Integration of alternative approaches and technologies at some of Agnico Eagle tailings storage facilities

BC MEND ML/ARD Workshop

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Introduction

- There is an important push from the industry to reduce risks due to the failures that have occurred in the recent years
- We are being encouraged to dewater the tailings
- Thickened and filtered tailings technologies have brought lots of opportunities and challenges

INTRODUCTION

- The last 10 years have been characterized by an amazing pace of change in tailings and mine waste management:

  - Establishment of solid governance and management systems to make sure risks are being managed, that roles and responsibilities are defined, and that accountability is clarified.

  - Capabilities of tailings dewatering techniques: transformational in the industry.

  - Overall knowledge-base and practice in tailings management have seen huge changes.

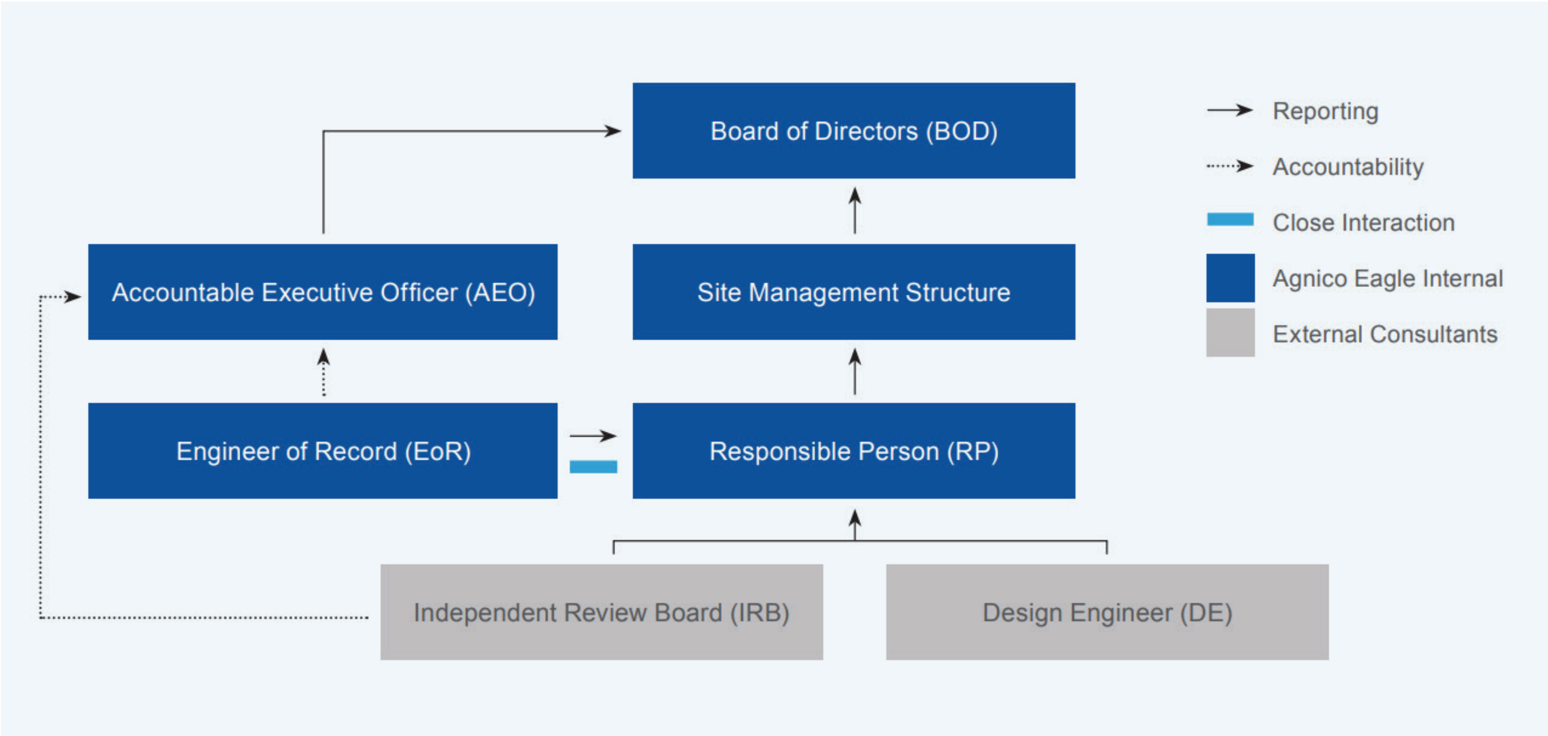
- Discussion on risks integrates the whole life-cycle of projects. Increased expectation these risks to be communicated internally and externally.

- Still, expectations are always increasing, and conversations are becoming more complex.

Outline

- Our Tailings Management Governance
- Each site is unique. We need to adjust to find the best tailings management solution. There's room to apply best available technology. **Examples of tailings management approaches at some of our mine sites.**
- When is it the right time to make a technology change? **Presentation of a case study at LaRonde Complex : Transition from slurry to filtered tailings.**

GOVERNANCE



- https://s21.q4cdn.com/374334112/files/doc_downloads/Sustainability/TM-Report/2023_AgnicoEagle_Tailings-Report-Update_Final.pdf

MINE CANADIAN MALARTIC – THICKENED TAILINGS AND IN PIT DISPOSAL

MINE CANADIAN MALARTIC

- Project initiated in 2007
- Alternative assessment conducted.
  - Choice of technology: Thickened Tailings
  - Preferred Site: Orphan Site.
  - New tailings to cover the existing ones : Old tailings to remain saturated.
  - Permeable embankments to promote consolidation. Construction of a network of surface water management structures.
  - Co-disposition with the waste rock stockpile
- Operations started in May 2011. Throughput of 55 000 tpd

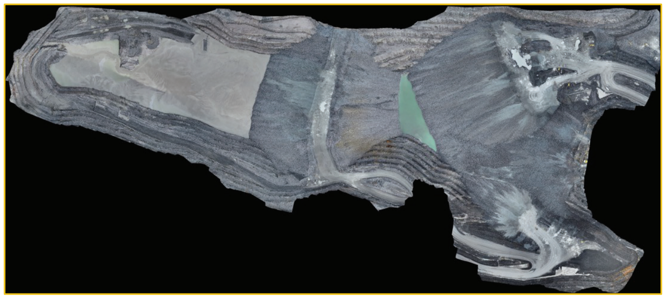
MINE CANADIAN MALARTIC

- Expansion approved in 2016 :
  - Extend current TSF towards East and optimize the footprint of the existing TSF
  - Take advantage of the open pit

- Ultimate storage capacity close to be reached at the TSF.
- Progressive closure activities: More actively since 2023.
- Cover consists in a layer of NPAG tailings with a neutralization potential, waste rock and overburden:
  - Teamwork with the operations to send appropriate ore to the mill, stockpile adequate waste rock for closure cover and to manage the overburden stockpiles.

MINE CANADIAN MALARTIC

- One of the largest open pit gold mine in Canada.
- Two pits: Canadian Malartic (2011-2023) and Barnat (2019 to date)
- Open Pit tailings disposal started in Canadian Malartic Pit in 2024
  - 1.8 km long
  - 1 km width
  - 360 m depth
- Will host :
  - 168 Mt waste rock
  - 108 Mt of tailings



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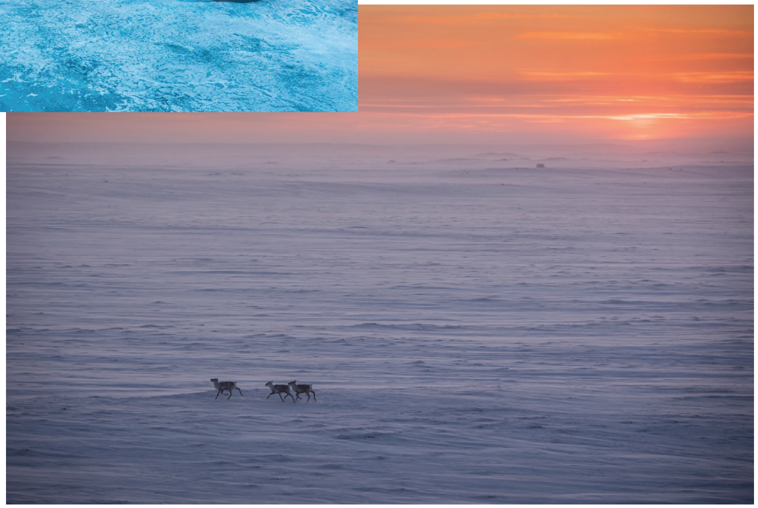
In Summary

- Overprinted an orphan site
- Thickened tailings with free draining structures and waste rock inclusions
- Co-disposition with waste rock
- Compact footprint
- Use the open pit for tailings disposal
- Simple closure concept easily constructible

MELIADINE – SITE CONDITIONS

- Site located in Nunavut.
- Southern Arctic Climatic Region. One of the coldest and driest regions of Canada characterized by long and cold Winters.
  - Mean annual temperature of -9.8 degrees
  - 394 mm of annual precipitations
  - High winds, average of about 22 km/h
- Continuous permafrost between 285 m to 430 m depth.

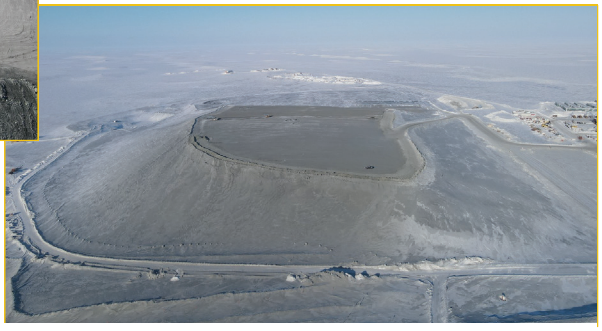


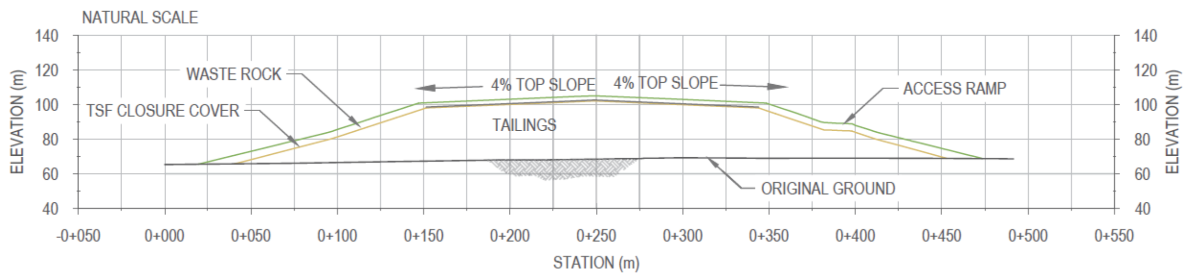
MELIADINE – ALTERNATIVE ASSESSMENT

- Initial assessment conducted in 2014: thickened slurry alternative chosen based on perceived operational risk factors, mostly dealing with handling filtered tailings under winter conditions.
- Agnico Eagle has continued to investigate the two tailings process alternatives, including assessing other northern mining sites where the filtered tailings process was being successfully used (i.e., Raglan and Fort Knox). In 2015, the filtered tailings option was presented in the water license application.
- Smaller footprint. Would delay overprinting of a lake.
    - Water to be recovered within the process plant for immediate recycle
    - Reduces the risk factors associated with storing water and tailings together (in line with recommendations provided after Mount Polley).
    - Increased costs of generating filtered tailings assessed. Economic viable.
- Operating risks of handling filtered tailings under winter conditions was assessed and was found to be manageable.

MELIADINE – DESIGN BASIS

- Throughput of less than 8,500 TPD.
- Filtered Stack : 33 m high.
- 4H:1V to 3H:1V slopes covered with waste rock.
- Key Performance Indicators:
  - Geotechnically stable
  - Geochemically stable
- Design to promote freeze back, with effects of climatic changes taken into account, and designed to satisfy the geotechnical and geochemical requirement should freeze back is not achieved.
- Promote progressive closure of the tailings facility.





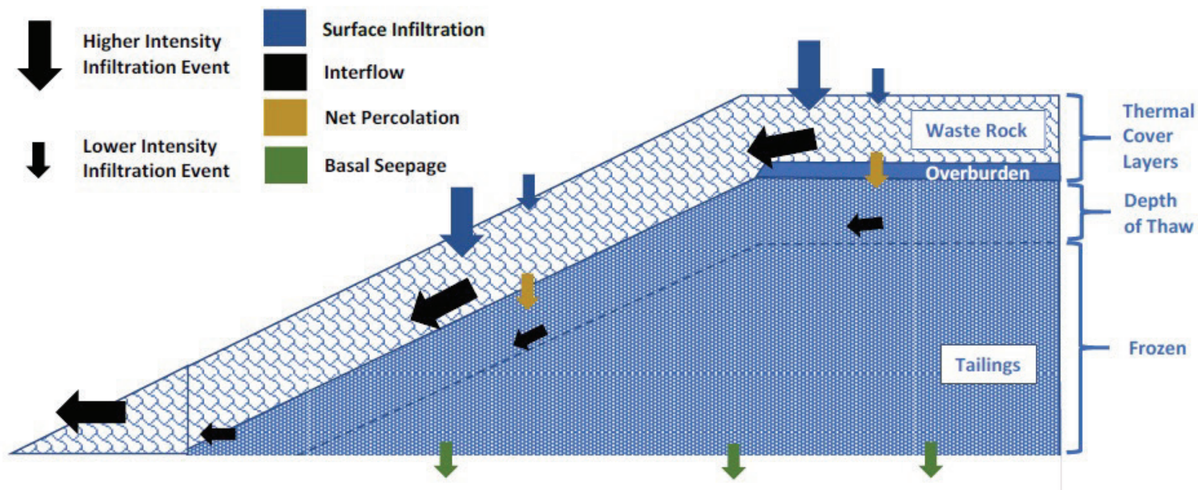
MELIADINE – FILTERED STACK

MELIADINE – GEOTECHNICAL CONSIDERATIONS

- Series of geotechnical testing completed on the tailings and on the foundations.
- Various climatic conditions considered.
- Design informed by a thermal model. Results used to determine the shear strength of the foundation material. Worst case also analyzed (assuming complete thawing).
- Material compacted by lifts of 300 mm. Methodology developed on site through test pads. Sporadic verifications of the in situ density using nuclear densometer tests. Recent integration of the Density Drive Sampler.

MELIADINE – GEOCHEMICAL CONSIDERATIONS

- Geochemical characterizations completed and updated as required and as per industry standards
- Regular testing being conducted on the tailings to determine if the material is PAG, NPAG or if it falls under the uncertain category.
- Thermal modeling and evaluation of seepage conditions conducted. Very minimal contribution from the TSF given the low hydraulic conductivity.



MELIADINE – CHALLENGES

- Freeze Dry : generation of dust during operations
- Temporary issue that will be resolved at closure
- Working on minimizing the exposed surfaces :
  - Placement of ice on surfaces
  - Use of dust suppressor
  - Placement of waste rock temporarily
  - Water trucks
  - Snow fences
  - Modified Sea cans

LARONDE – MID-LIFE CHANGE FROM SLURRY TO FILTERED TAILINGS

LARONDE - OVERVIEW

- LaRonde Complex located in the Abitibi region Québec, Canada. In operation since 1988.
- Current production:
  - Two different orebodies : LZ5 area and LaRonde area
  - Two concentrators grinding to different grains size distribution and leading to different streams of tailings named: LZ5 and LAR tailings.
  - Combined, the two mills have a capacity to process 9,000 t/d.
  - Paste backfill

LARONDE - OVERVIEW

Series of slurry tailings storage facilities (30% Solids content) built over time:

- Main TSF starter dam constructed in 1988.
- TSF expanded in 1997 to the East. Upstream raises built from 2003 to 2019. Deposition continued until end of 2022.
- Extension A4 TSF constructed in 2010 – initially a mine water pond converted in slurry tailings storage facility.
- Site transitioned from Slurry to Filtered Tailings in 2022.

Water Management

- Series of water ponds (Cell 5, Polishing Ponds 1, 2, 3A and 3B)
- Series of water treatment plants are being used at the site.
- The site has a final effluent

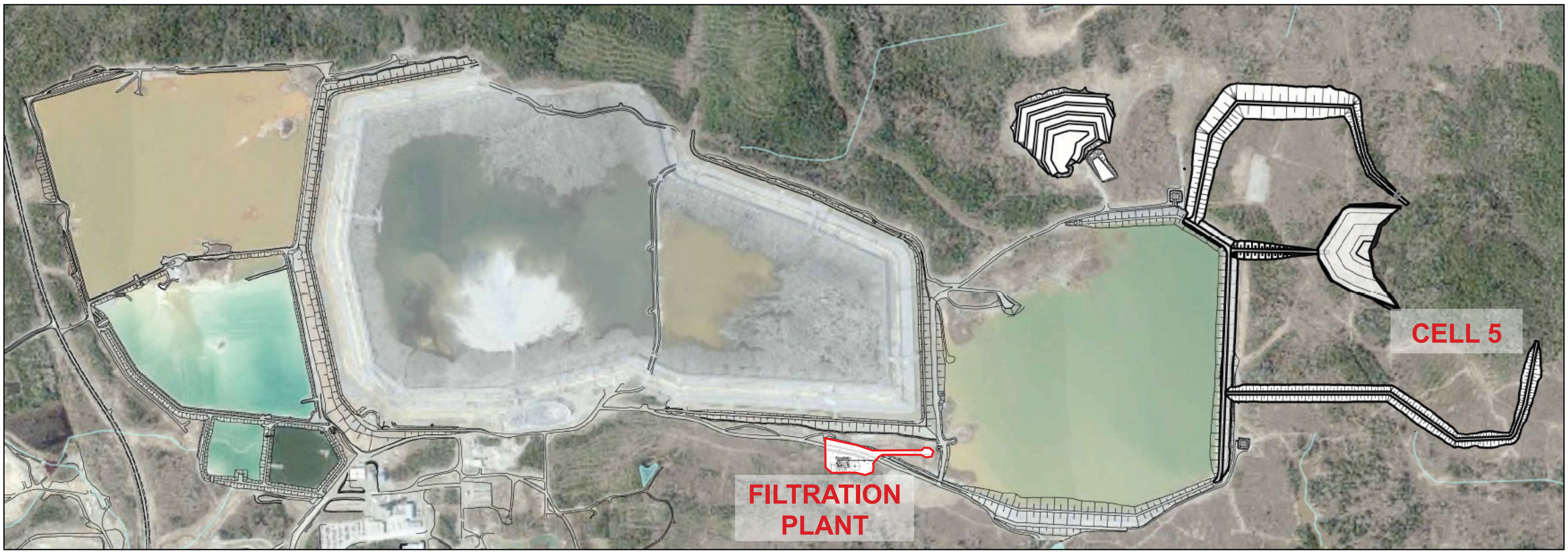
LARONDE – ALTERNATIVE ASSESSMENT

- Alternative assessment process initiated in 2013 for a new slurry TSF. Trade-off study performed in 2018 – Change of strategy.
- Preferred option: Site A4 + Filtered Tailings :
  - Optimize already impacted areas.
  - Removes the water pond.
  - Reduction of uncertainties regarding closure costs.
  - Possibility to use the filtered tailings as a construction material for the closure of other existing cells.

Lots of advantages to transition to filtered tailings compensating the CAPEX investment required. Reduction of the closure costs was a significant driver in the economic assessment.

LARONDE – TRANSITIONING FROM SLURRY TO FILTRATION

- Select the right location for the filtration plant and build it. Optimal location found to be close to the future stack.
- Construct a new mine water pond (Cell 5)



LARONDE – TRANSITIONING FROM SLURRY TO FILTRATION

Cell 5 North – October 2020

Cell 5 – October 2022

Cell 5 – October 2021

Cell 5 – September 2024

LARONDE – TRANSITIONING FROM SLURRY TO FILTRATION

Filtration plant – October 2020

Filtration plant – October 2021

Filtration plant – October 2022

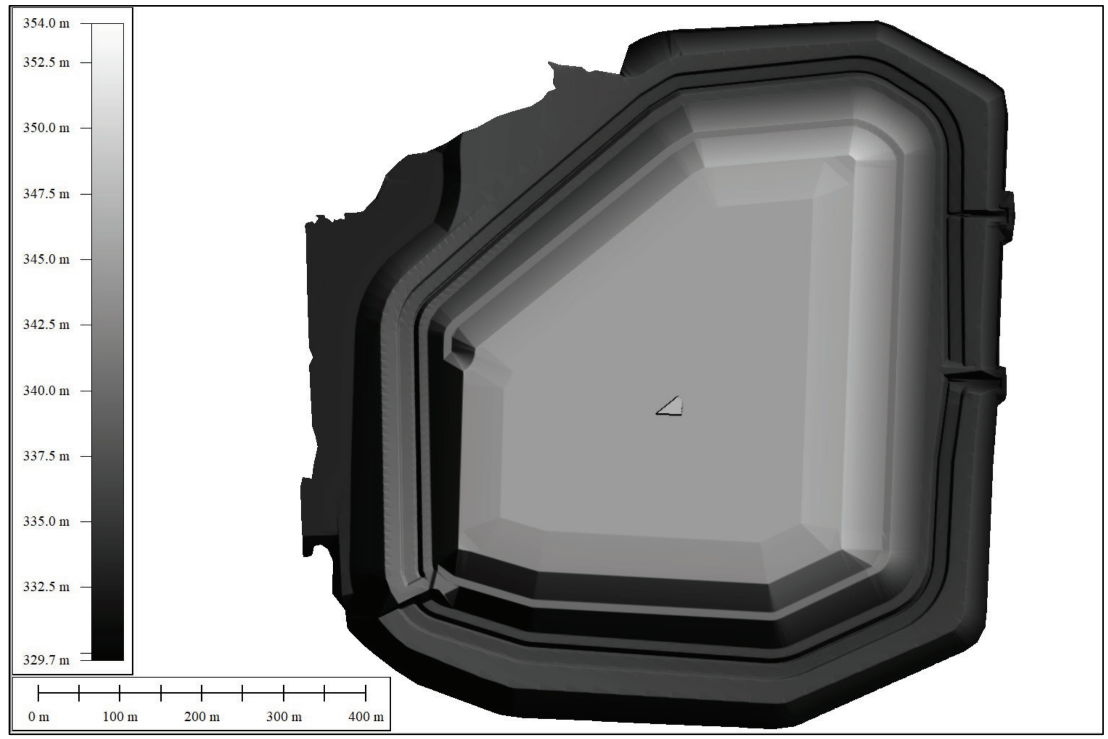
LARONDE – TRANSITIONING FROM SLURRY TO FILTRATION

LARONDE – CONCEPT

- Cover the slurry filled A4 cell
  - Construct a bridgelift using waste rock (reduces surface waste rock dumps)
  - Construct the filtered stack
  - Manage water

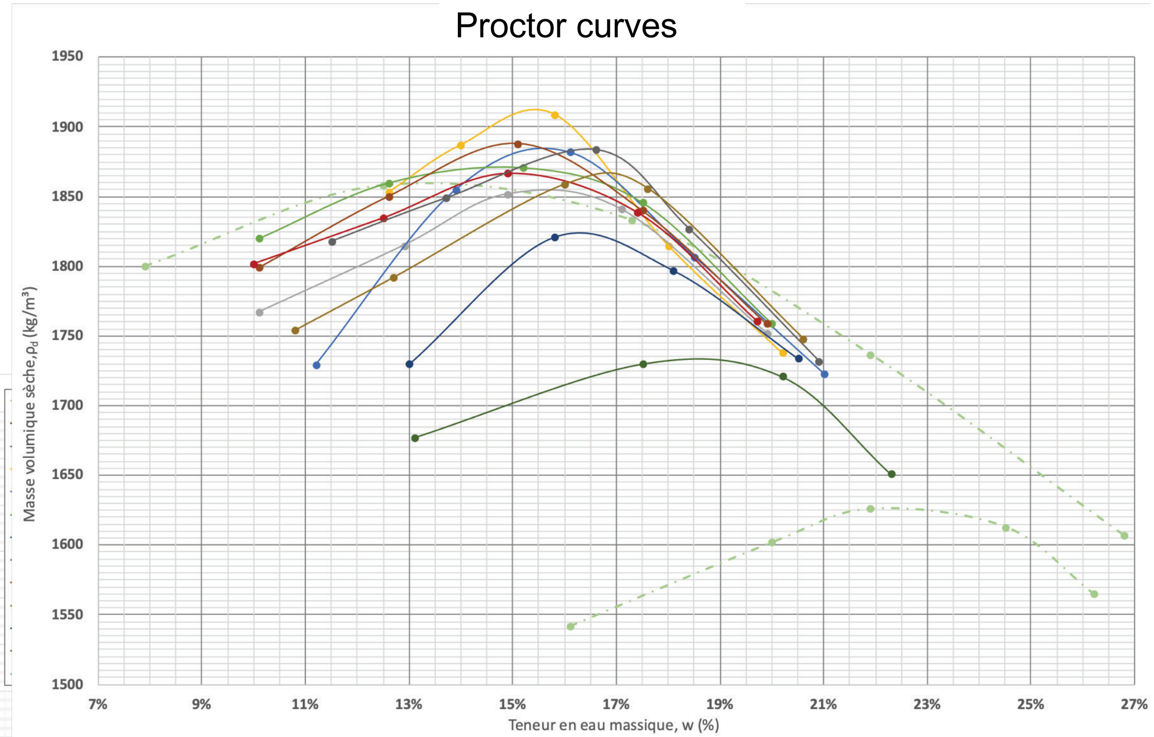
LARONDE – CONCEPT

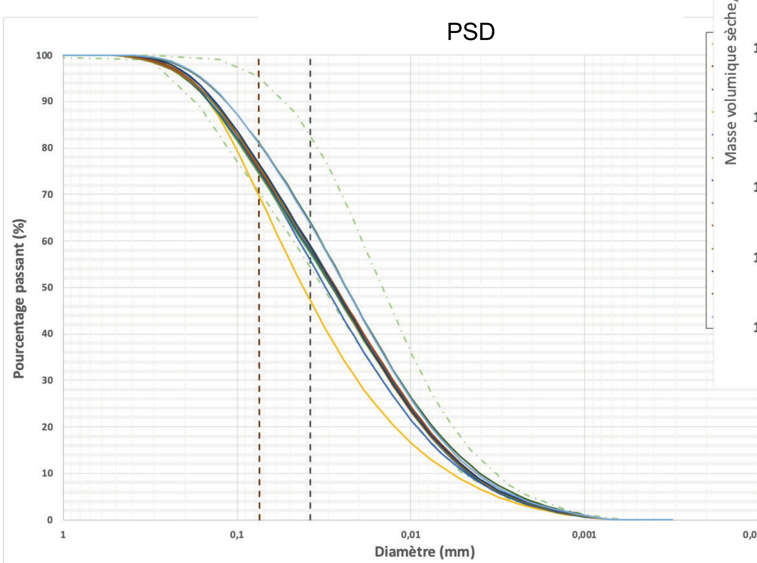
- Manage the geotechnical risks:
  - Geotechnically stable
  - High-end slurry tailings characterization
  - Verify assumptions throughout the life cycle
- Manage the geochemical risks:
  - Advance laboratory testing
  - Developed a sequence of construction to minimize risk of ARD
  - Verify the assumptions
  - Collaborate with universities to develop technologies that could help reducing the geochemical risks.



LARONDE – MANAGE THE VARIABILITY OF THE FILTERED TAILINGS

- Gradation curves vary depending on the tailings feed at the filtration plant and Standard Proctor varies depending on material





LARONDE – MANAGE GEOTECHNICAL RISKS

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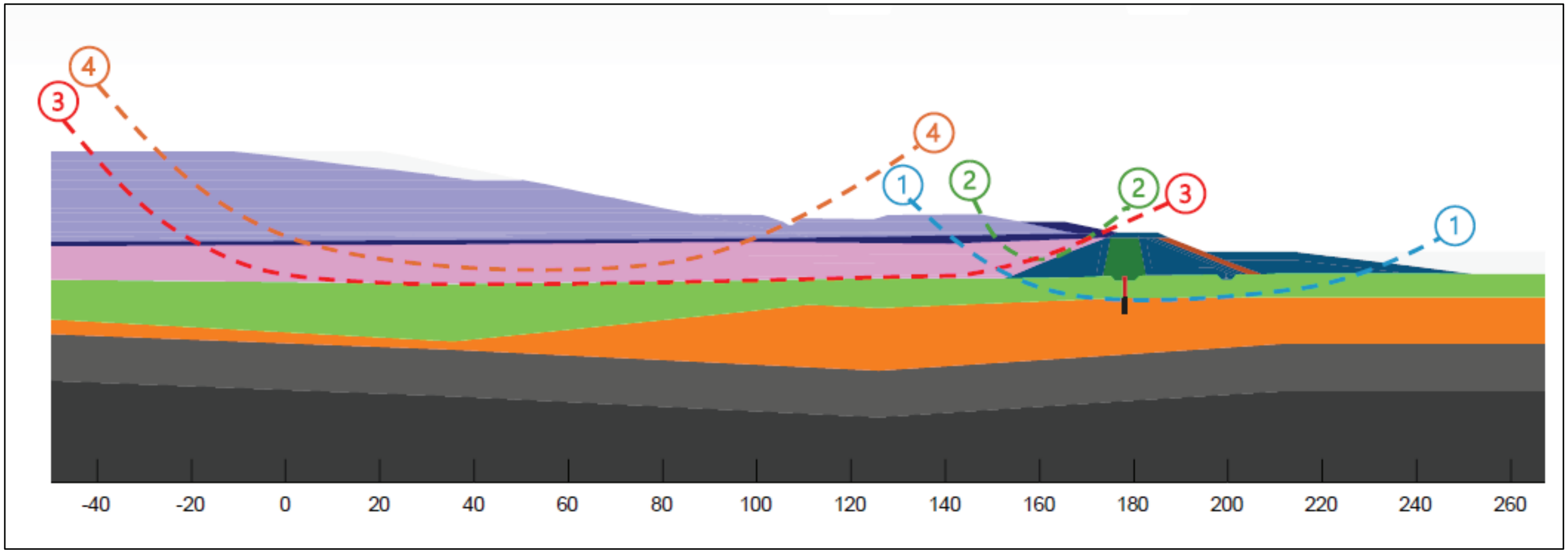
- Identify the potential failure mechanisms:
  - Overtopping : potential progressively reduced to a minimum
  - Internal Erosion : potential progressively reduced to a minimum
  - Instability : main potential failure mechanism to address – sequence of construction/deposition is the key, but it needs to be balanced to limit the geochemical risks



LARONDE – MANAGE GEOTECHNICAL RISKS

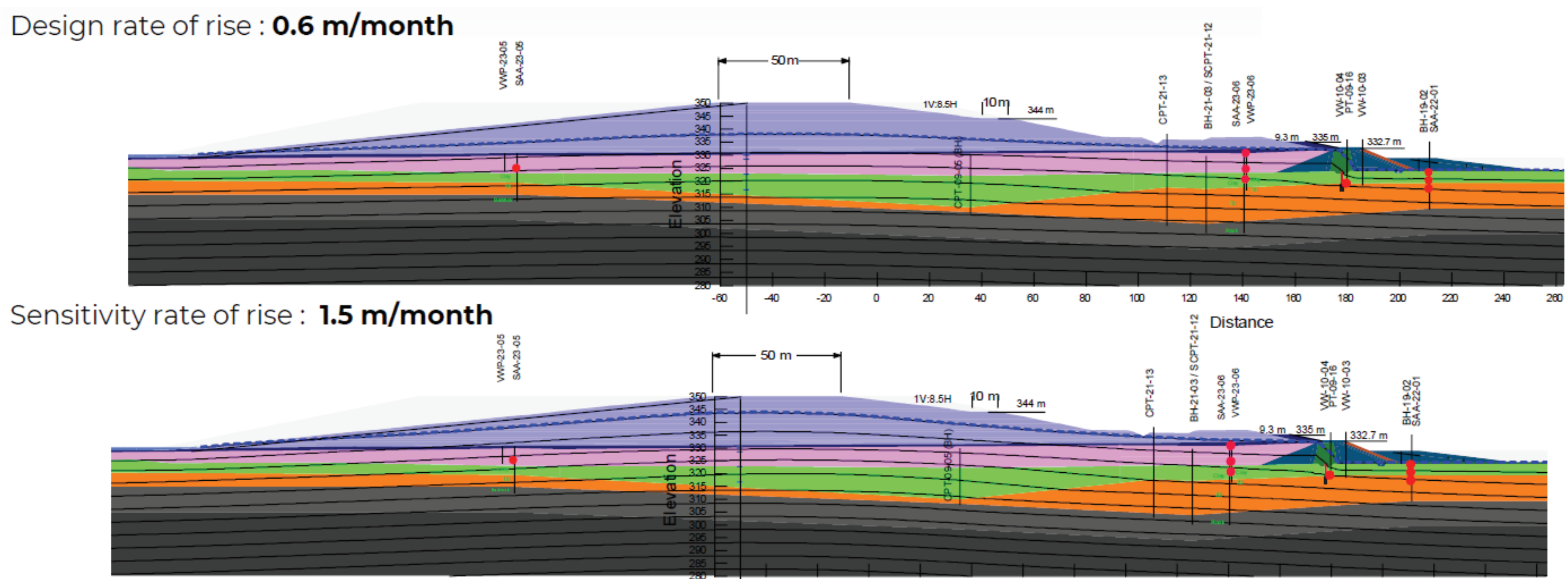
- Performed high-end slurry tailings characterization
- Thorough CPT interpretation with the use of the most recent published trends (undrained, partially drained and drained penetration considered)
- Performed sufficient laboratory tests on the filtered tailings to confirm dilatant behavior
- Adjusted the geometry to satisfy higher factors of safety
- Verify the assumptions throughout the life cycle
- What if? : go to stress-deformation modelling and use performance-based design

	Loading Case	Selected Minimum FS Criteria
1.1	Static, short term (immediately after lift deposition)	1.3
1.2	Static, medium term (immediately before subsequent lift deposition)	1.5
1.3	Post peak: liquefaction of tailings (considering Method A) combined with cyclic-softening of cohesive material	1.3
1.4	Pseudo-static: seismic loading	1.1
2.1	Post peak: liquefaction of tailings (considering reduced strength) combined with cyclic-softening of cohesive material	1.0
2.2	Post Peak: peak strength in tailings combined with strain softening in cohesive material	1.3
2.3	Post Peak: static liquefaction of tailings (considering Method A) combined with peak strength in cohesive material	1.3
2.4	Strain softening: static liquefaction of tailings (considering Method A) combined with strain-softening of cohesive material	1.1

Applied State Parameter Estimation Method	Drainage Conditions (Based on B_q)	
	LAR-A4 Medium	LAR-A4 Fines
Shuttle & Jefferies (2016) with drained widget	Drained penetration : $B_q < 0.05$	Drained penetration : $B_q < 0.05$
Plewes (1992) with material-specific CSL	Partially drained penetration : $0.05 > B_q < 0.19$	Partially drained penetration : $0.05 > B_q < 0.35$
Shuttle & Jefferies (2016) with undrained widget	Undrained penetration : $B_q > 0.19$	Undrained penetration : $B_q > 0.35$

LARONDE – MANAGE GEOTECHNICAL RISKS

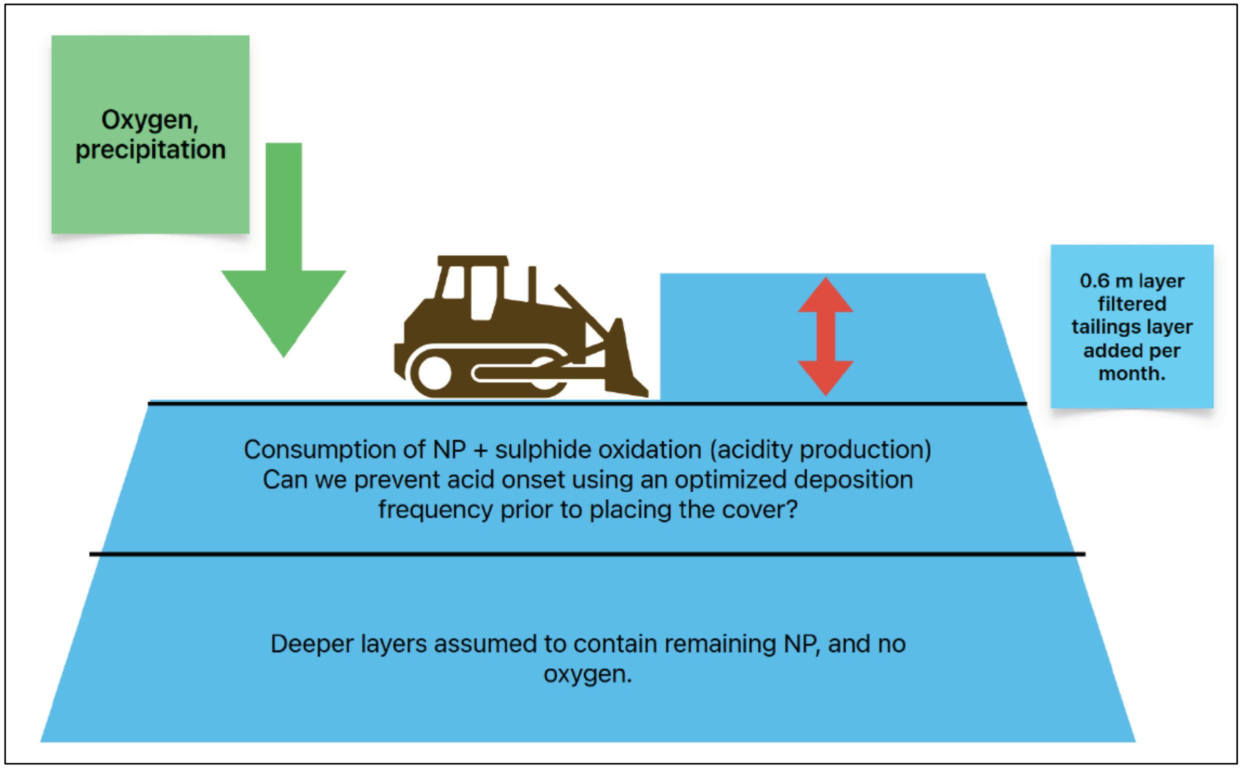
- Rate of rise is key to the geotechnical performance of the tailings stack.
- Clear thresholds extracted from the model.



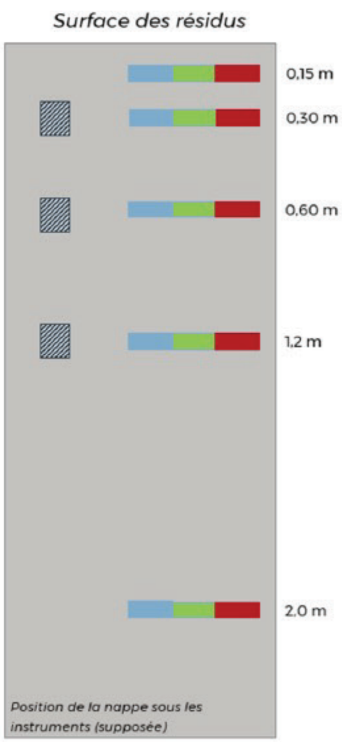
Porewater pressure isocontour at 50 kPa intervals

LARONDE – MANAGE GEOCHEMICAL RISKS

- Filtered tailings are reactive, but the time required to initiate the oxidation reactions leading to ARD remains uncertain.
- Lack of information on the variability geochemical/ physical composition of the tailings
- Scale effects (laboratory vs. field)

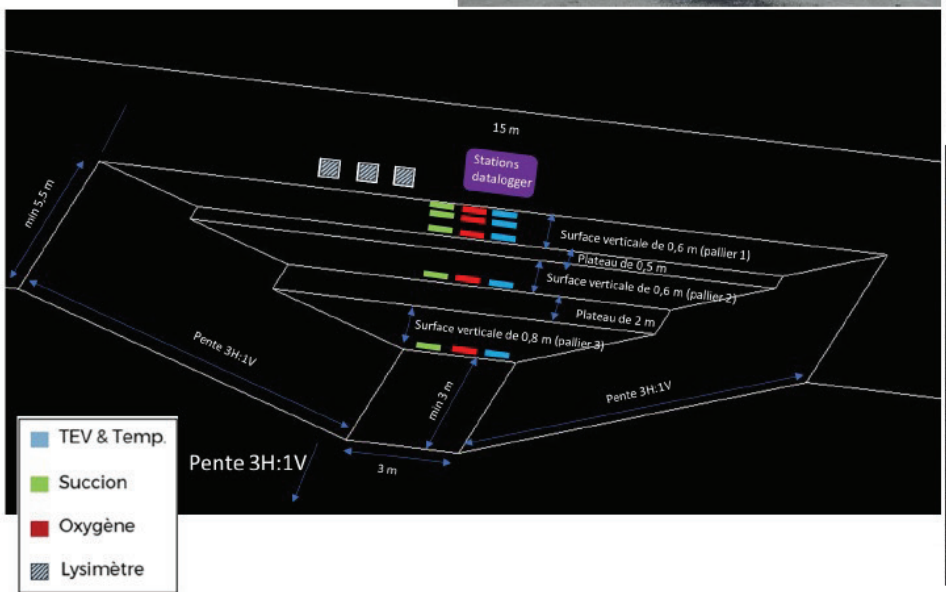


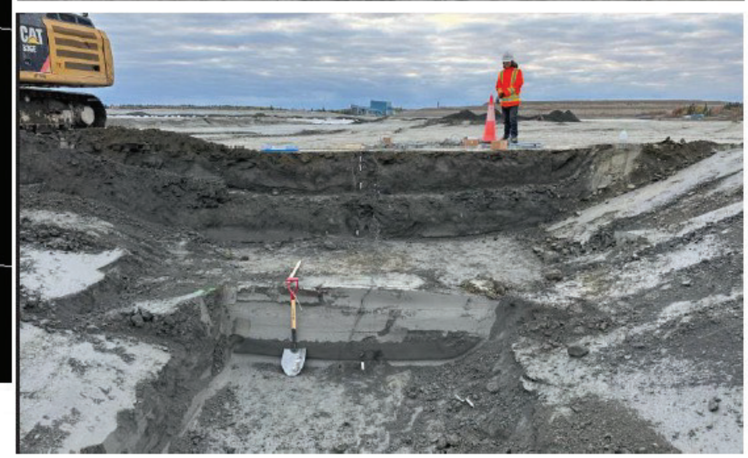
LARONDE – MANAGE GEOCHEMICAL RISKS



Instrumentation :

- Volumetric water content and suction probes
- Oxygen concentration probes
- Suction lysimeters





LARONDE – MANAGE GEOCHEMICAL RISKS

LARONDE – MANAGE GEOCHEMICAL RISKS

Geochemical risks are currently being addressed by controlling the sequence of placement and with the use of sacrificial liners.

Passivation being studied

LARONDE – CONSTRUCTION OF THE BRIDGELIFT

- Use of an existing tailings storage facility to store filtered tailings.
- Construction of a bridge lift with waste rock to build a platform on which future filtered tailings will be placed.
- The bridge lift was done in phases, and the key was the rate of placement, the monitoring of instruments and construction procedures

LARONDE – CONSTRUCTION OF THE FILTERED STACK

- 300 mm lifts until June 2023. 500 mm lifts since June 2023
- GPS bulldozer for precision placement (± 100 mm / 4 in.) and surface quality
- Compaction with 2 back & forth passes of compactor (adjustments made on field when needed)
    - 12-tons compactor for 300 mm lifts
    - 19-tons compactor for 500 mm lifts
- Compaction made as soon as the compactor has enough space (optimum water content, avoid freezing, rain, dry.
- Compaction also acts as a surface-sealer: protects from snow / rain / fast freeze penetration
- Optimization of sequence: snow removal, dust suppressant, distance from filtration plant, production, etc.

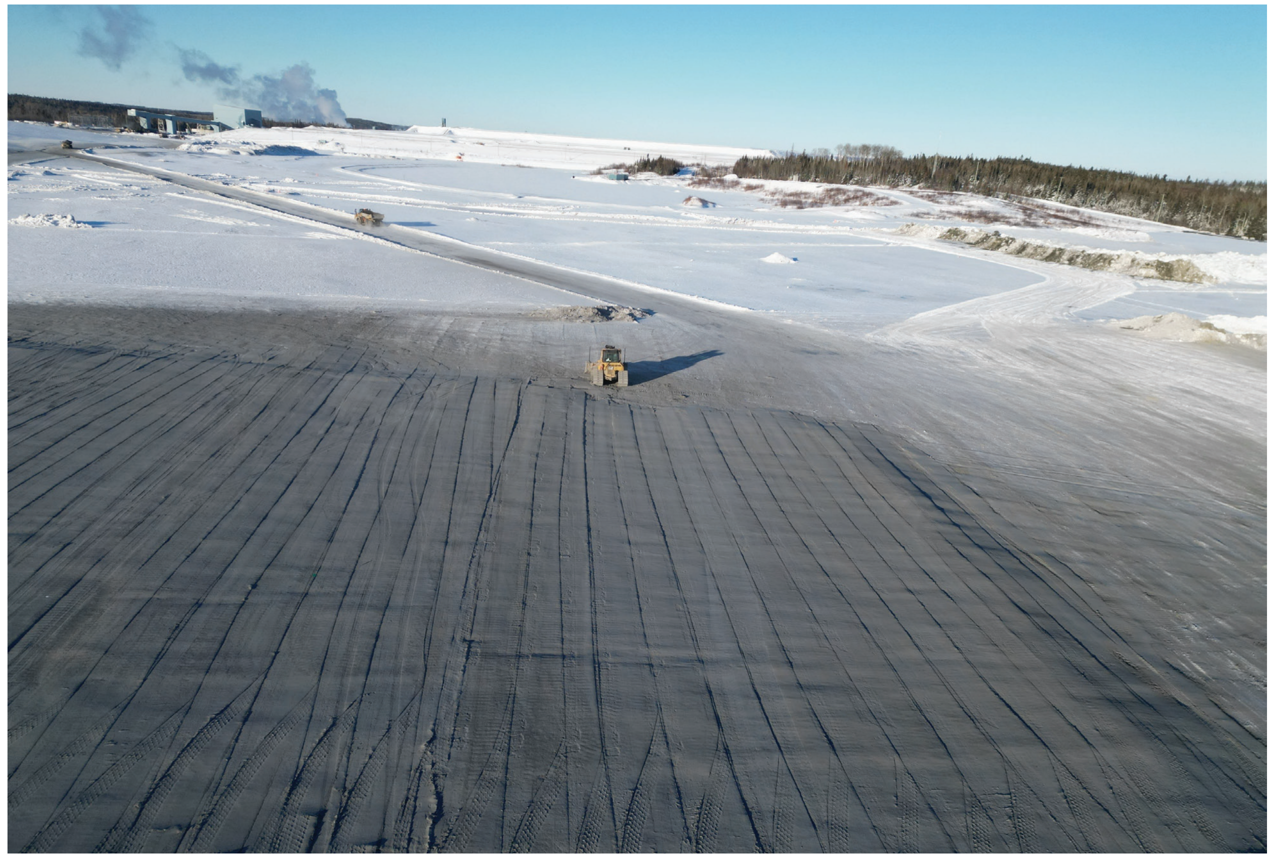
LARONDE – CONSTRUCTION OF THE FILTERED STACK

- Snow removed just before placement, to take advantage of the snow as a dust suppressant
- Grader (toothed blade)
- Loader
- Bulldozer
- Excavator
- Ice breaker
- Depends on conditions (temperature, hardness, quantity of snow, ice, etc.)
- Snow dumps made on the bridgelift: helped to melt during summer

LARONDE – CONSTRUCTION OF THE FILTERED STACK

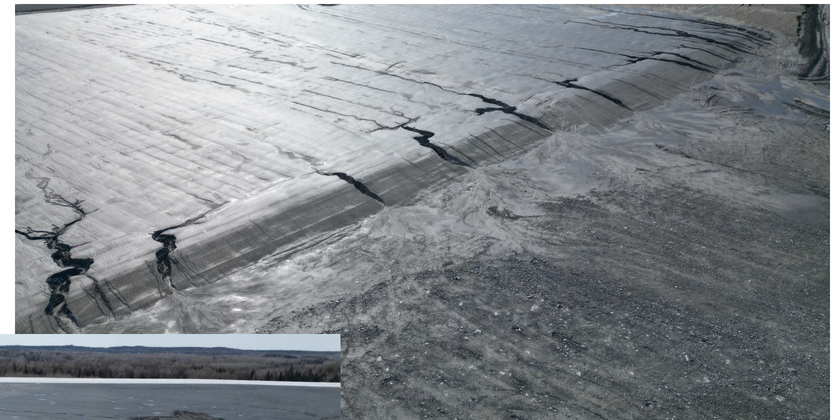
Surface quality

- Water accumulations → infiltration → softens surface → decrease compaction and trafficability
- If not removed, water, snow or ice could cause long-term issues such as slip surfaces, unexpected settlement, low trafficability, operation problems



LARONDE – CONSTRUCTION OF THE FILTERED STACK

- Good compaction, sloping and surface quality leads to good behavior
- Top surface of the filtered stack is generally hard, even under rain conditions.
- Localized erosion on side slopes. Repaired if needed.
- Humid conditions needs to be managed.
- During freshet, snow melt isn't a problem (no overall snow accumulation on stack). However, stack melting makes the surfaces softer for about 1 month.



LARONDE – CONSTRUCTION OF THE FILTERED STACK

In Situ Testing

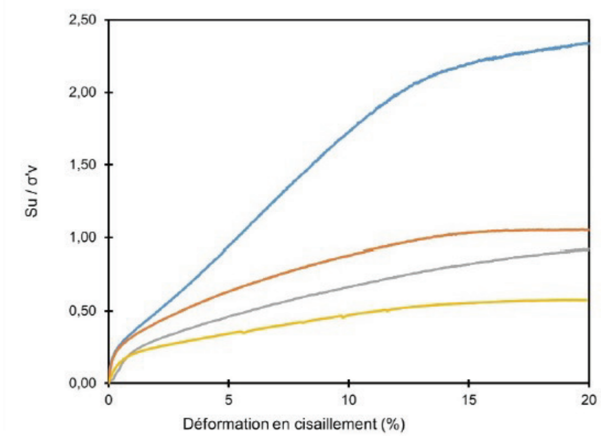
- Surveys
- Nuclear densometer
- Dynamic cone penetrometer
- Drive density sampler

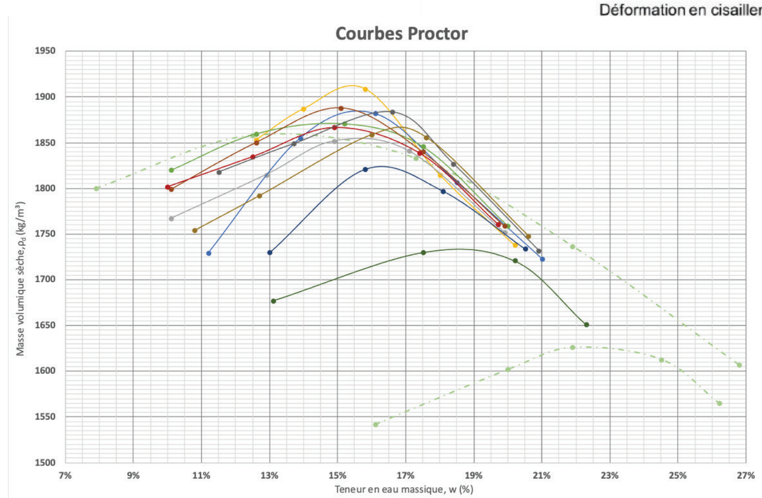
Including various trial compaction pads testing, on surface as well as in depth of layers

LARONDE – CONSTRUCTION OF THE FILTERED STACK

Lab Testing

- Samples collected every month
- Additional samples taken upon major changes in the material (after shutdowns, change in origin of materials, change in ratio of LAR/LZ5, in-situ testing out of spec)
- Properties measured are:
  - ω%
  - Gs
  - Proctor (ρd, ω% optimum)
  - Particle Size Distribution
  - DSS tests at target density
- Links, correlations, and trends are found from the results
- Results are within expectations and variations are explained easily





LARONDE – CHALLENGES ASSOCIATED TO THE BUSINESS CASE

- Not easy to build a business case for a change in tailings management approach, despite aim of having:
    - Physically and geochemically stable infrastructure that will pass the test of time and can be integrated in surrounding environment
- From experience, discussions on costs are always difficult:
    - Filtered tailings will tend to have higher CAPEX and OPEX
    - We need to leverage some key considerations:
        - Any construction involving geotechnical materials (dam construction) may have higher uncertainty – foundations preparation
        - Any construction involving mechanical systems and controlled materials may have lower uncertainty
        - Long term liability and closure costs tend to be under-estimated and should be part of the equation
- Costs conversation should involve the notion of uncertainty

CONCLUSION

- Impressed with the changes that have happened and continue to happen regarding mine waste management
- The discussion regarding residual risks (ALARP) is becoming increasingly complex
- Risk reduction, and if possible, risk elimination, should be the primary focus in the planning of these types of infrastructure
- Clear push to simplify design and to increase their robustness
- Expectation now that tailings dewatering technologies will be considered for any new projects
- Filtration is now a tool for a broader range of applications. However, it has its own challenges. Costs are definitely a big issue requiring a solid business case

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Thank you

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