Dams with Frozen Components: Fit For Purpose Tailings Management Solutions

Kendell Cator, P.Eng; Cameron Hore, CPEng, P.Eng; John Kurylo, MSc (DIC), P.Eng; Maritz Rykaart, PhD, P.Eng

SMA Saskatchewan Mining Association

SMA Environmental Forum 2018
Saskatoon, Saskatchewan
October 17–18, 2018

TMAC RESOURCES

srk consulting

Outline

- Introduction
- Foundation & Design Considerations
- Frozen Foundation vs. Frozen Core Dam
- Instrumentation
- Tailings Deposition
- Closure

Project Introduction

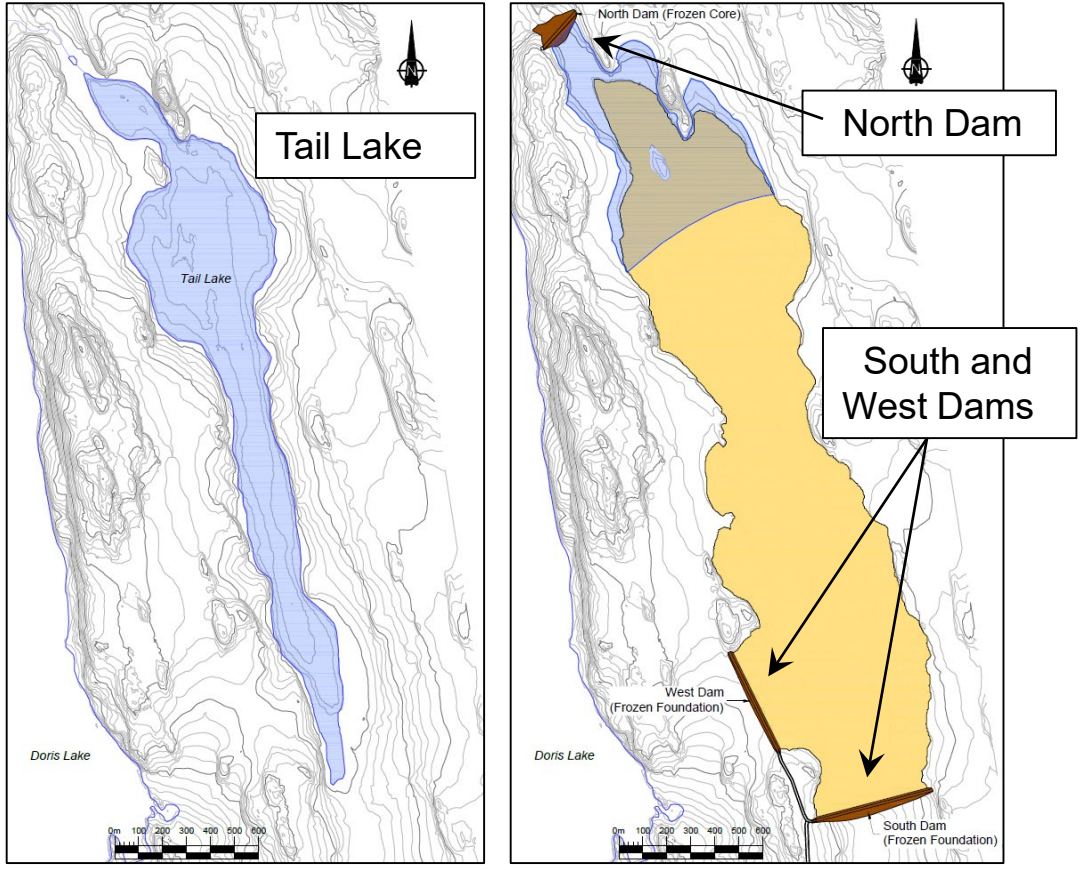
Image Source: https://jsis.washington.edu/archive/canada/file/archive/taskforce09/maps.shtml

Geographic location of mine

Mine Site

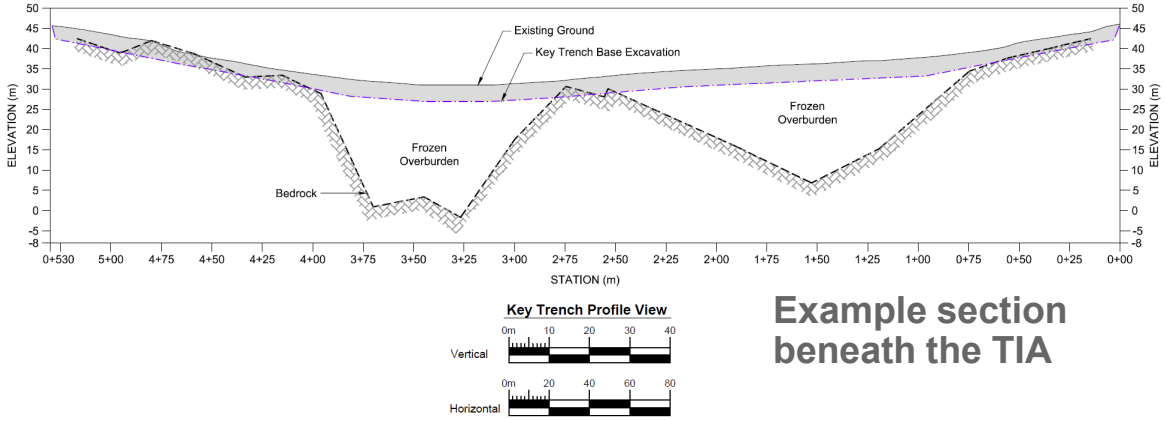
Tailings Impoundment Area (TIA)

- Former lake listed as Schedule II
- Sub-aerial deposition of tailings slurry
- Environmental containment
- High degree of safety



Foundation Conditions

- Continuous cold (-8^{o}C) permafrost
- Bedrock – basalt outcrops
- Thick deposits (>15m) of ice-rich sand and marine silts/clays
- Saline porewater



Example section beneath the TIA

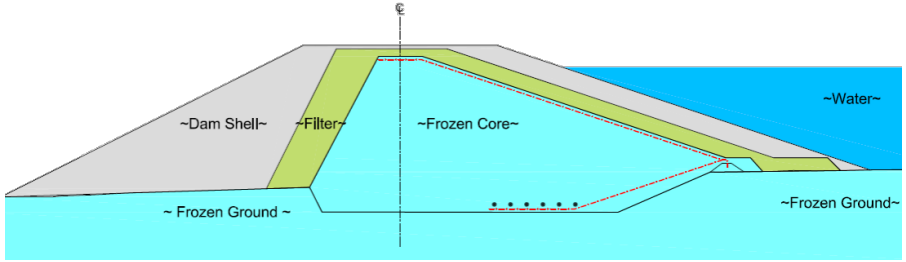
Design Considerations

Ice-rich material present beneath the TIA

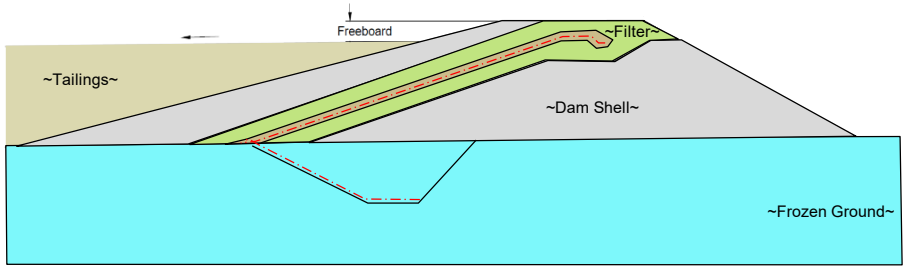
- Challenging foundation
  - Thick permafrost soils
  - Porewater salinity / depressed freezing point
  - Creep susceptible
  - Low strength soils when thawed
- Lack of borrow materials
  - Material with low permeability not available, or not suitable
- Climate and construction timing
- Project location

Definitions

- **Frozen Core Dam:** The water retaining structure is an impermeable frozen mass consisting of the dam core and foundation

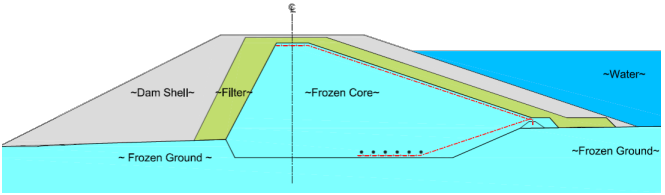


- **Frozen Foundation Dam:** A more classical (thawed) above ground structure that is bonded to a frozen (impermeable) foundation

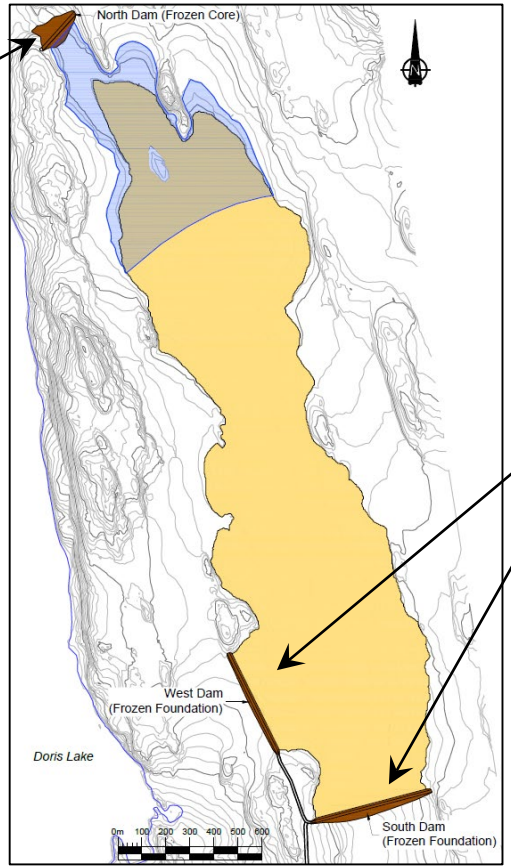


Tailings Impoundment Area (TIA)

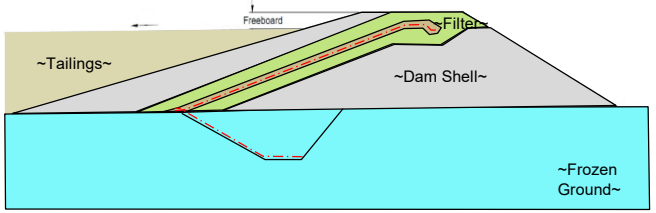
Frozen Core



North Dam



Frozen Foundation

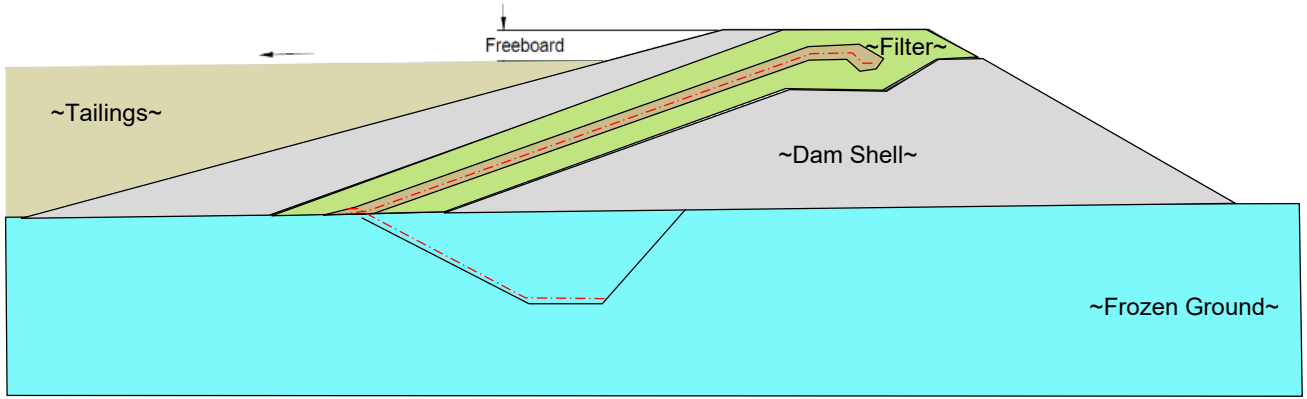


South and West Dams

Frozen Foundation Dam

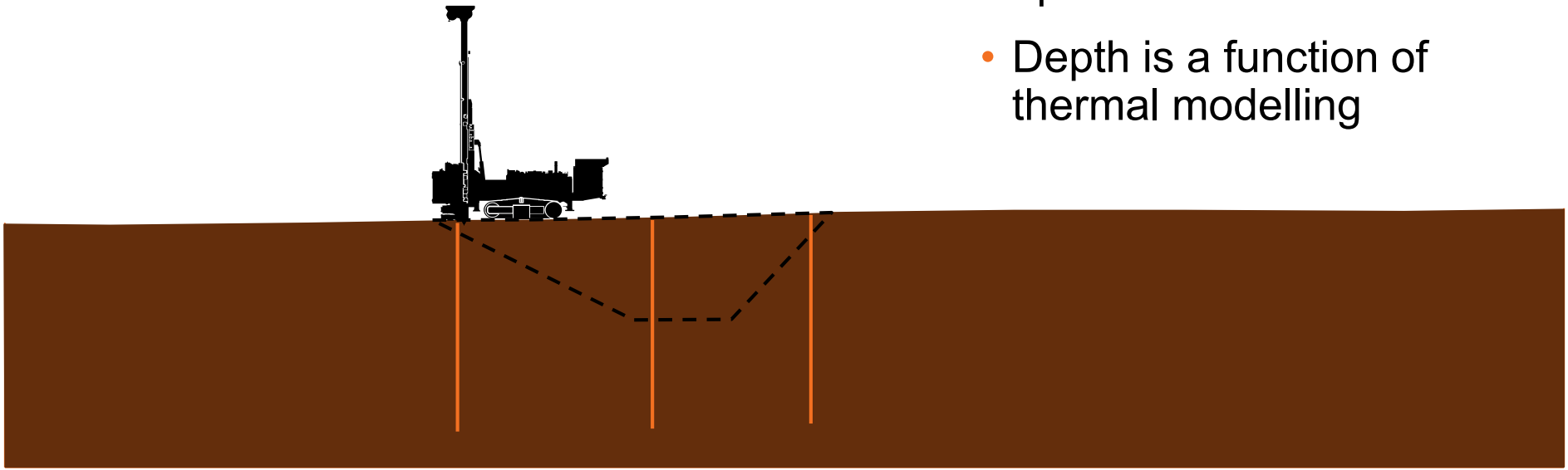
- Key that tailings (solids) deposited upstream

- Upstream geosynthetic clay liner (GCL) system keyed into the frozen foundation as a water retaining element for the unlikely case of foundation thawing / seepage



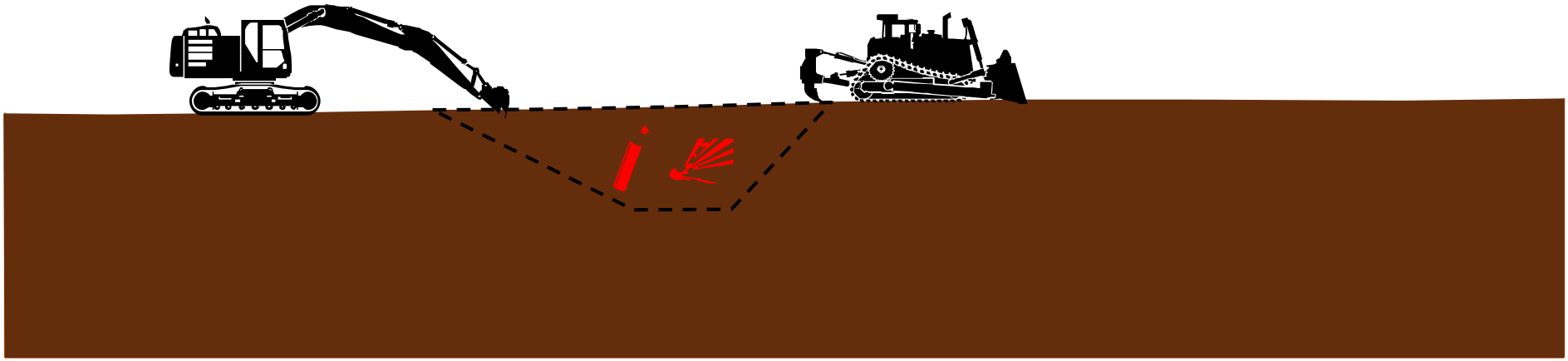
Frozen Foundation Dam

- Percolation testing
- Foundation confirmation
- Key trench depth optimization
- Depth is a function of thermal modelling



Frozen Foundation Dam

- Ripping in frozen overburden
- Drill/blast in bedrock
- 3 to 4 m depth

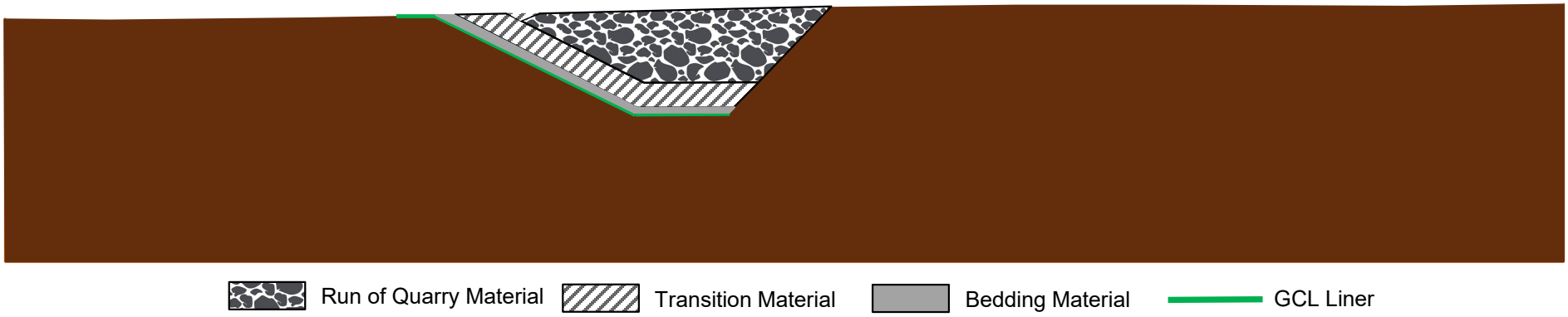


Foreground: Drilling of blast holes
Background: Key trench excavation

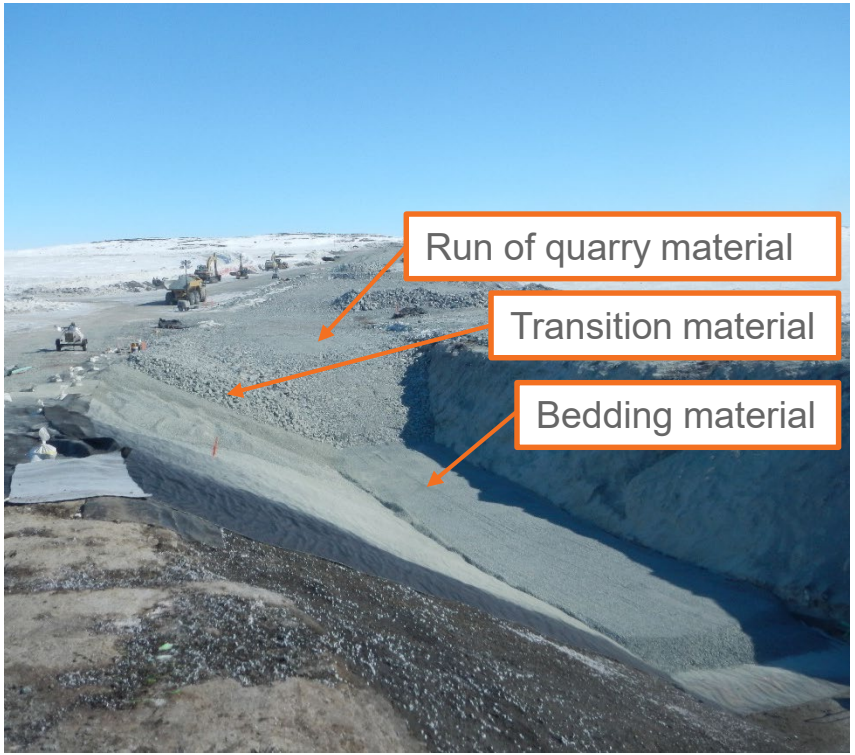
Near complete section of key trench

Frozen Foundation Dam

- Liner keyed into frozen foundation
- Winter construction



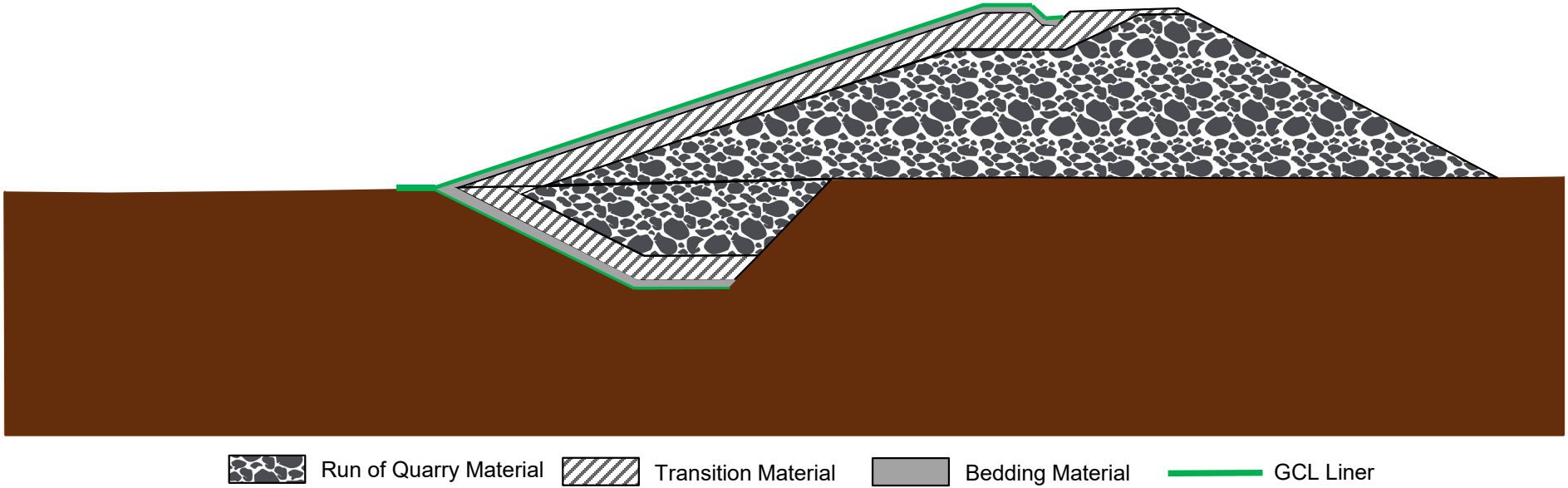
Deployment of liner on upstream slope of key trench

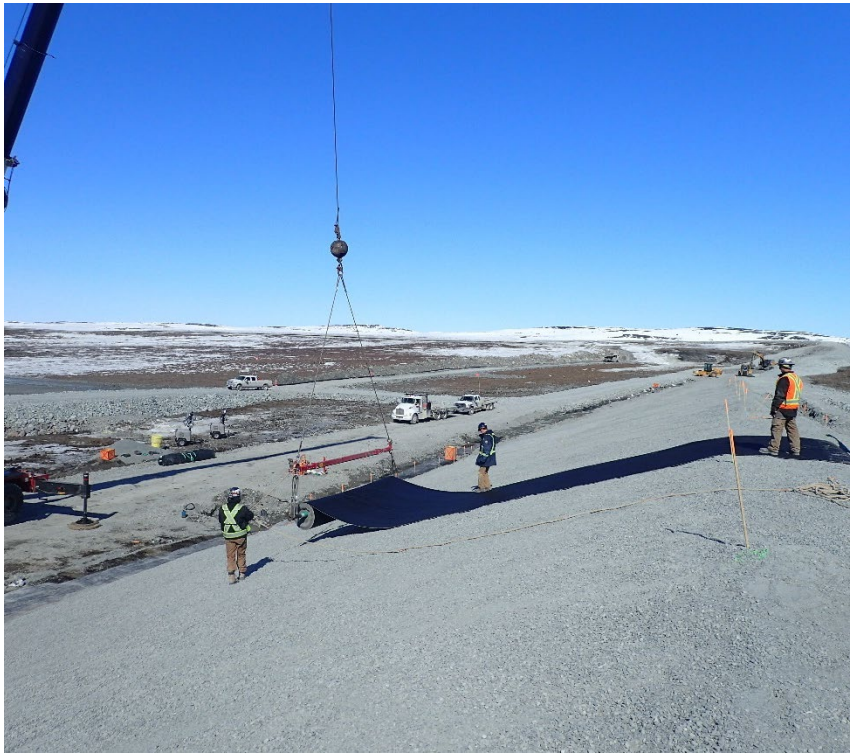


Backfilling of key trench above liner

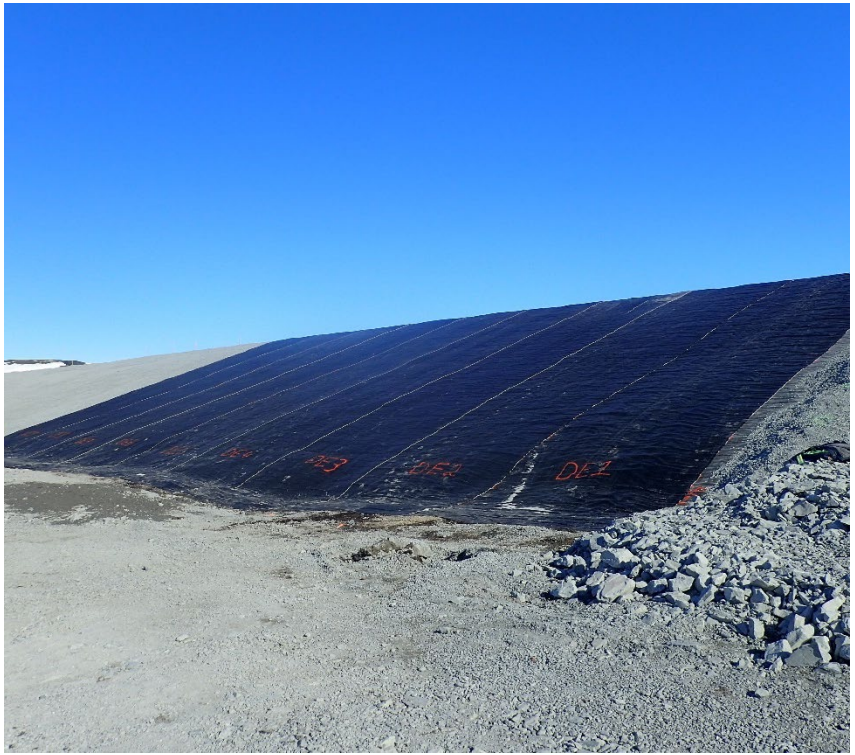
Frozen Foundation Dam

- Thermal protection
- Minimum cover section



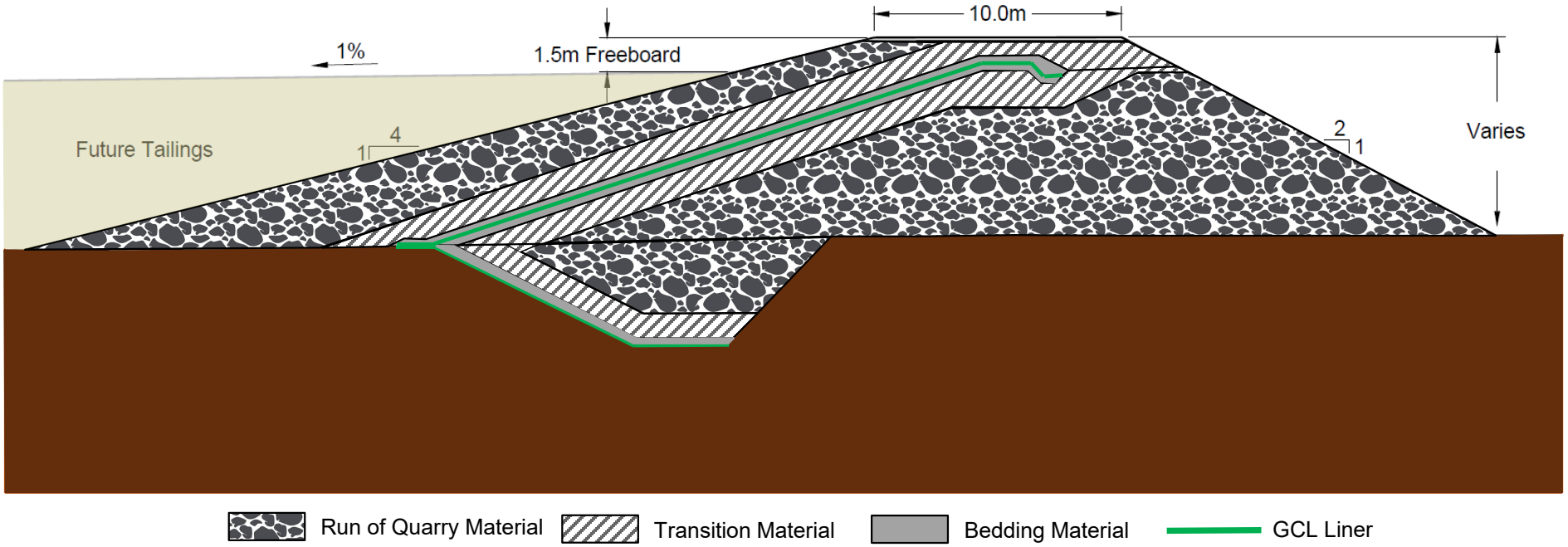


Deployment of liner on upstream slope of above ground fill



Deployed liner on upstream slope of above ground fill

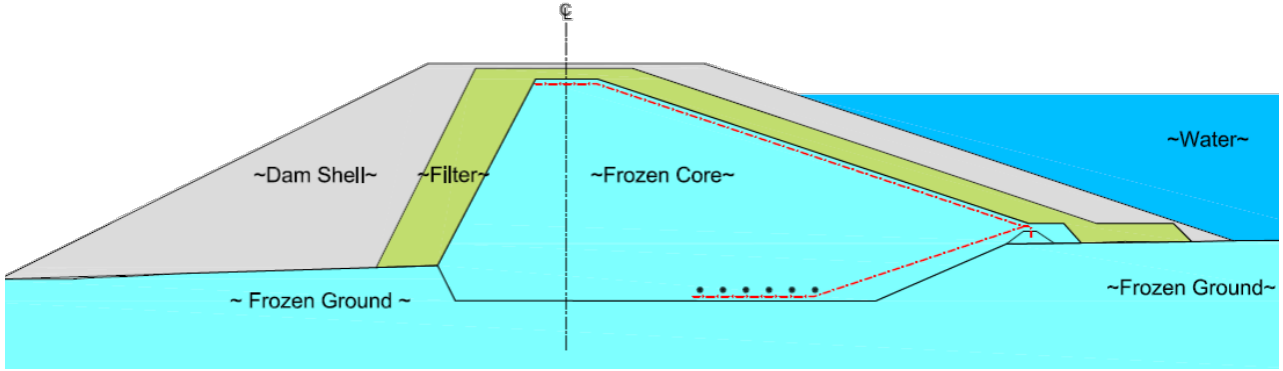
Frozen Foundation Dam



Frozen Core Dam

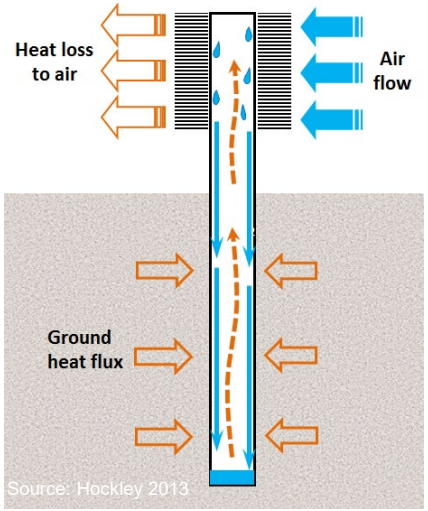
- Water retaining structure

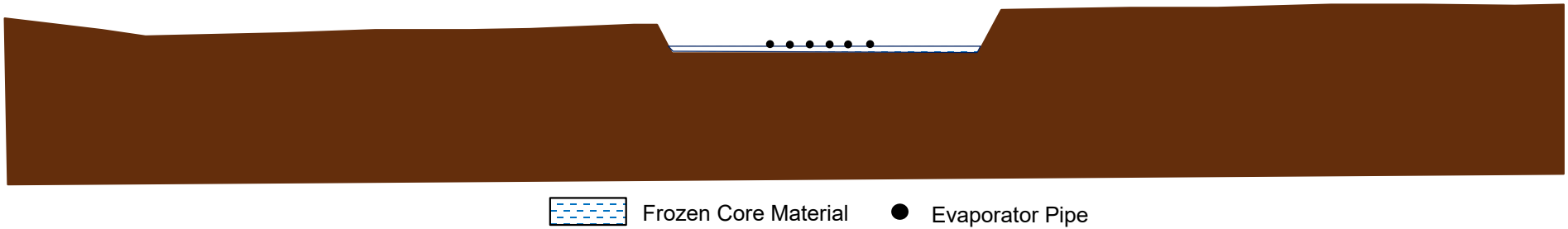
- Thermosyphon evaporator pipes provide passive cooling during the winter



Frozen Core Dam

- Passive refrigeration system
- Pressurized sealed pipes charged with a two-phase working gas (CO_2)
- Radiators help heat exchange



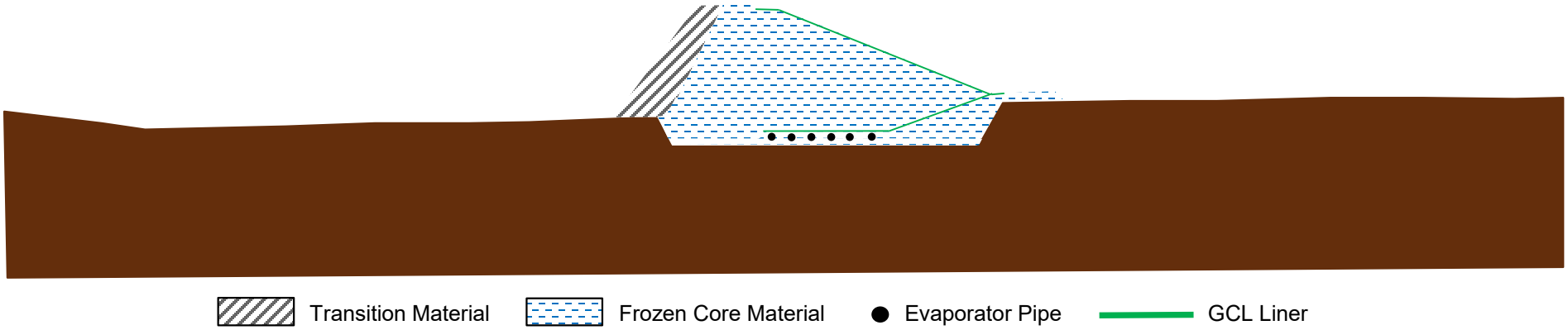


Thermosyphon evaporator pipes connected to radiator

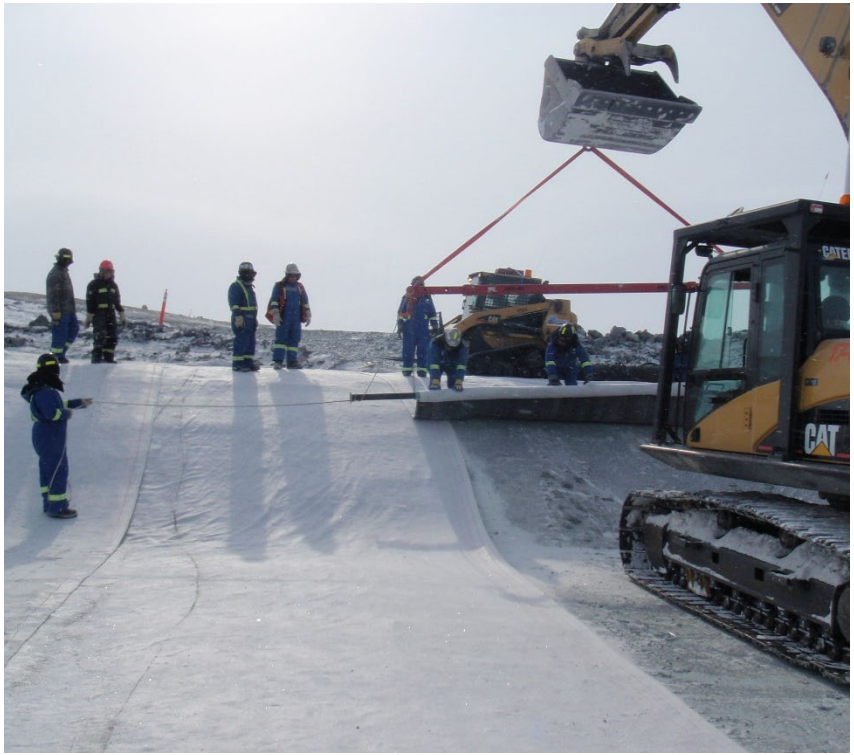
Thermosyphon evaporator pipes installed along the key trench base

Frozen Core Dam

- Saturated crushed rock
- Placed in thin lifts
- Freeze back prior to next lift

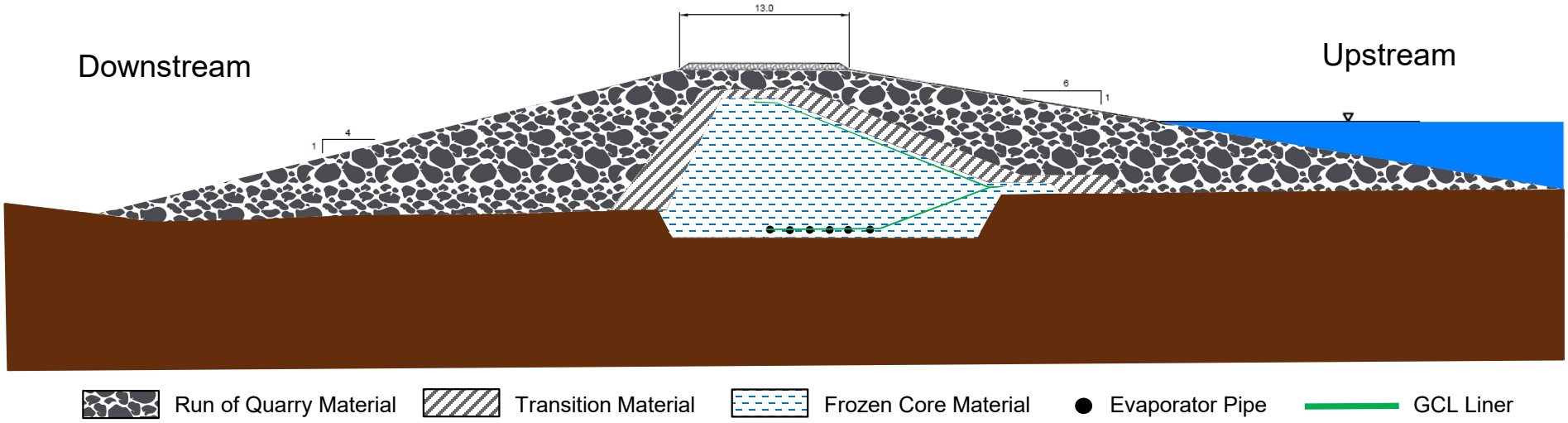


Frozen core construction



Liner installation in key trench

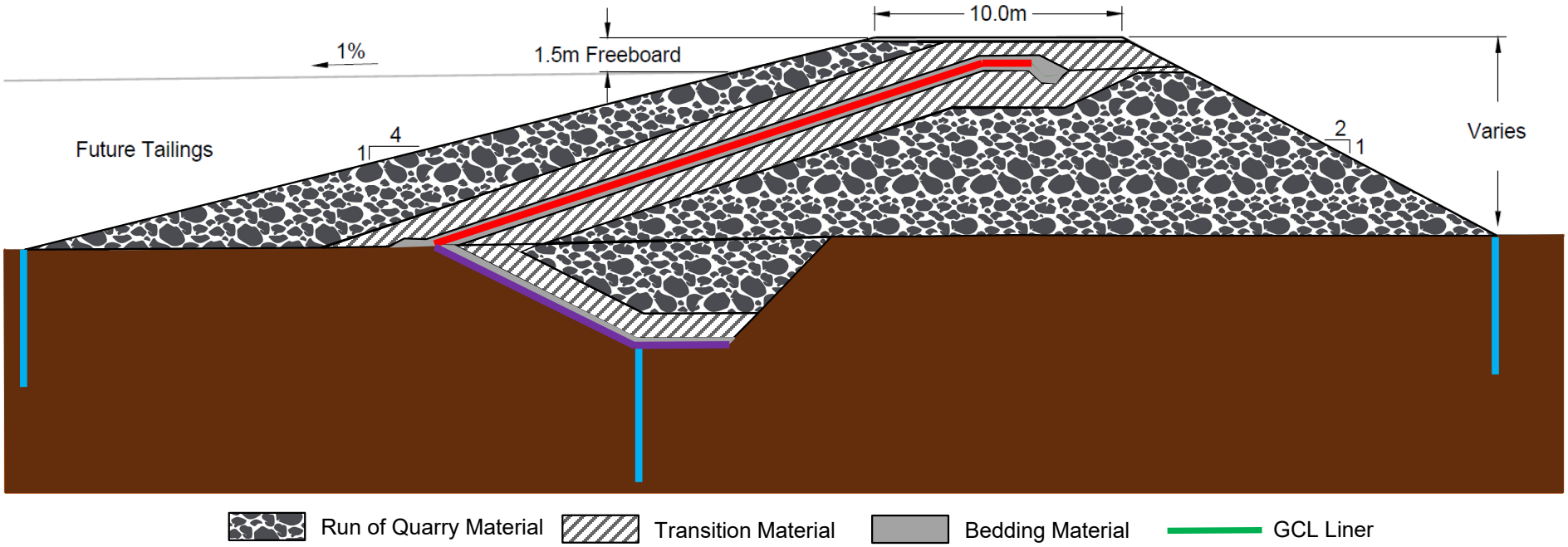
Frozen Core Dam



Instrumentation

Ground Temperature Cables

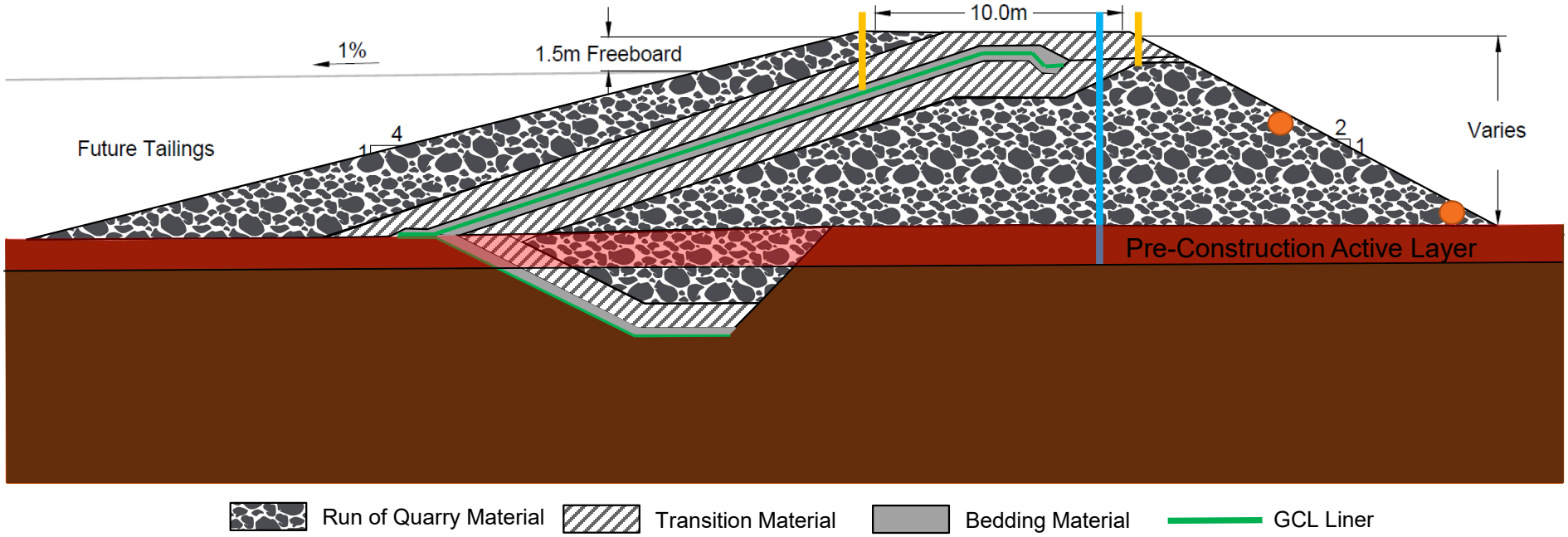
- Ground temperature cables monitor the thermal regime of the foundation and overall deformation performance



Instrumentation

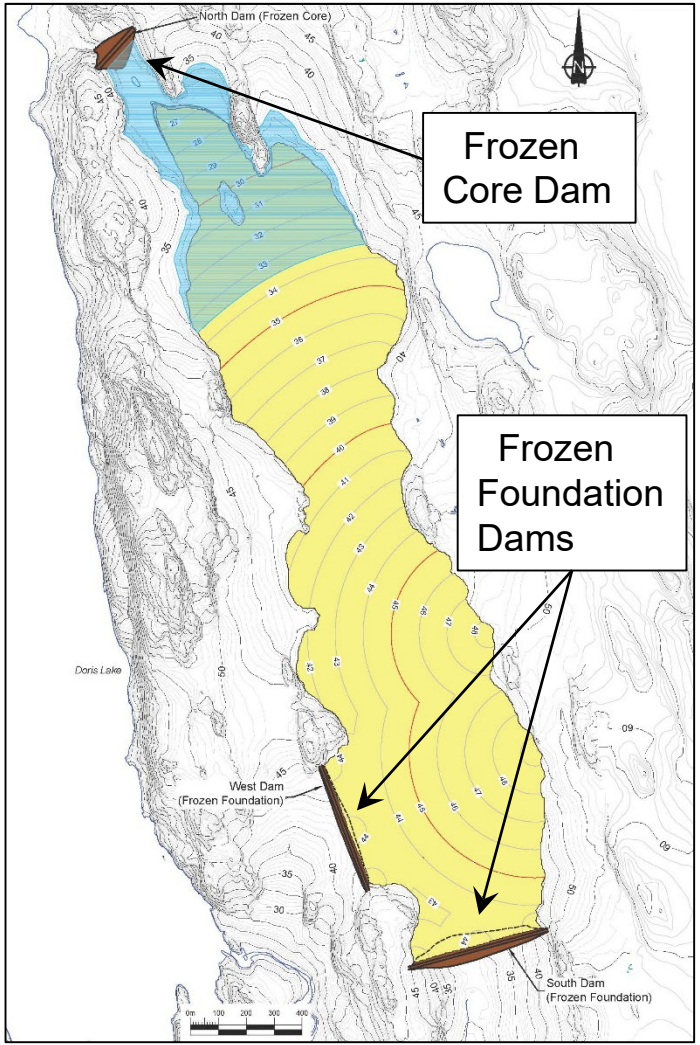
Settlement Monitoring

- Surficial, shallow, and deep settlement surveillance to monitor deformation

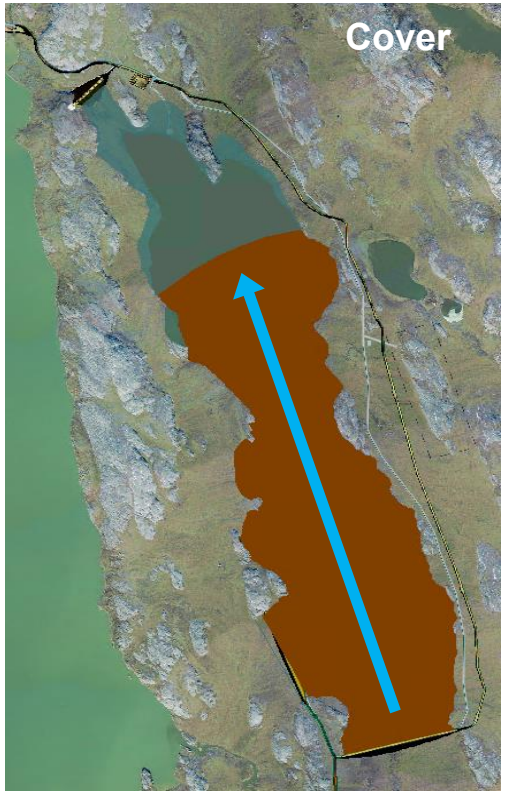


Tailings Deposition

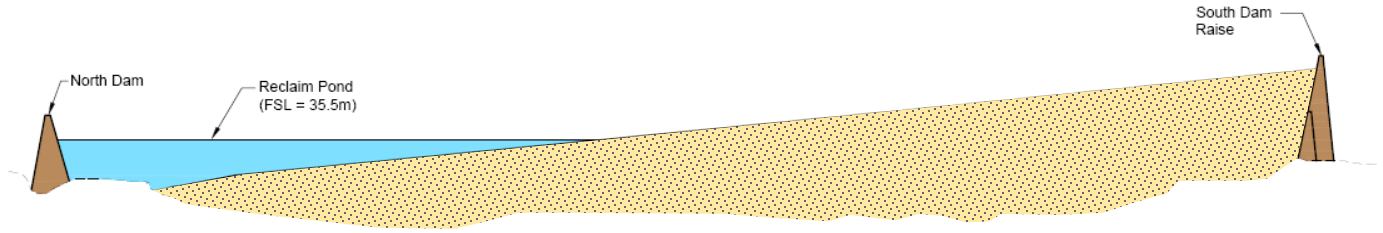
- Development of substantive tailings beaches from the Frozen Foundation Dams (West and South Dams)
- No tailings deposition against the Frozen Core Dam (North Dam)
- Least amount of environmental risk
- Tailings freeze back



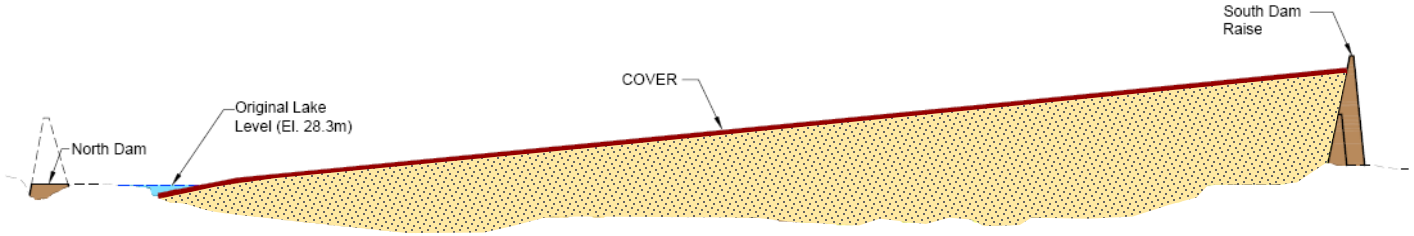
Closure of the TIA



Closure of the TIA



End of Mine



Post Closure

LEGEND

Existing Ground Surface

Deposited Tailings

Conclusions

- Imperative to maintain the frozen state of the core and foundation of these containment structures to:
  - Retain primary element of impermeable functionality
  - Mitigate long term deformation
- Unique and innovative containment designs were required to overcome site-specific challenges
- Tailings management designs need to be adapted to account for local conditions to ensure the design is appropriate and will provide a high degree of safety in environmental containment

Questions?

srk consulting

MAC RESOURCES