Dry Stack Tailings in Cold Regions: Opportunities and Constraints

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Objective

- What opportunities do dry stack tailings provide?
- What constraints must be considered when evaluating dry stack tailings?
- What are specific opportunities and constraints for dry stack tailings in cold regions?

Overview

1. Tailings continuum
2. Examples of cold regions dry stacks
3. Dry stack opportunities
4. Dry stack constraints
5. Opportunities specific to cold regions
6. Constraints specific to cold regions
7. Conclusions

Tailings Continuum

Tailings classification	Solids content	Transportation
Whole slurry	30-40%	Centrifugal pump
Thickened	45-65%	Centrifugal pump
Paste	65-70%	Positive displacement pump
Filtered (aka dry stack)	80-85%	Truck or conveyor

Data from Davies et al. 2010

Filtered Tailings in Cold Regions

Map from Nations Online Project 2015

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Greens Creek Mine, Alaska

Operator:

Hecla Greens Creek Mining Company

Operating:

1989 - present

Mill throughput:

2,200 tons/day

Total capacity:

13 million tons

Image from Independent Expert Engineering Investigation and Review Panel, 2015

Pogo Mine, Alaska

Operator:

Sumitomo Metal Mining Pogo LLC

Operating:

2006 - present

Mill throughput:

2,600 tons/day

Total capacity:

20 million tons

Image from Umedera 2014

Mount Polley Tailings Breach

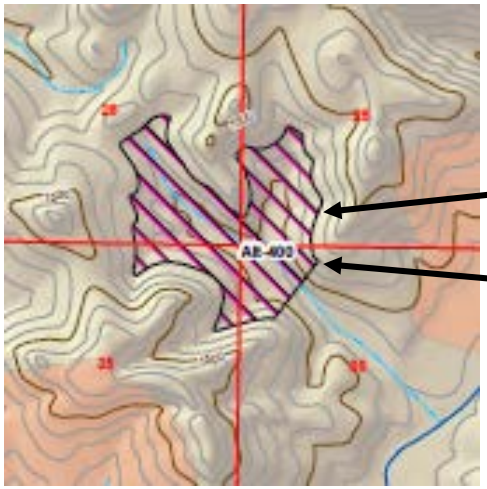
Review Panel Recommendations:

- Eliminate surface water from tailings impoundments
- Promote unsaturated conditions within tailings
- Achieve dilatant conditions within the tailings deposit

✓ Filtered tailings provides opportunity for increased physical stability

Filtered Tailings Opportunities

- ✓ Reduced tailings footprints:
  - More efficient storage
  - Less disturbance
    - Reduced facility area within watershed
    - Favorable for avoiding significant water courses
    - Less permitting and lower reclamation costs

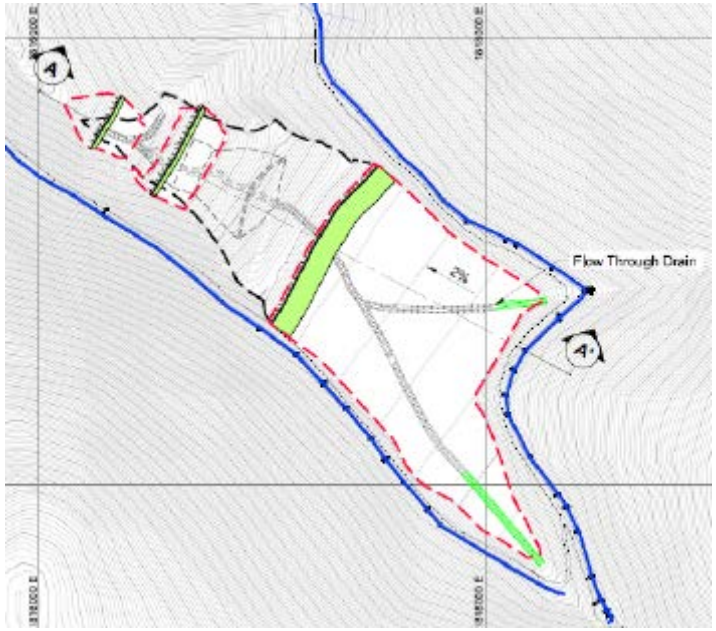


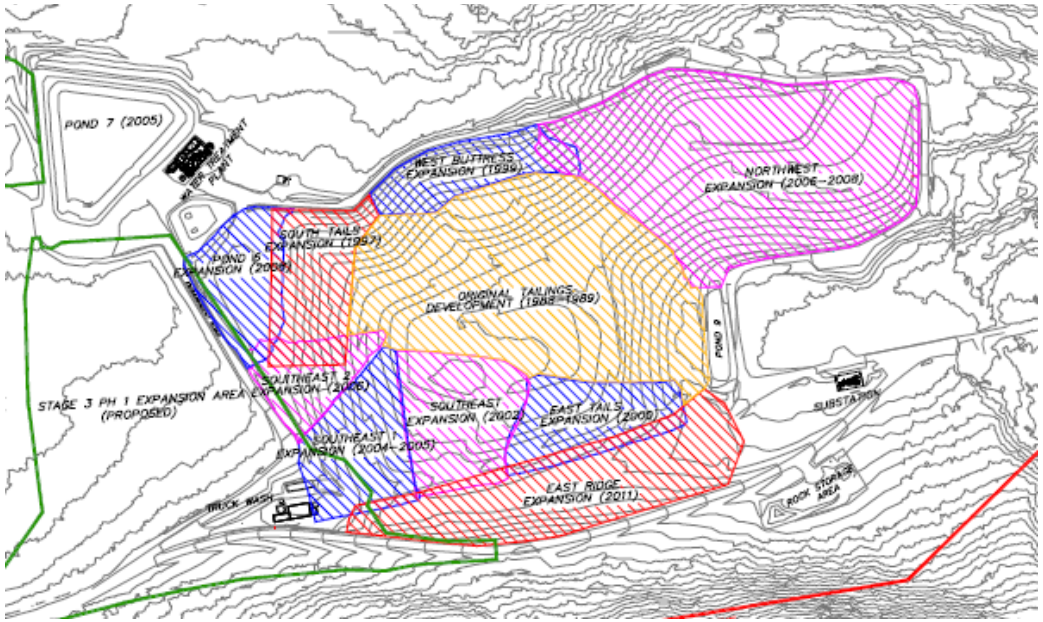
Whole slurry tailings capacity: 60 million tons

Filtered tailings capacity: > 80 million tons

Filtered Tailings Opportunities

- ✓ Flexibility in stack shape
  - Greater range of suitable terrain for deposition
  - Opportunity to design for stable post-closure landform





Images from Sumitomo Metal Mining Pogo 2012, Hecla Greens Creek 2015

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Filtered Tailings Opportunities

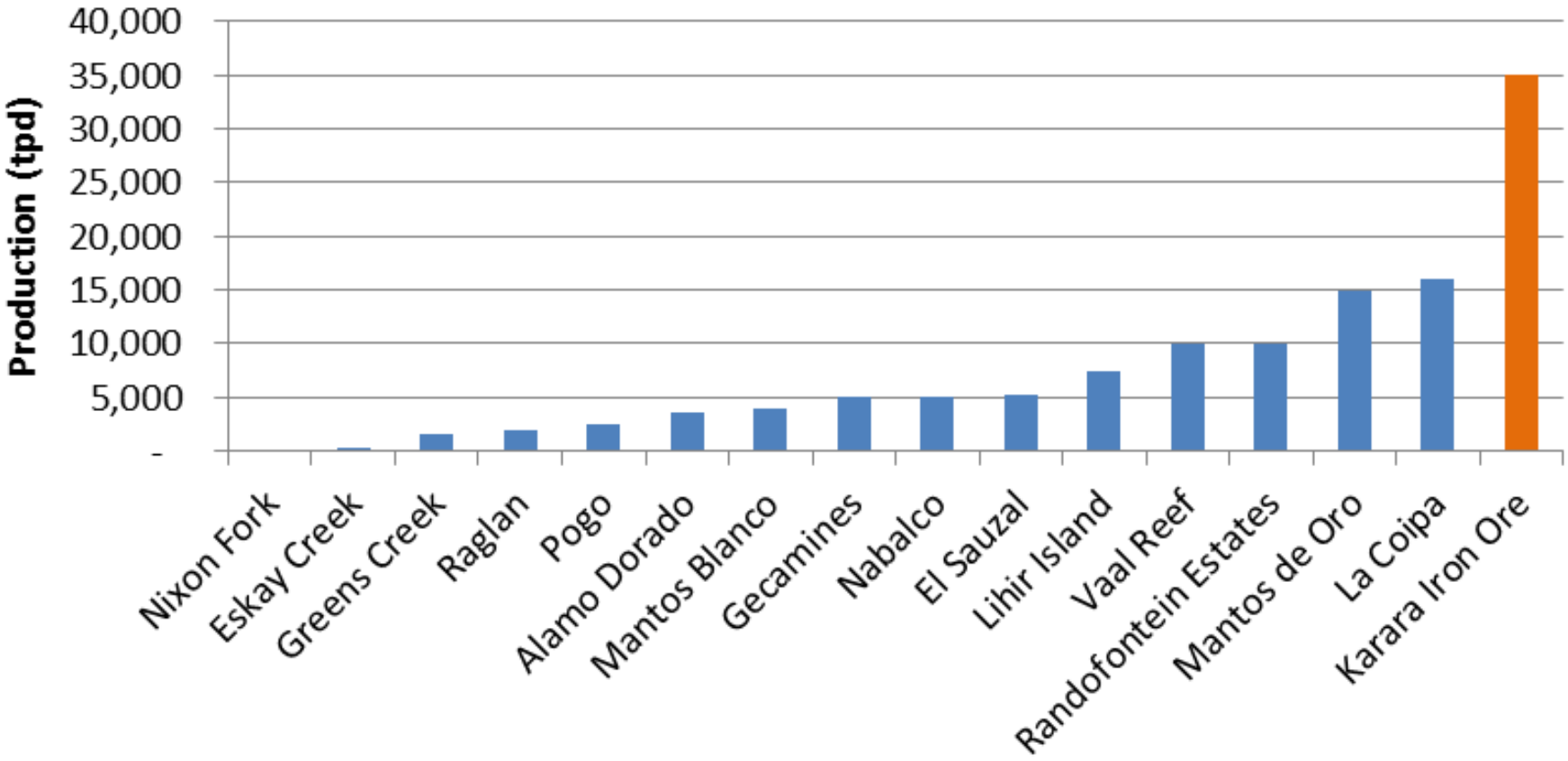
- ✓ Reduced capital costs
  - Full height dam not needed
  - Dam raises not needed
- ❖ However…filter plant needed

Filtered Tailings Opportunities

- ✓ Reduced seepage through tailings
  - Less water contacting tailings
  - Lower seepage management costs
- ✓ Reduced post-closure care requirements
  - Reduced water management requirements
  - Reduced maintenance and inspections

Filtered Tailings Constraints

- Current throughputs:



Data from AMEC 2008, Hore and Luppnow 2014

Filtered Tailings Constraints

- Operational constraints:
  - Difficulty dewatering finer grinds
  - Trafficability, particularly in wet climates
  - Need for equipment at the stack for timely spreading and compacting

Filtered Tailings Constraints

- Higher operating costs
  - Power requirements
  - Maintenance staff
  - Spreading/compacting equipment (low utilization)

Filter press

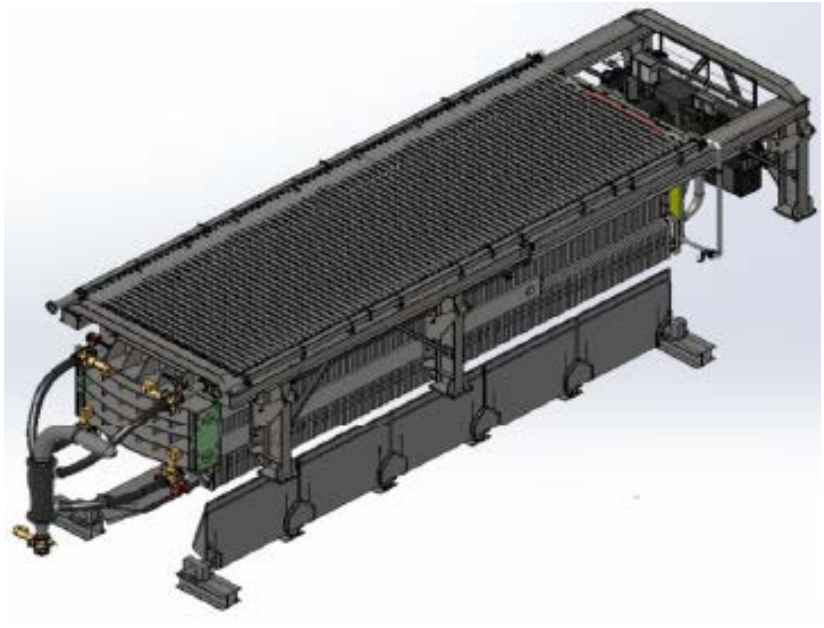


Image from Outotec 2013

Filtered Tailings Constraints

- Increased potential for oxidation of and acid generation from sulfidic tailings
  - Unsaturated conditions allow air entry

$$2FeS_2 + 7O_2 + 2H_2O = 2Fe^{2+} + 4SO_4^{2-} + 4H^+$$

Cold Regions Opportunities

- ✓ Increased tolerance for differential thaw settlement
  - If foundation has ice-rich permafrost and degrades
  - Stack generally less sensitive to settlement than dam retaining slurry tailings and water

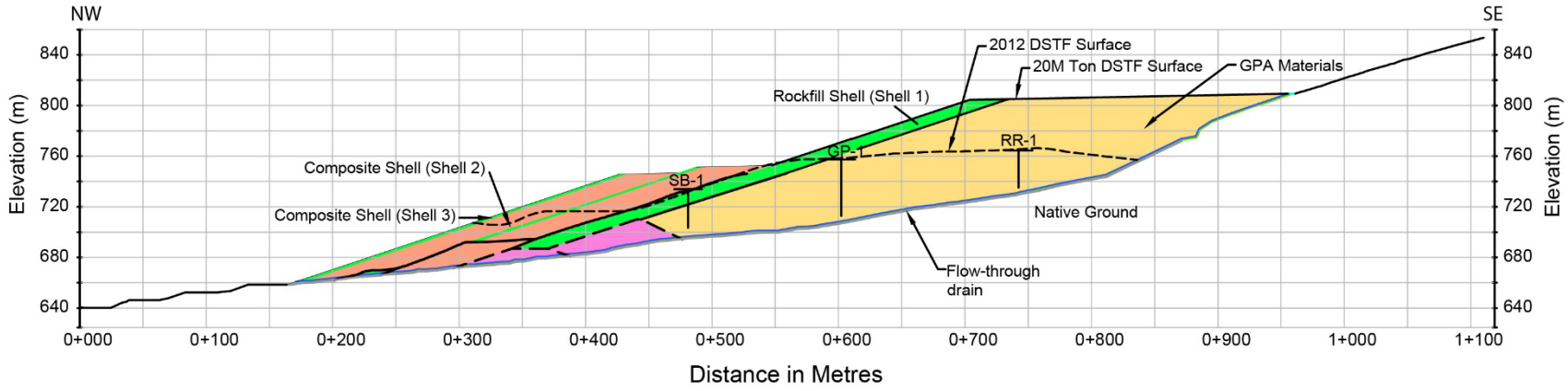


Image from Neuffer et al. 2014

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Cold Regions Opportunities

- ✓ Increased physical and chemical stability if permafrost is present in stack
  - Increased shear strength (assuming minimal excess ice)
  - Decreased permeability to air and water
  - Decreased oxidation rates

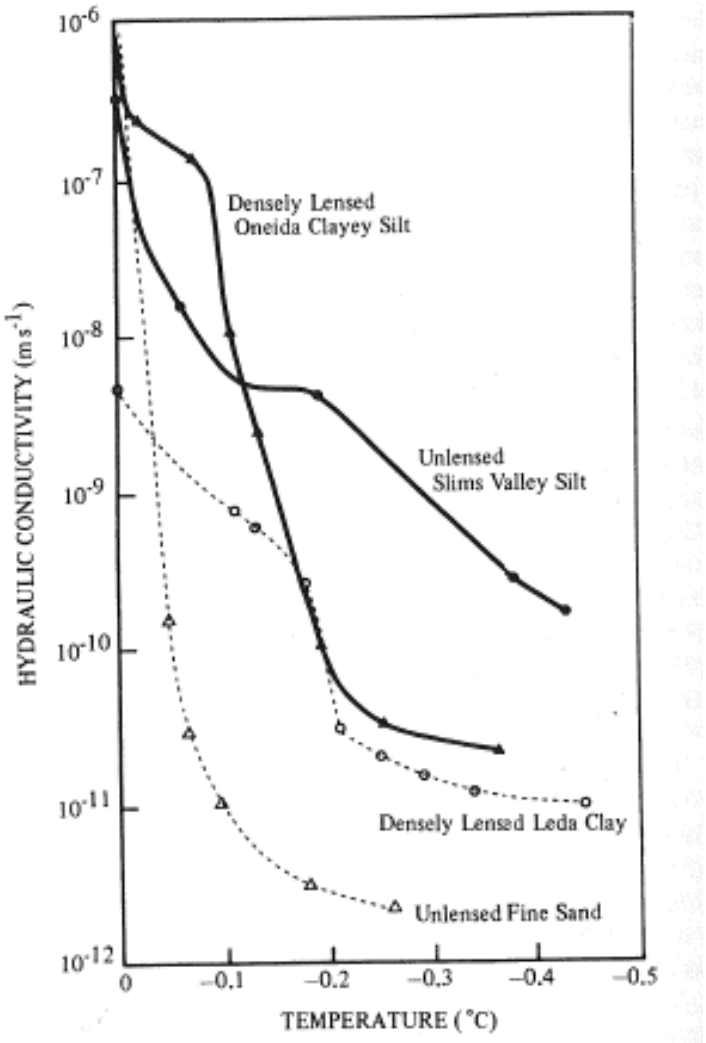

Image from Burt and Williams 1976

Cold Regions Opportunities

- ✓ Reduced difficulty with winter water management
  - No tailings pipelines to operate and maintain
  - May have lower operation and maintenance requirements for water pipelines

- ❖ However…requires other water storage facilities

Cold Regions Constraints

- Tailings placement in freezing conditions
  - Freezing of tailings prior to spreading and compaction resulting in lower tailings densities
  - Example workaround: site-specific testing to establish maximum time between dumping and spreading + compacting

Duration of Pile Exposure	Compaction Effort Trial	Nuclear Densometer		% to Maximum Dry Density
		Density (pcf)	Moisture (%)	
1 Day	4 Passes	102.0	16.2	93.3
	6 Passes	105.4	15.4	96.4
	8 Passes	105.1	16.7	96.2
2 Days	4 Passes	102.3	16.8	93.6
	6 Passes	103.7	16.1	94.9
	8 Passes	106.4	16.7	97.3
3 Days	4 Passes	98.4	16.8	90.0
	6 Passes	100.6	16.9	92.0
	8 Passes	102.7	17.1	94.0
7 Days	4 Passes	90.0	15.5	83.4
	6 Passes	87.8	15.3	81.4
	8 Passes	86.4	15.6	80.1

Data from Sumitomo Metal Mining Pogo 2012

Cold Regions Constraints

- Tailings placement in wet conditions
  - Placement of wet tailings can result in
    - Lower tailings densities
    - Increased potential for saturated zones
  - Examples of how to address:
    - Compact and grade surface to promote drainage
    - Place tailings in multiple, small cells to allow pore pressure dissipation

Cold Regions Constraints

- Surface water management
  - Run-on diversions
    - Construction in permafrost - alteration of thermal regime
    - Ice and snow accumulation in channel
  - Erosion protection for stack slopes
    - Tailings are erodible
    - Spring break-up
    - Summer/fall rain events

Example of armored slope for erosion protection

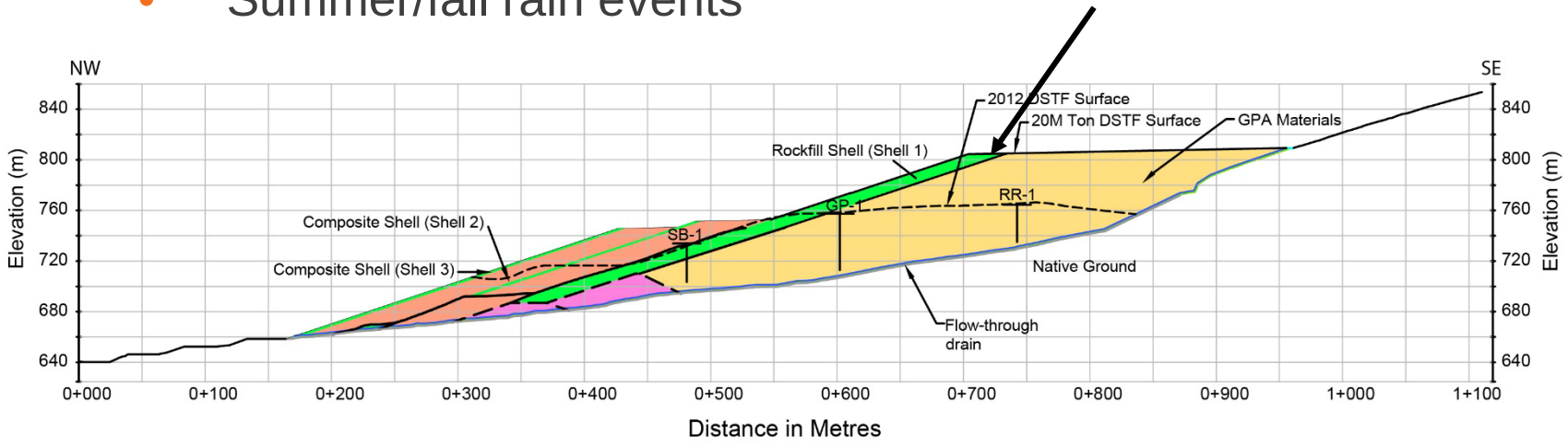

Image from Neuffer et al. 2014

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Cold Regions Constraints

- Foundation stability in ice-rich soils
  - Differential settlement of underdrains can lead to development of saturated zones in overlying tailings
  - Downslope movement of stack due to
    - Excess pore pressure in degrading, ice-rich permafrost and/or
    - Creep in ice phase of laterally continuous, ice-rich permafrost

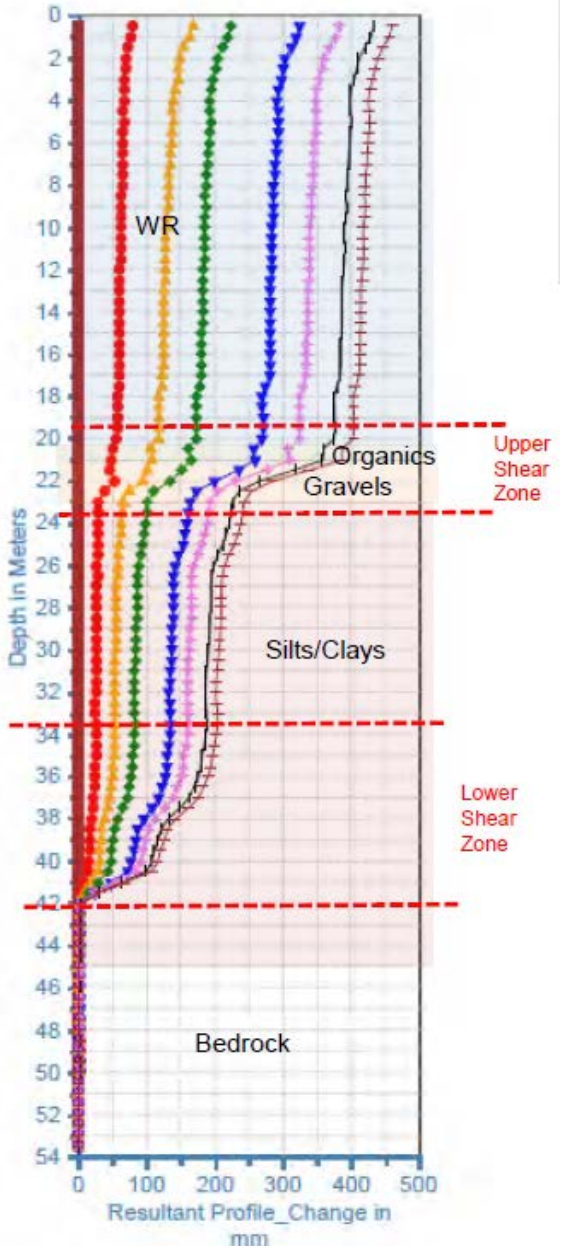

Image from SRK 2015

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Cold Regions Constraints

- Snow management
  - Remove snow prior to tailings placement to avoid entraining ice or water in tailings

Image from Neuffer et al. 2014

Cold Regions Constraints

- Dust management
  - Fugitive dust can be significant during dry periods
  - Mitigation strategies:
    - Compaction
    - Watering
    - Minimizing traffic
    - Armoring
    - Windbreaks
    - Concurrent reclamation

Image from SRK 2009

Recap

1. Tailings continuum
2. Examples of cold regions filtered tailings
3. Filtered tailings opportunities
4. Filtered tailings constraints
5. Opportunities specific to cold regions
6. Constraints specific to cold regions

Conclusions

- Mineral development in cold regions will continue to expand
- Operator objectives:
  - Increase physical stability of tailings
  - Decrease risks of tailings storage
- Filtered tailings is one way to achieve these objectives
  - Opportunities and constraints specific to a site and project must be considered

Thank you! Questions?