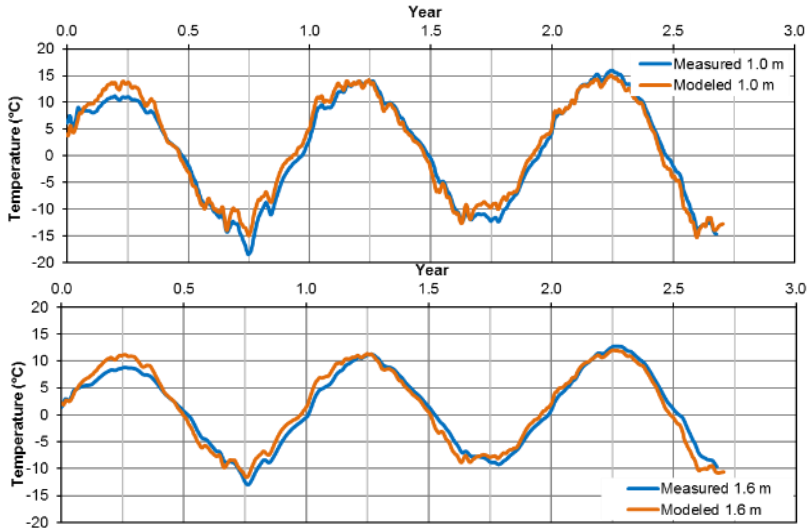


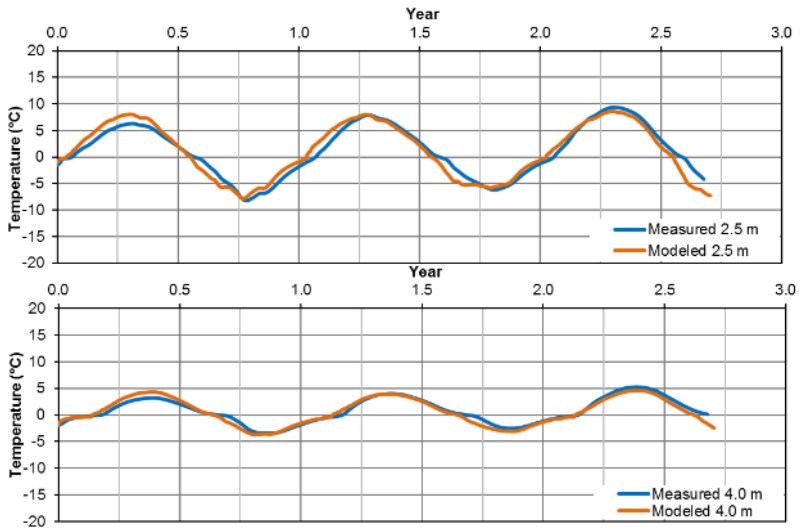


Validation of Thermal Model

Measured ground temperature from Beaver Creek Test Section 5 (Control YG5)

Model ground temperature (thermal conduction model)





Building on data from nearby Yukon Government Test Section…value added data

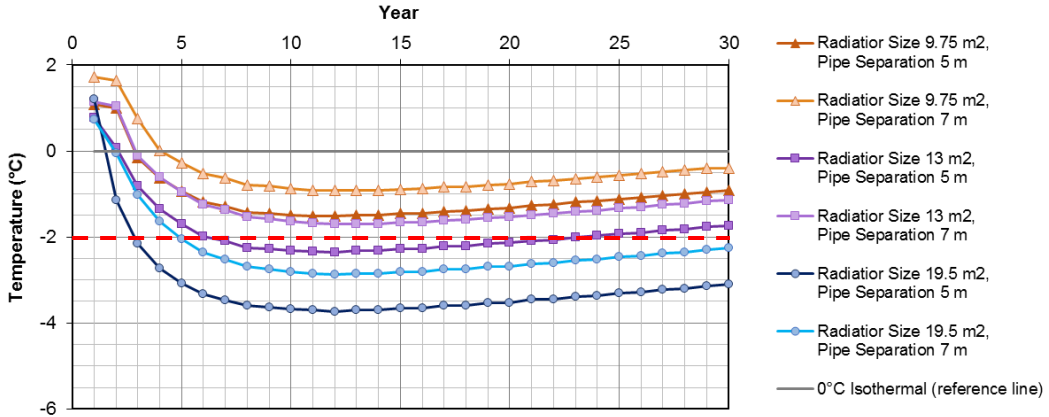
Optimization of Design

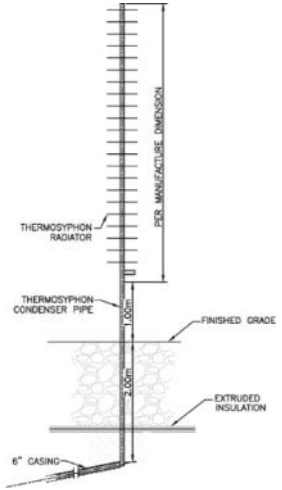
Maximum annual ground temperature

Warmest location mid-point between two evaporator pipes

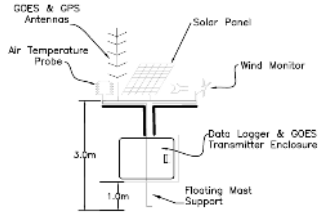
Warmest Monitoring Location

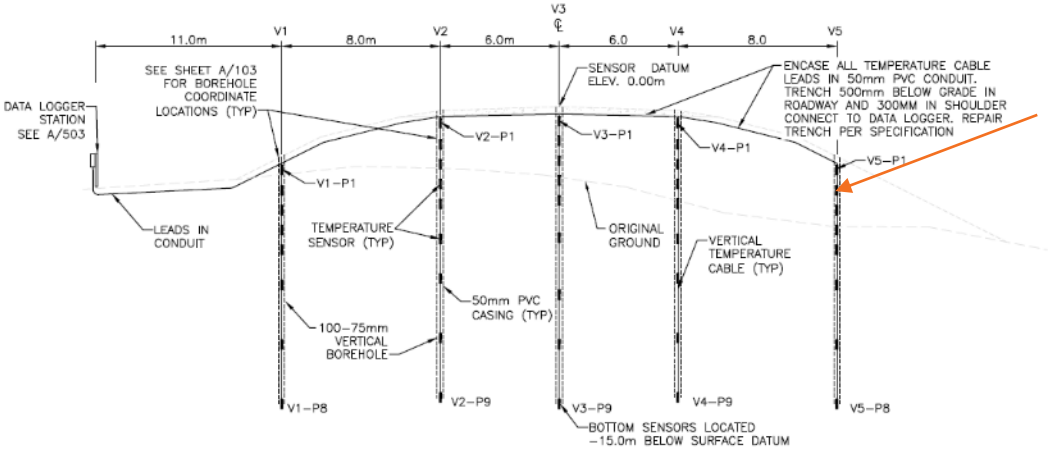
Model Scenario	Radiator Surface Area (m^2)	Evaporator Pipe Separation (m)	Years before Thermal Criteria Reached	Years Less than -2°C
1A	9.75	5	30	0
1B		7	30	0
2A	13.00	5	5	19
2B		7	30	0
3A	19.50	5	2	28
3B		7	4	26





Monitoring



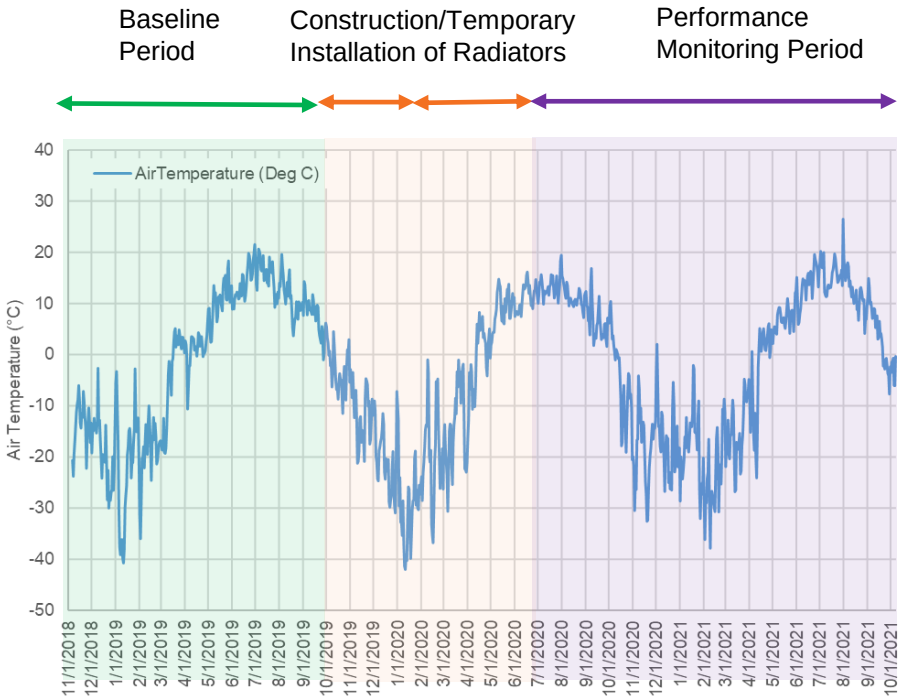


Vertical Ground Temperature Cables

Monitoring Component	Location	Purpose	Data Collection Frequency
Ground Temperature Monitoring	Monitoring Station 1 & 2	Verify thermal performance	Every four hour
Meteorological Monitoring	Monitoring Station 2	Support validation of thermal performance	Hourly
Thermal Infrared Images	Thermosyphon Radiators	Verify thermosyphon function	Annually, Air temp <-5°C
Visual Inspection	Design Section	Thermosyphons & highway distress	Annually, Early September

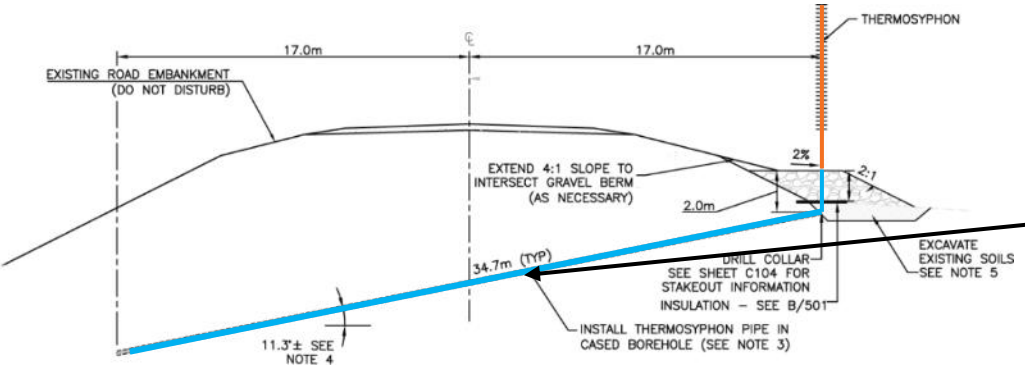
Monitoring Data Record
2018 – Present

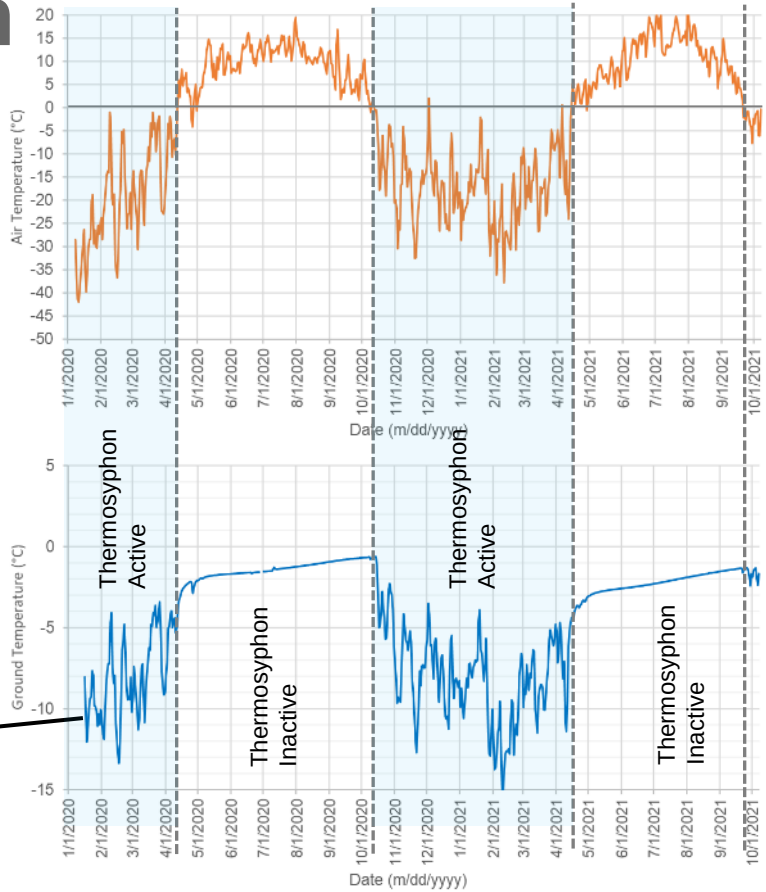
- Data Periods
  - Baseline Period (Green)
  - Construction Period (Dark Orange)
  - Temporary Installation of Radiators (Light Orange)
  - Performance Monitoring Period (Purple)
- Winter of 2020-2021 (this last winter)
  - First winter with the thermosyphons generally constructed per the design



Thermosyphon Function

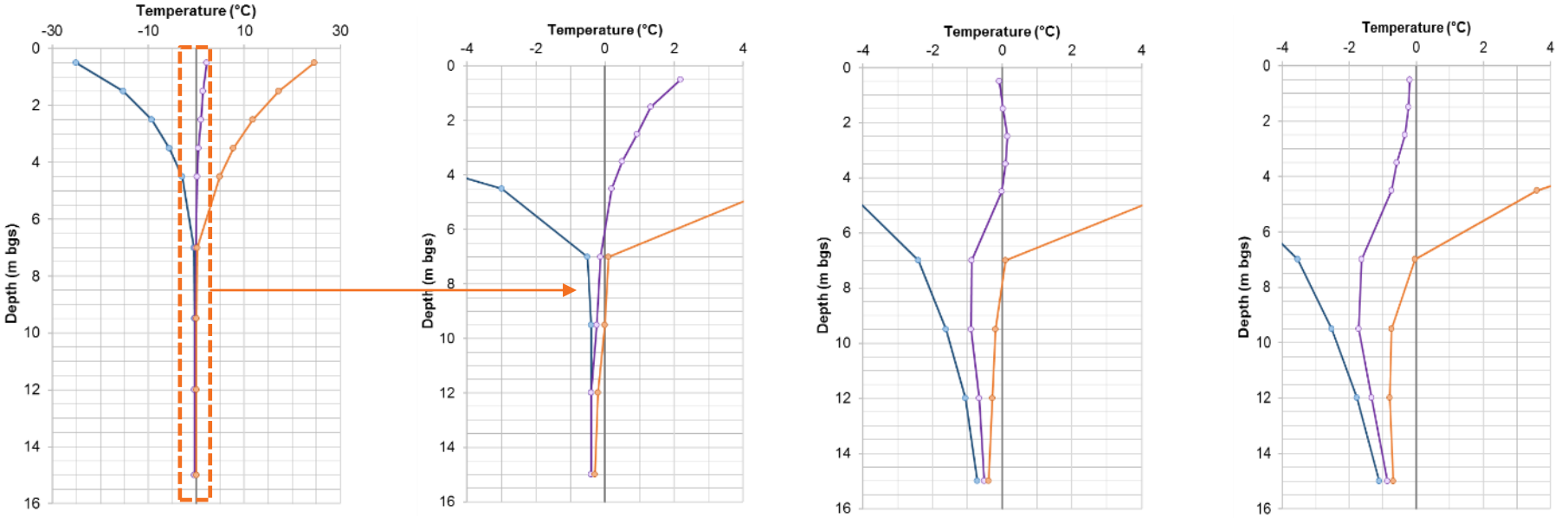
- Heat extraction at the evaporator pipe
  - Expected thermal response to thermosyphon
  - Thermosyphon active from Oct. 14 to April 13
  - Freezing season average ground temperature approx. -8°C (min. -15°C)





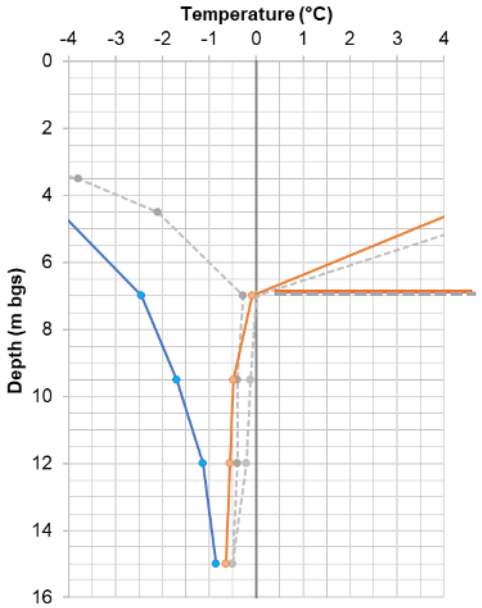
Ground Thermal Regime – First Year of Performance

- Ground cooling observed within massive ice body
- Maximum ground temperature decreased

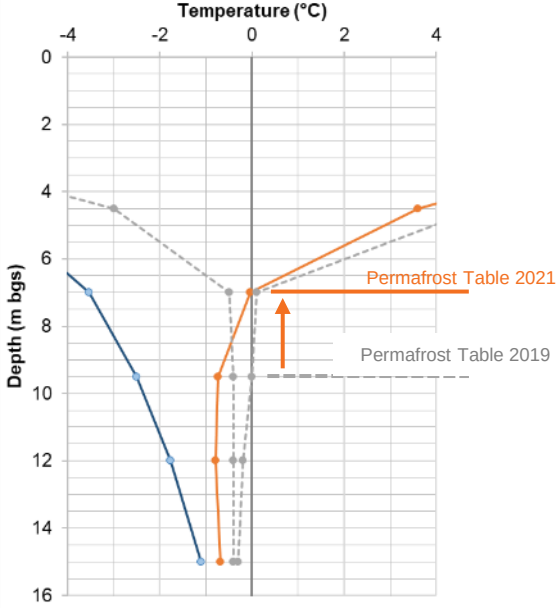


Ground Thermal Regime – First Year of Performance

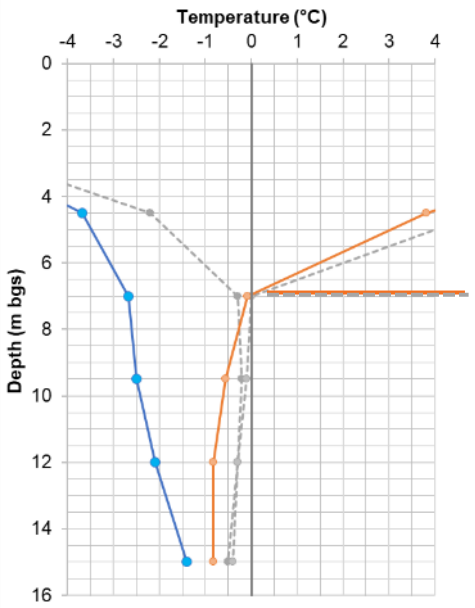
East Shoulder



Centerline



West Shoulder



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