# Quantitatively Assessing the Benefits of Managing Gas Entry into Waste Rock Dumps During Placement to Reduce Long-Term ML-ARD Risk


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**MEND 2016**


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*Specialists in Geochemistry and Unsaturated Zone Hydrology*

# Cost benefit of placing waste differently

***Risk- not in my lifetime***

***Less Risk- In my lifetime***

- ***Demonstrate Economic Benefit for mine planners***
- ***Demonstrate to regulators performance without a cover system***

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# Cost benefit of placing waste

*A*

***Construction cost***

*B*

***Construction cost***

***CA***
***for a cover***

***for a cover***

## *We need to change the question*

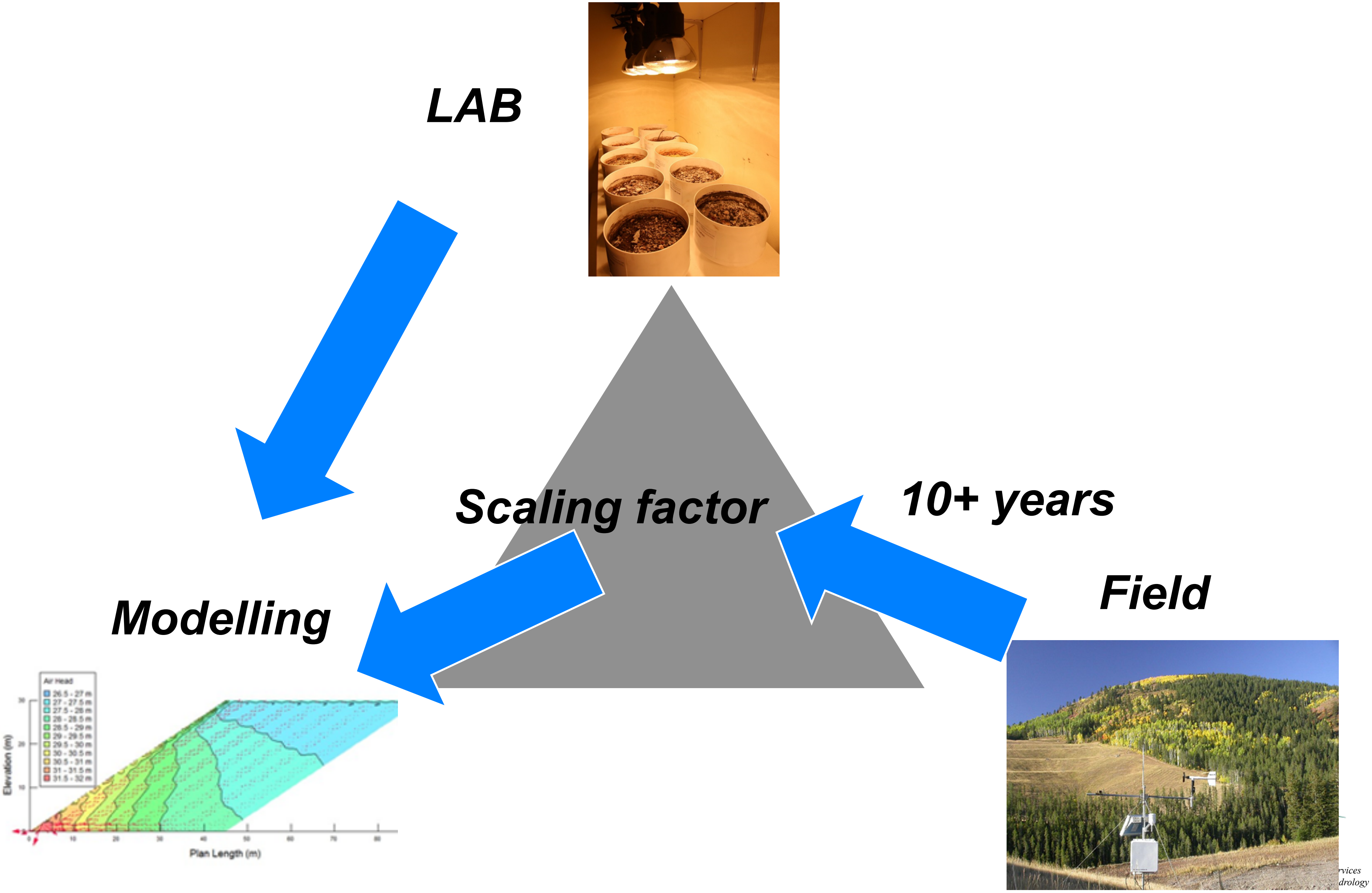
***CAPEX and OPEX cost for a long term treatment***

***CAPEX and OPEX cost for a long term treatment***

# The million $ problem

- Message:
  - not that placement method (and thus gas flux) has significant control on ML-ARD (we already know it does)... But…
- Require a cost effective site specific assessment approach:
  - Where risk/cost tradeoff assessment of how WRDs are constructed can be completed at the mine planning stage and closure cost estimation can be improved significantly.
  - A relative difference can be quantified
  - Decisions can be made on a site specific basis

# "Standard approach"



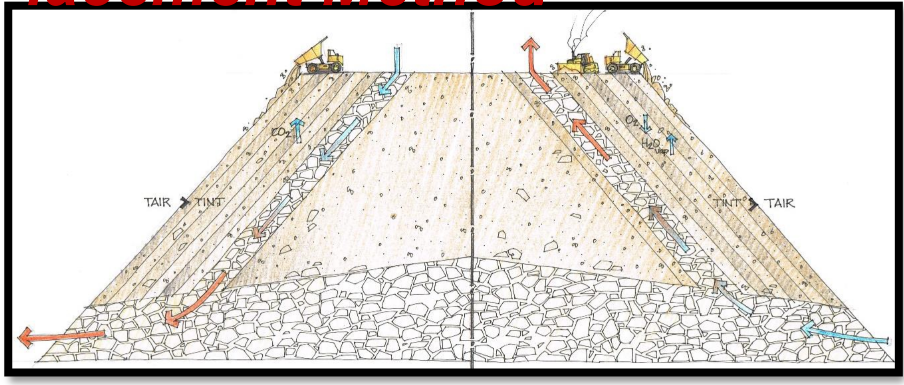
# How do lab tests incorporate site specific factors?

## 1) Climate

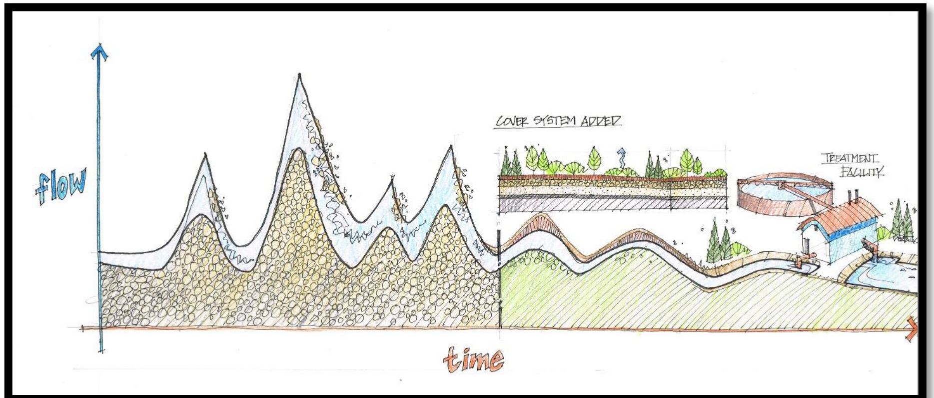

## 2) Geochemistry

## 3) Physical Characteristics

## 4) Structure of WRD due to Placement Method




## 5) Closure Measures (covers, treatment, etc.)



# Why site conditions matter

- Reaction rates are controlled by oxygen supply, gas flux is therefore more important than sulfur grade or lab derived “kinetic pyrite oxidation rate”
- Concentration is controlled by liquid solid ratio, seepage rate is therefore more important than “leach test results”

Because the dynamic flux of oxygen and seepage is site specific, we need a site specific assessment method to define risk

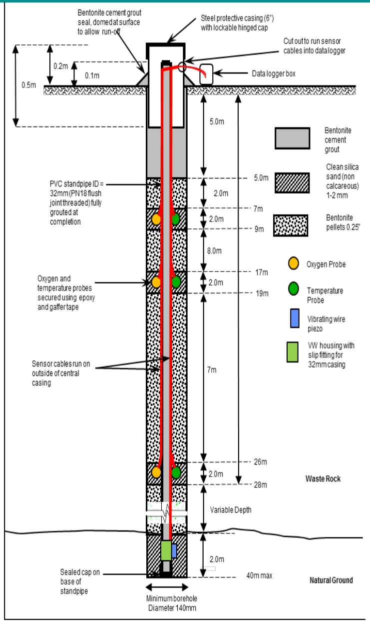
# Guidance does not "endorse" standard methods

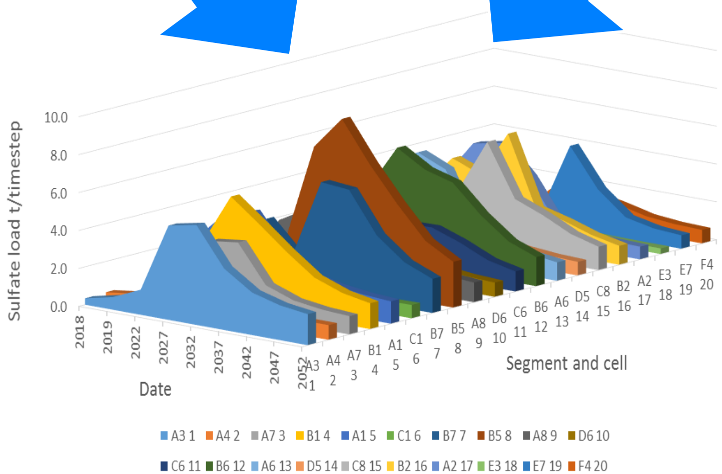
Laboratory test results will be empowered where it can be shown that they are correlated with field rates, or that the test accurately simulates the rate and balances among important processes, such as oxidation, dissolution and entrainment. Where possible, the design of trickle leach tests should be modified to simulate key aspects of the weathering and leaching conditions, such as the redox potential, drainage pH and the leaching rate ($m^3/kg/yr$) and residence time.

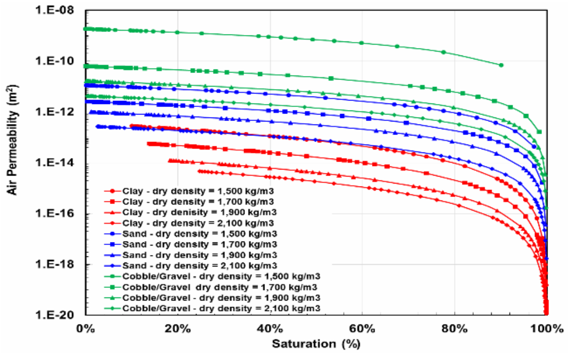
This quote from MEND, habitually ignored by nearly all AMD studies, does not endorse the use of standard methods.


***Insanity: doing the same thing expecting a different result***

# First Principals Approach: Site specific "scaling" (not using an arbitrary factor)

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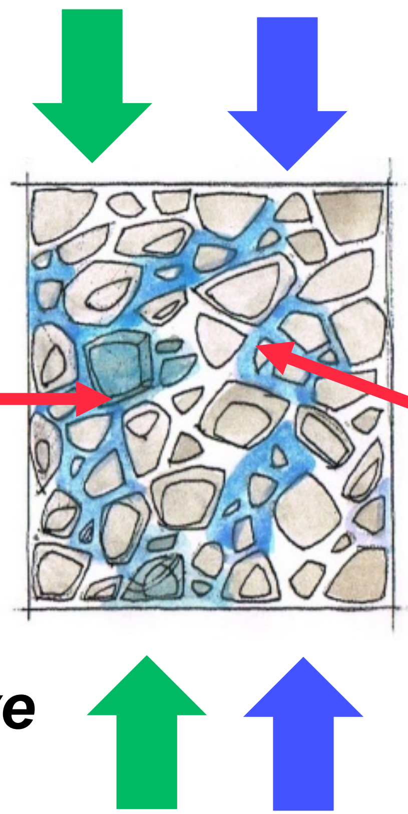
# What are the first principals?

**Pyrite + Water + Air (oxygen) = Sulfuric acid + metals + salinity**

***Climate (temperature)***

***Diffusive***

***Water flux***



***Particle size (dissolution rate acid producing and buffering)***

***Sulfide content IOR (intrinsic oxidation rate***

***Advective gas flux***

***Advective vapour flux***

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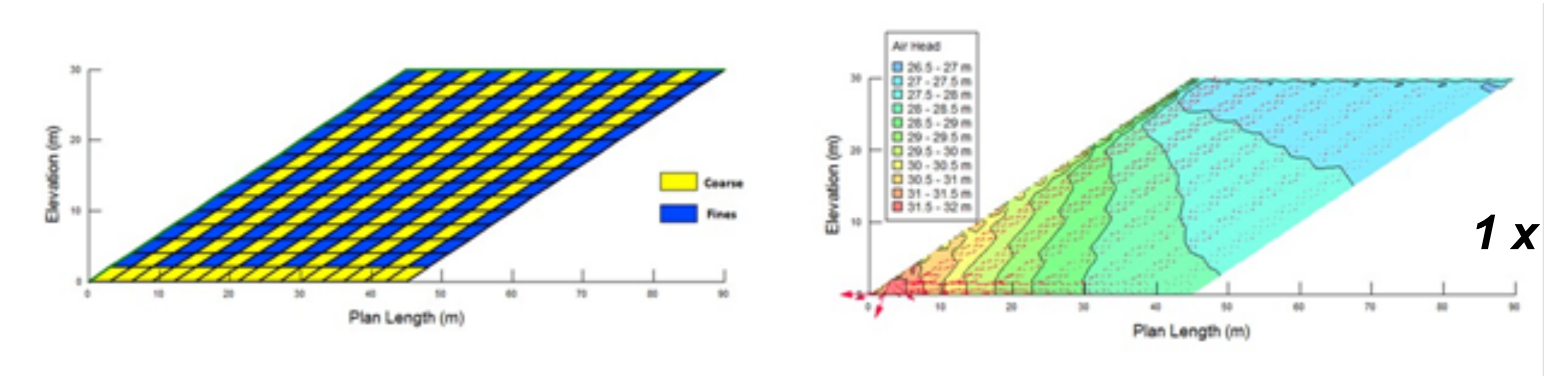
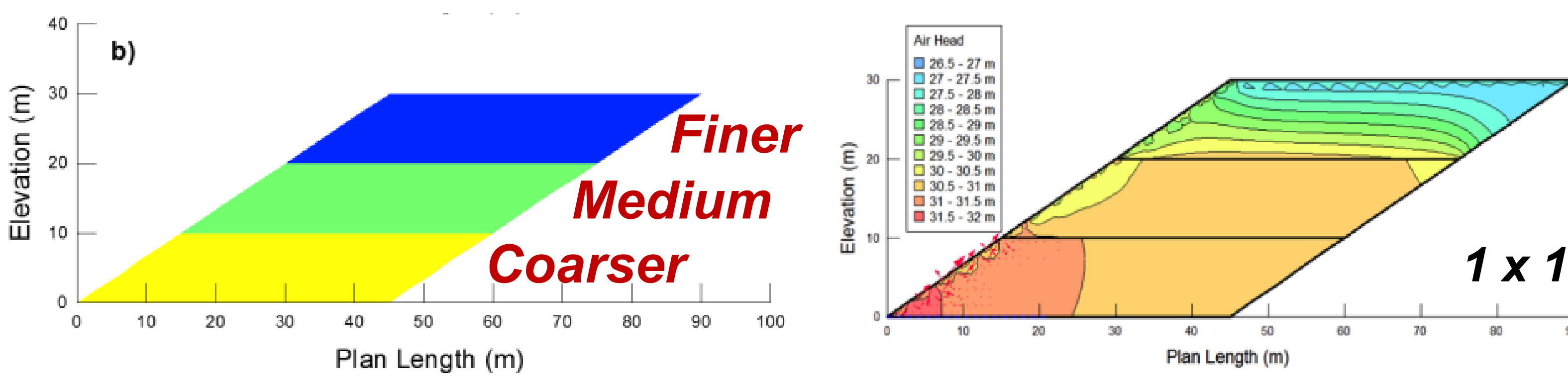
# Key is controlling air flux rates

## *Structure Effect on Air Flow*

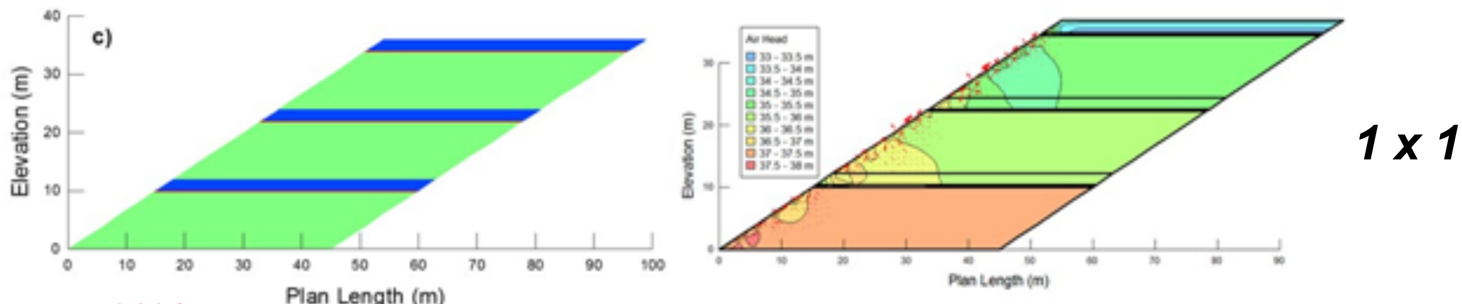



***1 x 10$^{-1}$ m$^3$/m$^2$s***




**3 Orders Lower**

***1 x 10$^{-4}$ m$^3$/m$^2$s***




**2 Orders Even Lower**

***1 x 10$^{-6}$ m$^3$/m$^2$s***

*Pearce et al 2015*

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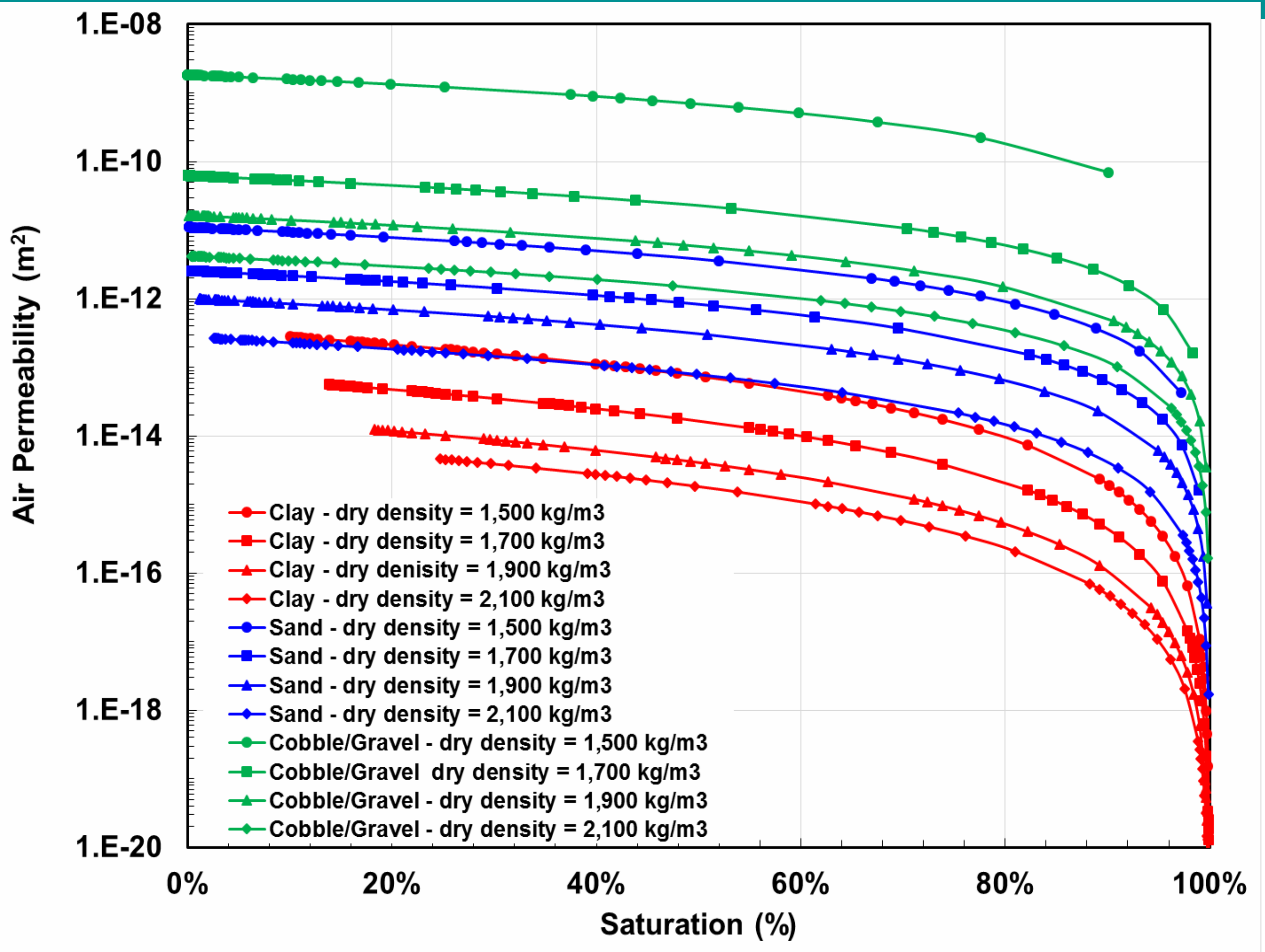
# Key is air permeability which depends on saturation state and “compaction”

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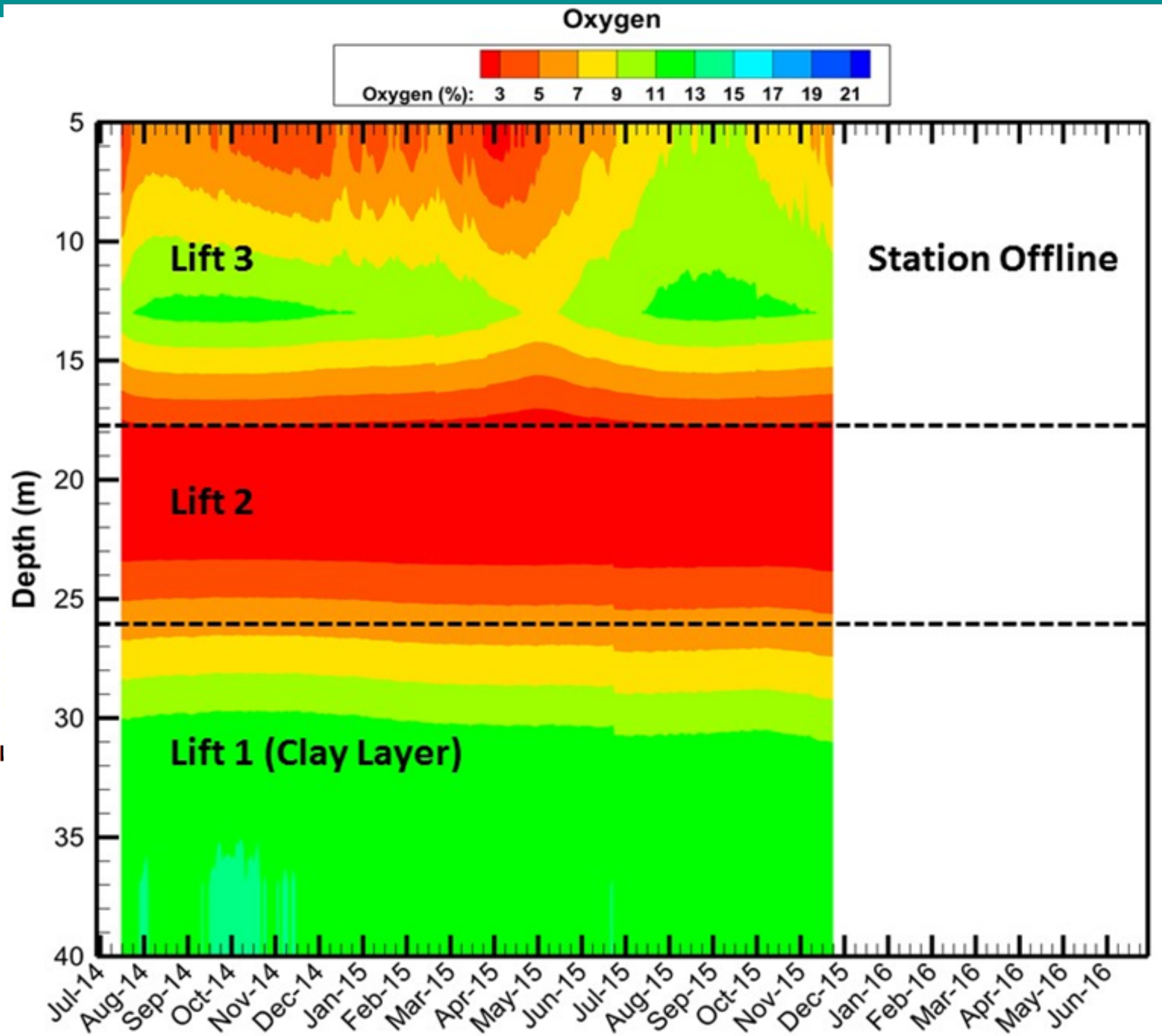
# Oxygen is not always a limiting factor

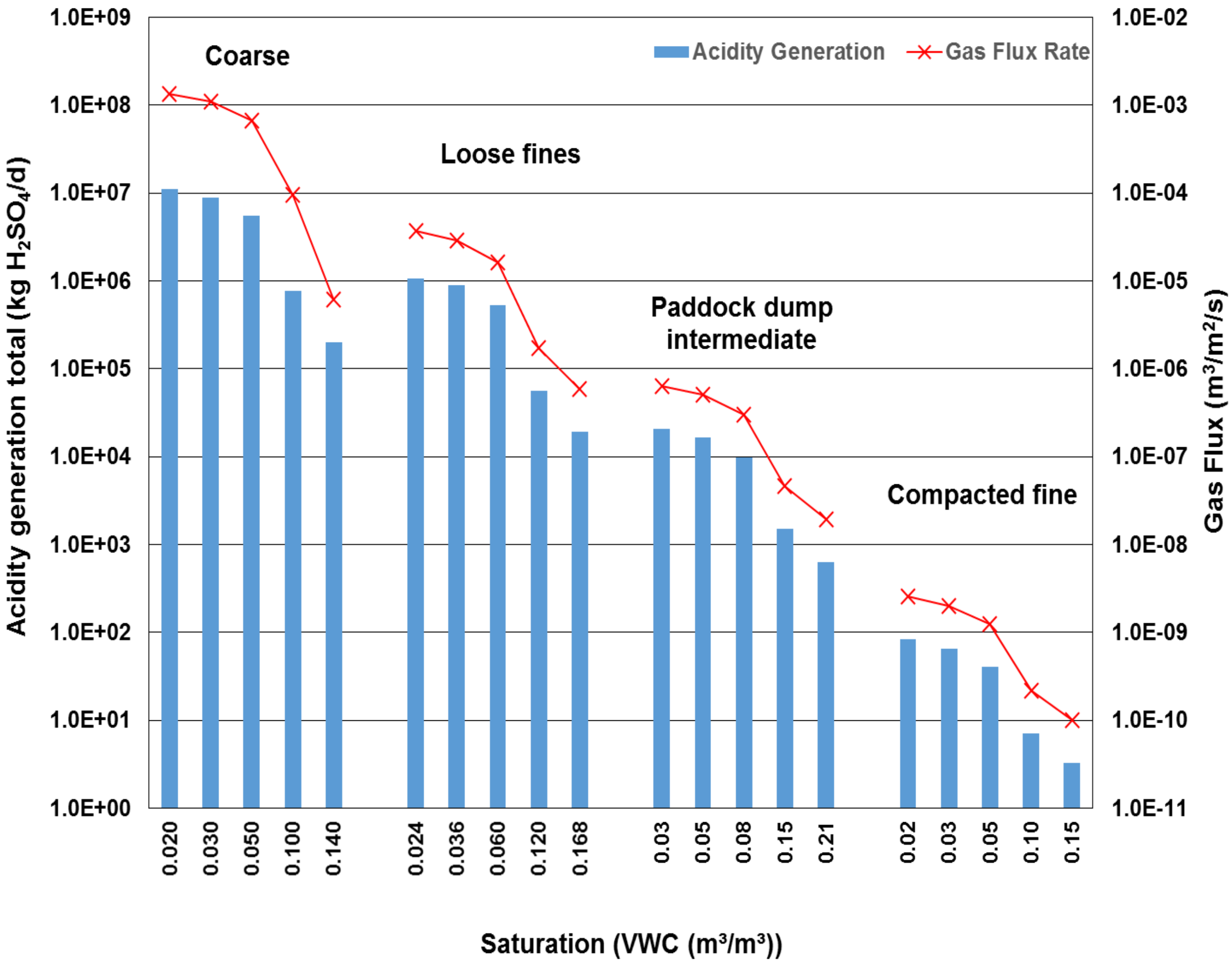



$^{-6}$ kg/m$^3$/s

ained conditions

d

# Acidity generation as a function of material type

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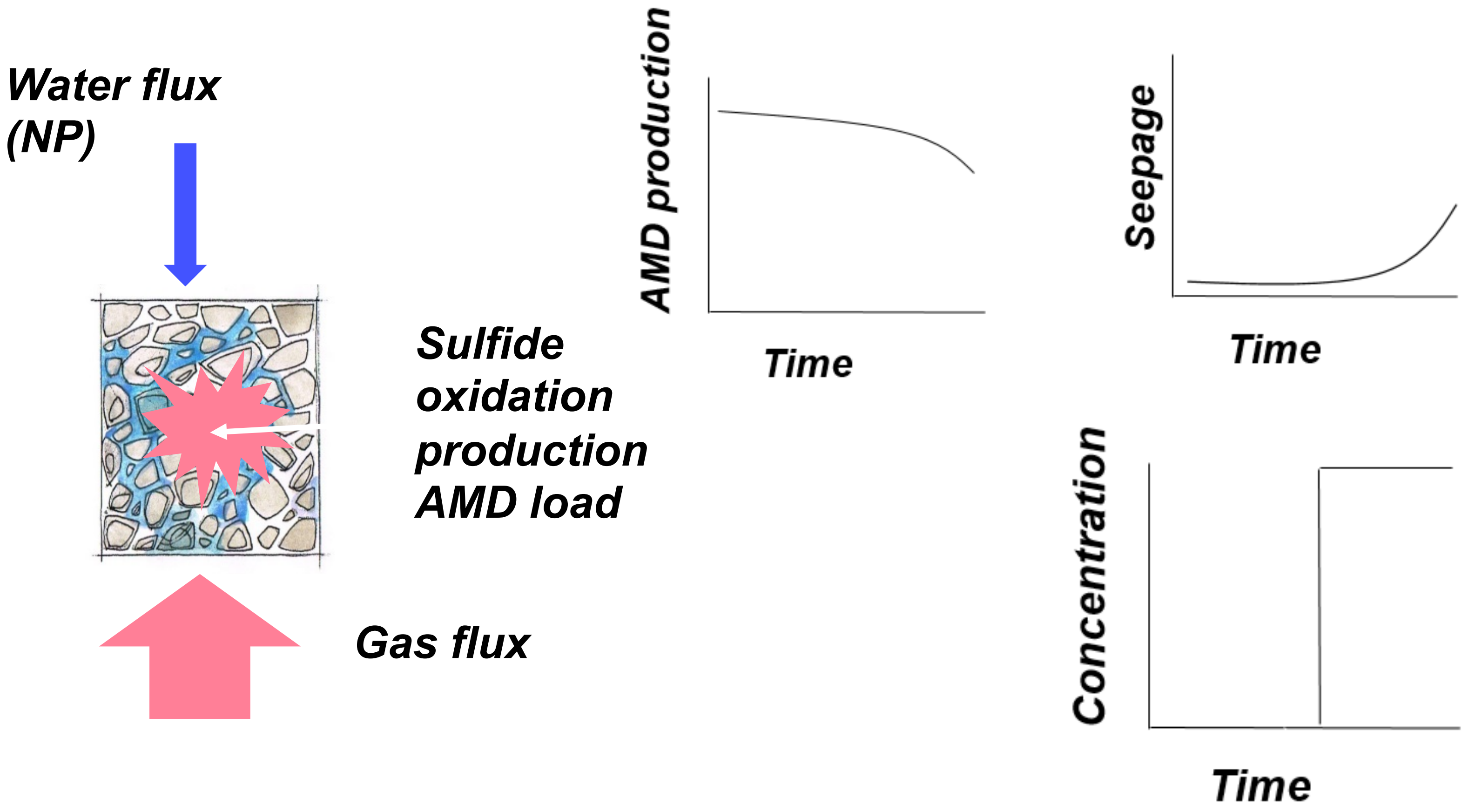
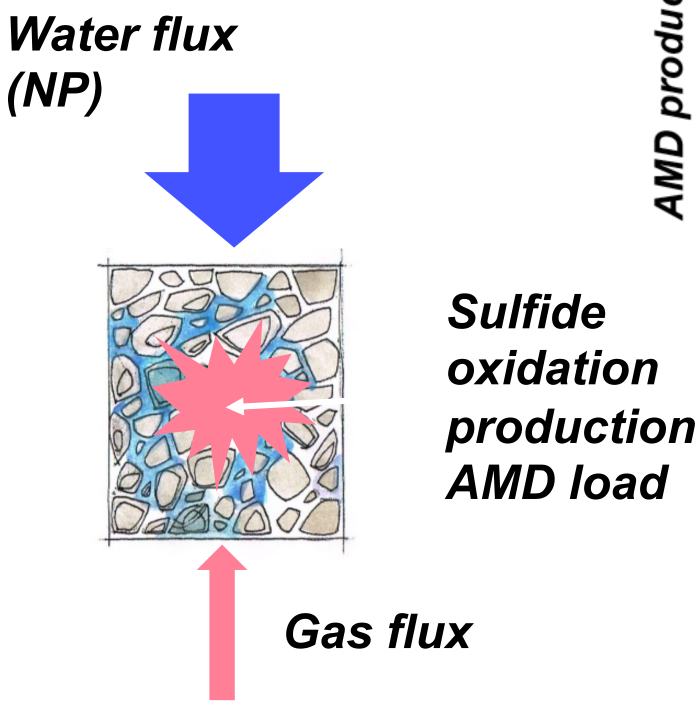
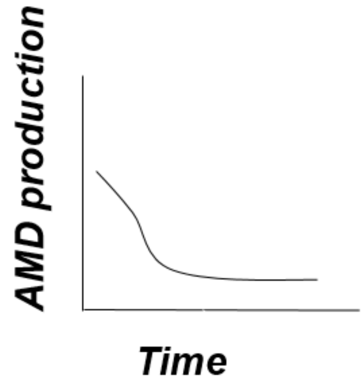
# Semi arid site setting, coarse "NAF" waste rock (0.3% S material) high gas flux low water flux

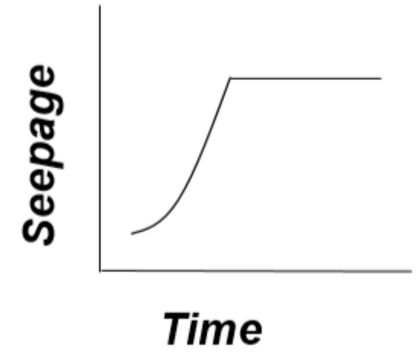


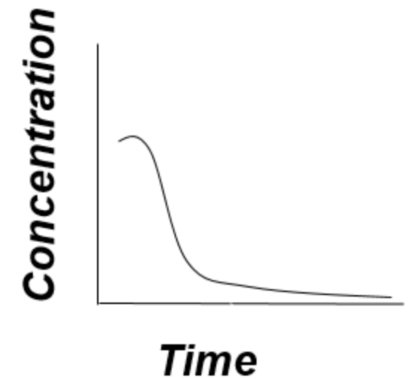
# Low LS ratio concentrates solutions: In field acidity can be 100,000 mg/l+

# Tropical site setting, fine texture waste rock (0.3% S material) low gas flux high water flux



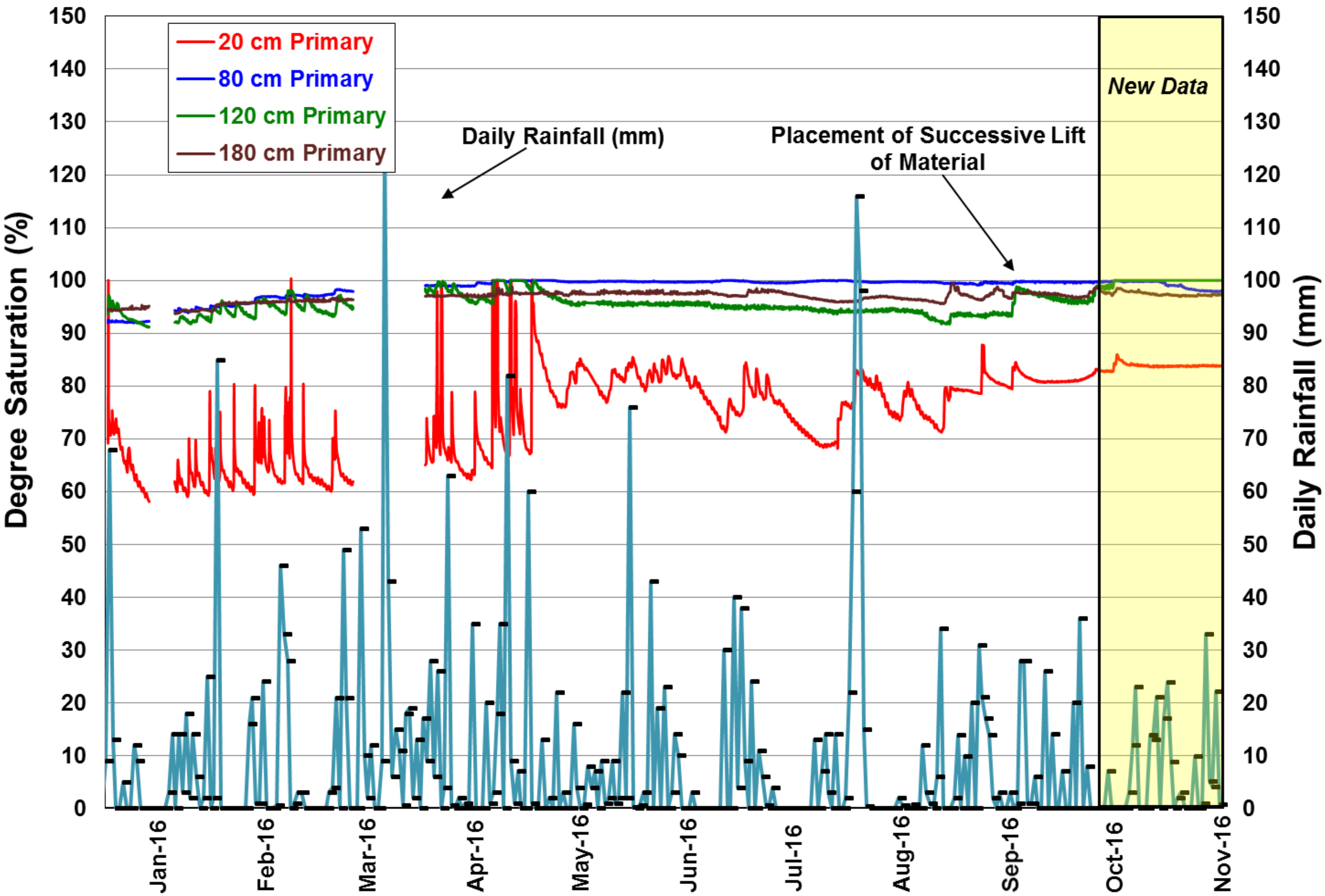



# Tropical (4m ppt yr) 2-3% sulfides (reactive), integrated waste rock and tailings facility, presence of finer textured materials (argillic volcanics)

**HIGH RISK?**

# Climate + materials = low gas flux potential

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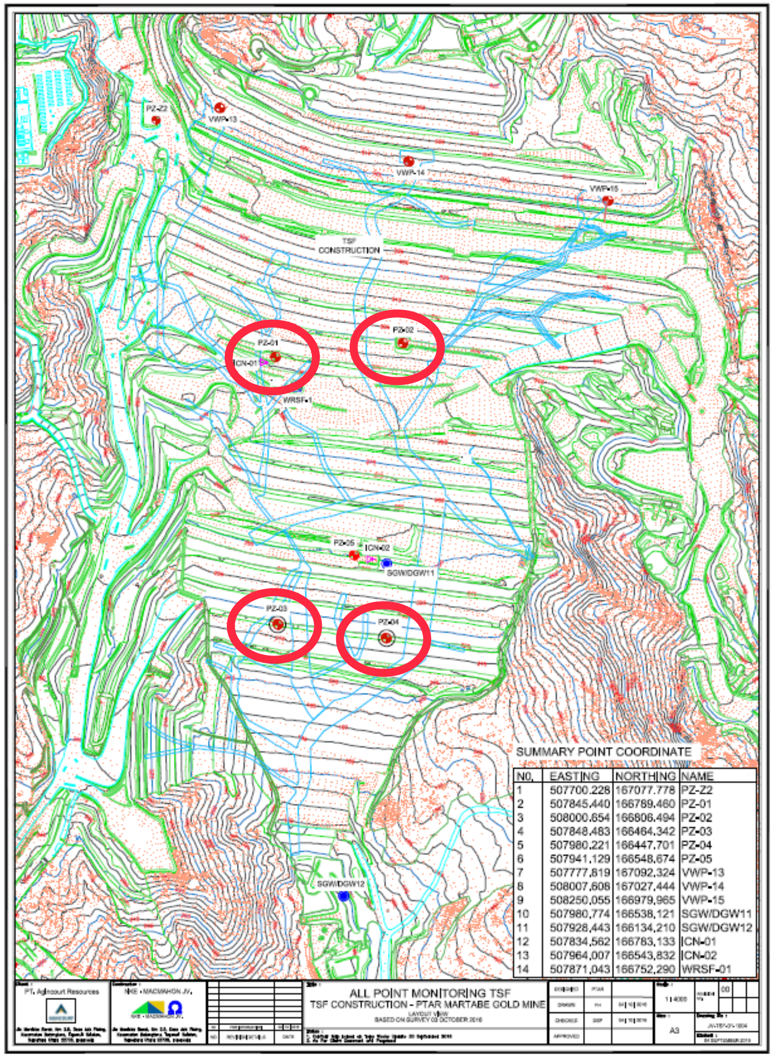
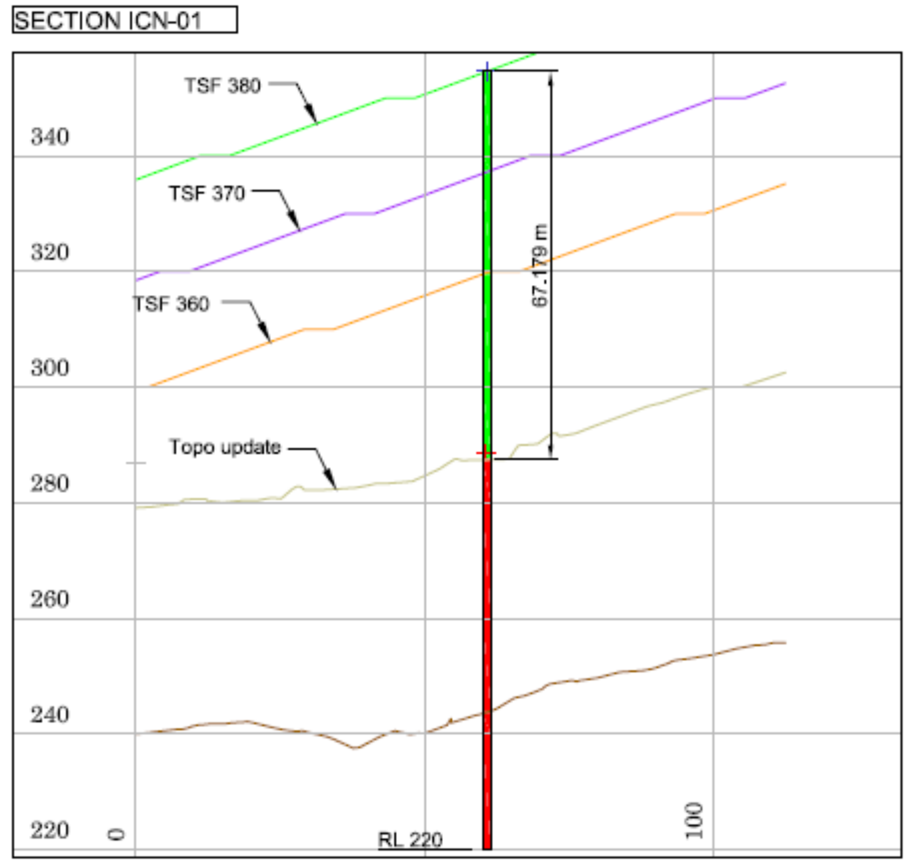
# Drilling into embankment (2016)




| N0, | EASTING | NORTHING | NAME |
|---|---|---|---|
| 1 | 507700.228 | 167077.778 | PZ-Z2 |
| 2 | 507845.440 | 166789.460 | PZ-01 |
| 3 | 508000.654 | 166806.494 | PZ-02 |
| 4 | 507848.483 | 166464.342 | PZ-03 |
| 5 | 507980.221 | 166447.701 | PZ-04 |
| 6 | 507941.129 | 166548.674 | PZ-05 |
| 7 | 507777,819 | 167092,324 | VWP-13 |
| 8 | 508007,608 | 167027,444 | VWP-14 |
| 9 | 508250,055 | 166979,965 | VWP-15 |
| 10 | 507980,774 | 166538,121 | SGW/DGW11 |
| 11 | 507928,443 | 166134,210 | SGW/DGW12 |
| 12 | 507834,562 | 166783,133 | ICN-01 |
| 13 | 507964,007 | 166543,832 | ICN-02 |
| 14 | 507871,043 | 166752,290 | WRSF-01 |

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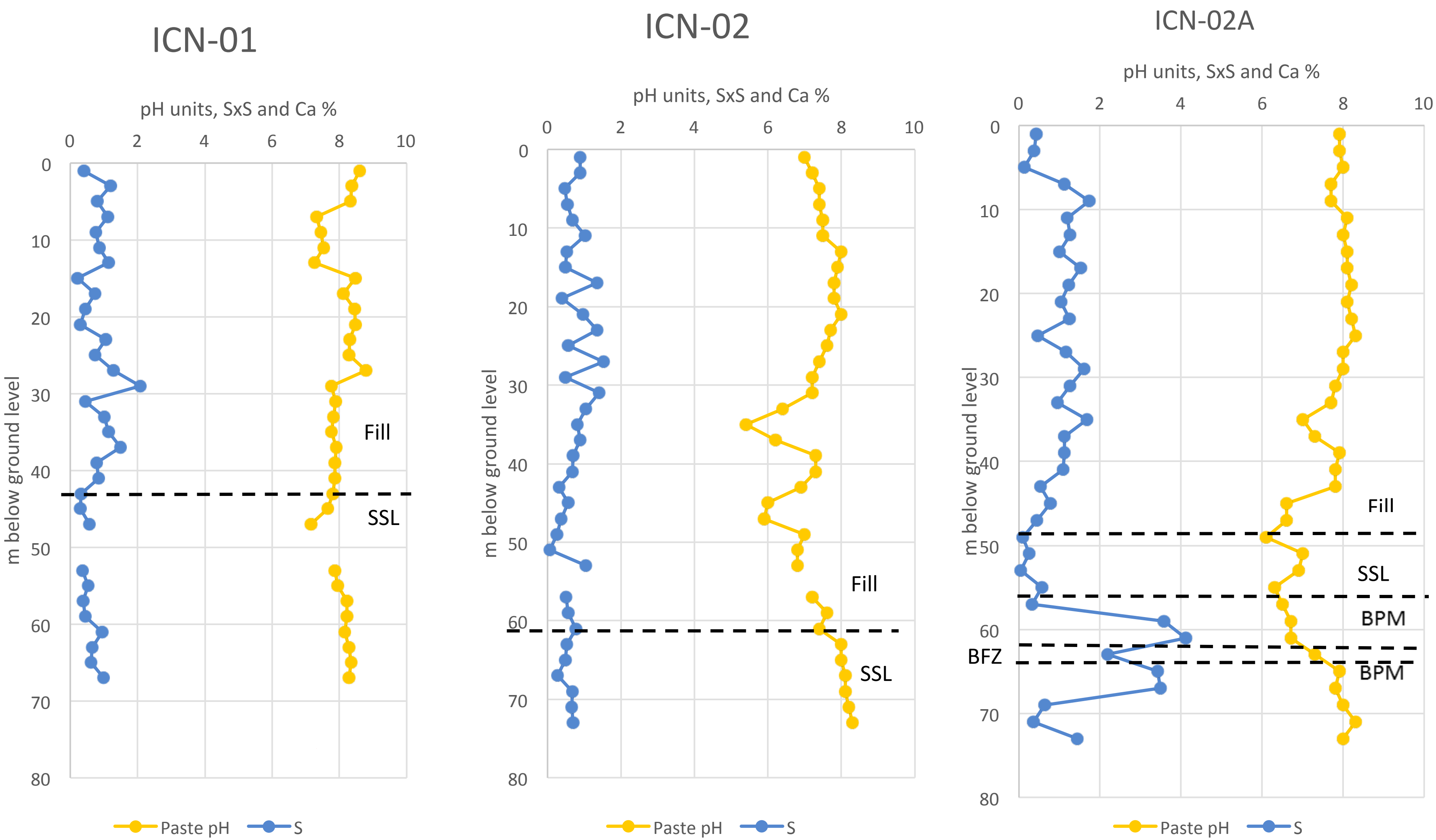
# Geochemistry vs depth



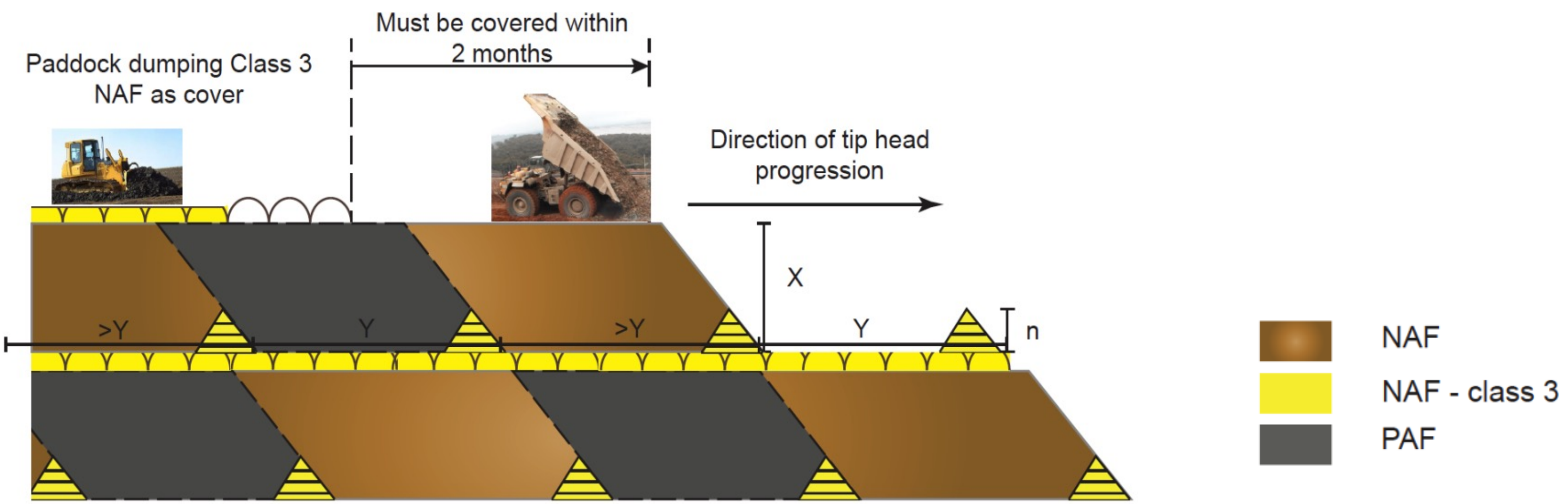
# A Path Forward

- Alternative to managing these long-term risks "later" is by addressing the risk while the waste rock is being placed ("now")
  - Still have control over how it is constructed, clean slate
- Leads to a more robust mine waste rock management approach.
- A complete description of the WRD assessment tool developed by OKC can be found Pearce et al., 2016

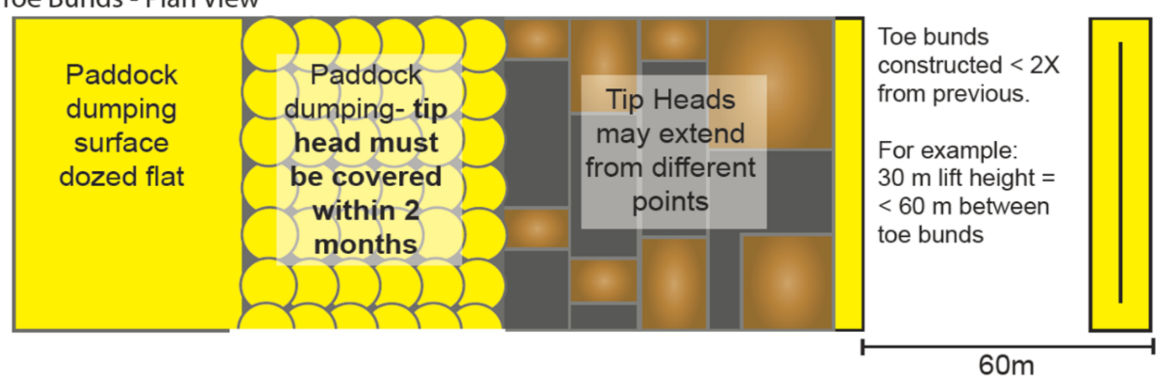
# DumpSim Assessment Tool

- **Based on thermodynamic and hydraulic principles that have been coupled.**
- **$Temp_{in} = Temp_{ext}$, else $Int_{heat}$**
- **$Int_{heat} \propto c_{th}$ and $H_E$ from POR/COR** (both estimated accurately)
- **Reaction kinetics and heat transfer $\propto$ Air Flux**
- **DumpSim uses unsaturated zone hydrology to link the rate of reactions (POR/COR) with thermodynamics to determine heat flux and transfer.**
- **Incorporates critical water content limitations to reaction rates (validated by field + lab data)**
- **Gas flux is a main driver.**

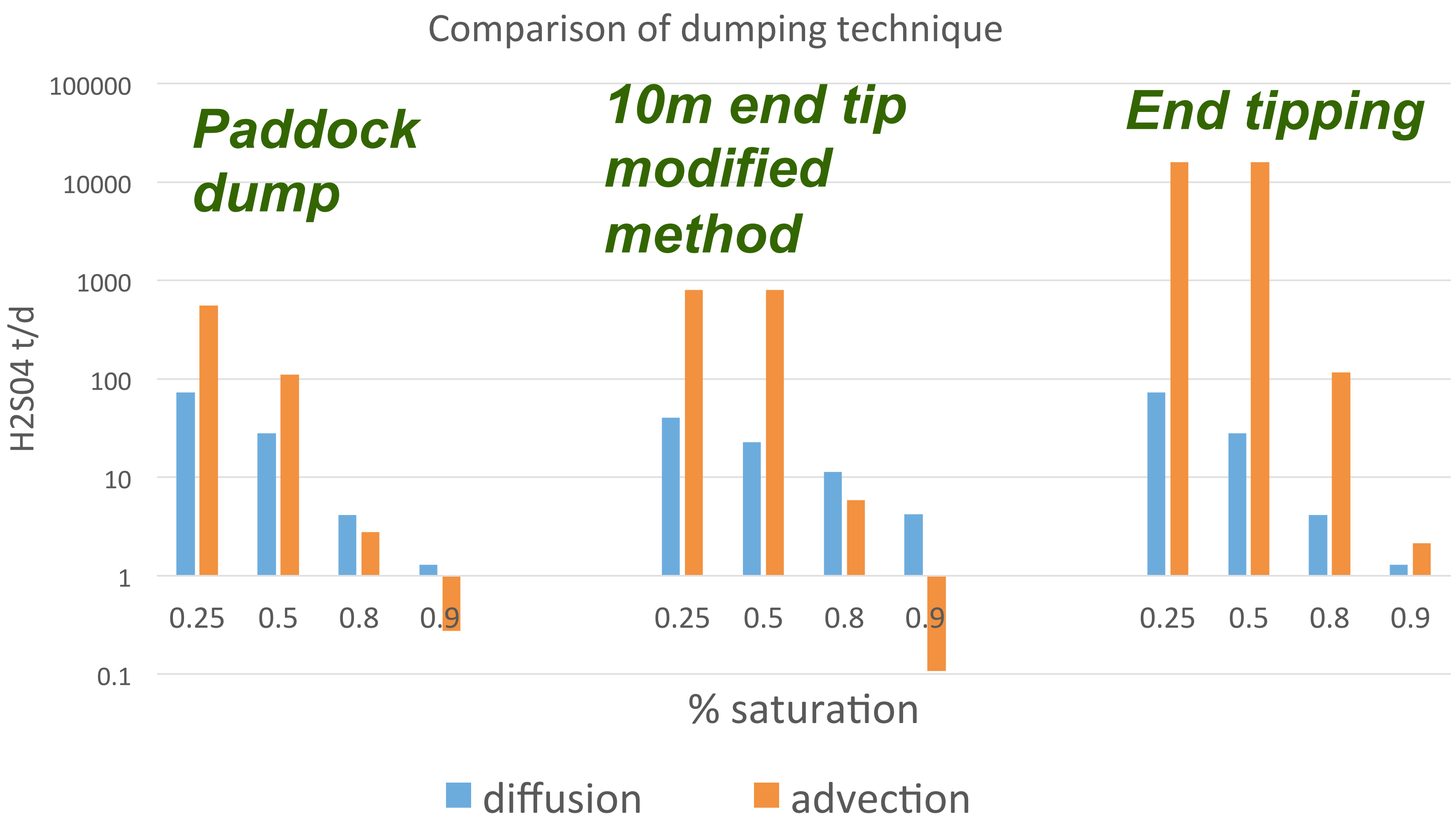
# Design and assess placement method to mitigate gas/temperature risks




Toe Bunds - Plan View



# Multi criteria assessment of AMD load based on placement method



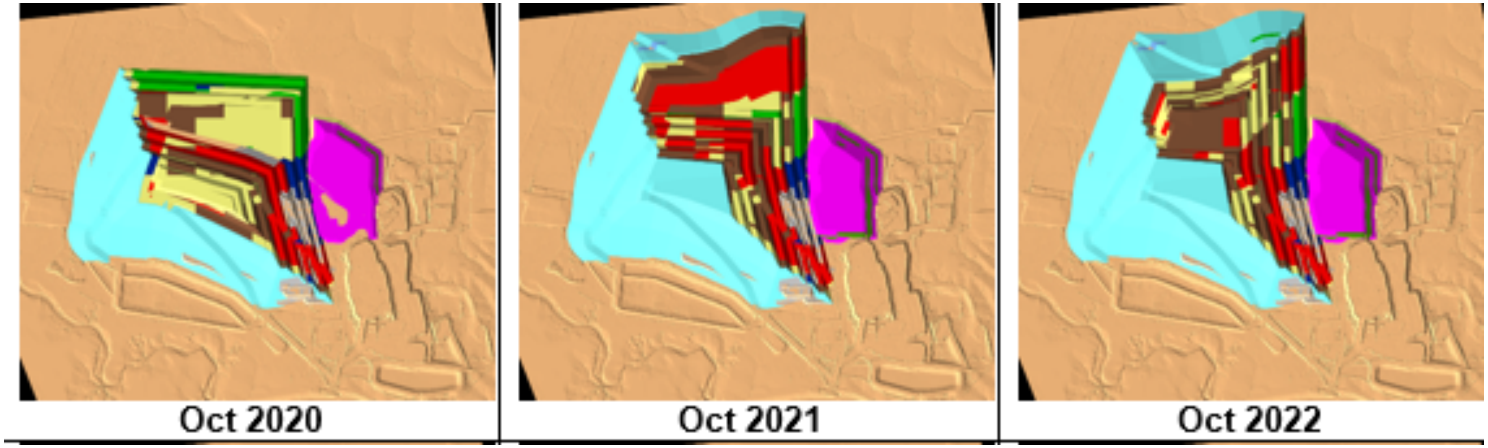
- Allows a risk-weighted cost-benefit analysis of construction methods over life of mine to assess closure scenarios and the requirement for closure mitigation measures such as cover systems.
- Allows optimized management of material for example paddock dumping may be too costly for all materials, but a sulphur grade cut-off can be established such that the material with high acidity and/or temperature risks could be selectively managed in this manner.
- Identifies direct link between construction methods and the potential development of ML/ARD risks and impacts.
- Allows assessment of the benefit of progressive ML/ARD management as compared to deferring to final closure solutions…
  And, in the case of cover systems:

So we understand what the cover system can realistically achieve

# There is a Need for…

## Quantitative Assessment Tools

*…To properly evaluate the economic and environmental risks of different ML/ARD mitigation measures… one that may not include a cover system*



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