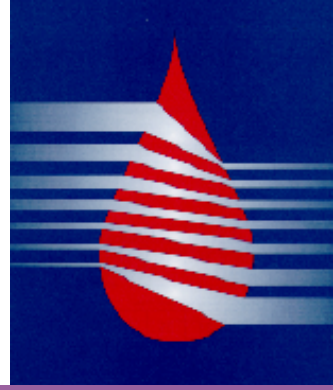
BC-MEND Metal Leaching and Acid Rock Drainage Workshop



December 1 - 3, 2020 | Vancouver, British Columbia, Canada | Zoom Conference

A Case Study of the Influence of Shorter Tips in Mine Rock Storage on Internal Air Flow Capacity

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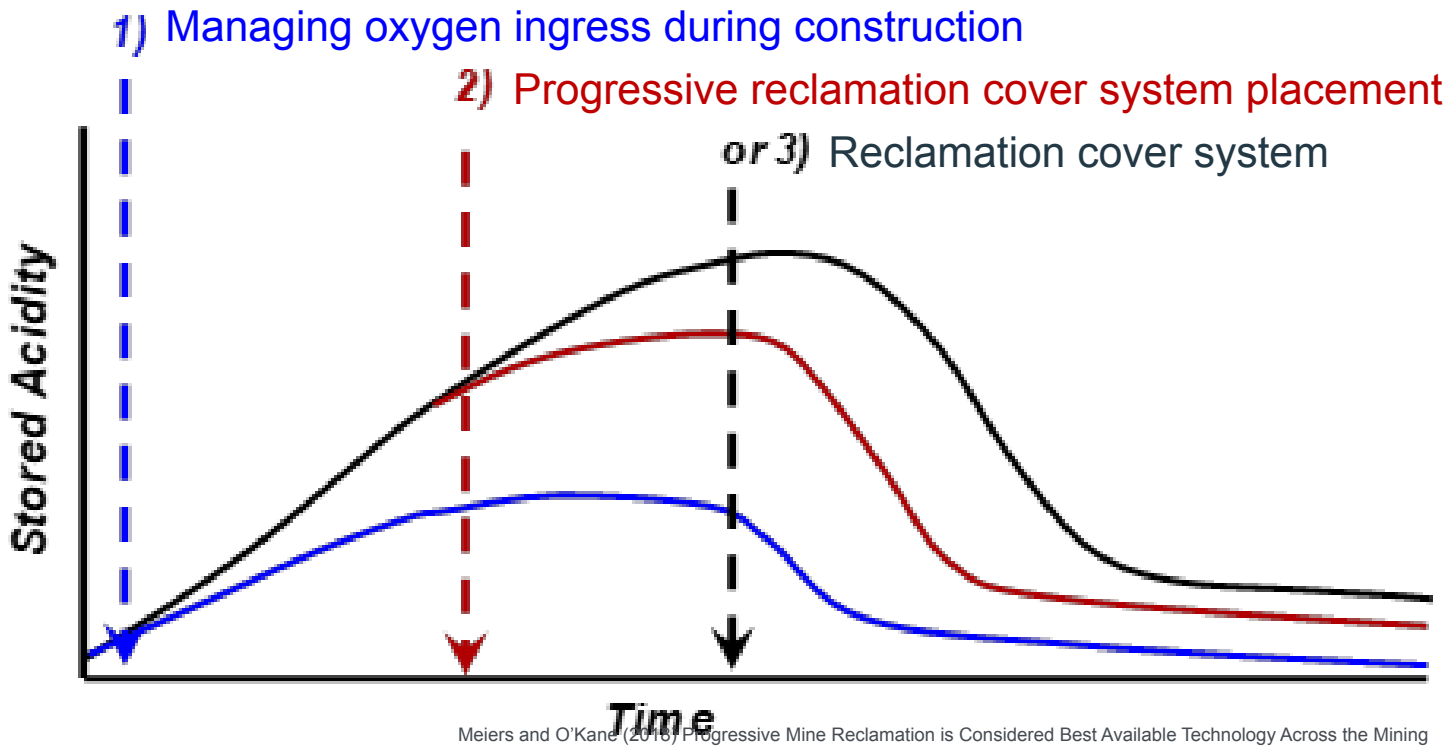
December 3, 2020

Presentation Discussion Points

- The concept of managing air flow and mitigating ML/ARD during construction
- Mine rock storage facilities (MRSFs), How do they function
  - Air flow
  - Water flow
- MRSF geometry
- Strategies for managing air flow
- Blind Case Study – MRSF constructed with short tips
  - Internal conditions and observed ML/ARD
- Summary and discussion points

The Concept of MRSF Design

- The benefit of reducing the generation of stored oxidation products (load) during MRSF construction / operations:
  - Manage the risk now… when there is less uncertainty (consider License to Operate, stakeholders, investors, environmental regulations, etc); and
  - Less reliance on managing oxygen and net percolation with final closure cover system

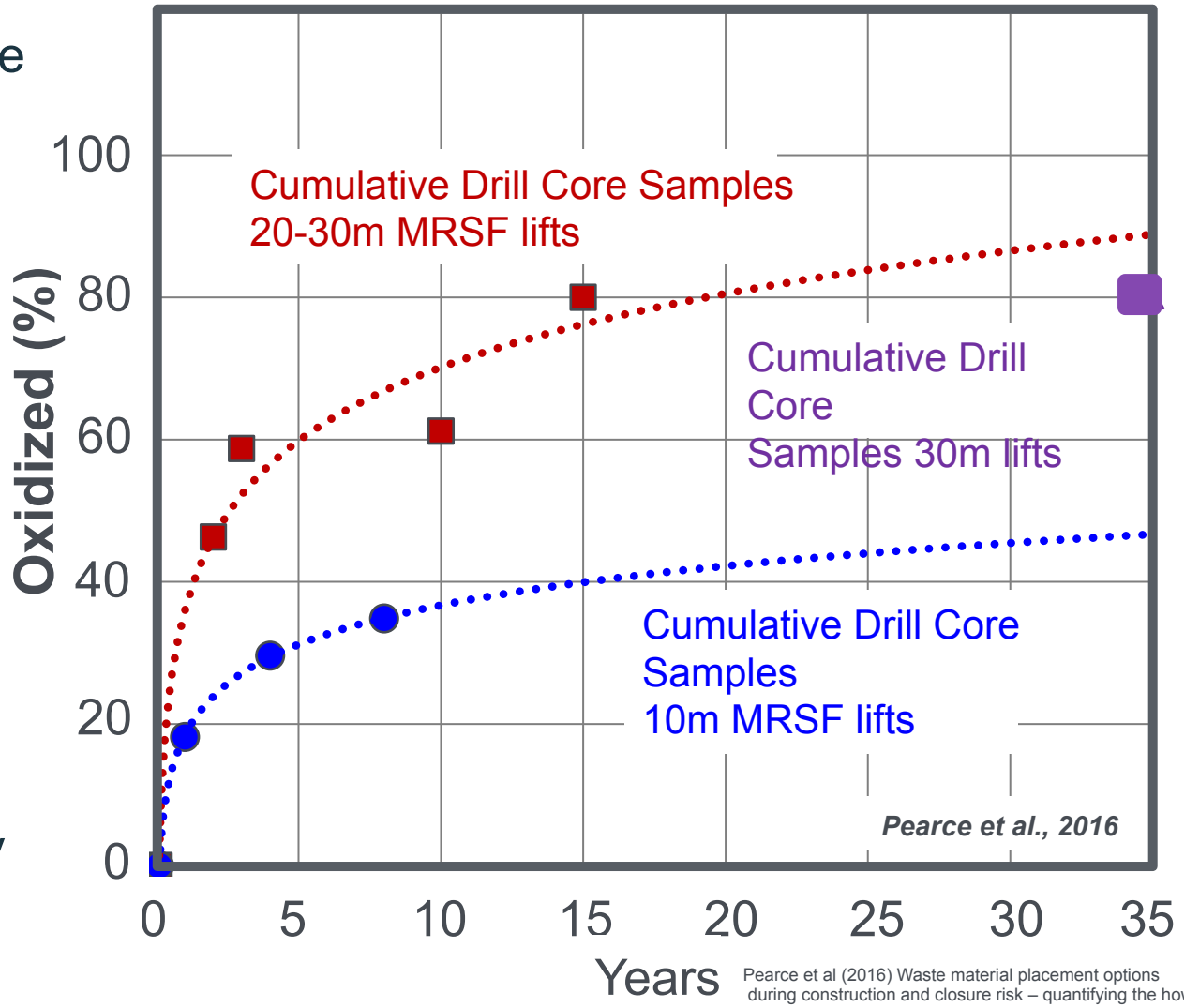


Meiers and O'Kane (2016) Progressive Mine Reclamation is Considered Best Available Technology Across the Mining Industry…
How can we enhance this practice to include Mine Rock Dump Design. Planning for Closure, Santiago, Chile. November 7-9.

The Concept of MRSF Design

- MRSF structure influence oxidation rate and hence stored acidity
- Oxidation rate greater early during construction

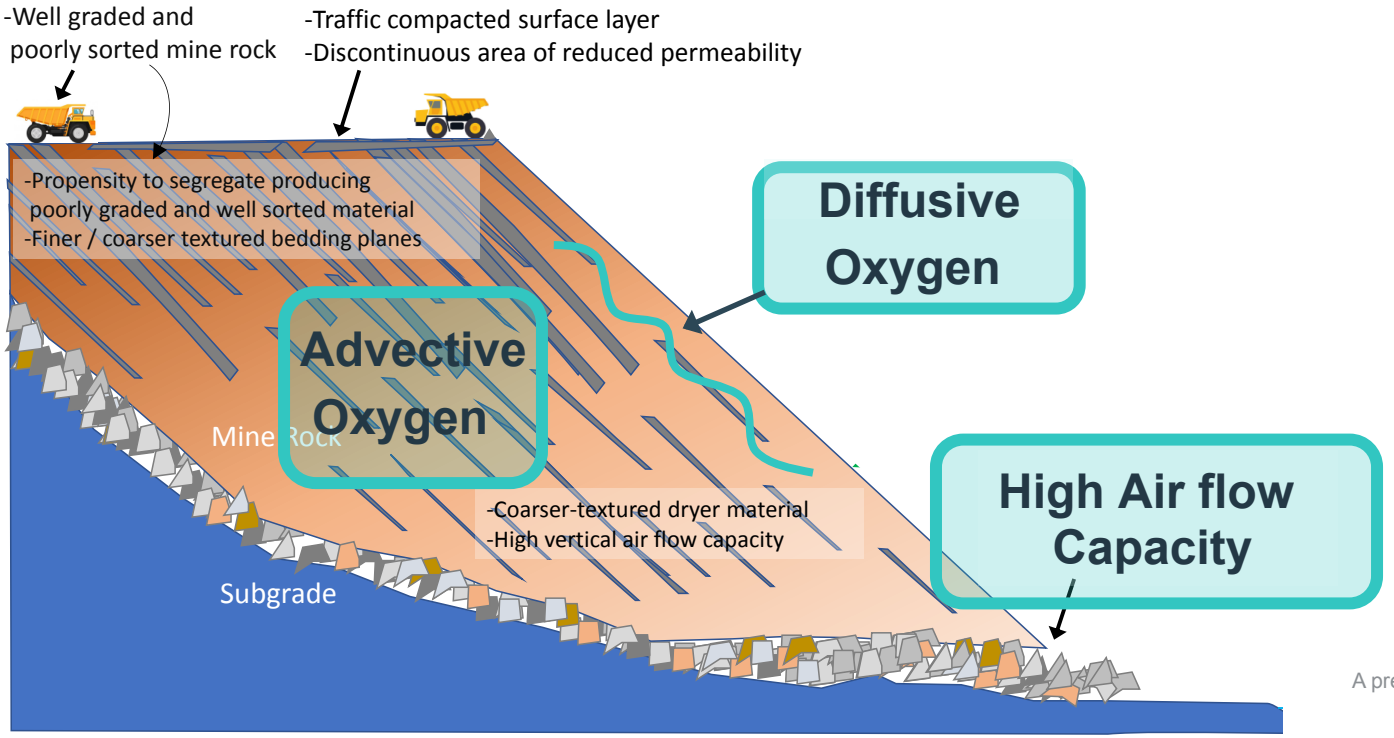
- Aspects for closure:
  - Water quality
  - Cover system performance criteria O2/H2O
  - Framing laboratory geochemical characterization



Pearce et al (2016) Waste material placement options during construction and closure risk – quantifying the how, the why and the how much. Mine Closure 2016. Perth Australia.

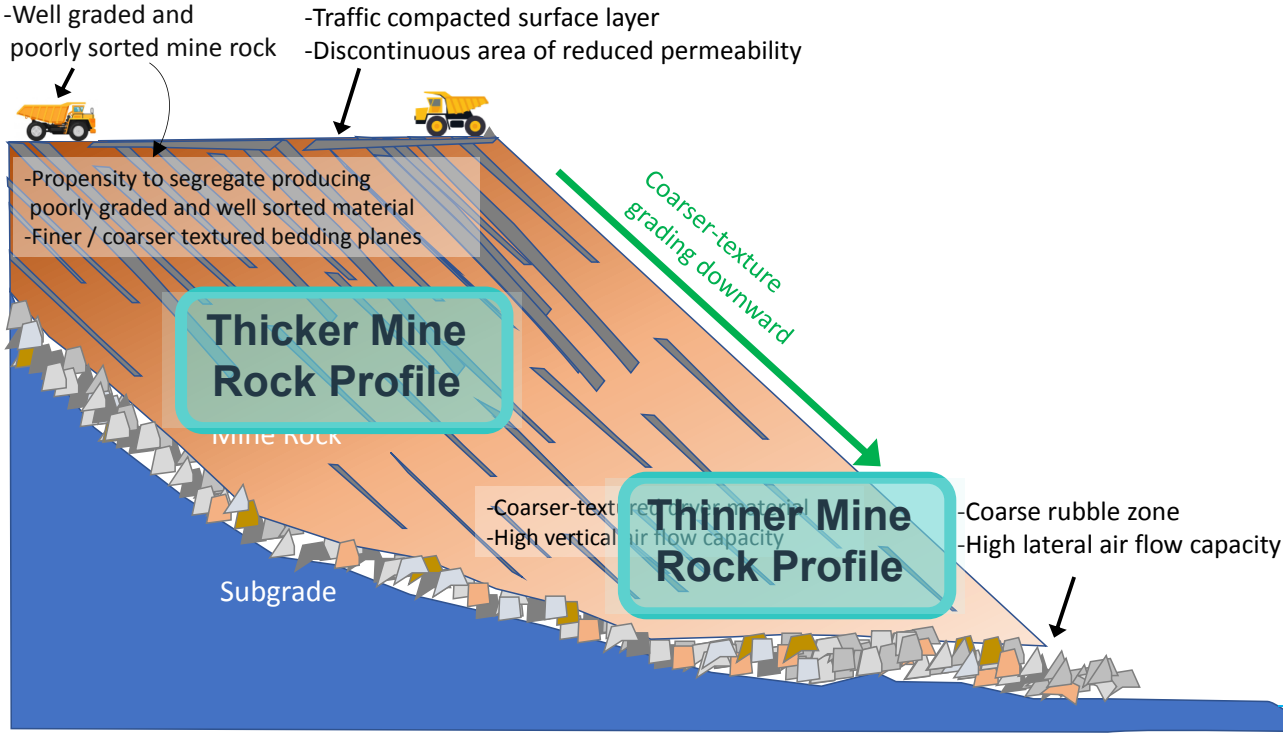
MRSFs, How Do They Function - Air Flow

- Advective air flow driven by differential pressure
  - Internal heating (exothermic heat release)
  - Climate (diurnal and seasonal)
  - Gas Composition (density)
  - Wind
- Diffusive oxygen ingress is less than advective… but linked to mine rock placement method and surface area



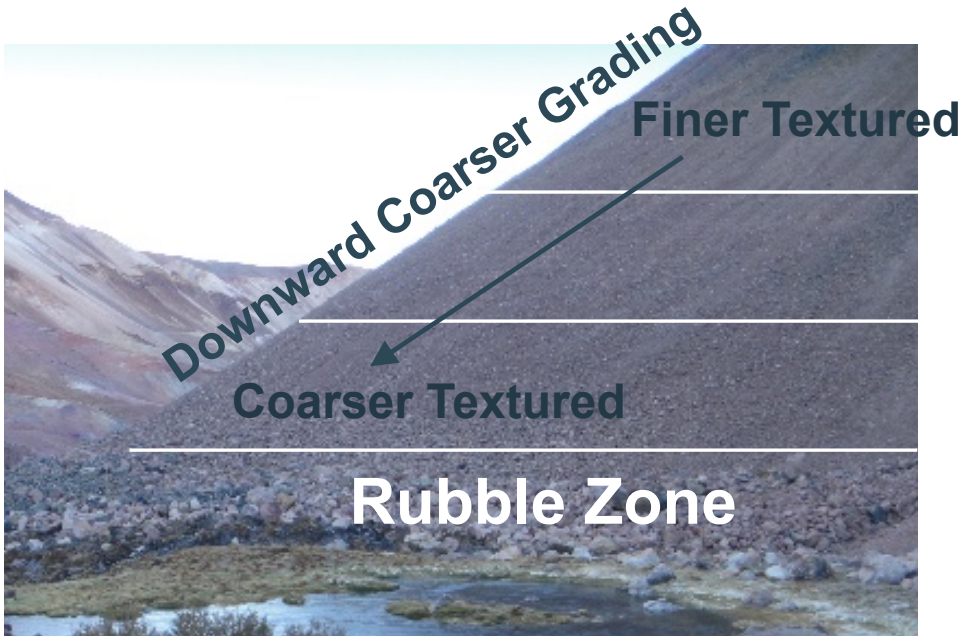
MRSFs, How Do They Function - Water Flow

- Basal Seepage: Understanding MRSF Water Storage Capacity / Wetting Up Period is critical in understanding loading
  - When is basal seepage expected to initiate and anticipated period to peak flow. Inform on collection and treatment
  - Increase confidence in current water quality and flow rates (load)



MRSF Geometry

- Segregation during placement, related to tip height and material texture.
- Structure provides high air flow capacity
  - Coarse rubble zones at base of tip
  - Coarser downward grading



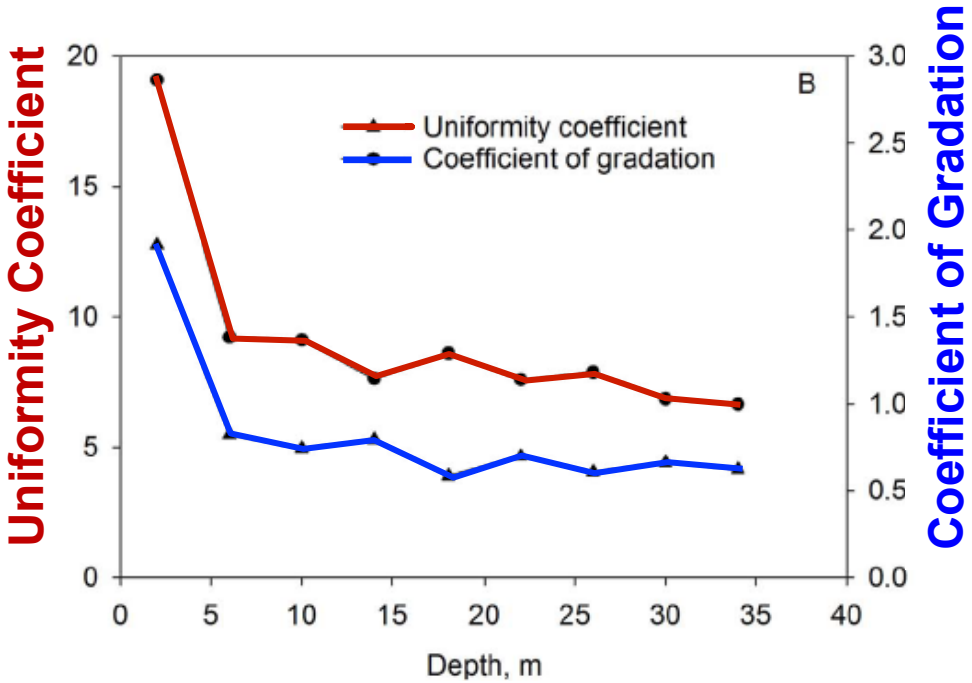
MRSF Geometry – Downward Grading

Coarser downward grading, related to tip height and material texture…

- Site in the Chile, high elevation, dry conditions (Zhang and Liu 2017)
- Project to support operational performance of heap leach and water flow
- Reported greatest decrease in *Uniformity Coefficient* and *Coefficient of Gradation* over the surface to 5 m depth interval

What else effects segregation…
climate, water content

- Greater placed water content can increase cohesive nature, increasing tip face angle, and…. segregation/sorting



Zhang, S., Liu, W. 2017. Application of aerial image analysis for assessing particle size segregation in dump leaching. Hydrometallurgy. 171:99-105.

MRSF Geometry – Sorting and Segregation

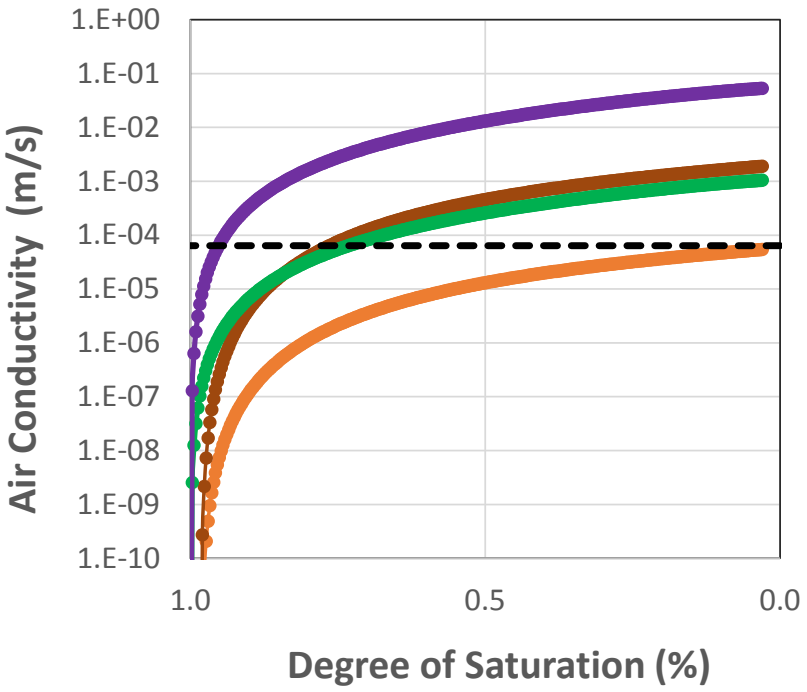
- Segregation and sorting of grain sizes
  - Well-graded mine rock end tipped provides segregation and “sorting” of the gain sizes
  - In general, segregation is observed at tip heights greater than 4 to 6 m (Wilson 2011) but material dependent
  - Rule of thumb threshold of >50% passing the 2.3 mm grain size for materials in “limiting” air flow… but need to consider climate, degree of saturation, geochemistry

Textured Bedding plains

Wilson, W. 2011. Rock dump Hydrology: An overview of full-scale excavations and scale-up experiments conducted during the last two decades. Seventh Australian Workshop on Acid and Metalliferous Drainage

MRSF Geometry – Managing Air Flow

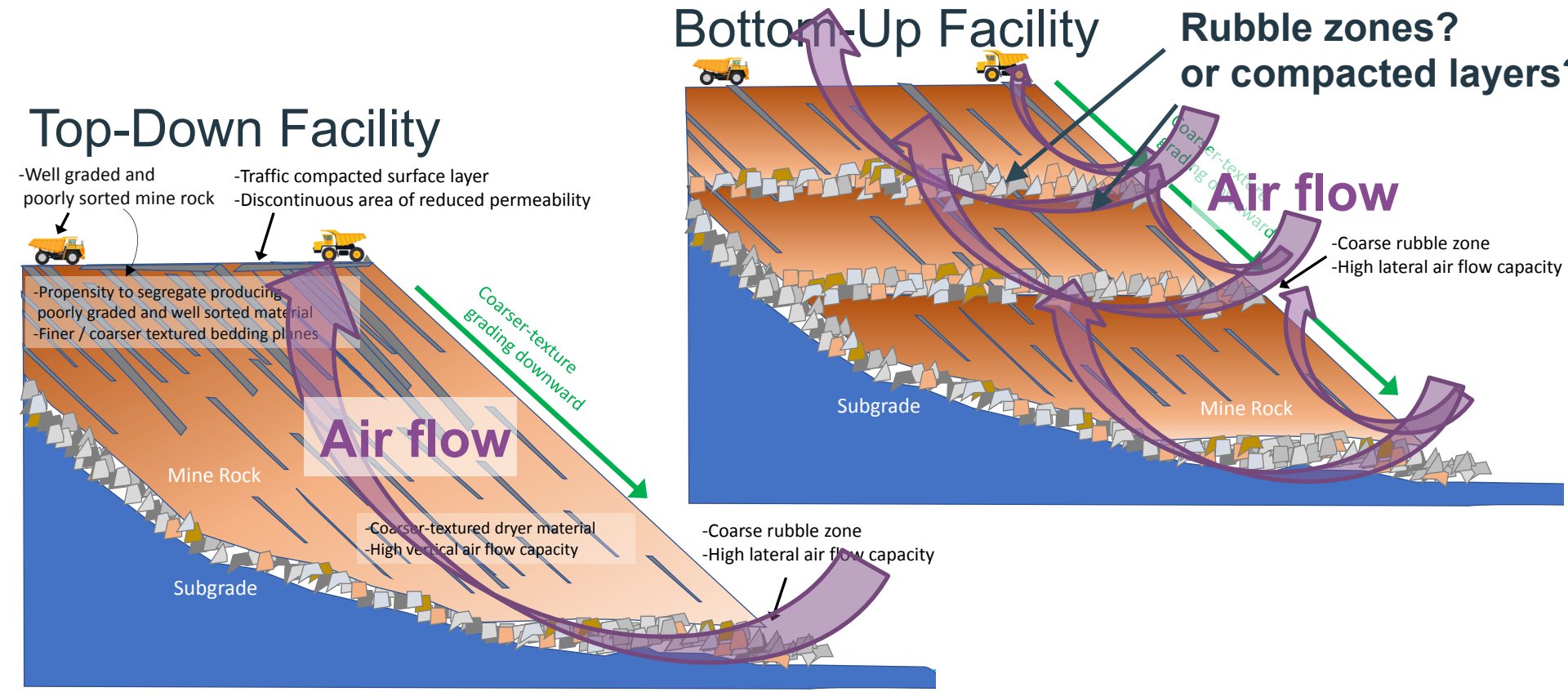
- How might different mine rock placement methods relate to managing air flow supply?
- Can we rely on short tips as sole means of managing ML/ARD…?
  - Will shorter tips need to be coupled with alternate method…?
  - Will different placement strategy meet criteria for air flow…?



Oxygen Ingress Limit

MRSF Geometry – Shorter Tip Heights, the Concept

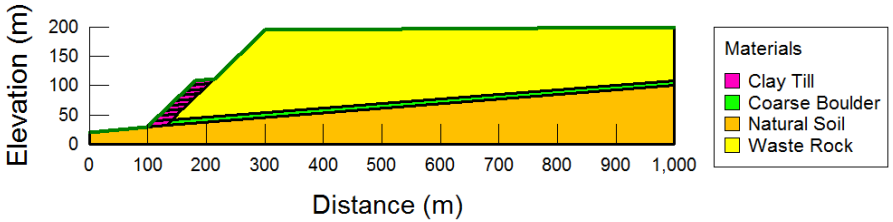
- When utilizing shorter tips, what are we constructing:
  1. Traffic compacted layers and reduced vertical air flow; or
  2. Increased lateral air flow capacity, more rubble zones



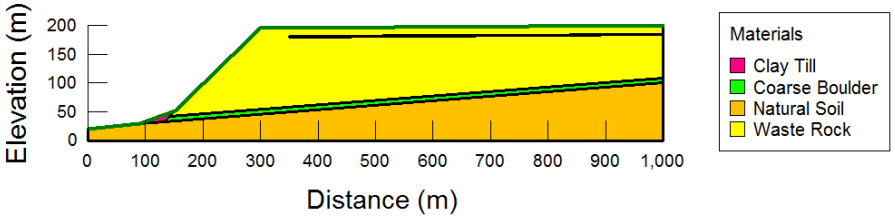
Managing Air Flow – Strategies

- Strategies for managing air flow include reducing vertical and lateral air permeability
- Not limited to 1) tip height, 2) engineered layer, 3) toe berms 4) encapsulation
  - Final reclamation cover system

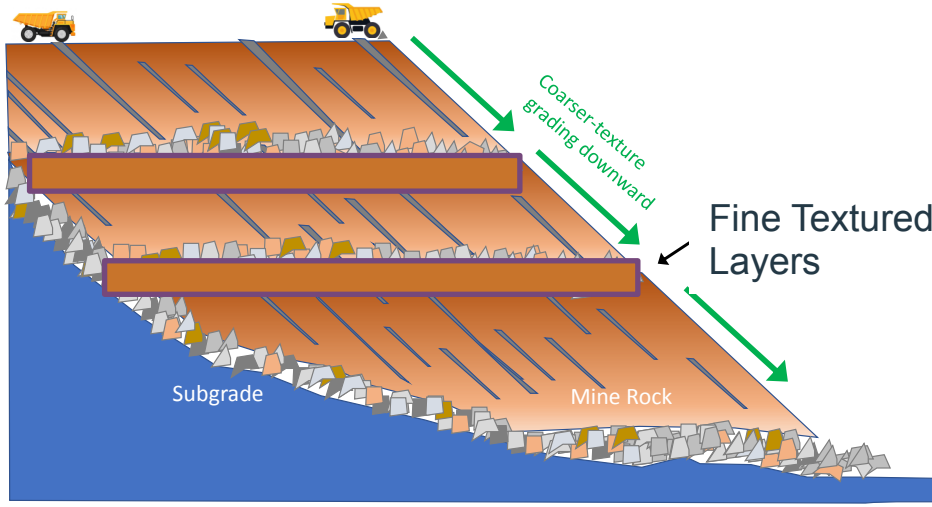
Toe Berm



Top Engineered Layer



Engineered Layers



Meiers et al (2018) Including mine rock facility design to enhance progressive reclamation. BC TRCR

Case Study – Site and Location

- Mine site located in Quebec, Canada
- Northern temperate climate
  - Koppen-Geiger Climate – Cold, Without Dry Season, Warm Summer (Dfb)
- Annual precipitation is ~850 mm
- Average annual air temperature ~0^{o}C
- Average summer and winter temperatures ~15^{o}C and -17^{o}C

Case Study – MRSF Geometry

- MRSF operated for approximately 15 years
- Contains approximately 34M tonnes of mine rock
- Footprint of ~62 ha and height of ~50 m
- Constructed primarily in 5 m lifts but up to 10 m
  - Strategy was to shed precipitation to delay basal seepage and mobilization of oxidation products. Assumed finer textured traffic layers were desired
- Slopes reclaimed to 3:1
- Limited MRSF biographical information

Case Study – Cover System

- Reclaimed with a fine textured Evapo-Transpiration cover system, nominally >1m thick, constructed over a two-year period following operations
- Fine textured
  - 40% silt and trace clay;
  - 55% sand; and
  - 5% gravel
- Net percolation estimated at 25% to 50% (~200 to 400mm/yr) of precipitation based on climate and estimates from INAP 2017
  - Likely closer to 400mm

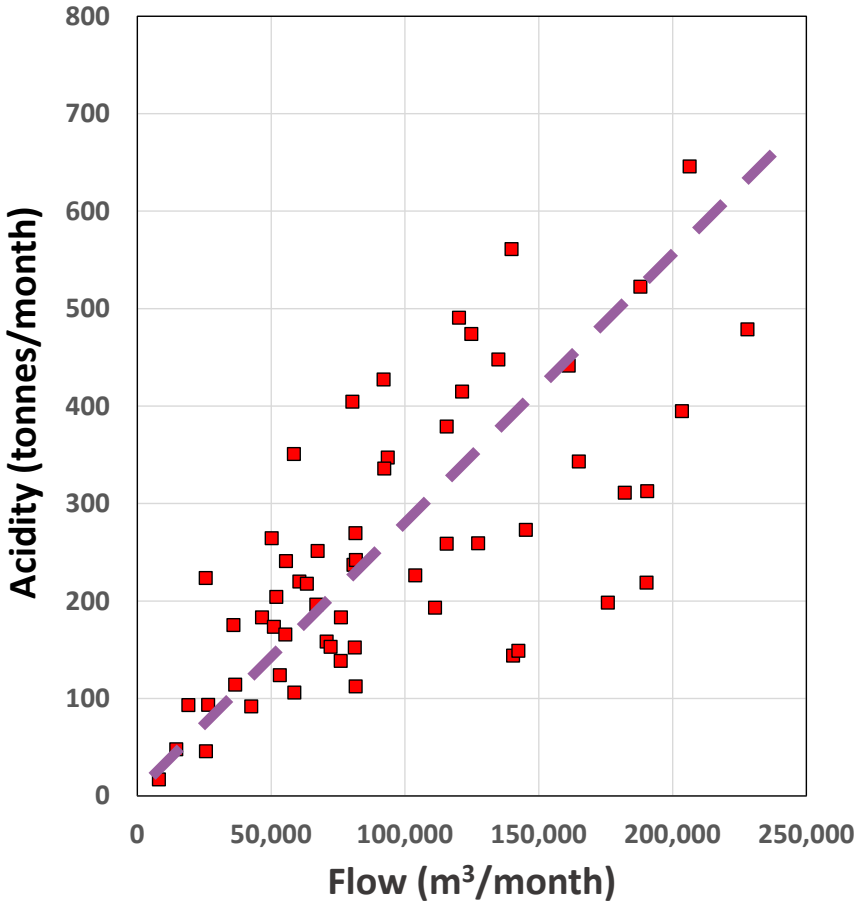
International Network for Acid Prevention (INAP) 2017. Global Cover System Design Technical Guidance Document

Case Study – Mine Rock

- The Mine Rock consists of rhyodacitic breccia, welded acid tuffs and dacitic tuffs
- Acid generating
  - ~90% of waste rock samples having NPR <1
- Both coarser and finer textured mine rock observed in test pits

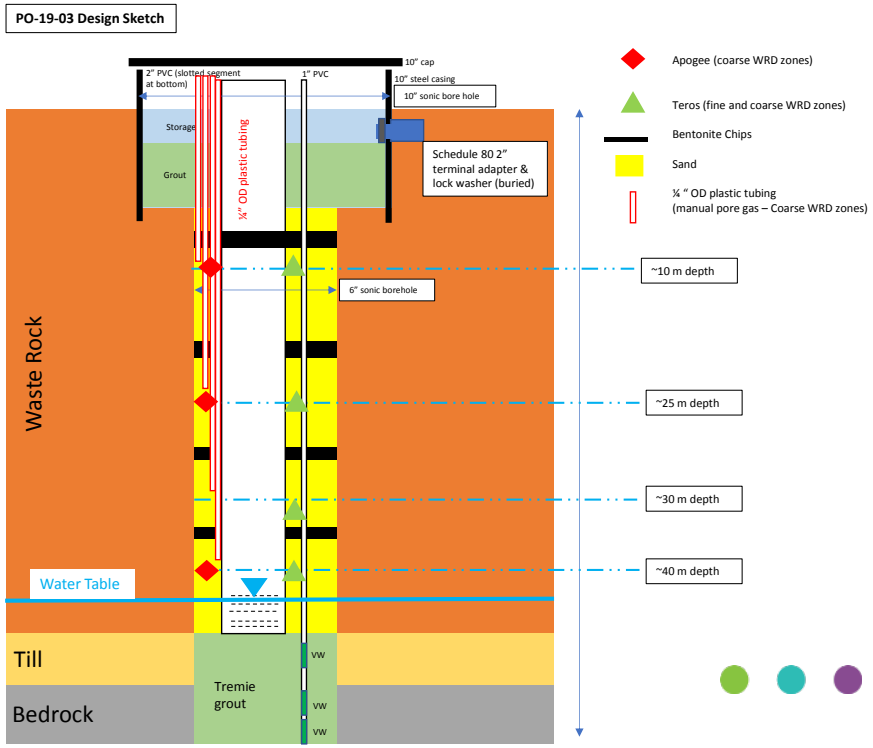
Case Study – Water Quality

- Seepage collected along the north side of the MRSF through a subsurface drain and collection ponds along the south side
- Seepage directed to a Water Treatment Plant
- Water Treatment Plant inflow
  - Acidity concentration about 2,300 mg/L to 3,800 mg/L
  - Annual load of acidity about 2,700 to 3,100 tonne year
- Trend in water quality suggests stored load of oxidation products and potential solubility based system
- Long-term treatment expected



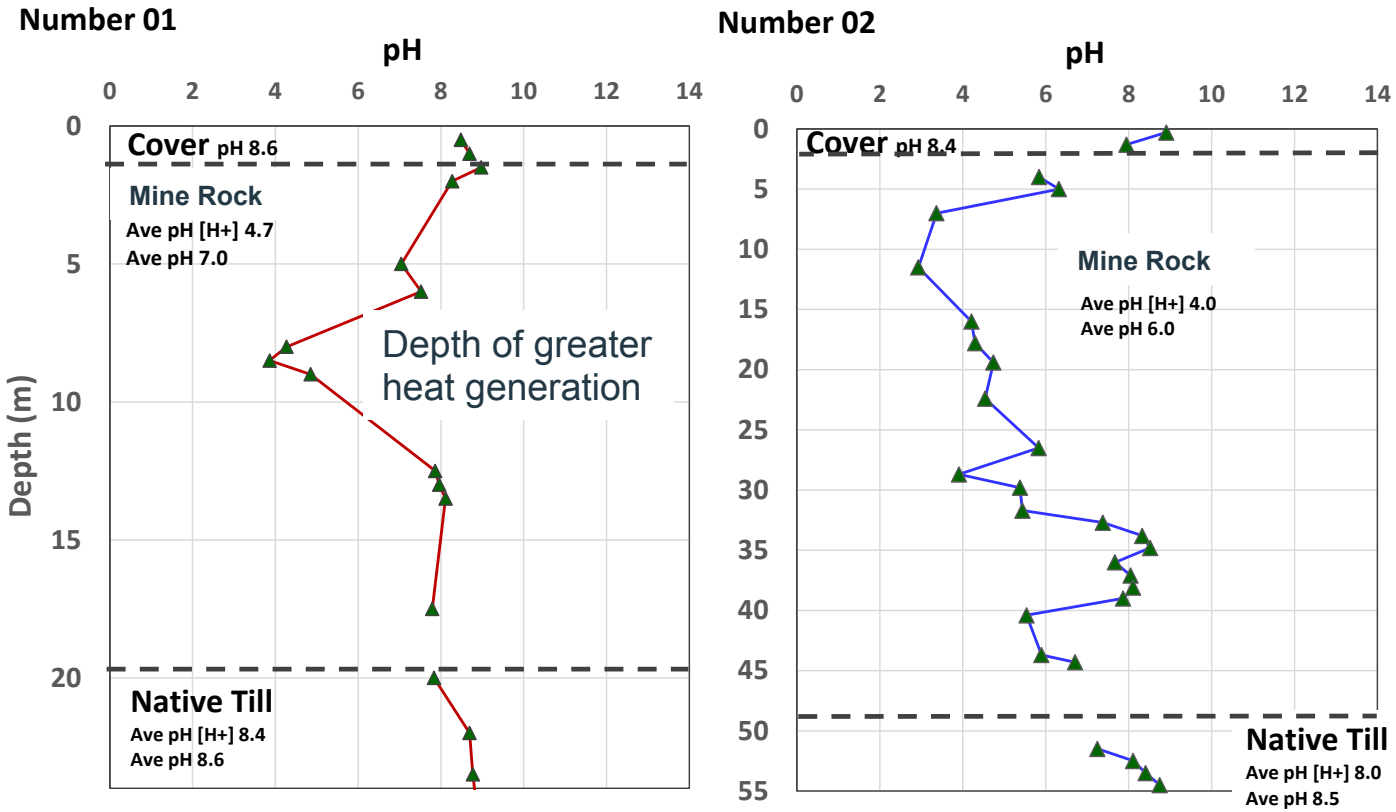
Case Study – MRSF Internal Conditions

- Material characterization and field monitoring program to inform on long-term ML/ARD
- Two sonic drill installations
  - Samples collection, limit recirculation contact waters
- Objective of program:
  - Characterization of geochemical conditions, water content, and texture
  - Provide automated in-situ:
    - Temperature,
    - O_2 and CO_2 concentration,
    - Differential pressure,
    - Matric suction



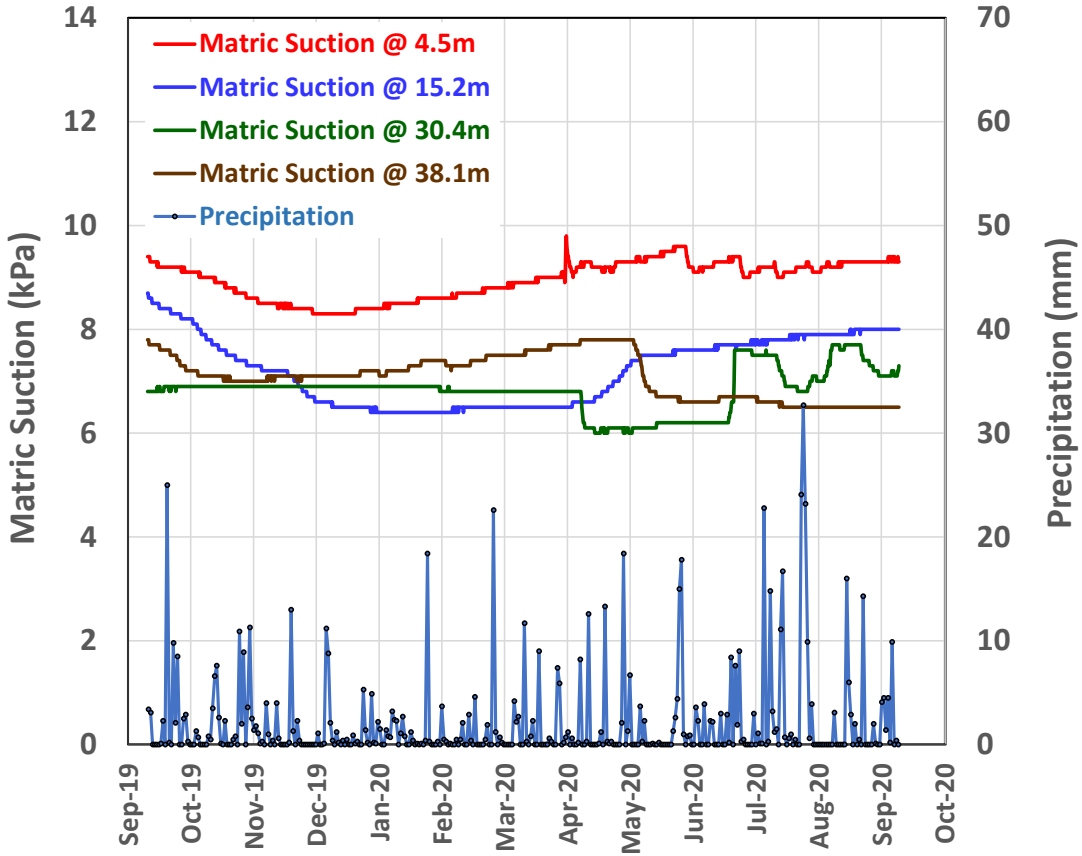
Case Study – Paste pH

- High proportion of samples are PAG (>90%) with observed acidic conditions in the profile
- Cover and till subgrade maintains alkaline conductions



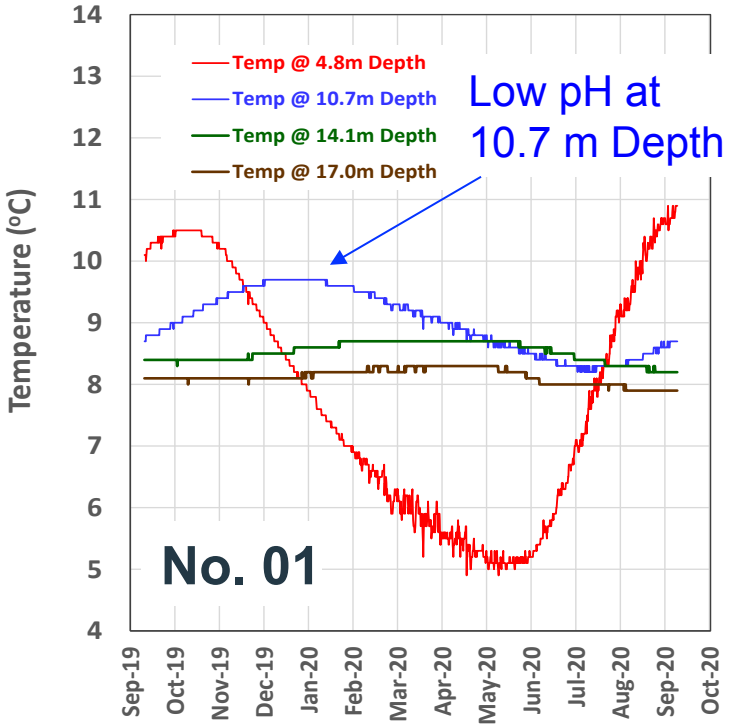
Case Study – Matric Suction

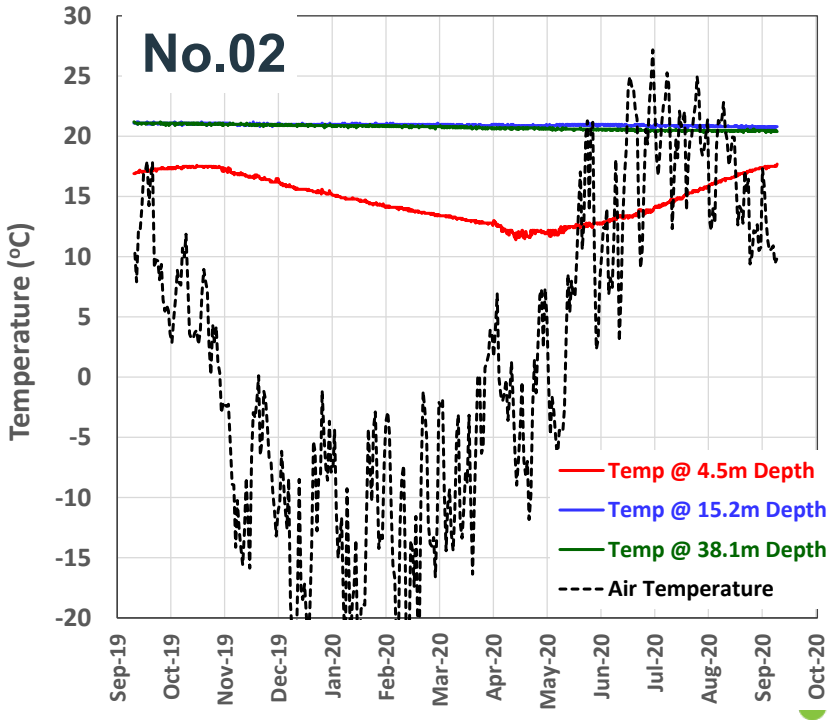
- Matric suction in the range of 6 to 10 kPa suggests:
  - MRSF is wetted up and current basal seepage will not increase; hence, load will not increase due to change in flow
  - Back of the envelope wetting up analysis conducted
    - MRSF will wet up over the “short-term”
  - Appears to be some response to precipitation at the 4.5 m depth



Case Study – Temperature

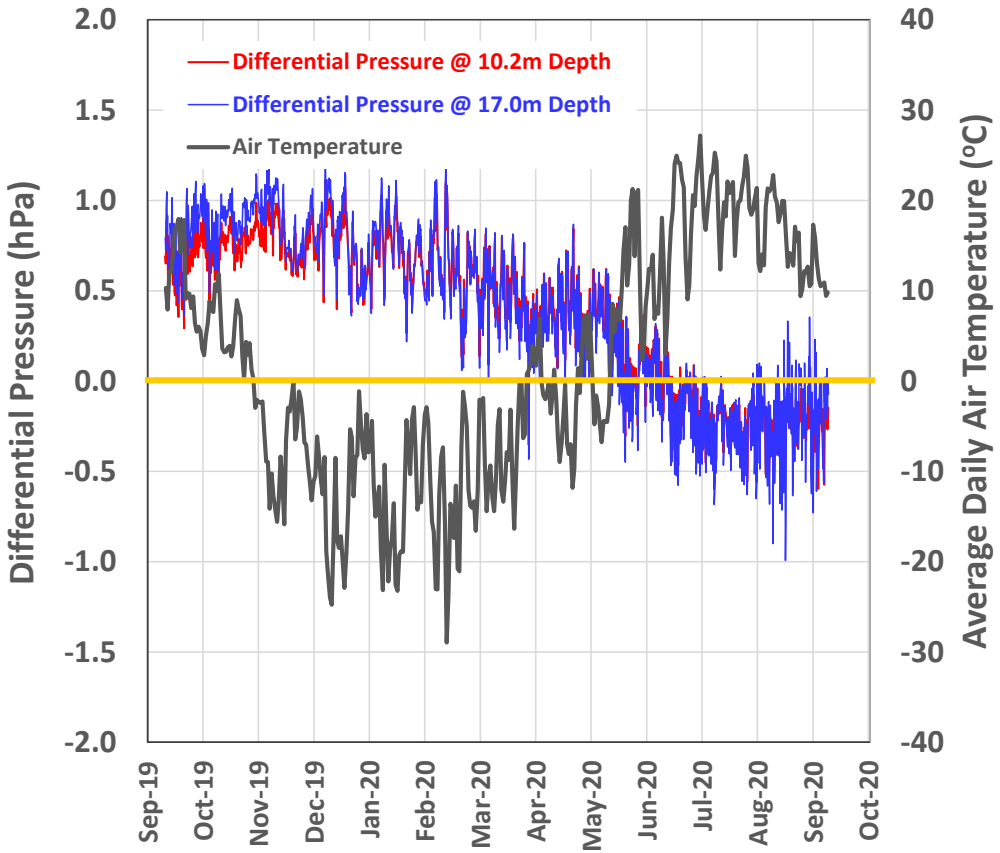
- Influence of seasonal temperature change on mine rock observed at 5 m depth
- Seasonal exothermic heat release at No. 01, with temperature increasing over the winter period (exothermic heat offsets loss of heat due to increased air flow)
- At No. 02, internal temperature relatively constant at 20°C





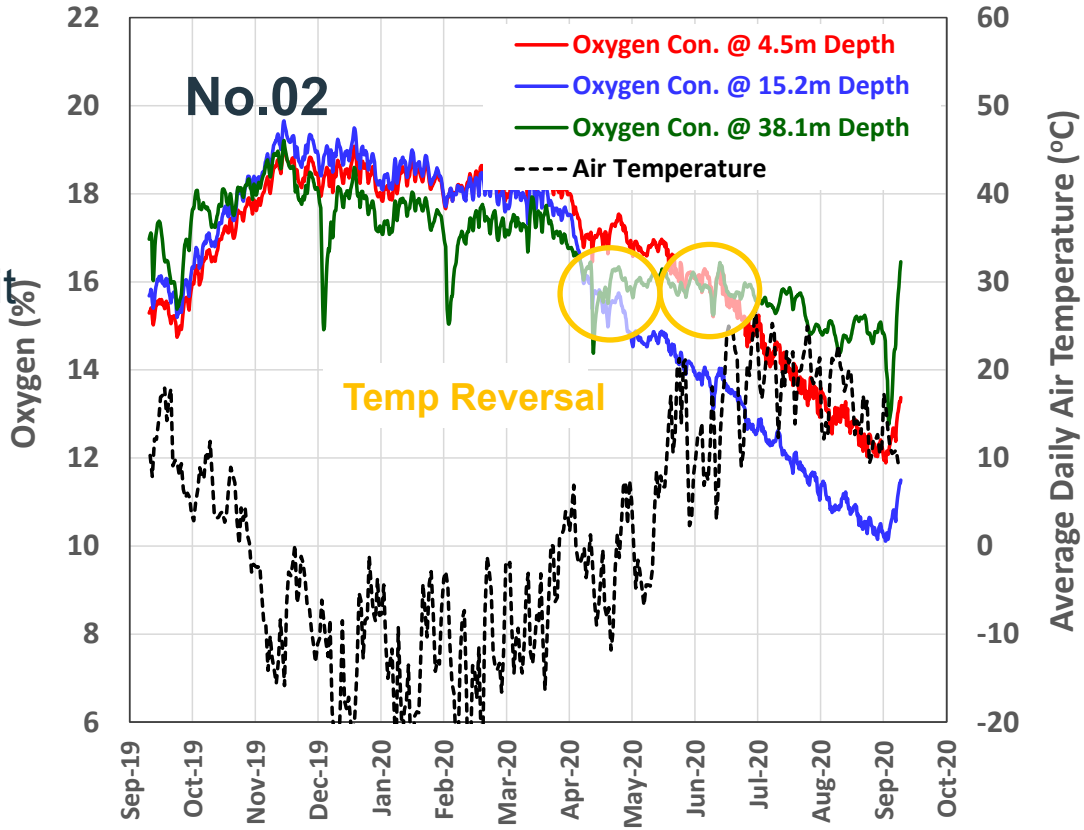
Case Study – Differential Pressure

- Differential pressure ranges from approximately 1 to -0.5 hPa.
  - Flow is primarily inward at the toe and upward for about 8 months of the year and potentially reverses direction in the summer
- Increase in differential pressure provides increase in air flow



Case Study – Oxygen Concentration

- Seasonal oxygen concentrations fluctuate from approximately 10% to 19% or near atmospheric
- Strong correlation between air temperature and oxygen concentration
- Increased differential temperature results in increase in air flow
- Winter oxygen supply overprints performance in summer
  - What is the average?
- Appears to be limited benefit from fine textured cover system in managing advective air flow
- Manual CO_2 1.3% to 5.7%



Summary and Discussion Points

- There's a need to build a database of thermal, moisture, pressure, and gas responses for alternative MRSF designs
  - Advance conceptual model
  - Inform on numerical modelling, etc

The Case Study:

- MRSF has high air flow capacity with short tips that will…
  - Facilitate ongoing oxidation reactions and likely require collection and treatment in perpetuity
- Fine textured cover system appears to have limited effect on reducing advective air flow
- Air flow primarily upward and inward at the toe but could reverse in the summer

A Consideration:

- Was there a missed opportunity to “optimized” value in the mine rock through a mine rock management plan

References

- The International Network for Acid Prevention (INAP) 2017. Global Cover System Design – Technical Guidance Document https://www.inap.com.au/research/#globalCoverSystem
- Pearce, S., Lehane, S. and Pearce, J. 2016c. Waste material placement options during construction and closure risk reduction – quantifying the how, the why and how much. Mine Closure 2016 Conference. Perth Australia. March.
- Zhang, S. and Liu, W. 2017. Application of aerial image analysis for assessing particle size segregation in dump leaching. Journal of Hydrometallurgy 171 99-105.
- Wilson, W. 2011. Rock Dump Hydrology: An overview of full-scale excavations and scale-up experiments conducted during the last two decades, in LC Bell & B Braddock (eds), Proceedings of the Seventh Australian Workshop on Acid and Metalliferous Drainage, pp 307-322.

Thank You!