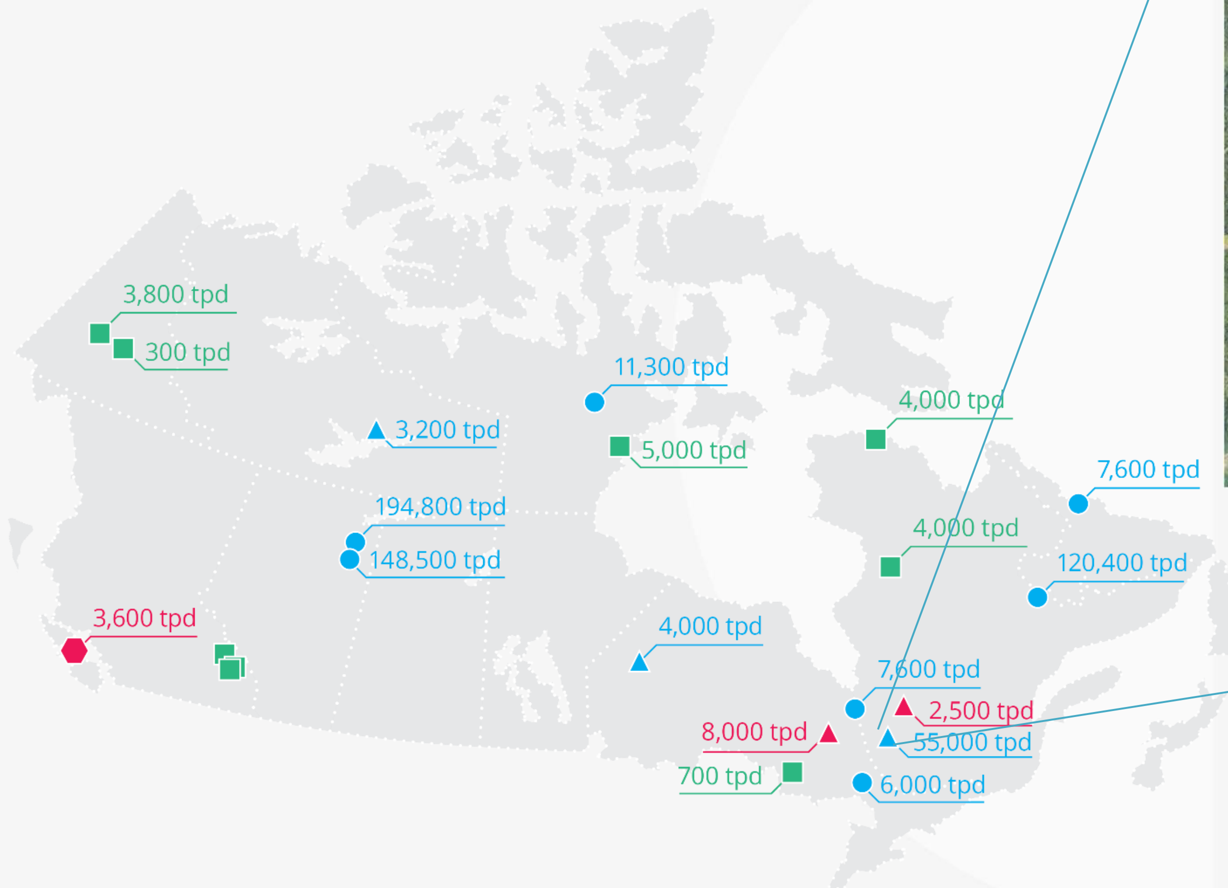
Case Study – Canadian Malartic



Map Data: Canadian Malartic

Facility Type

- Conventional
- High-Density Thickened / Paste
- Filtered

Canadian Malartic - Details

Image references: Doucet et al. 2015 (Top), Canadian Malartic (Bottom)

Location: Val-d'Or, QC

Mine Type: Open Pit – Gold

Production Rate: 55,000 tpd

Tailings Facility Type: Conventional (with High Density Thickened Tailings) (64-65% solids)

Climate: 910 mm average annual precipitation; 650 mm annual evaporation; with net positive balance.

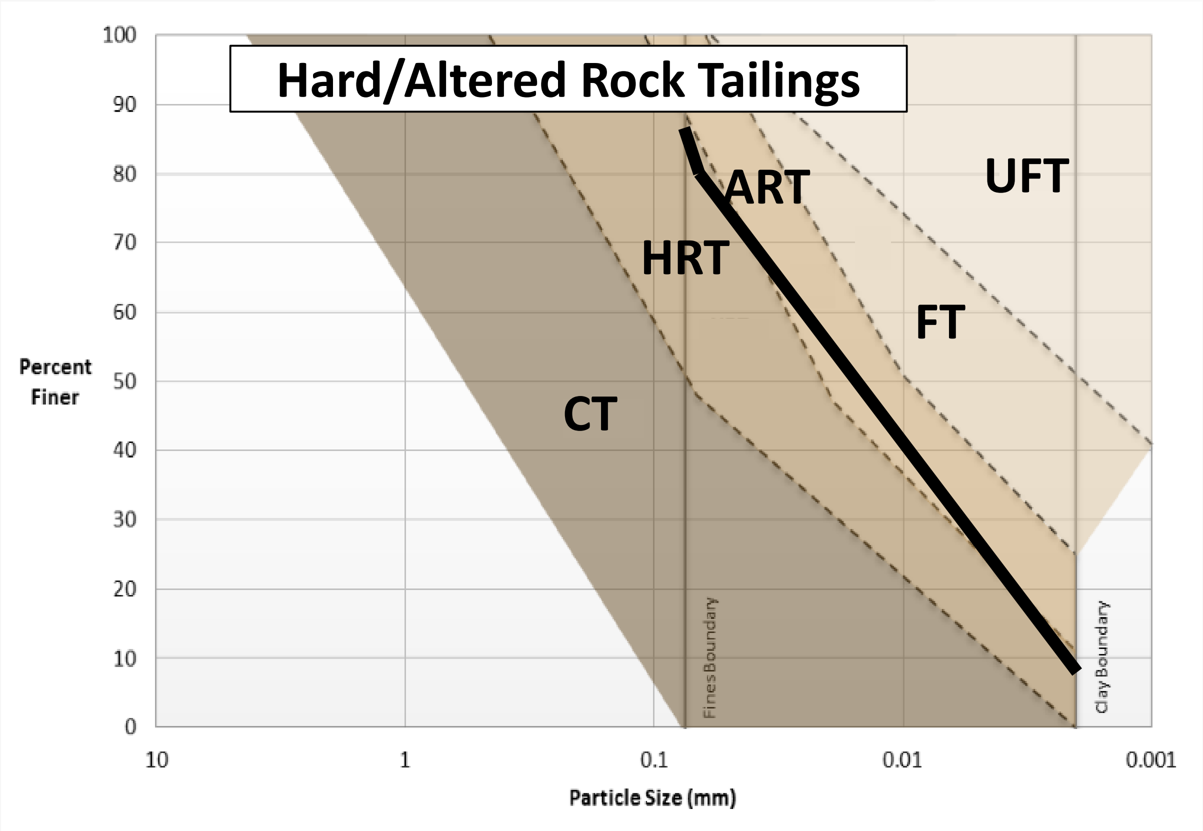
Status: Operating since 2011

Canadian Malartic - Water Management

Image reference: Canadian Malartic

- The supernatant and runoff water reports to the reclaim water pond located south-east of the facility.
- The internal overflow spillways are situated near the centre of the South Perimeter and the Central Perimeter dykes.
- The supernatant and runoff water is 100% recycled to the process plant.

Physical Classification



According to the 2014 NI 43-101 Technical Report:

- According to the classification scheme in Directive 019, a significant proportion of the ore, waste rock and tailings classify as potentially acid-generating or leachable.
- Cyanide is used in the process.

Canadian Malartic - Reason for Facility and Technology Selection

- Dam safety and limiting water storage on the site.
- Thickening tailings also reduces the need for containment structures, reduces the footprint of the tailings facility and improves water recovery.

Image reference: Canadian Malartic

Why Does it Work?

- Continuous improvement and flexibility in the tailings facility type.
- External water management.

Challenges:

- Tailings processing not achieving design targets.

Image reference: Canadian Malartic

Case Study – Musselwhite

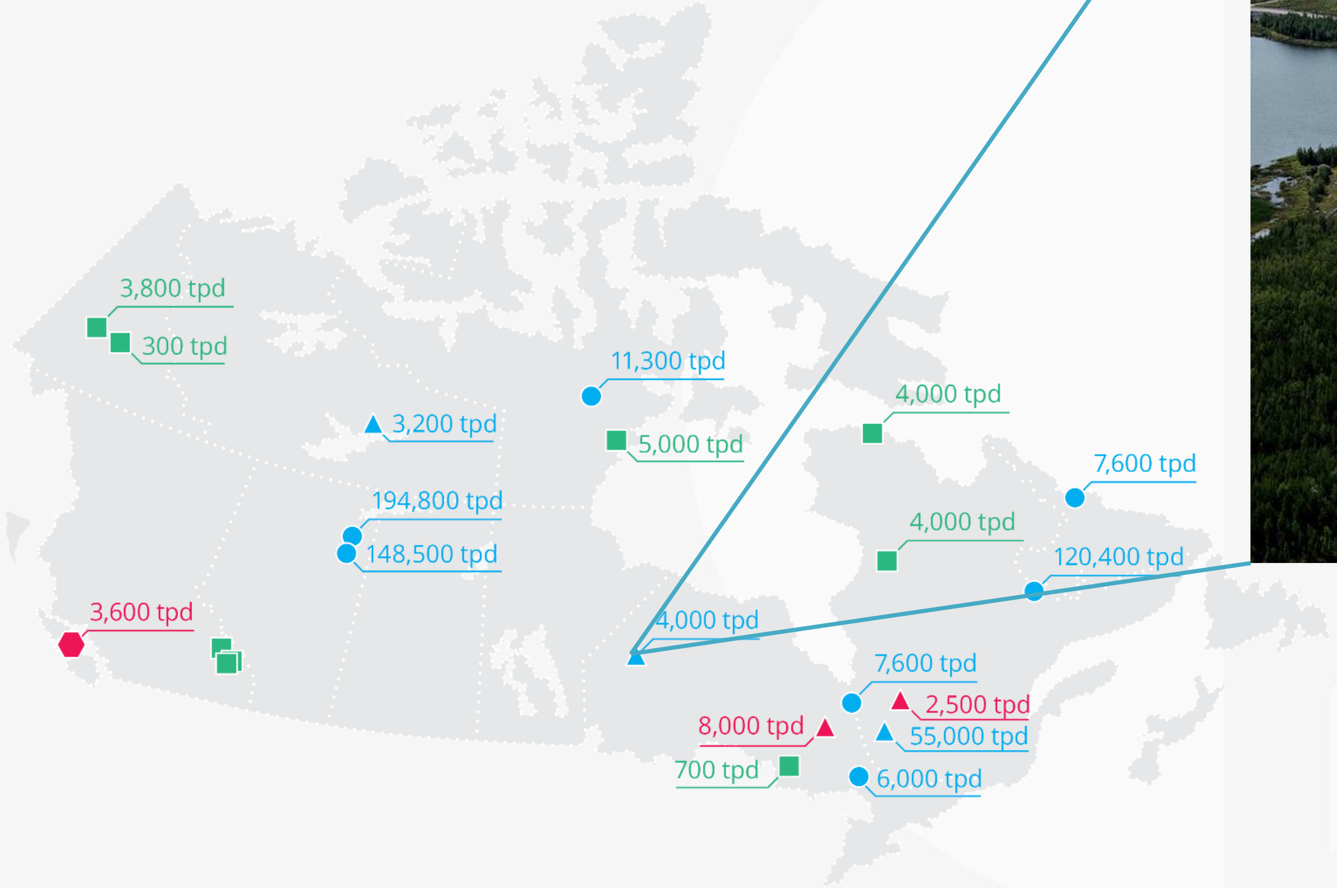


Image reference: Goldcorp 2017

- Conventional
- High-Density Thickened / Paste
- Filtered

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Musselwhite - Details

Image reference: Goldcorp 2017

Location: 475 km north of Thunder Bay, ON

Mine Type: Underground - Gold

Production Rate: 4,500 tpd

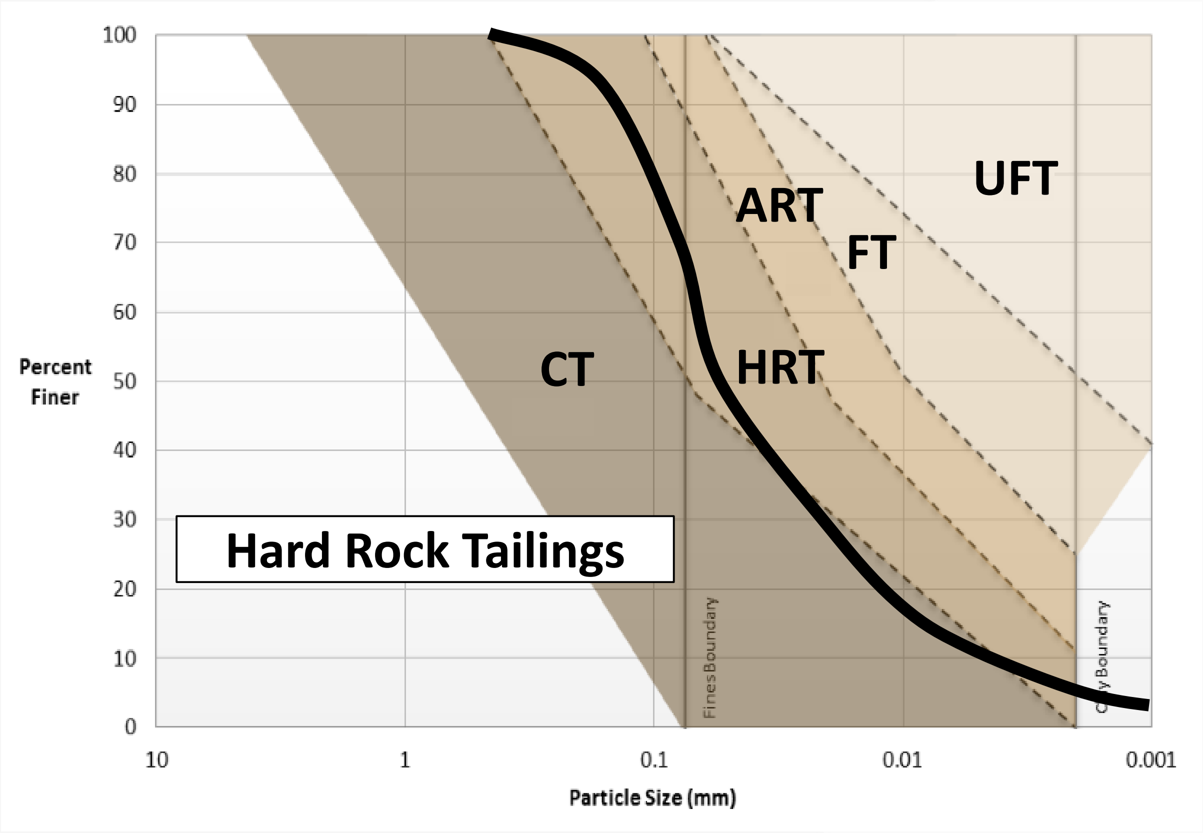
Tailings Facility Type: Thickened Tailings – Conventional

Climate: 730 mm precipitation annually; 410 mm evaporation annually, net positive water balance

Status: In operation since 1997

Musselwhite - Tailings Properties

Physical Classification



- Slurry dewatered from 50% solids content by weight to about 68%.
- Deposited tailings has a concave beach slope profile
  - slopes as high as 3 to 4% close to the spigots discharge points
  - decreasing to 2% towards the center of the facility

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Geochemical Classification

- Low to moderate sulphide content (0.2% to 2%).
- Classified between PAG, Uncertain, and NPAG.
- Lag times to acid generation > 5 years.
- Water treatment is used on site.

Musselwhite - Reason for Facility and Technology Selection

- Adopted to increase the capacity of the existing facility by stacking thickened tailings layers over their existing facility (Jewell and Fourie 2015).
- Changed closure concept from wet cover to dry cover for final closure.
- More desirable from a community perspective, as this strategy allowed the mine to maintain the same footprint, minimize long-term seepage impacts and align with future progressive reclamation plans.
- Benefits of reduced operational expenditure (OPEX), capital expenditure (CAPEX) and operational risk compared to a comprehensive analysis of other tailings disposal methodologies.

Musselwhite - So What?

Why it Worked:

- Changed to thickened tailings in 2010
- Known material properties and materials available for testing

Challenges:

- Dust management
- Change in closure design approach

Case Study – Greens Creek

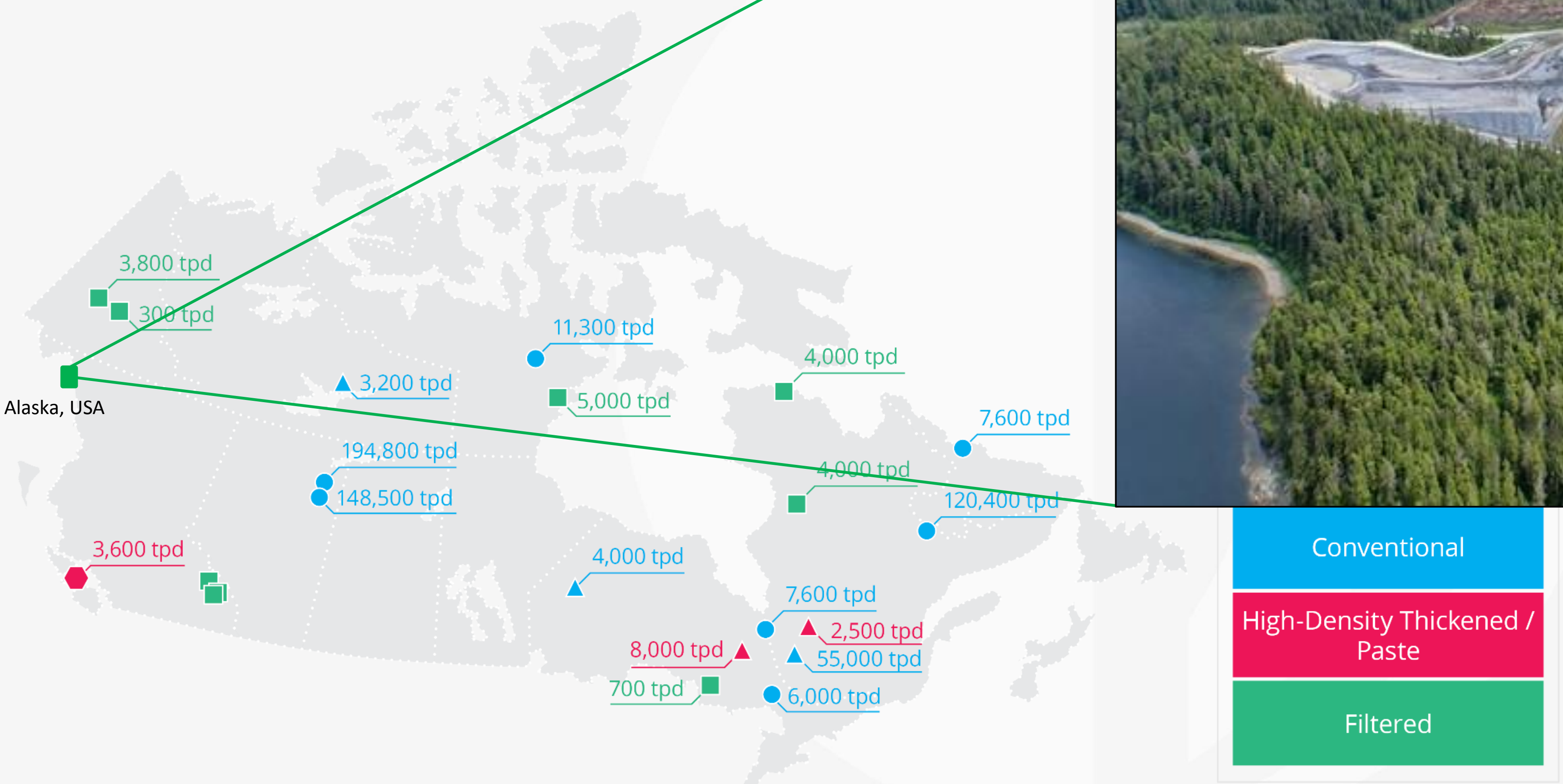

Image reference: Louisberger 2015

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Image reference: BingMaps, Digital Globe 2017

Location: 30 km southwest of Juneau, AK

Mine Type: Underground – Polymetallic Silver

Production Rate: 2,200 tpd

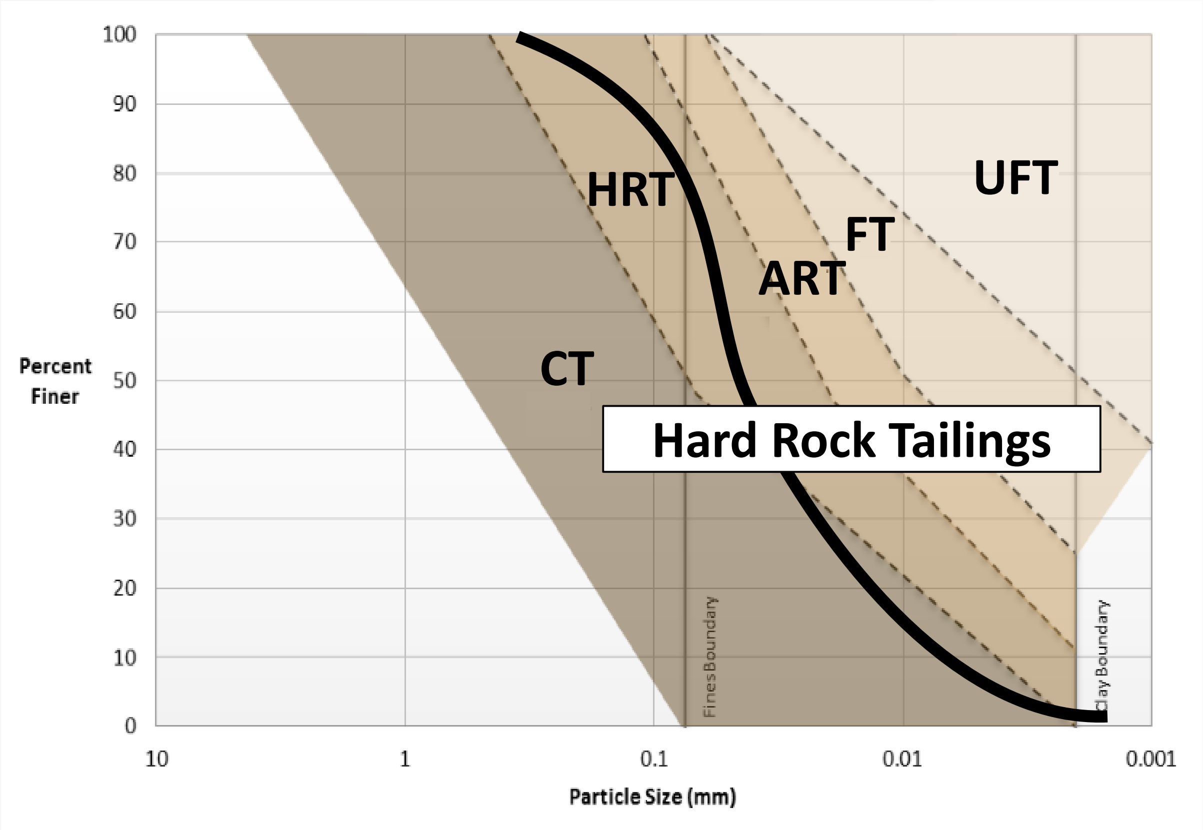
Tailings Facility Type: Filtered Pile

Climate: High rainfall (1450 mm precipitation annually, half as snow; 400 mm evaporation), coastal

Status: In operation since 1989

Greens Creek - Tailings Properties

Physical Classification



Geochemical Classification

- Potential for metal leaching (primarily lead)

Image reference: Condon 2006

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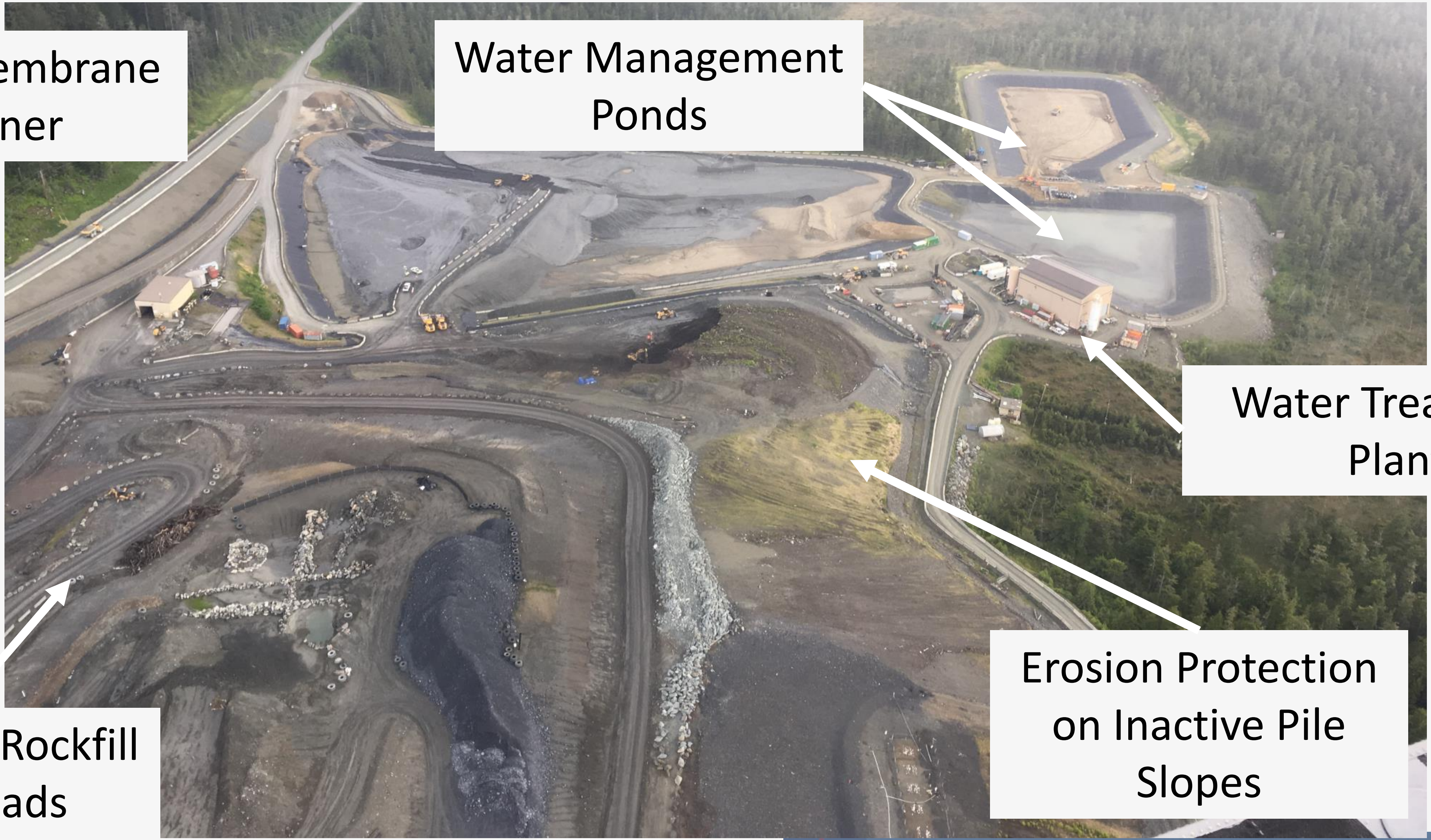
Greens Creek - Tour of the Facility



Greens Creek - Reason for Facility and Technology Selection

Filtered tailings was adopted to minimize overall footprint and for site-specific environmental and geotechnical considerations.

Because there is no pond on the tailings surface, there is little potential for tailings to be mobilized and transported significant distances if the pile were to fail during a seismic event.

Image reference: Condon 2012

Greens Creek - So What?

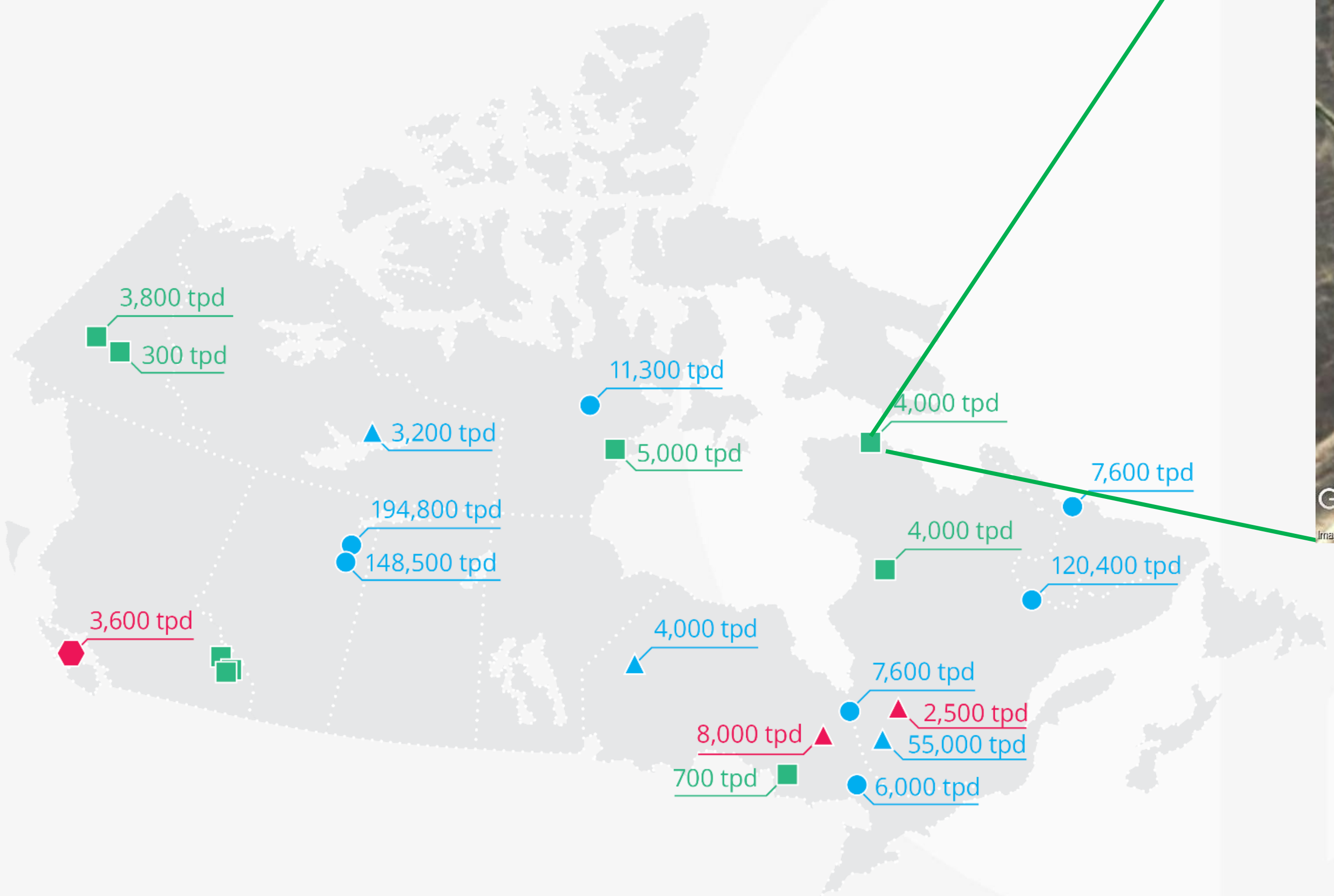
Why it Works:

- Material properties
- Site conditions conducive to the cost balance for filtered
- Low production rate
- Back-up storage options

Challenges:

- Trafficability
- Water and erosion management
- Requirement for water treatment

Case Study – Raglan Mine



Map Data: Google, Landsat / Copernicus

Conventional

High-Density Thickened / Paste

Filtered

Raglan Mine - Details

Image reference: Levac 2016

Location: Nunavik Region, QC

Mine Type: Underground (Open Pit) – Nickel-Copper

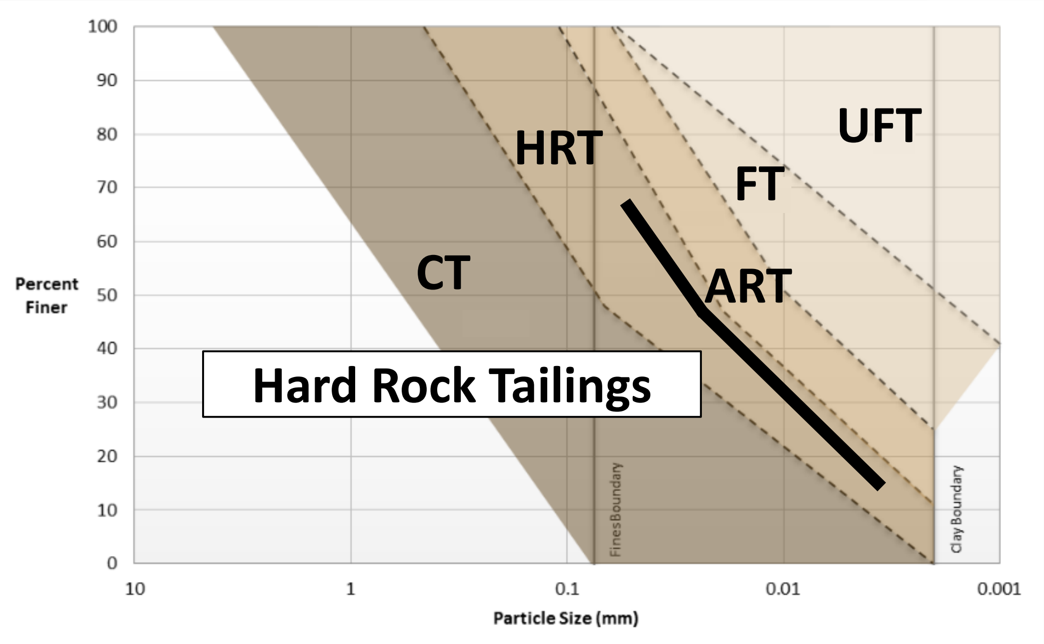
Production Rate: 4,000 tpd

Tailings Facility Type: Filtered

Climate: 520 mm precipitation annually (50% as snow) and ~ 100 mm evaporation annually, continuous permafrost

Status: In operation since 1997

Physical Classification



- Filter pressed tailings to 18-20% m.c.

Geochemical Classification

- The tailings contain up to 8% sulphides, mostly as pyrrhotite (Garneau 2012).
- Generates acidic runoff enriched in metals when exposed to air and moisture above freezing temperature.
- Water is treated prior to discharge.

Image reference: Raglan, a Glencore Company 2017

Raglan Mine - Reason for Facility and Technology Selection

- Economic and waste water management-related.
- Borrow material for constructing starter facilities for a conventional impoundment were scarce.
- Cost trade-off between process requirements and waste water management and water treatment costs.
- Raglan is located in an area that has a limited water source (especially during the winter), which prompted the company to initiate the zero process water discharge (a system that recycles water from mill process) in 2002.

Raglan Mine - So What?

Why it Worked:

- Challenging climate and water management area to work in helped overcome the cost decisions.
- Low production rate and suitable tailings properties.

Challenges:

- Closure planning that accounts for climate change (permafrost encapsulation or geomembrane).

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1. **Introduction**
   - Study Objectives
   - Methodology
   - Spoiler Alert: Key Conclusion
2. **Tailings Management Strategy Considerations**
   - Tailings Properties
   - Site Conditions
   - Dewatering Technologies and Facility Types
3. **Case Histories**
   - Canadian Projects using Dewatering Technologies
   - Select Case Studies
4. **Conclusions**

Case Study Lessons Learned For Dewatered Tailings Projects

- Tailings physical properties need to be suitable for technology selection. Testing should be comprehensive (physical and chemical) at the planning and trade-off stages.

- Achieving design targets (e.g. solids content, slopes) can be challenging during start-up and operations, and continuous effort and investment is required.

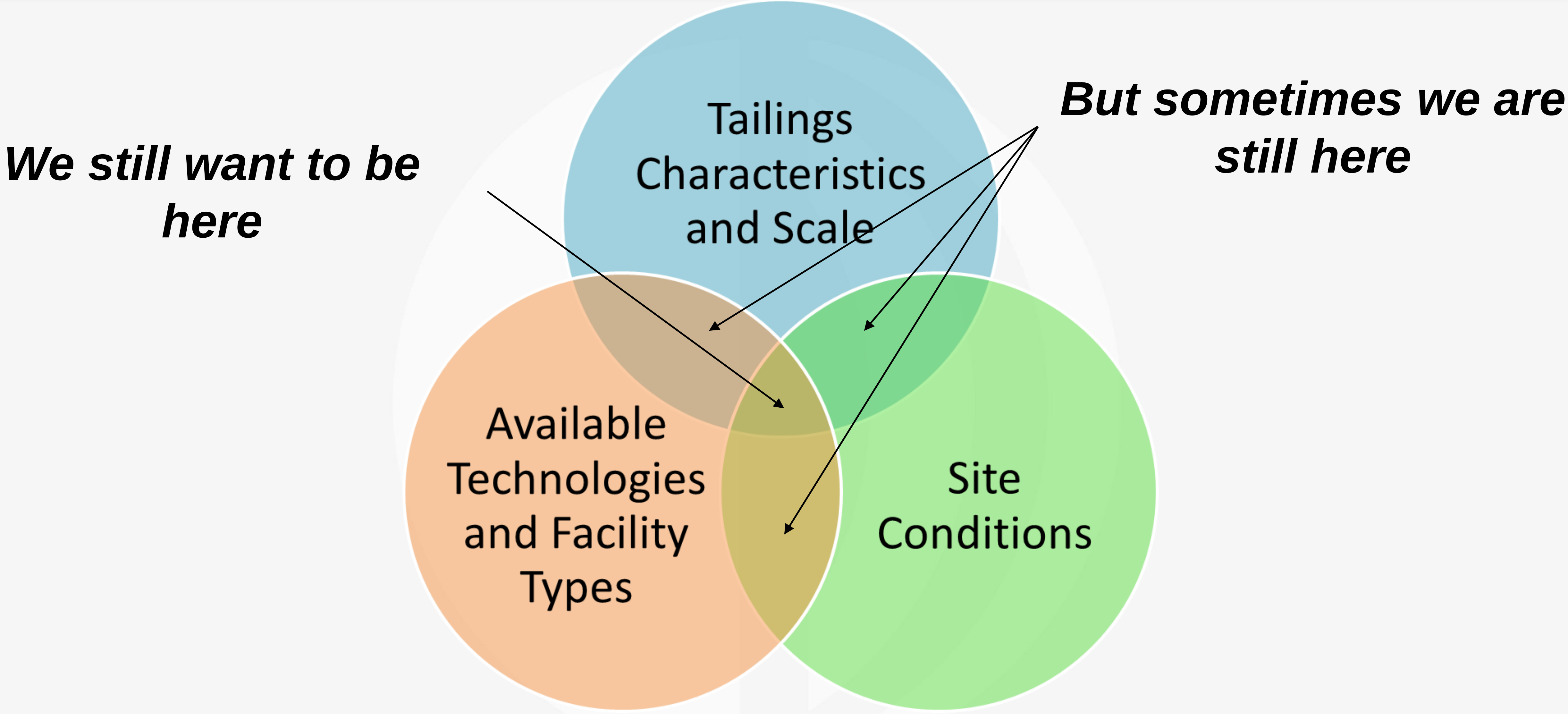
- Need allowance for operational upsets (e.g. back-up storage).

- Water management cannot be avoided.

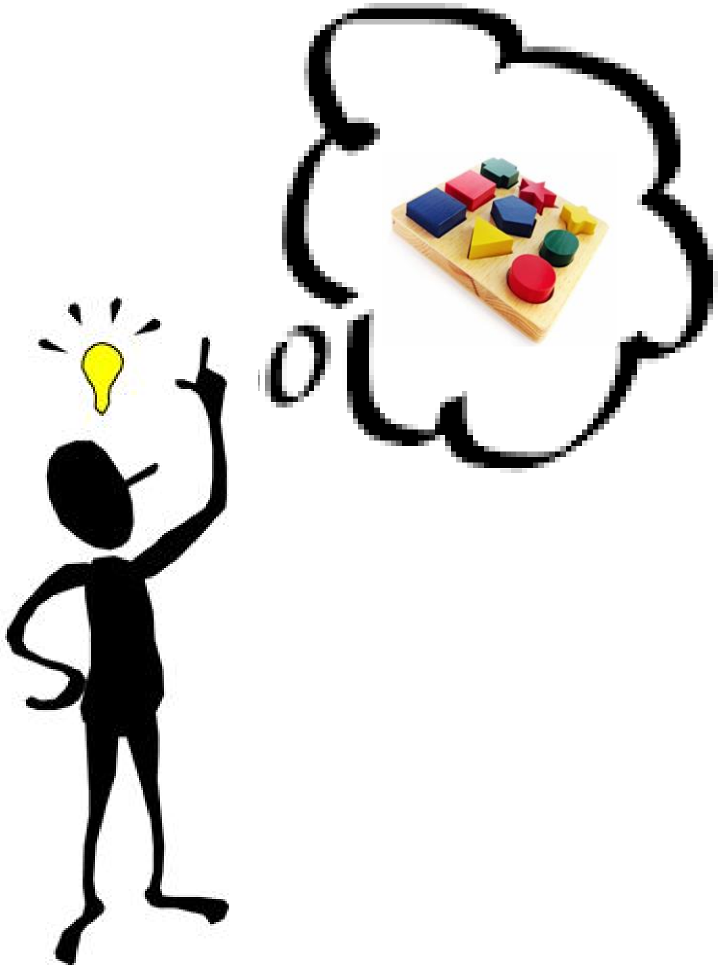
Case Study Lessons Learned For Dewatered Tailings Projects

- More work is required to evaluate the relationship between geochemical properties and dewatered facility's closure.
- We need to share more information as an industry to progress as an industry.
- Dewatered tailings are not widely applied in Canada. The dewatered projects reviewed as part of this study have been implemented with variable success, ranging from not successfully to marginally successful to providing real benefit.

Case Study Conclusions



Need to consider **SITE** and **ORE DEPOSIT SPECIFIC CONDITIONS** and **RISK PROFILE** of potential alternatives



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MEND Tailings Study Report link:

http://mend-nedem.org/wp-content/uploads/2.50.1Tailings_Management_TechnologiesL.pdf

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