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Mine Waste Management

The Balancing Act between Geochemistry & Geotechnical Design

Issue

Often Conflicting Management Strategies

What may be good for long-term physical stability may be contrary to long-term geochemical stability.

Modified after:

Wilson, G. Ward and Robertson, A. MacG. The Value of Failure. Geotechnical News. June 2015

General Criteria for Managing Waste & Water

All Life Stages (Operations, Closure, Post-Closure)

- Manage tailings and waste rock in a safe manner
- Manage tailings and waste rock to prevent onset of ML/ARD
- Divert clean water / Minimize collection of contact water

Water…A Common Theme

- Geotechnical Stability:
  - Eliminate surface water from the impoundment
  - Promote unsaturated conditions in the tailings with drainage provisions
  - Increase tailings deposit strength by compaction
- Geochemical Stability:
  - Water covers good
  - Saturated conditions

Water…A Common Theme

- Mining Process requires water:
  - Fresh water
  - Reclaim/Recycle water
  - Potable water
- Receiving Environment:
  - Sufficient flow for aquatics
  - WQ affects

Management Strategies

Type of Impoundment

Cross Valley

Perimeter

Type of Deposition

Slurry

Thickened

Alternative Deposition Options

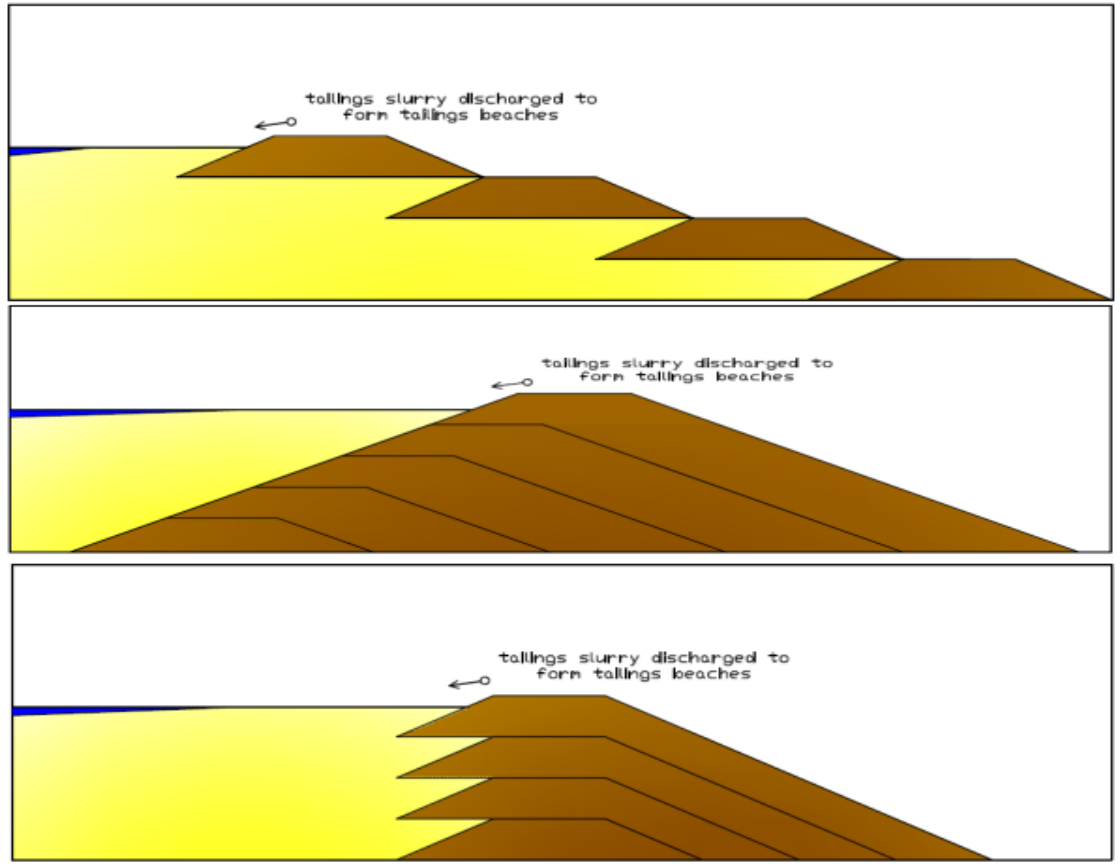
In-Pit Tailings

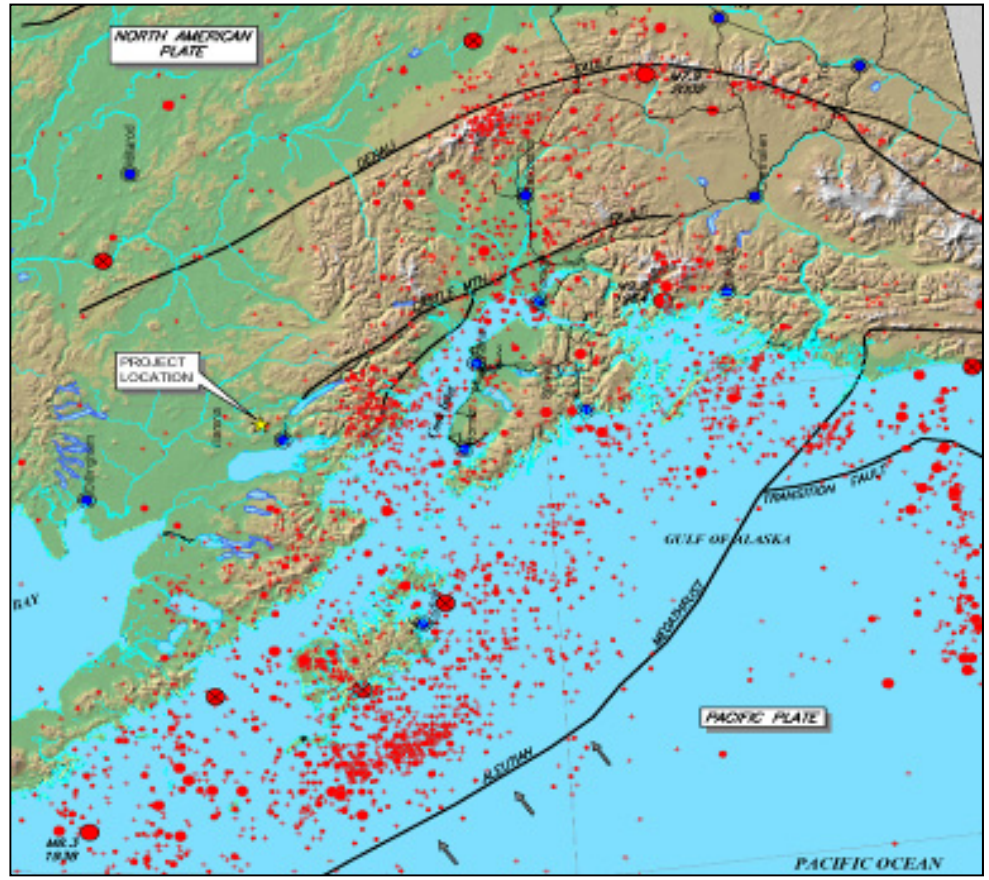
Paste Backfill

Filtered Options

Site-Specific Considerations

Physical Stability





Physical Stability

Best Available Technologies….

Considerations

- **Site conditions** — climate, mine site layout, topography, public health and safety risks, and potential social and environmental impacts
- **Tailings characteristics** — physical properties and geochemistry
- **Footprint** (area of disturbance)
- **Storage volume** and potential for expansion
- **Transportation and placement** — pipeline, conveyor, truck; proximity and elevation of the proposed site in relation to the processing plant
- **Water management** — dewatering effort, seepage control, potential surface drainage and groundwater impacts
- **Dust** control
- **Closure, decommissioning and reclamation** — long-term tailings containment, stability, seepage and water quality, public health and safety risks, and potential social and environmental impacts.
- **Life cycle costs**

Best Available Technologies

Alternatives Assessment

Geotechnical Considerations

The Independent Expert Engineering Investigation and Review Panel Report (Panel Report) for the Mt. Polley tailings dam failure provided suggestions for improvement of tailings physical stability through measures which:

- Eliminate surface water from the impoundment
- Promote unsaturated conditions in the tailings with drainage provisions
- Increase tailings deposit strength by compaction

These measures are referred to as principles of

'Best Available Technology'

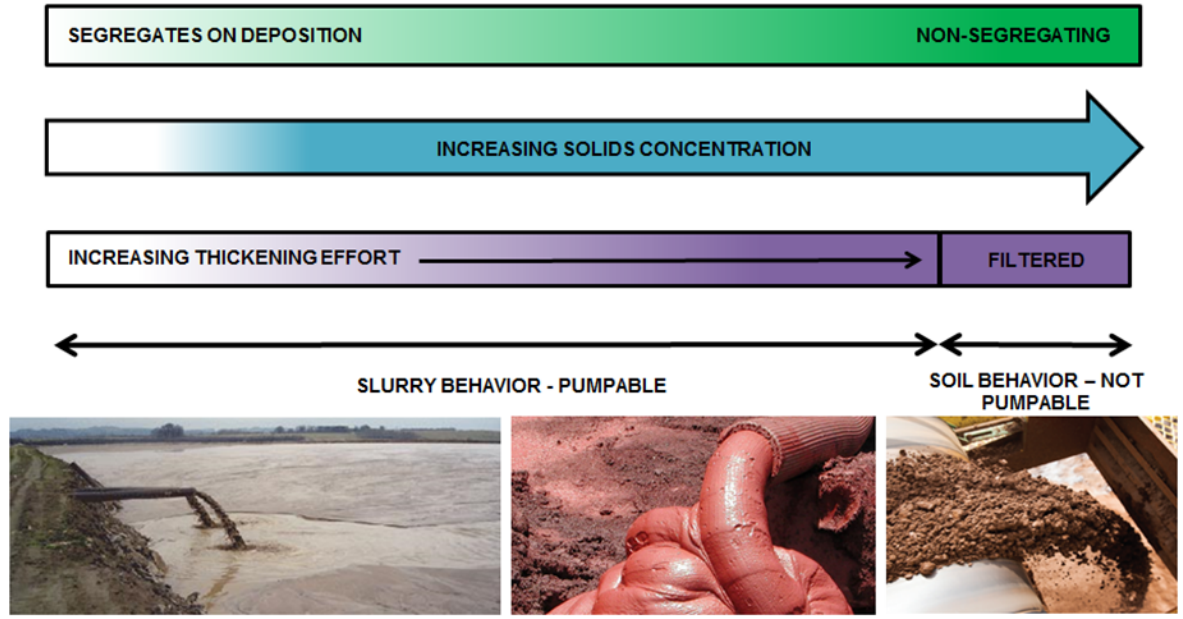
The focus of these principles is on physical stability of the tailings mass.

Alternatives Assessment

Tailings Technology

Mine tailings are described by their approximate solids content at delivery – a range referred to as the tailings continuum qualitatively describes:

- Solids content
- Thickening effort
- Method of delivery to facility
- Segregation during placement



Advantages and disadvantages:

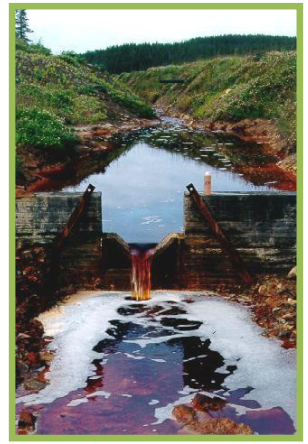
- Project-by-project basis
- For full project life (construction, operations, closure, post-closure)

Alternatives Assessment

Geochemical Considerations

Mine waste rock and tailings are classified as potentially acid generating (PAG) or non-acid generating (NAG) - NAG waste rock can be further classified based on metal leaching potential.

- Alternative methods for waste rock storage can provide chemical stability (resisting or delaying the onset of metal leaching or ARD).
  - Submergence will prevent oxidation and acid generation (by removal of air)
  - Submergence will prevent/reduce metal leaching
  - Submergence simplifies preventing “air entry”



Alternatives Assessment

Which BAT?

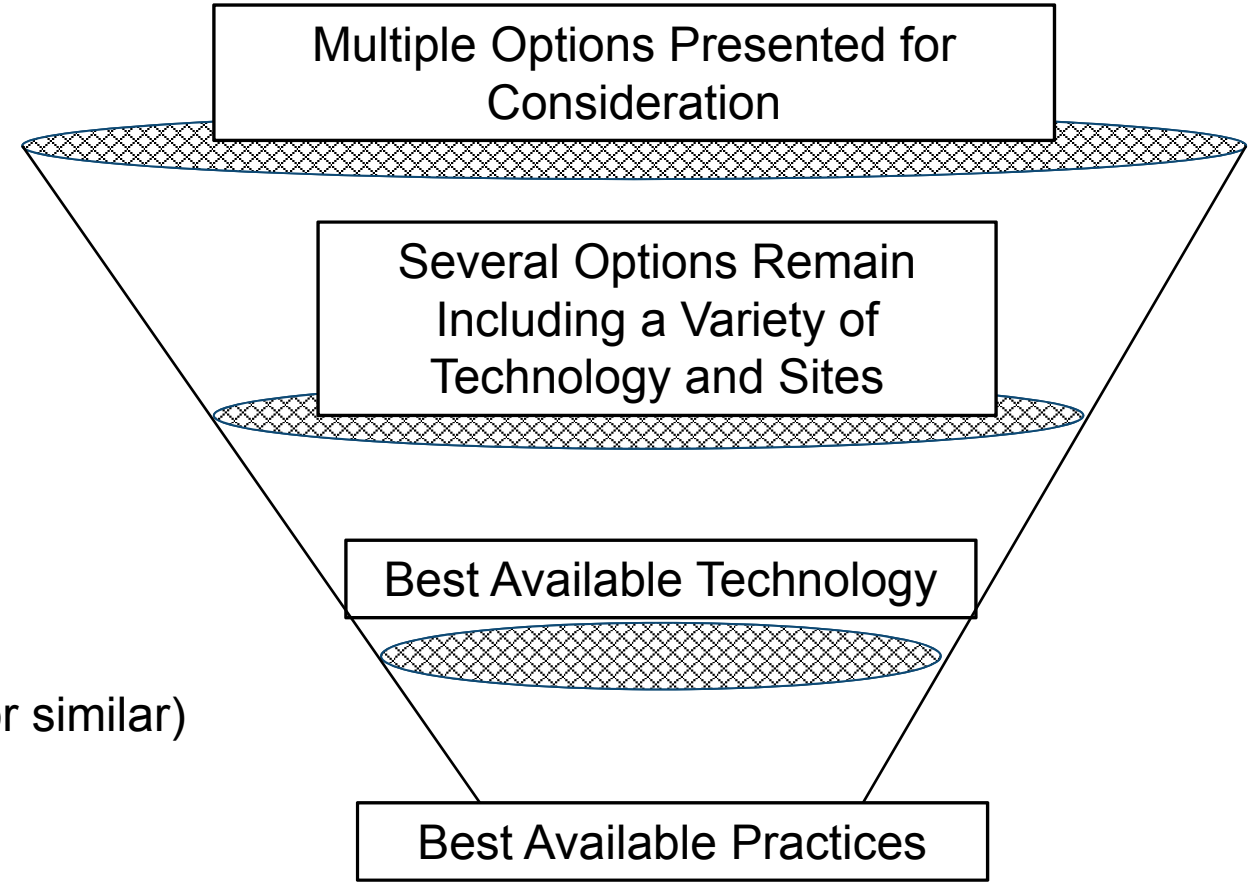
Alternatives Assessment

Which BAT?

Pre-screening (Fatal Flaw)

Multiple Accounts Analysis and/or
Risk Based Analysis

Residual Risk Management
(Failure Modes Effects Assessment or similar)



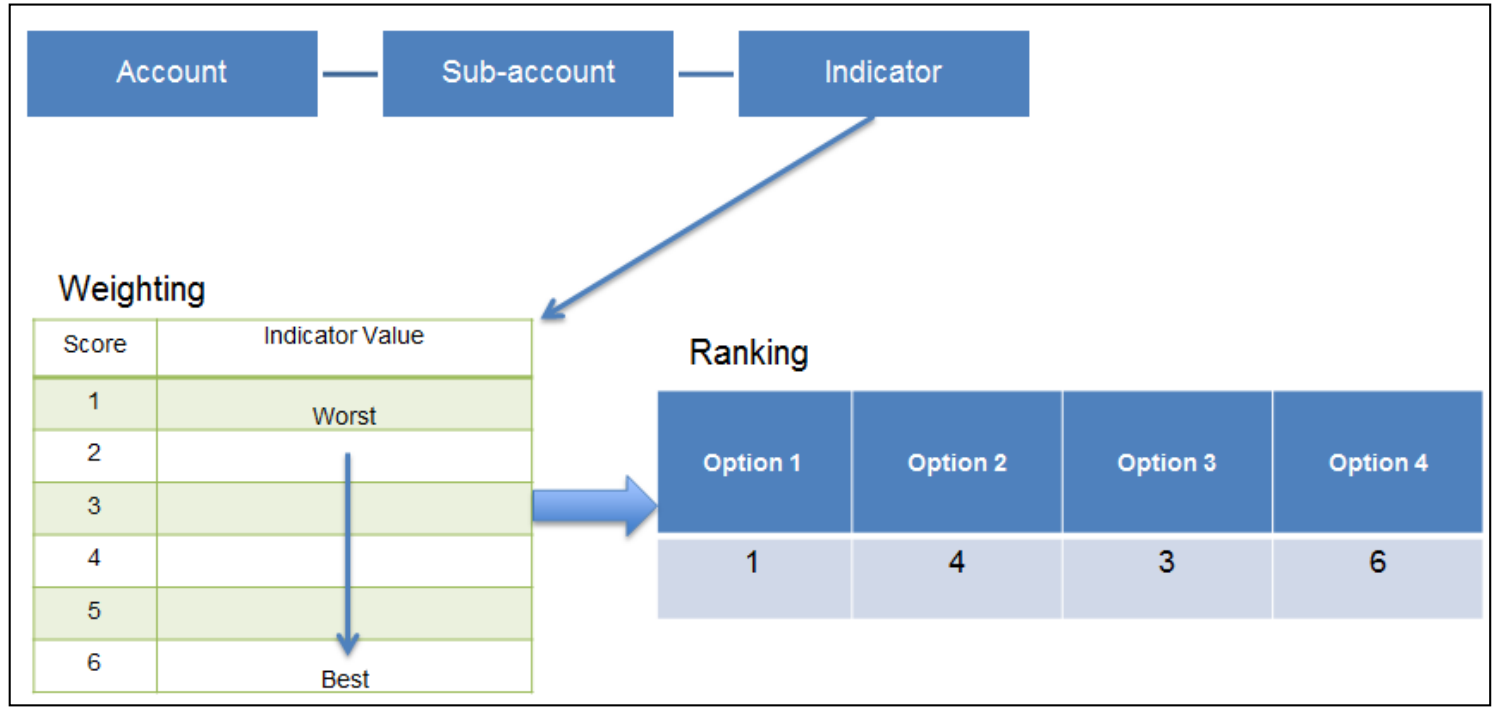
Multiple Accounts Analysis

Ranking System

A numerical ranking system based on a series of accounts and indicators.

- Typically follows framework from Environment Canada: Guidelines for the Assessment of Alternatives for Mine Waste Disposal

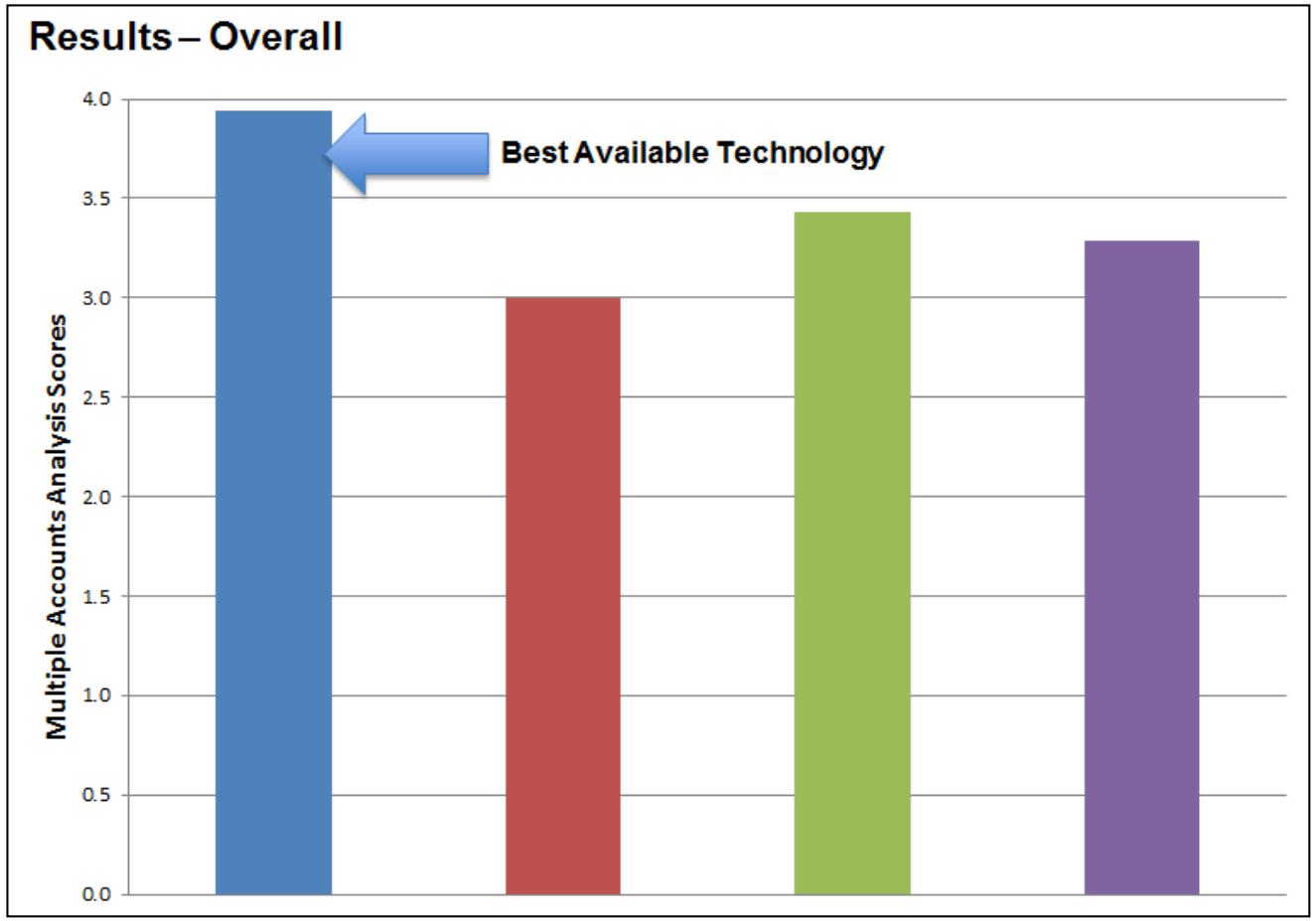
- No master criteria list
- Complexity is project specific
- Schedule 2 Amendment may necessitate this framework



Multiple Accounts Analysis

Results

Comparison of relative merits based on multiple defined criteria to find best option:



Risk Based Analysis

Ranking System

A numerical risk ranking developed by multiplying likelihood and consequence:

LIKELIHOOD SCORE	DESCRIPTOR
1	Very rare
2	Unlikely
3	Possible
4	Likely
5	Almost Certain

CONSEQUENCE SCORE	DESCRIPTOR
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Catastrophic

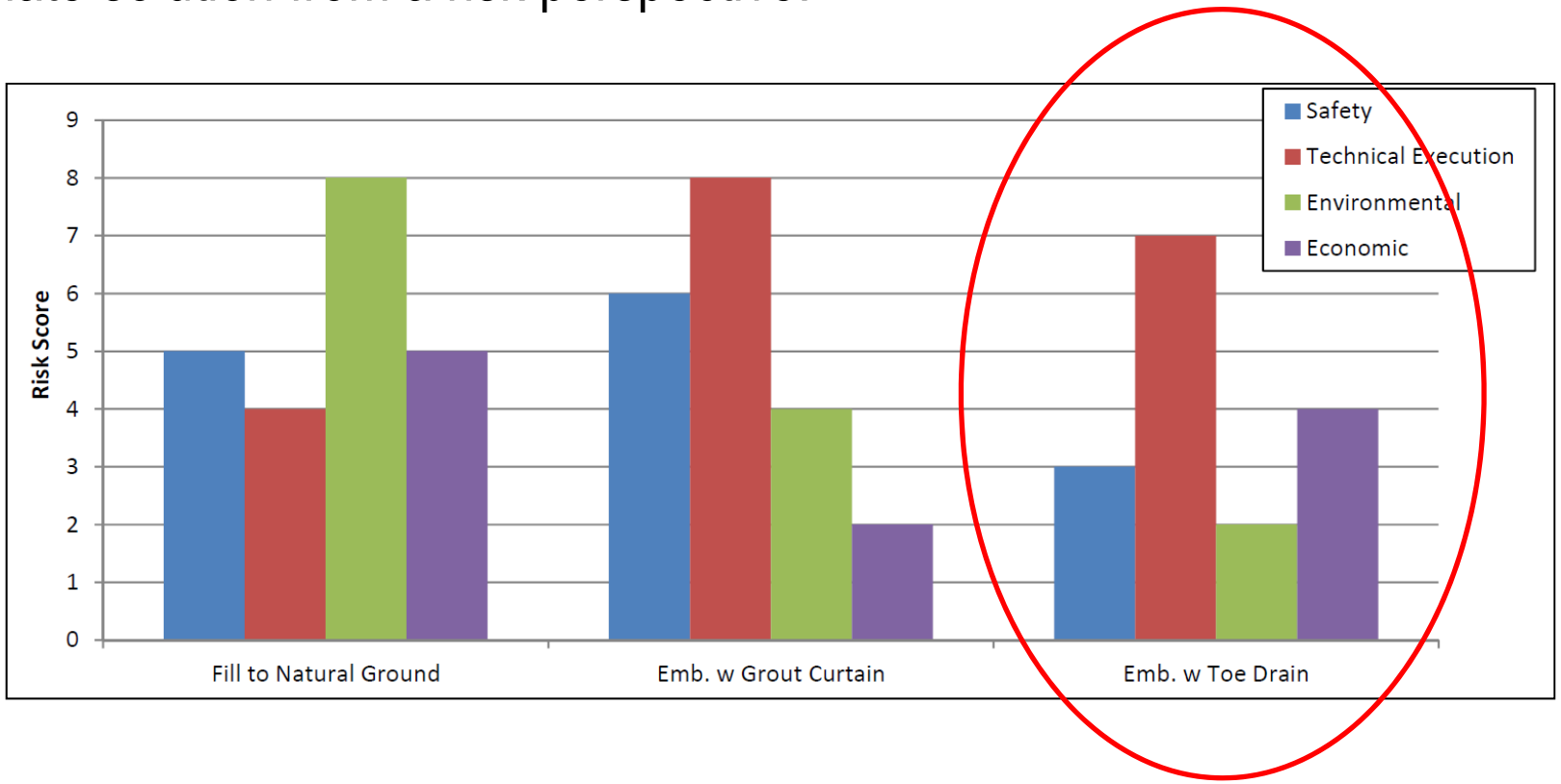
Hazards could include:

- Technical aspects, environmental impacts, aboriginal rights and title impacts, economic losses, etc.

Risk Based Analysis

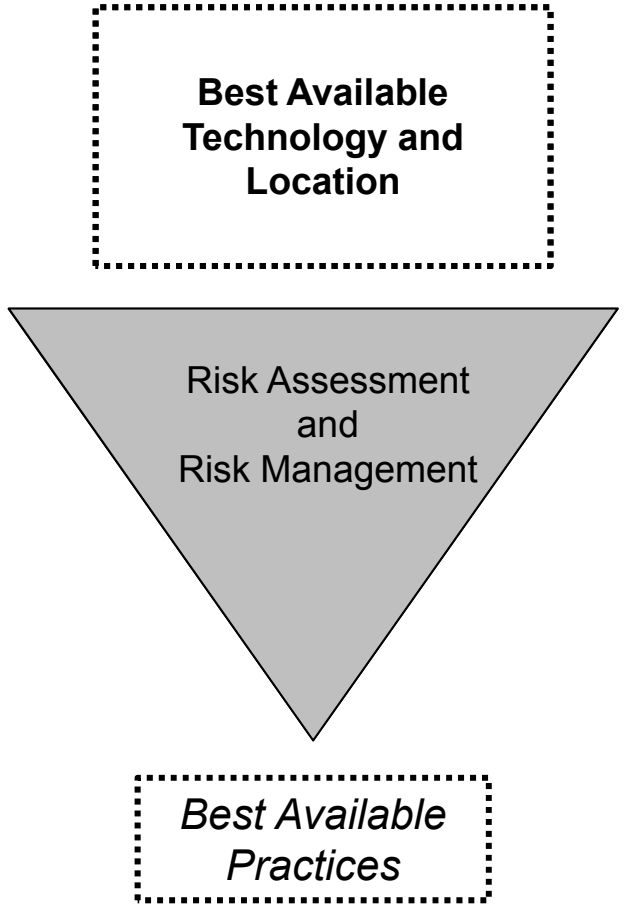
Results

Comparison of relative risk based on several defined hazards to find most practical and appropriate solution from a risk perspective:



Alternatives Assessment

Identifying Best Available Practices (BAP)



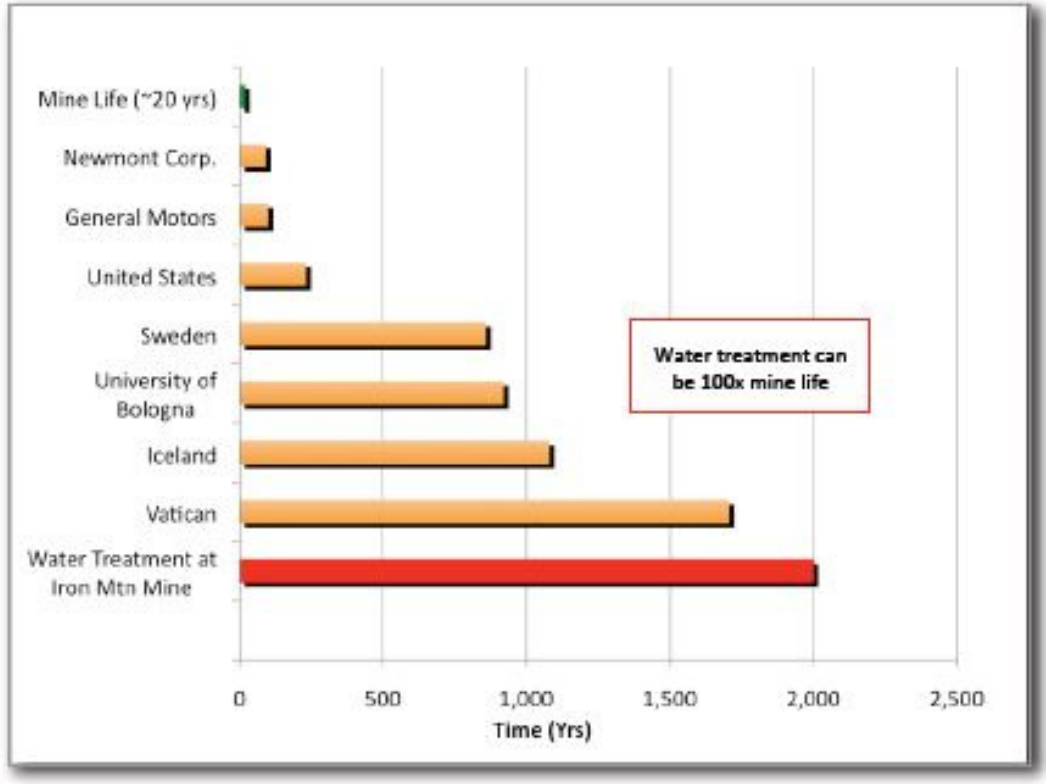
Selected Candidate

Residual Risk Assessment
Failure Modes and Effects Assessment (FMEA)

- Creates catalogue of risk management incorporated in the design
- Identify additional measures to manage residual risk

Final Thought….

There is a Balance Between Physical & Geochemical Stability



Modified after:

Kempton, H., Bloomfield, T.A., Hanson, J.L., and Limerick, P. 2010. Policy Guidance for identifying and effectively managing perpetual environmental impacts from new hardrock mines. Environmental Science & Policy, Volume 13, Issue 6, October 2010, Pages 558-566. Final Journal version available at: http://dx.doi.org/10.1016/j.envsci.2010.06.001.,

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