Diavik Waste Rock Project: Hydrologic Observations from a Tracer Test and Test Pile Deconstruction

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MEND ML/ARD Workshop

RioTinto INAP NSERC CRSNG Canada Foundation for Innovation
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Objectives

Research Group: Gain a comprehensive understanding of the geochemical, hydrologic, thermal, gas transport, and microbial evolution of waste rock at the Diavik Diamond Mine

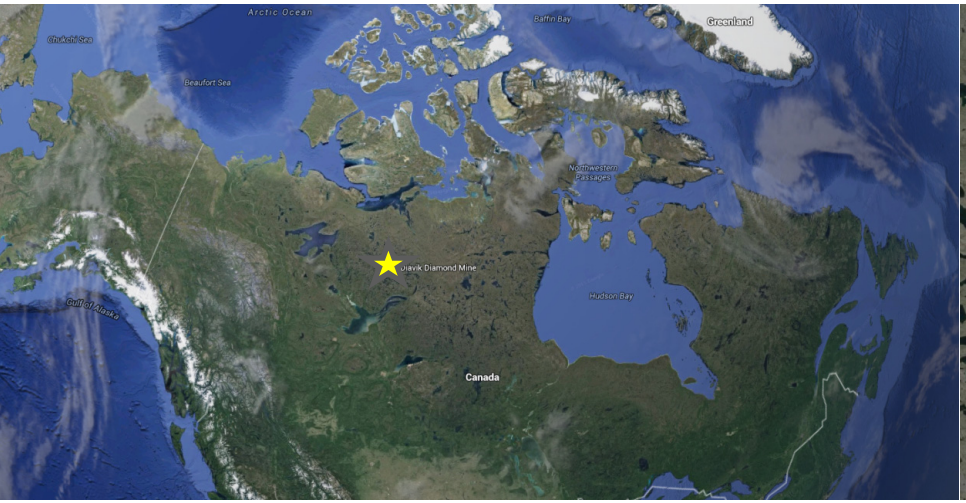
Presentation:

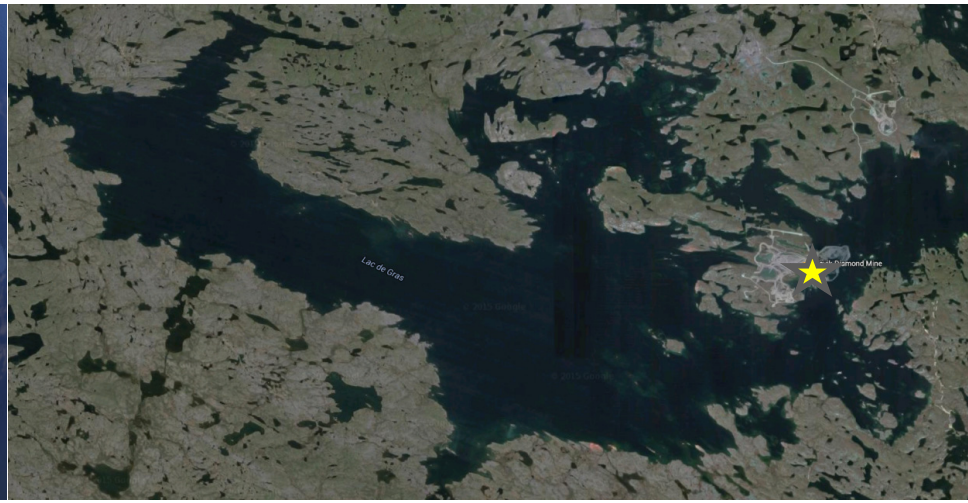
1. Quantify wet-up time, pore water velocity, and residence time within a 14 m tall uncovered waste rock test pile based on in-situ instrumentation and a nine year tracer test

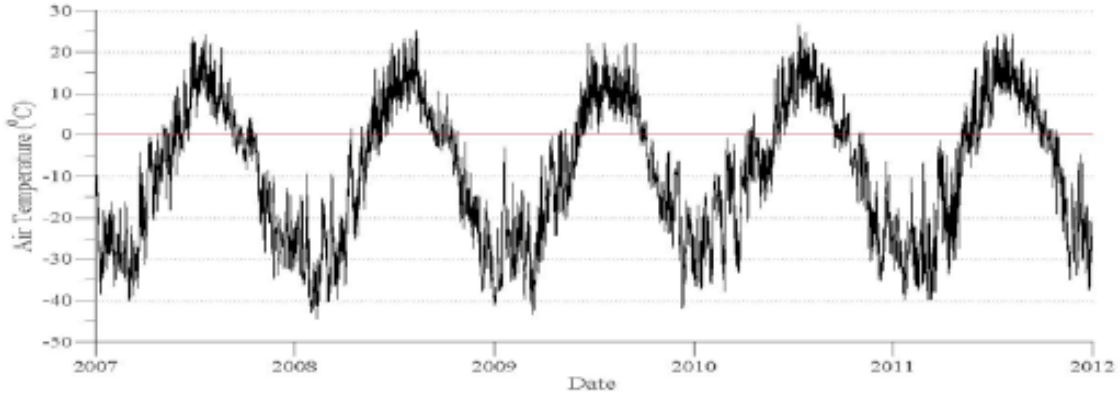
2. Comparison of in-situ vs volumetric moisture contents mapped during the deconstruction of a test pile

3. Characterization of ice distribution in a test pile compared with observations from the full scale waste rock dump at Diavik

Site Description: Location

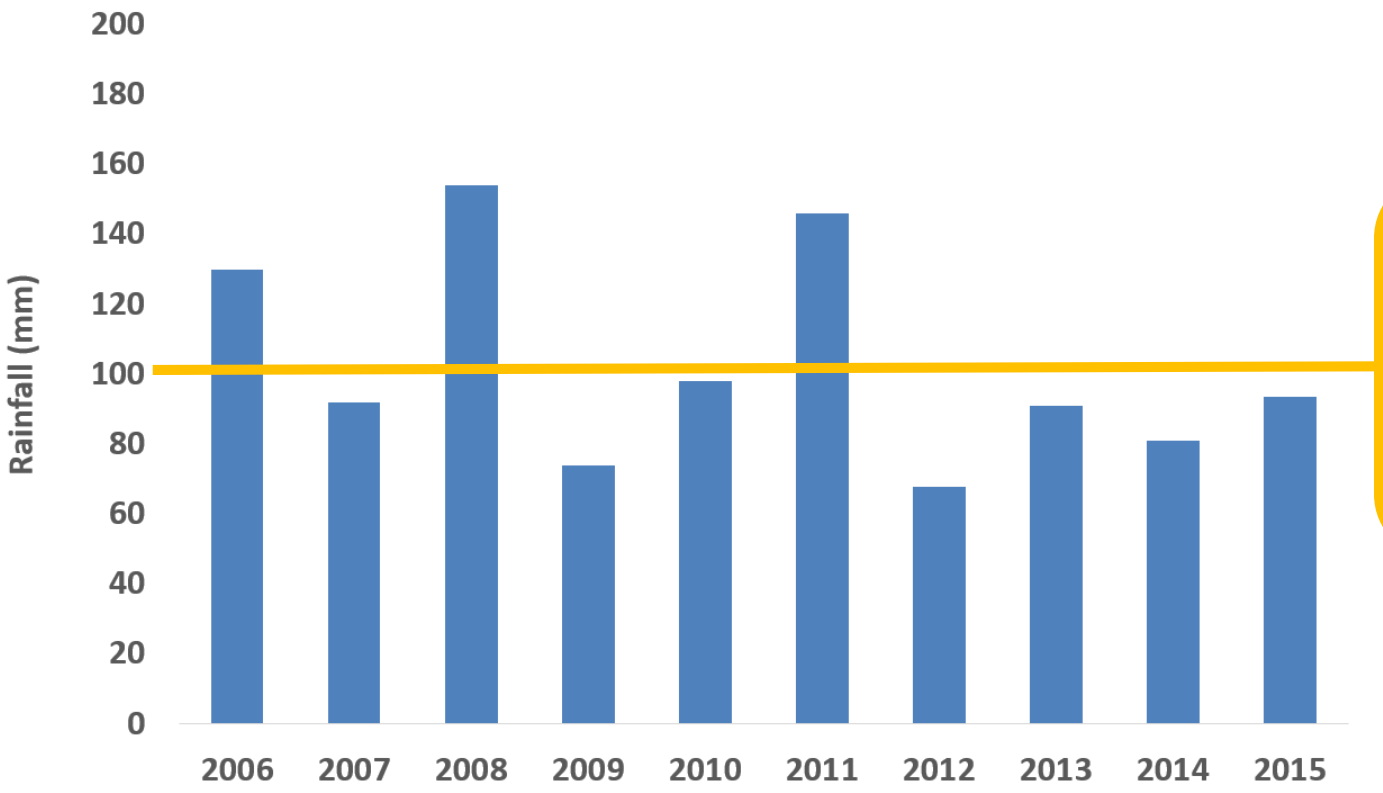






Zone of continuous permafrost
MAAT ~ -9°C

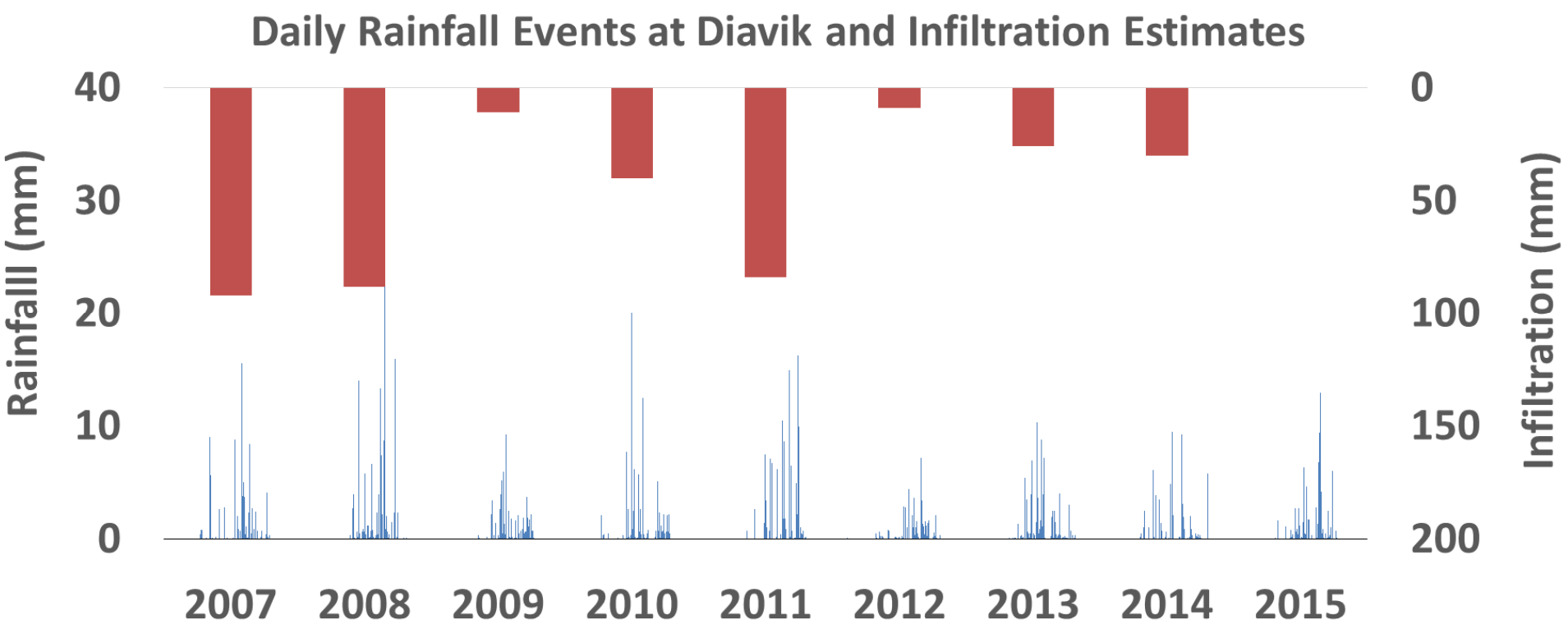
Site Description: Rainfall



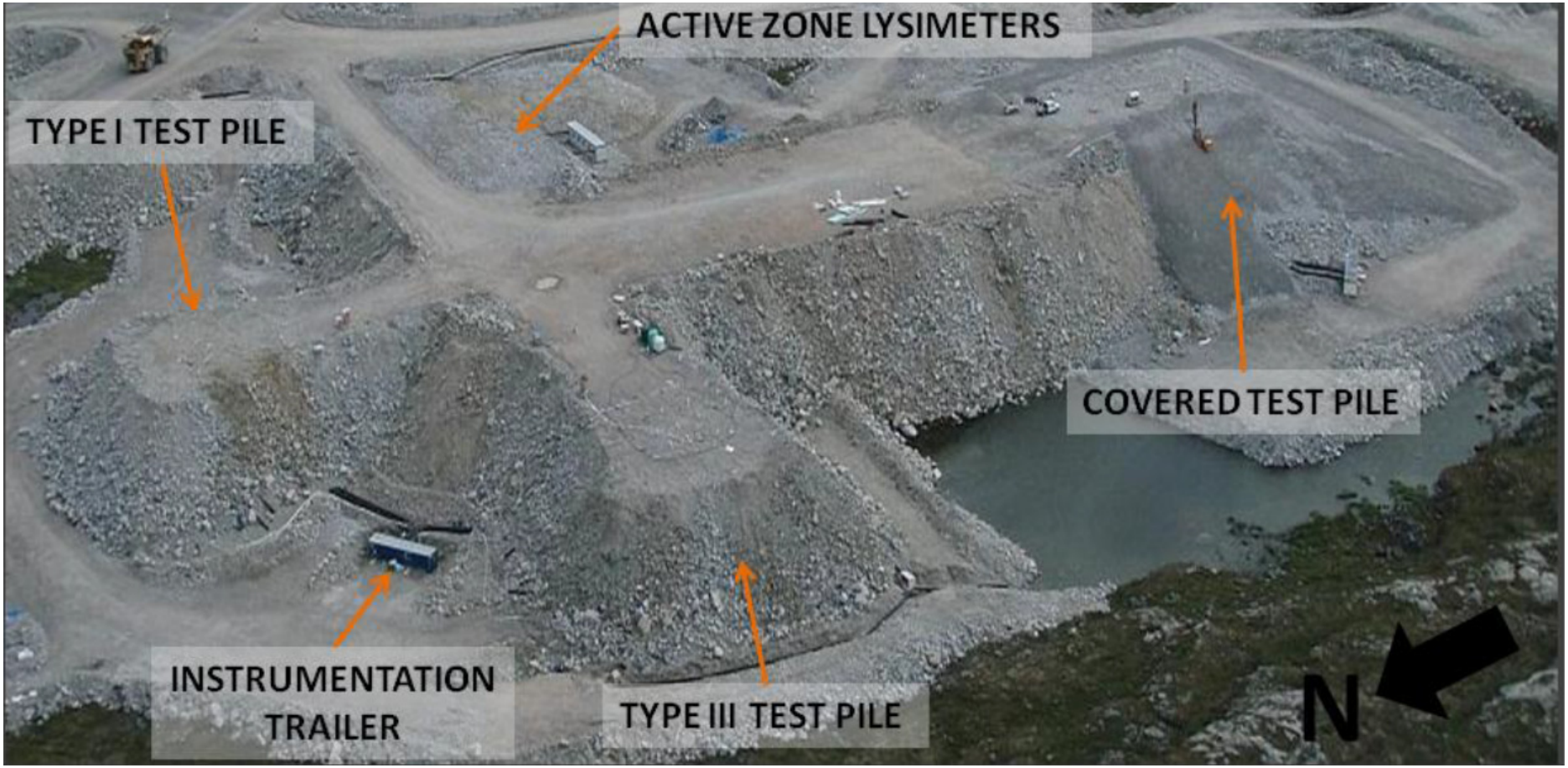
Average Rainfall over project 103 mm/yr

Current four year dry cycle approx. 83 mm/yr

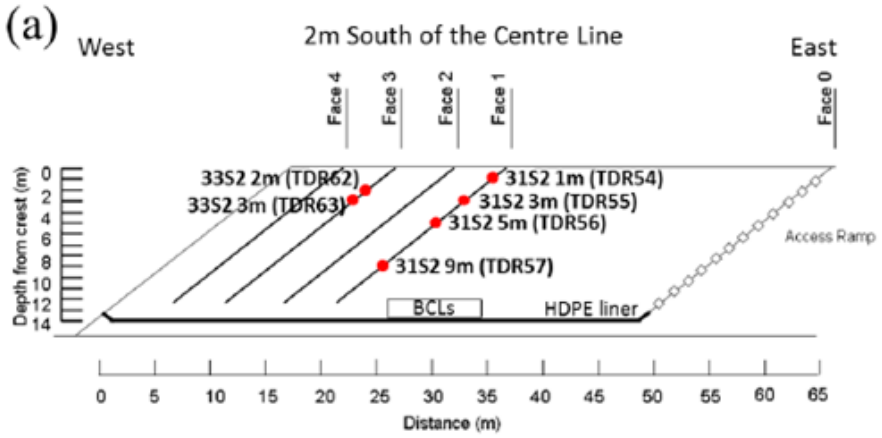
Site Description: Rainfall

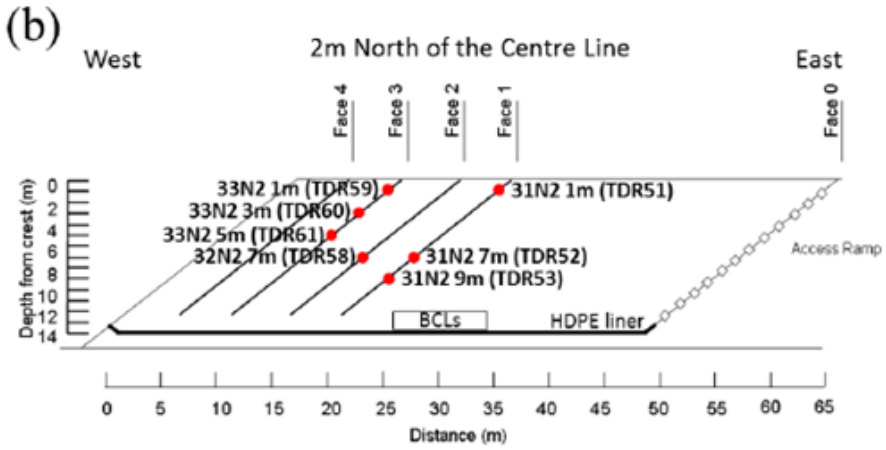


Test Piles

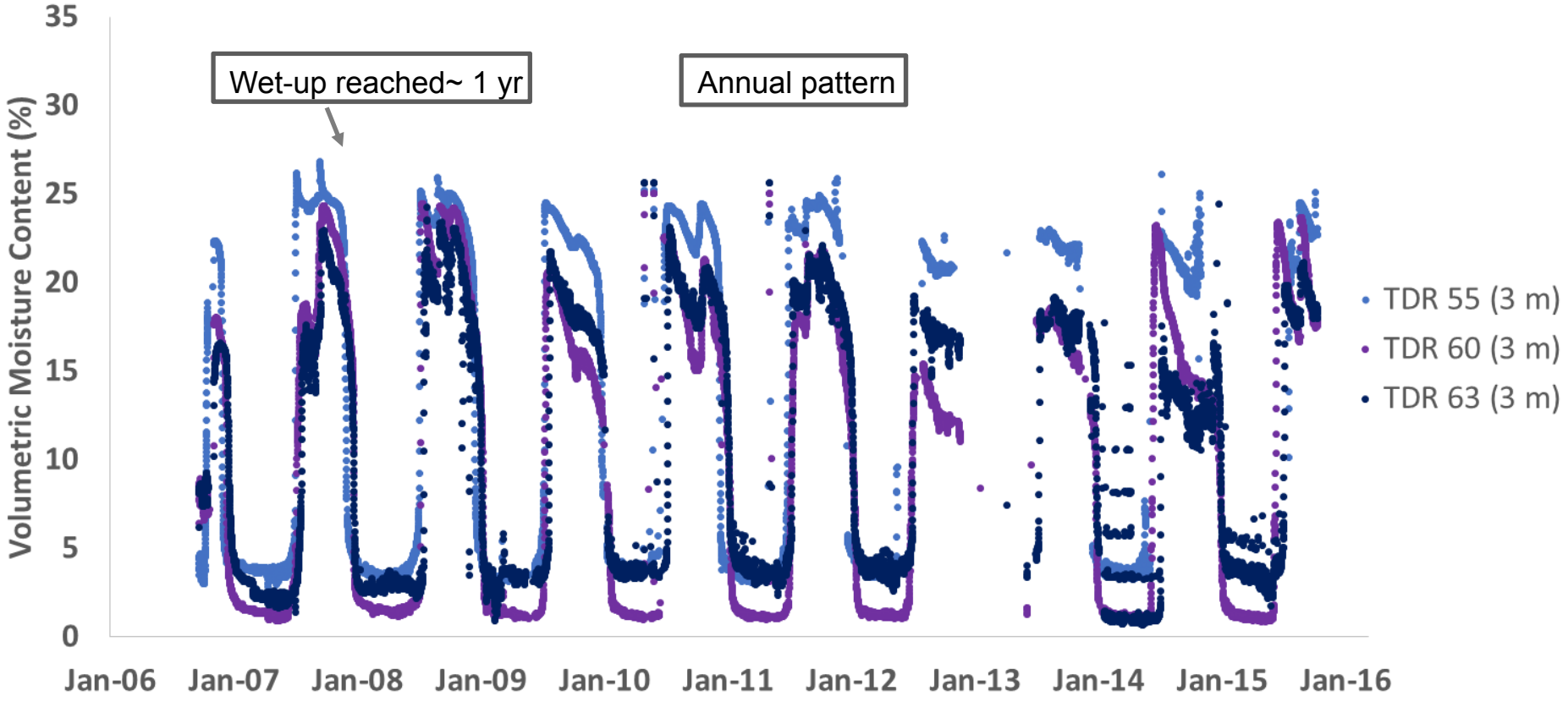

ACTIVE ZONE LYSIMETERS
TYPE I TEST PILE
COVERED TEST PILE
INSTRUMENTATION TRAILER
TYPE III TEST PILE
N

Type III Pile: TDR Locations

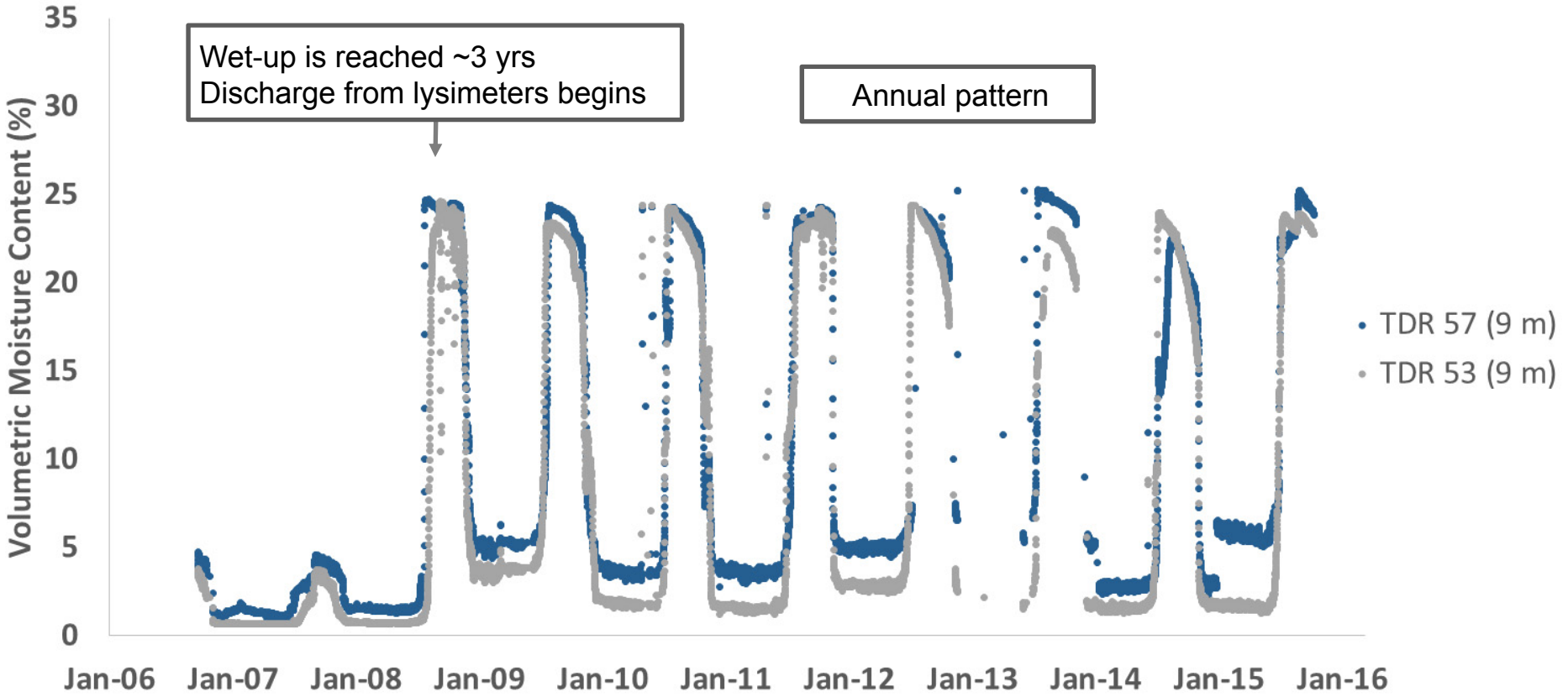




Type III Pile: Volumetric Moisture Content - 3 m Depth



Type III Pile: Volumetric Moisture Content - 9 m Depth

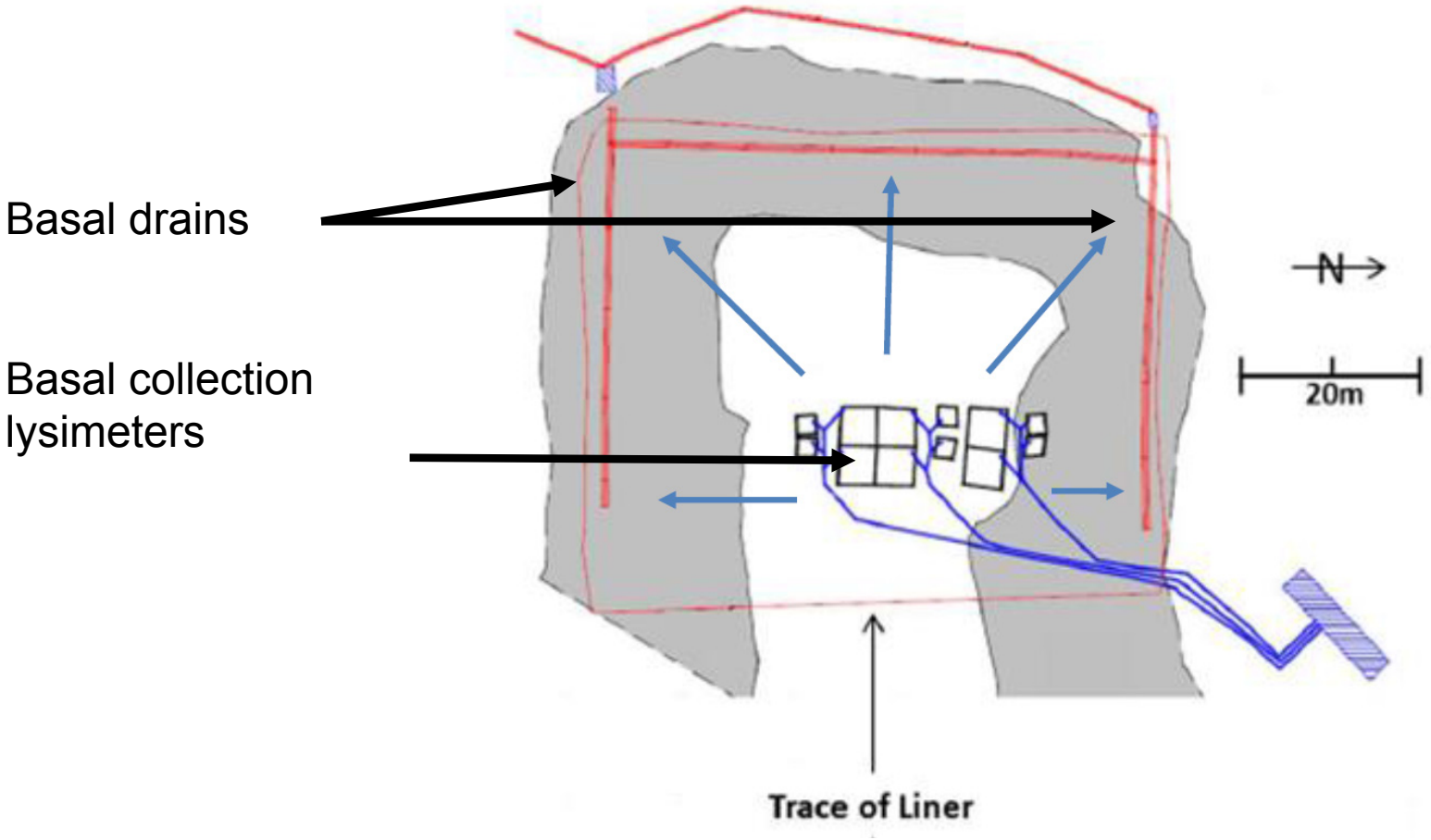


Type III Pile: Bromide Tracer Test

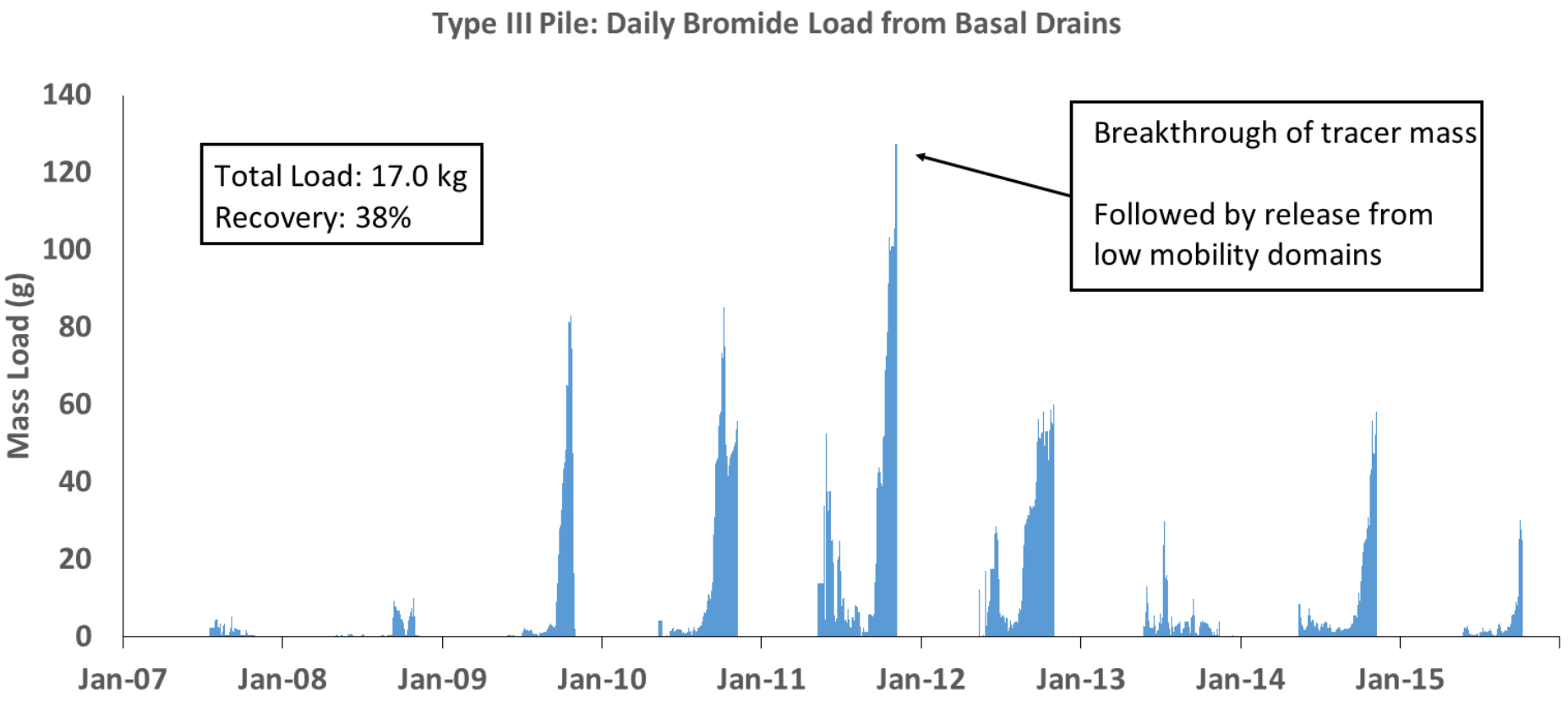
- **Goal:** quantify flow velocities and residence times for pore water in the core of the pile

- **Method:**
  - Bromide tracer applied to the crest
  - 29 mm event at 7.8 mm/hr
  - Observed using SWSS in the upper 9m of the pile
  - Recovery of the tracer through basal drains and BCLs

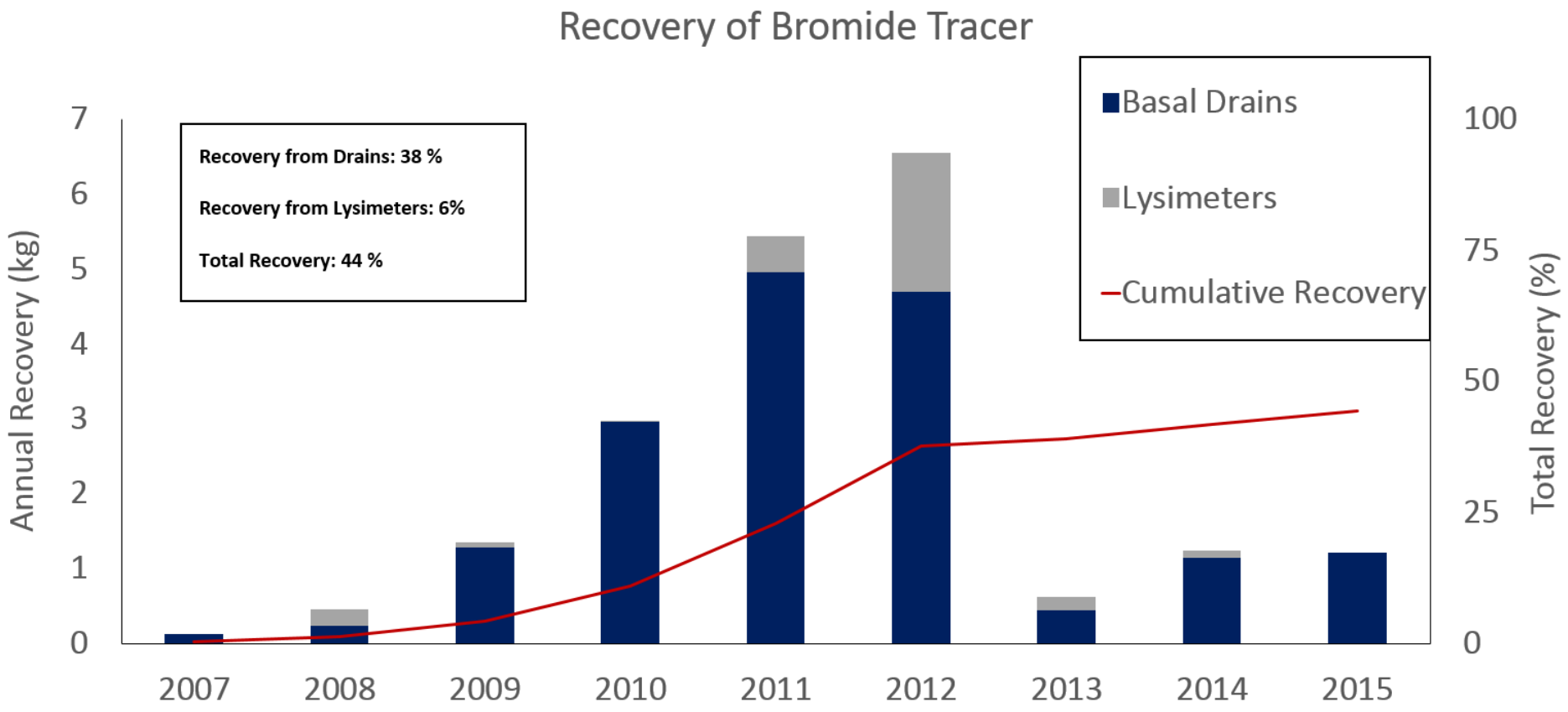
Type III Pile: Bromide Tracer Test



Type III Pile: Bromide Tracer Test

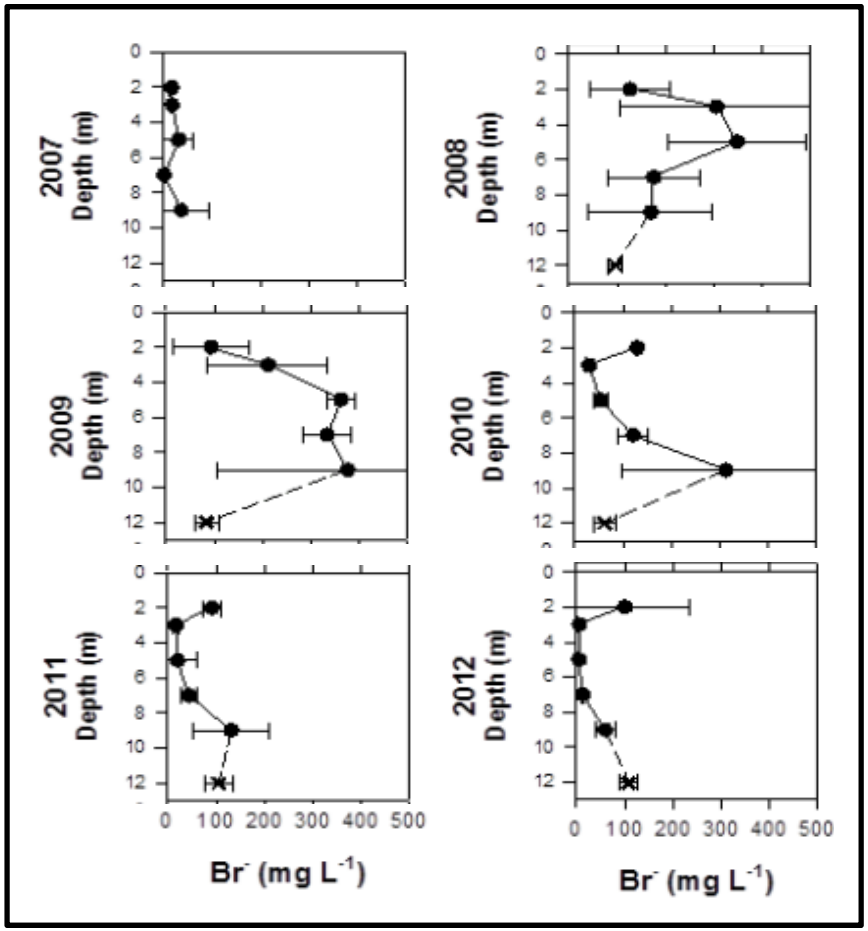


Type III Pile: Bromide Tracer Test



Type III Pile: Bromide Tracer Test

- SWSS data show downward migration of tracer mass through test pile
- SWSS indicate preferential flow up to 0.7 m/day at time of tracer application
- SWSS show pore water moves 2.3-2.9 m/yr
- **Velocity:** 1-2 cm/day when thawed (May-Nov) based on TDR, thermal measurements, and SWSS samples
- **Transit time:** ~ 2.3 years based on peak of mass recovery from basal drains, and considering only months when internal temperatures greater than zero

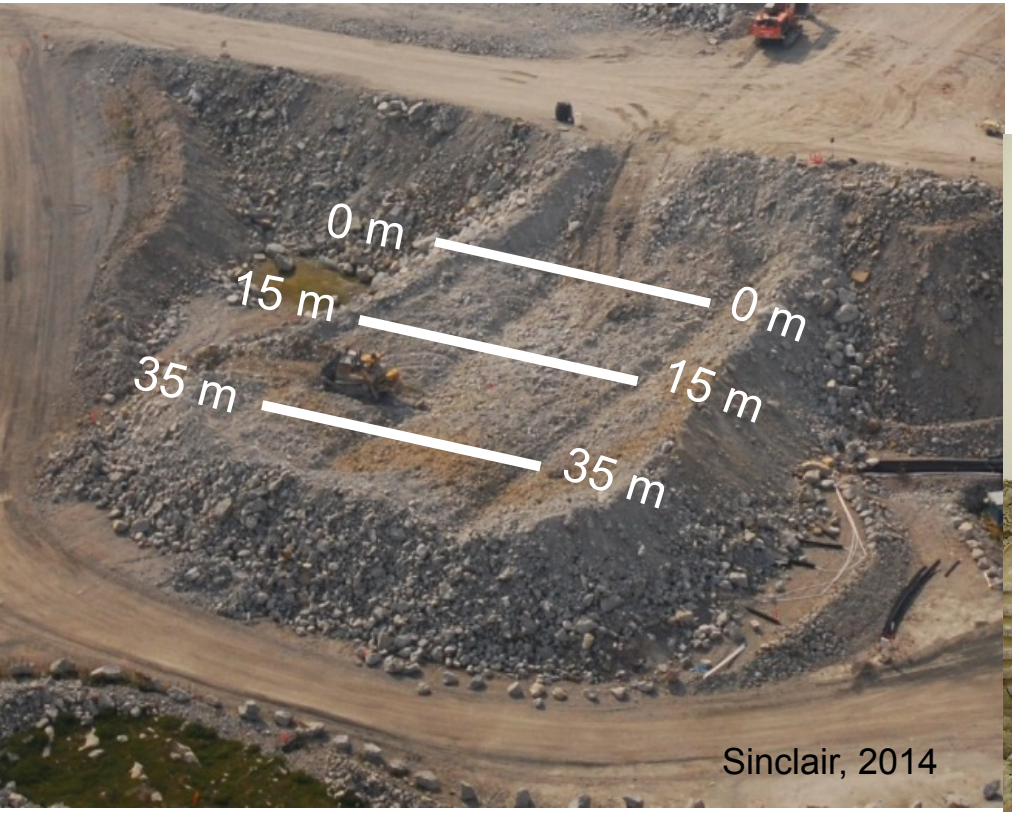


Sinclair, 2015

Type III Pile: Tracer Mass Remaining

- After nine years: Where is the remaining 56% of the tracer?
  - Low velocity flow paths / zones
    - –Observed in 2 m SWSS
  - Current work underway of understanding the role of ice formation influencing recovery of tracer

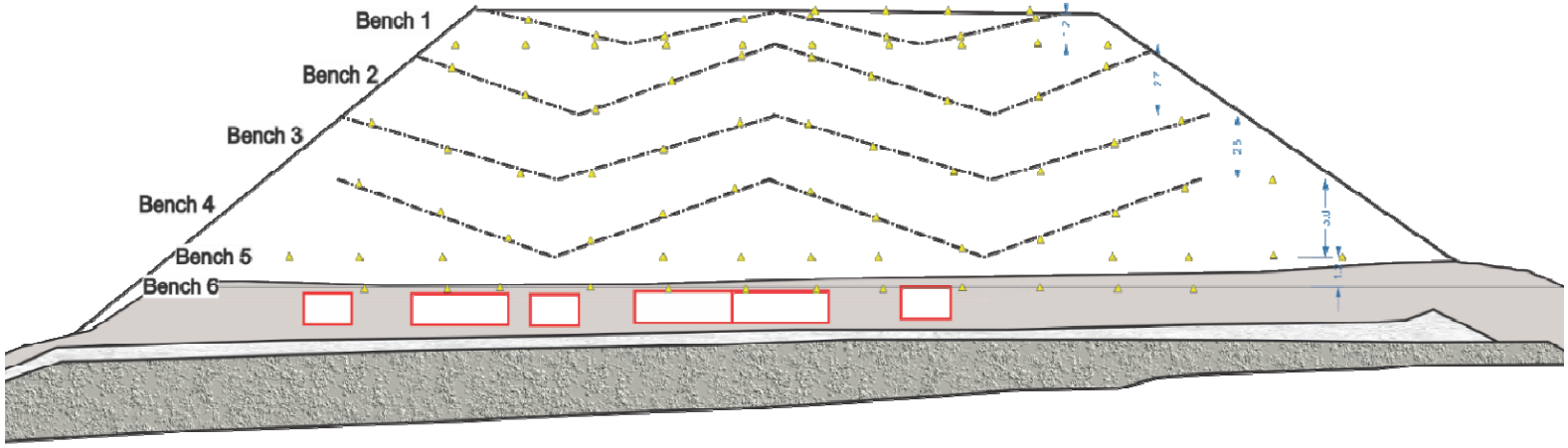
Type I Pile: Deconstruction



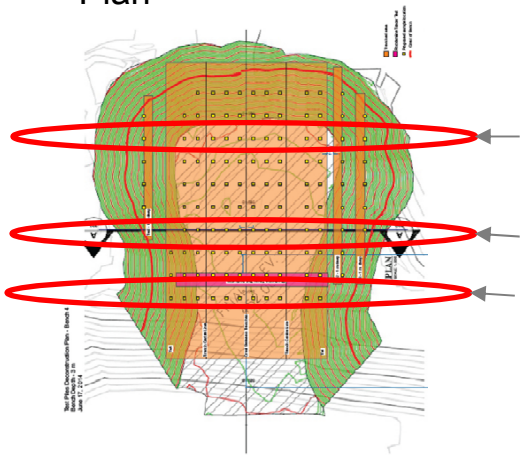
Sinclair, 2014

Type I Pile: Deconstruction

West – East Cross Section



Plan



35 m Profile

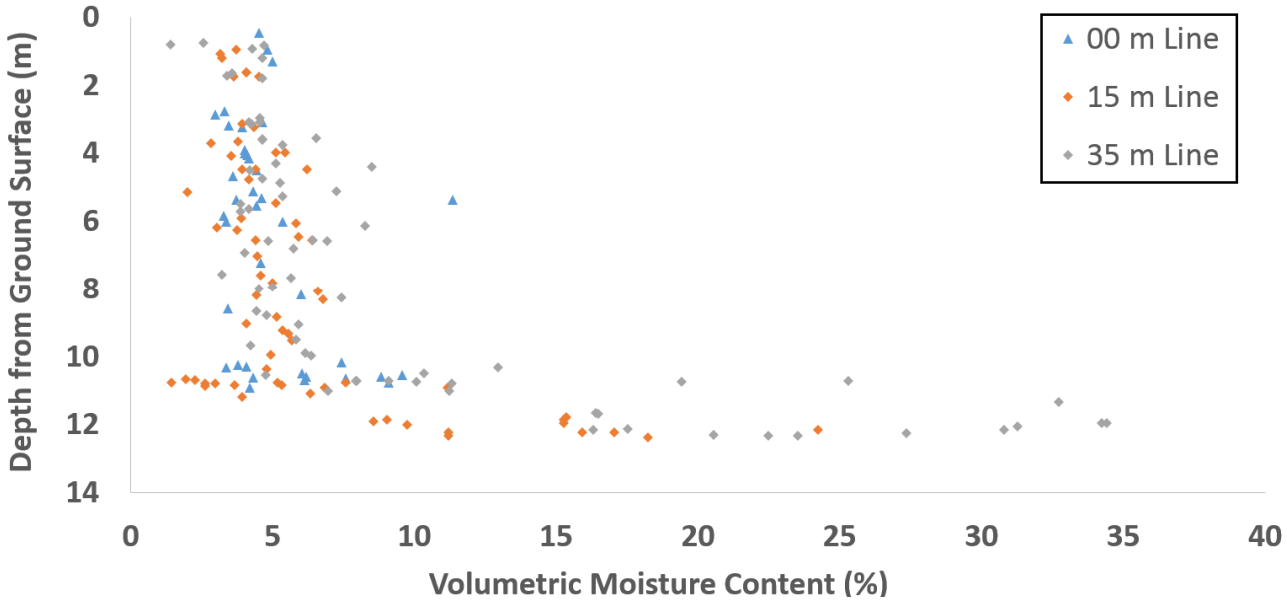
15 m Profile

0 m Profile

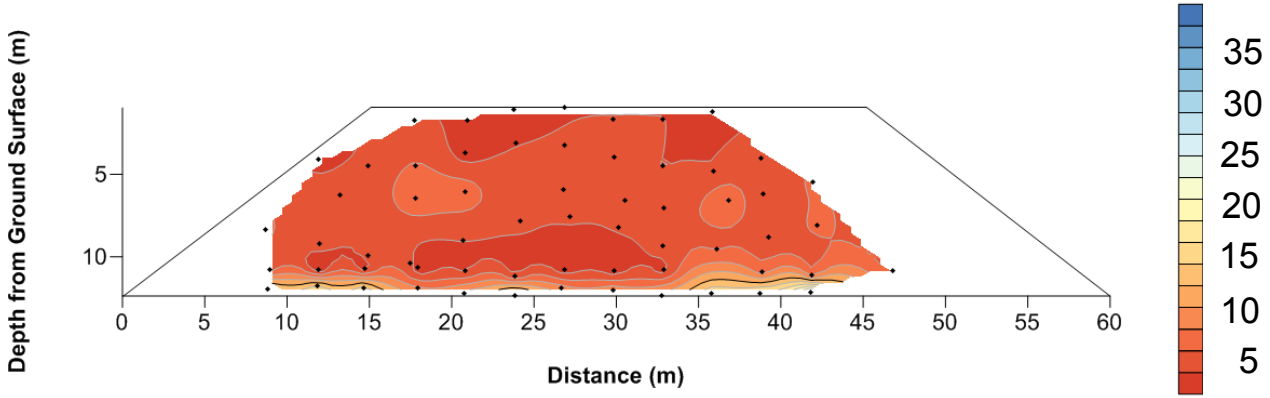
- Approximate Trench Sample Location
- Approximate Trench Location
- Basal Collection Lysimeter (BCL)
- Type 1 BCL cover
- 2" Type 1 Crush over Geomembrane
- Coarse PK

Atherton, 2015

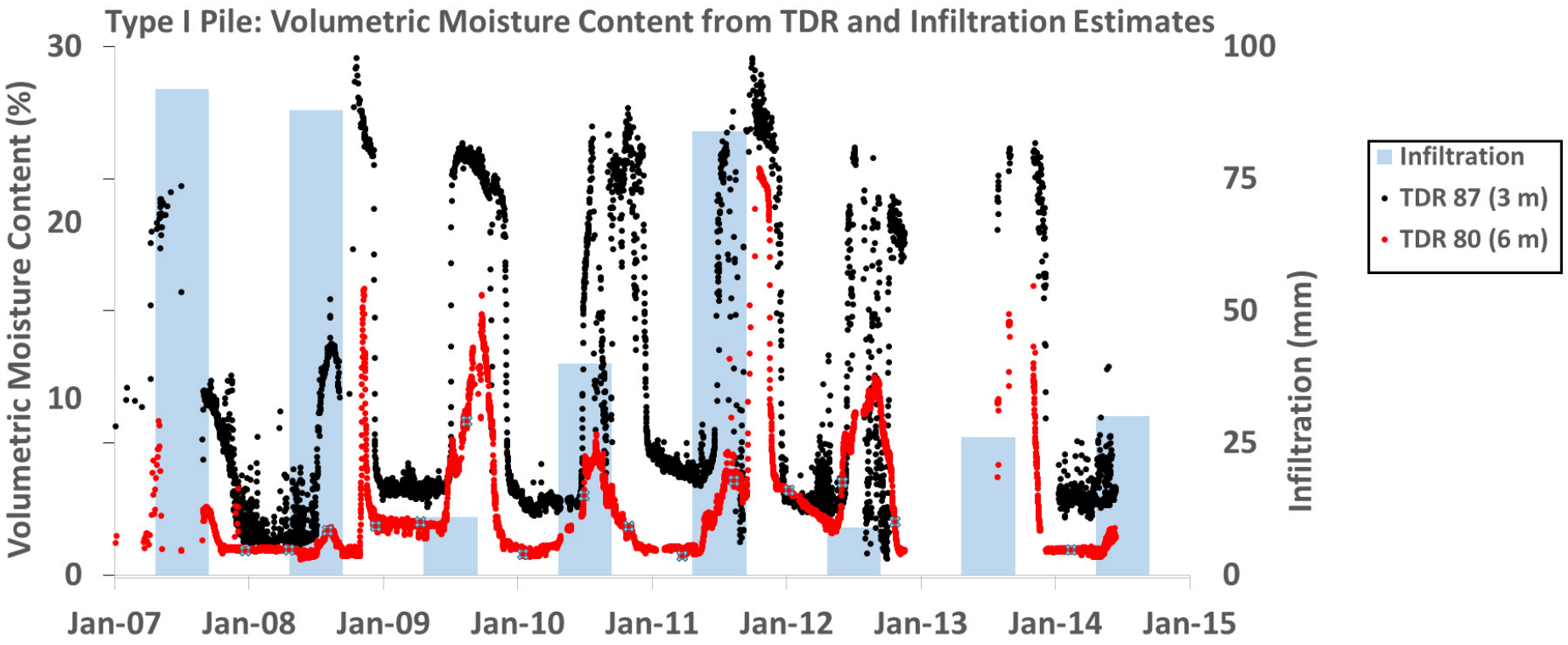
Type I Pile: Volumetric Moisture Content



Cross section through 15 m line



Type I Pile: VMC from TDR Probes and Infiltration



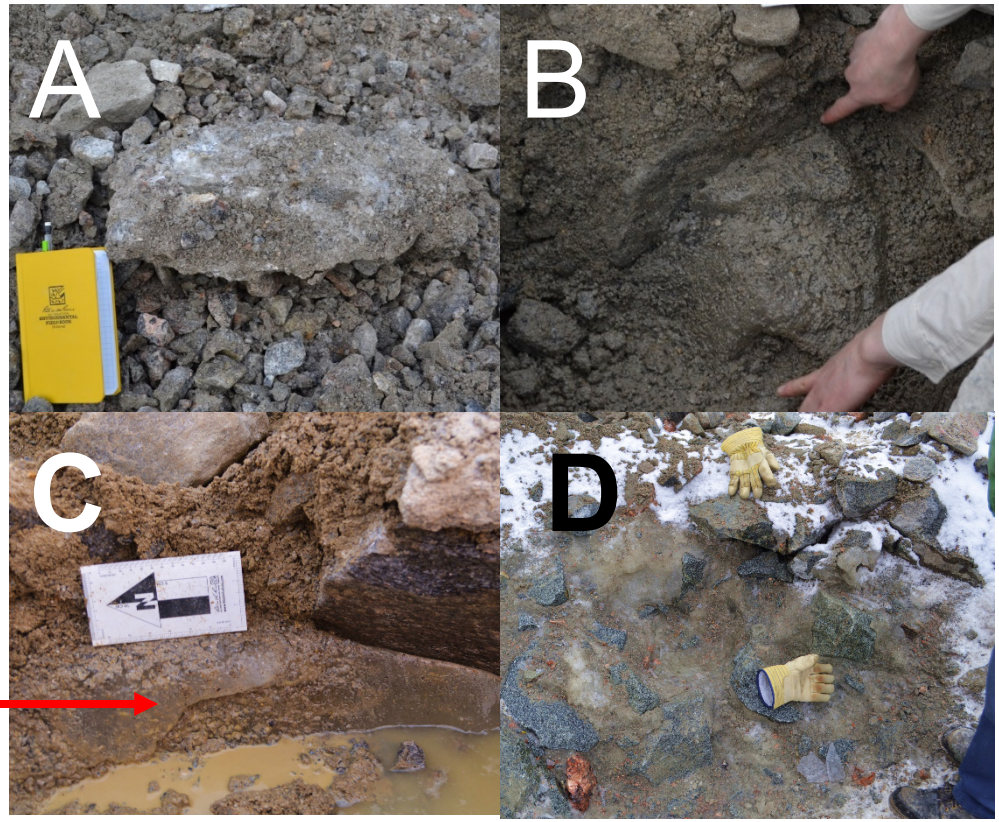
Type I Pile: Ice Characterization

A: Matrix Ice

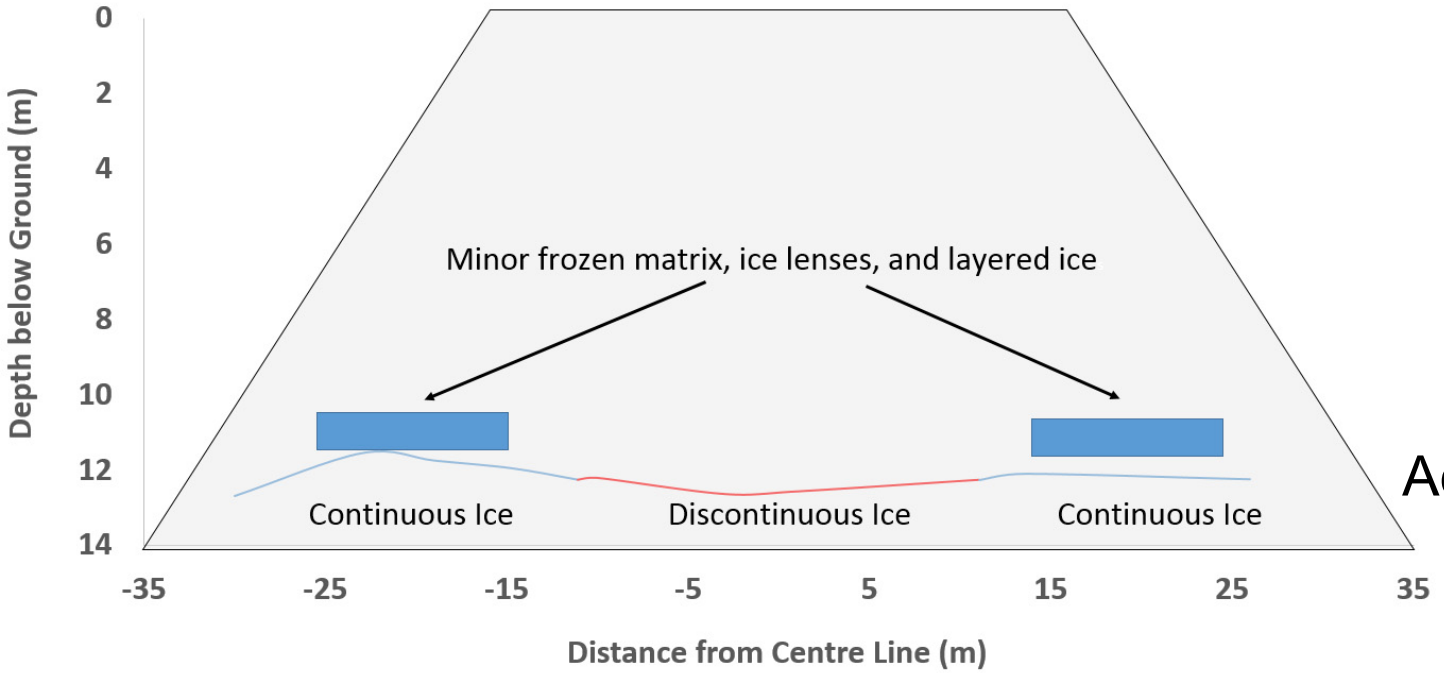
B: Ice lenses 10-30 cm

C: Ice lens with freeze thaw seam – Multi year ice

D: Continuous ice

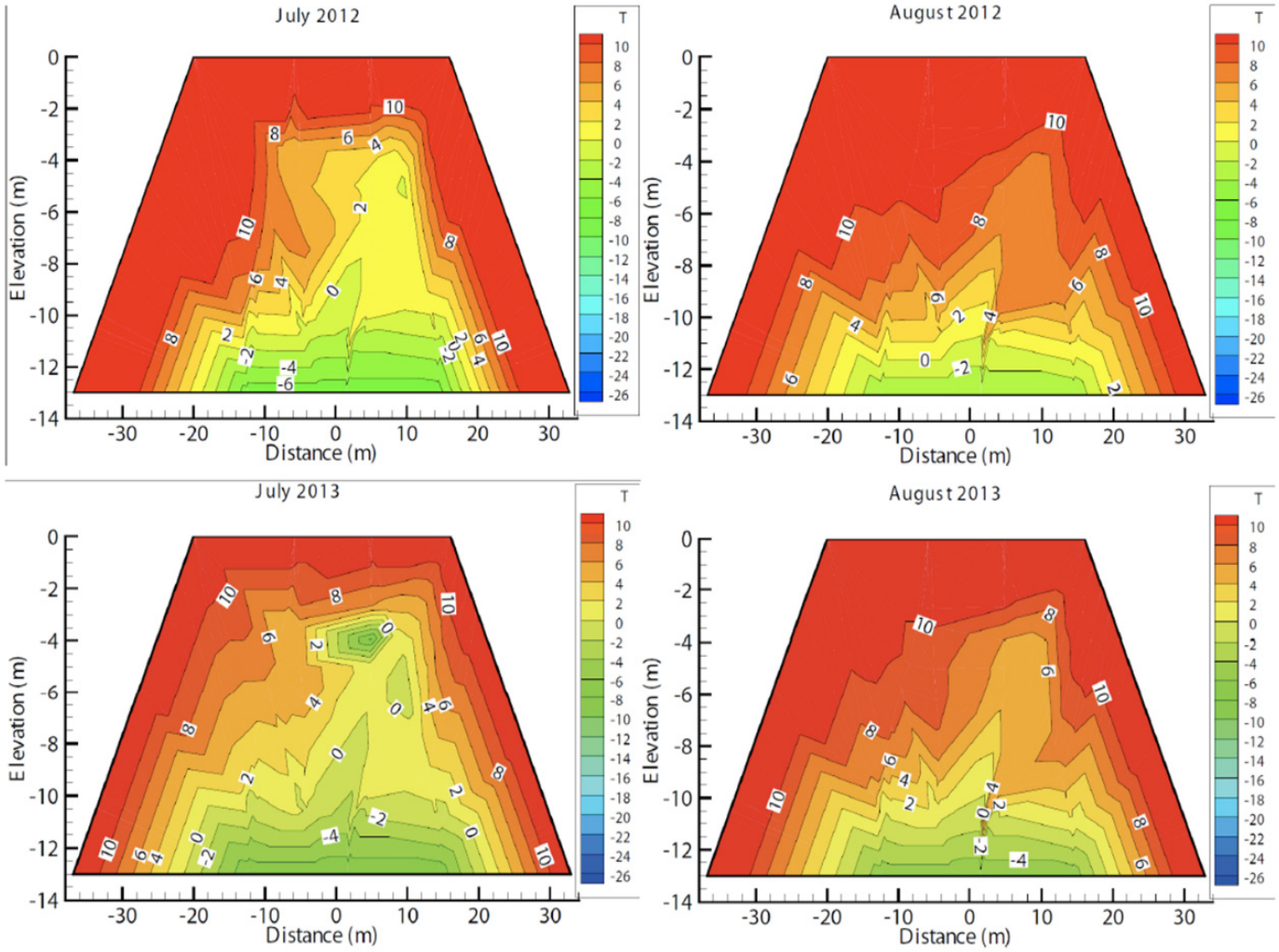


Type I Pile: Cross section of Ice Distribution in Test Pile



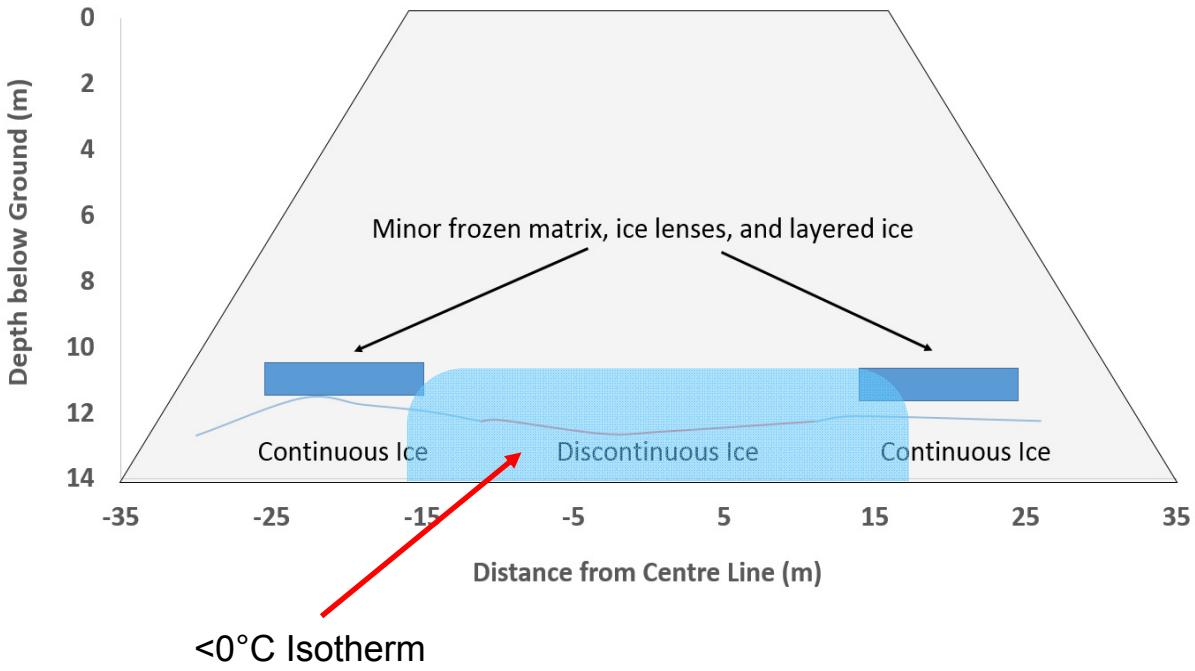
Active zone = 12 m

Type I Pile: Thermal Regime

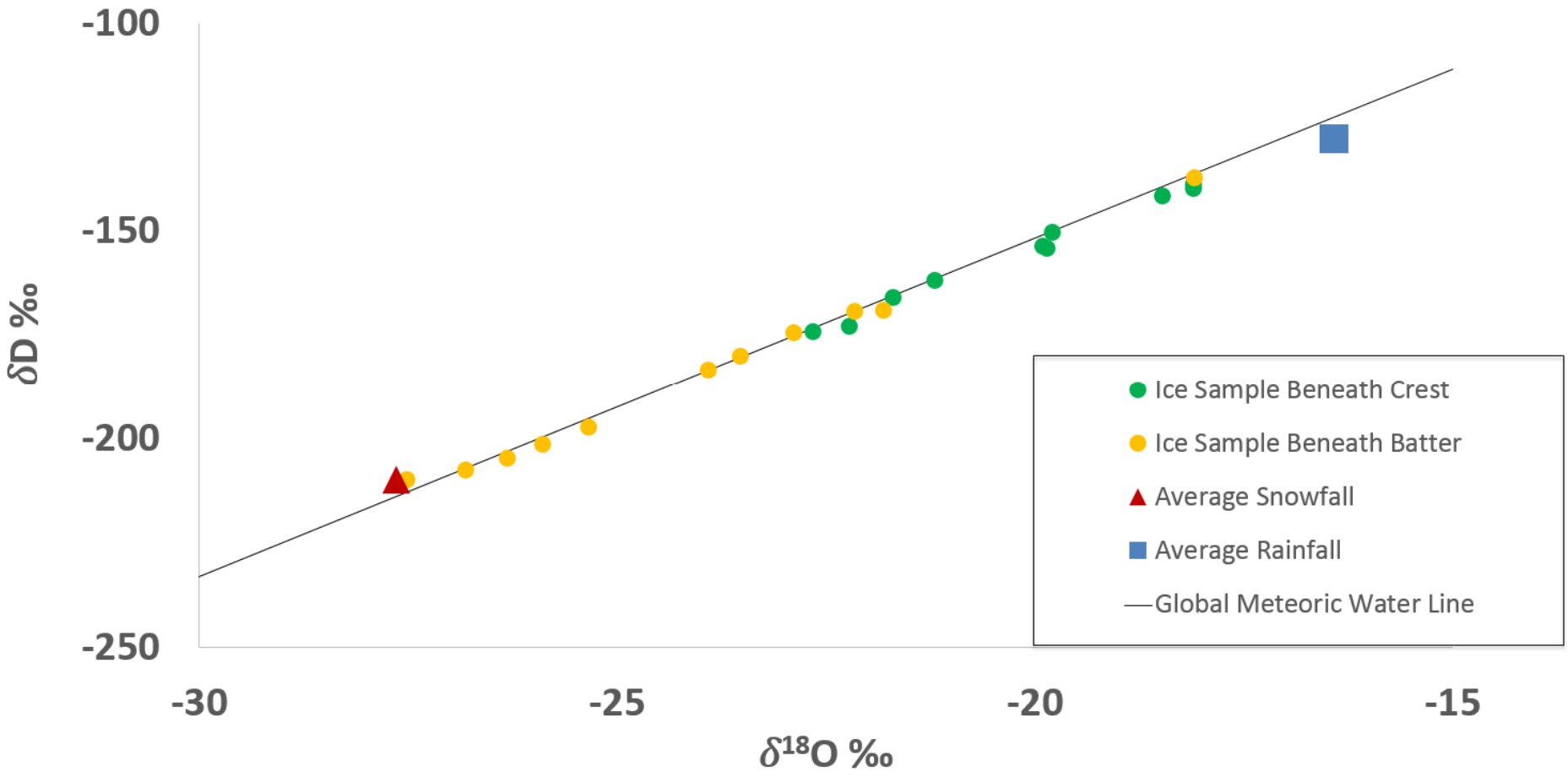


Type I Pile: Ice Characterization

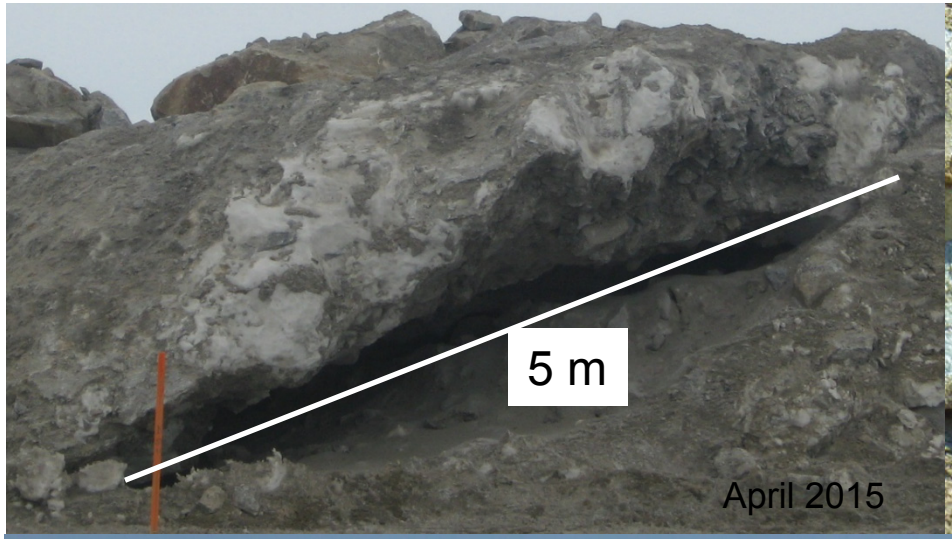
- The most significant ice accumulation is in areas which reach above freezing temperatures (0 – 6 °C)
- The batters are not thawed for long enough of a period to melt continuous ice
- Thawed matrix adjacent to ice lenses in batters suggests matrix ice is first to melt, creating the potential for water to be transmitted

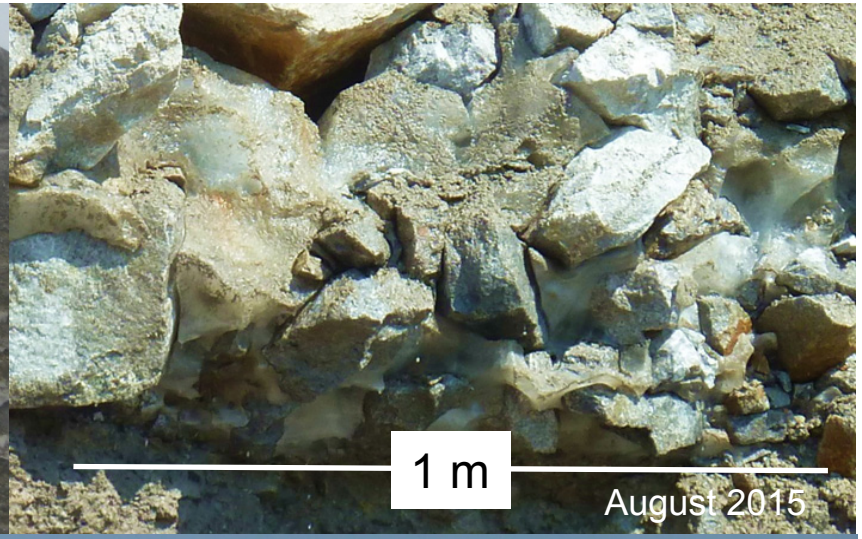


Type I Pile: Ice Isotopic Characterization

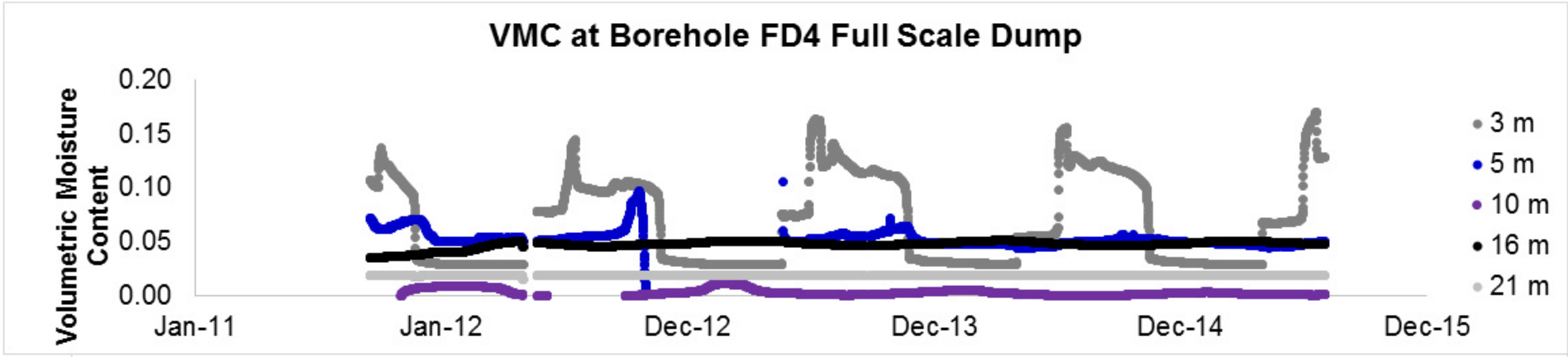


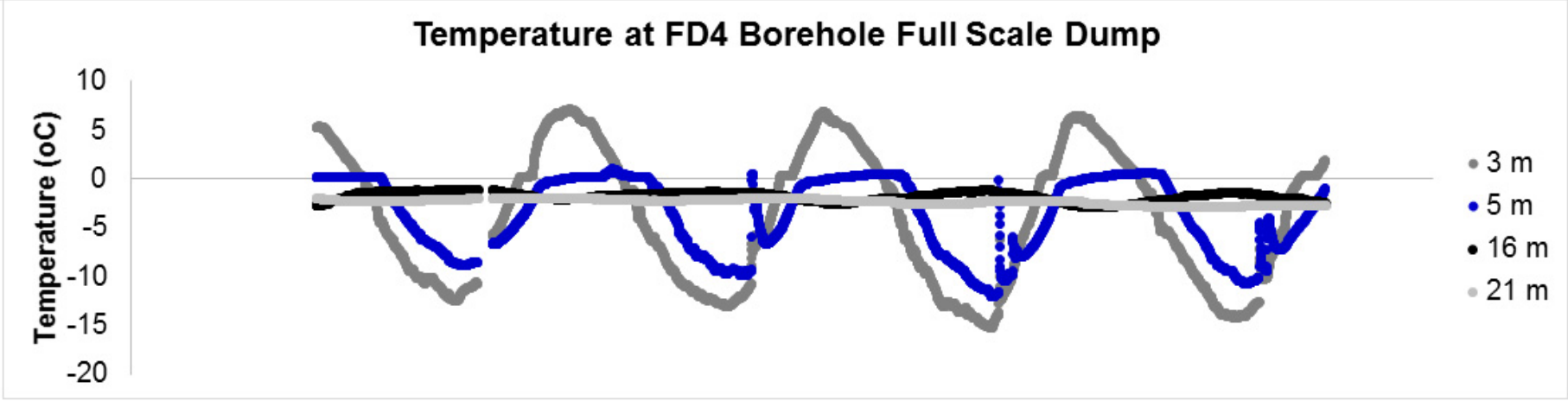
Full Scale Pile: Ice Characterization





Full Scale Pile





Summary

- 14 m tall uncovered test pile required a wet-up time of 3 years as indicated by volumetric moisture content and outflow from basal collection lysimeters
- Pore water moves at a velocity of 1-2 cm/day when thawed
- Average transit time of the more mobile pore water within test pile is approximately 2.3 active years
- A nine year record of a conservative tracer test has less than 50% mass recovery
  - Low velocity flow paths
  - Potential complication by ice accumulation

Summary

- Moisture contents during deconstruction were in agreement with TDR probes, supporting historic data
- Significant ice accumulation is able to remain in areas of the active zone during the late summer
- Ice is continuous beneath the batters of the pile and discontinuous beneath the crown where infiltration is limited
- Characterization of ice and behaviour of moisture in the full scale pile are similar to observations from test piles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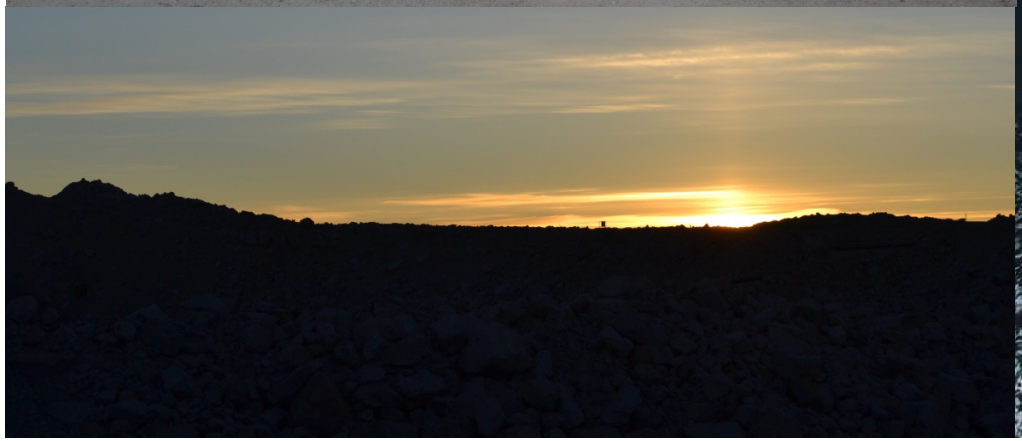

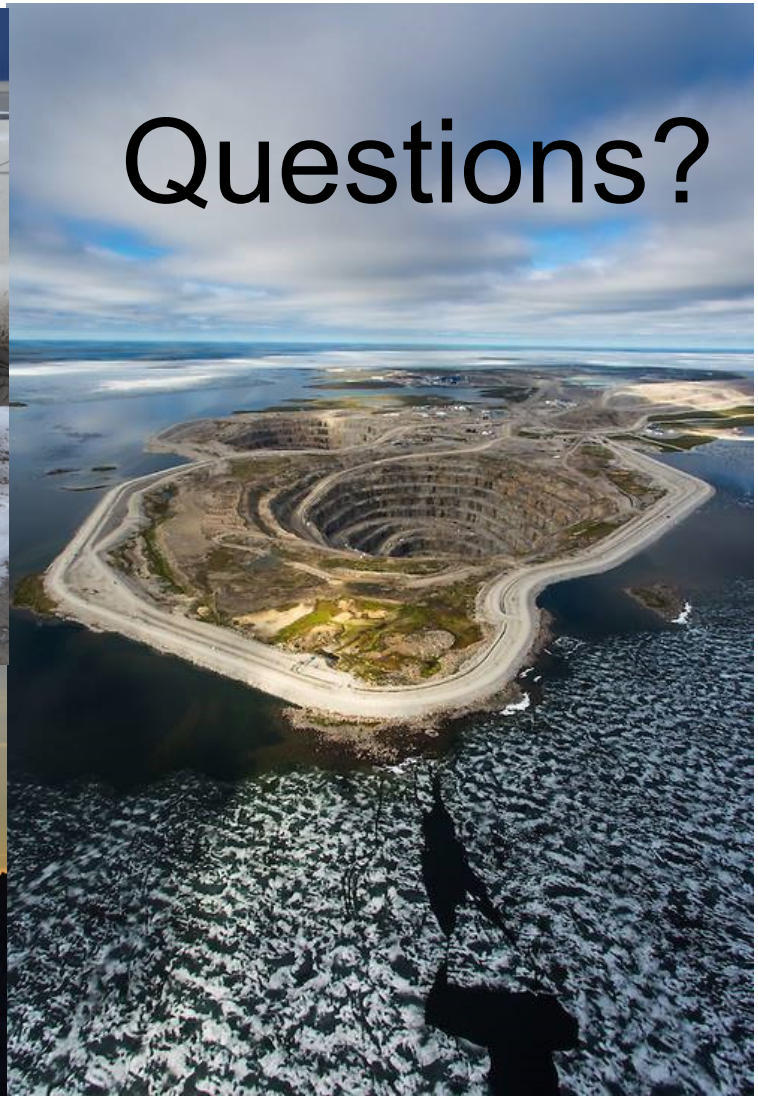
Questions?