Natural Resources Canada
Ressources naturelles Canada

Overview of the Performance, Risks and Requirements of ML/ARD Mitigation of Constructed Tailings Storage Facilities Part 1

William (Bill) Price

2024 BC MEND ML/ARD Workshop

November 26 and 27

Canada

Outline

General Principles and Factors to Consider

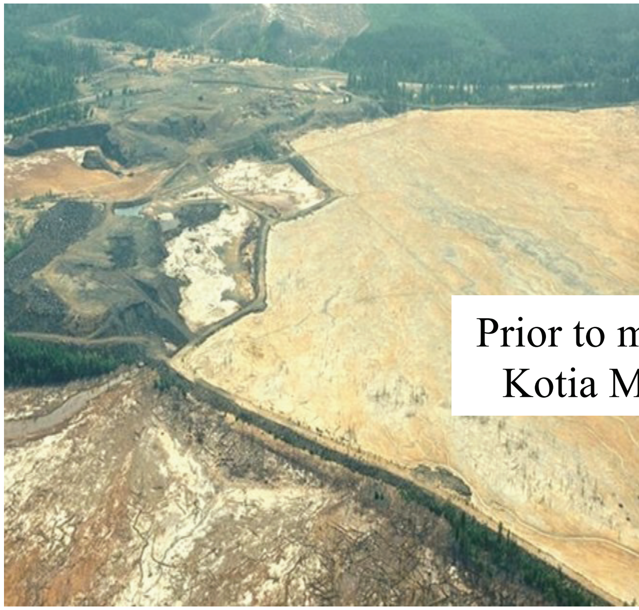
Subaqueous Storage

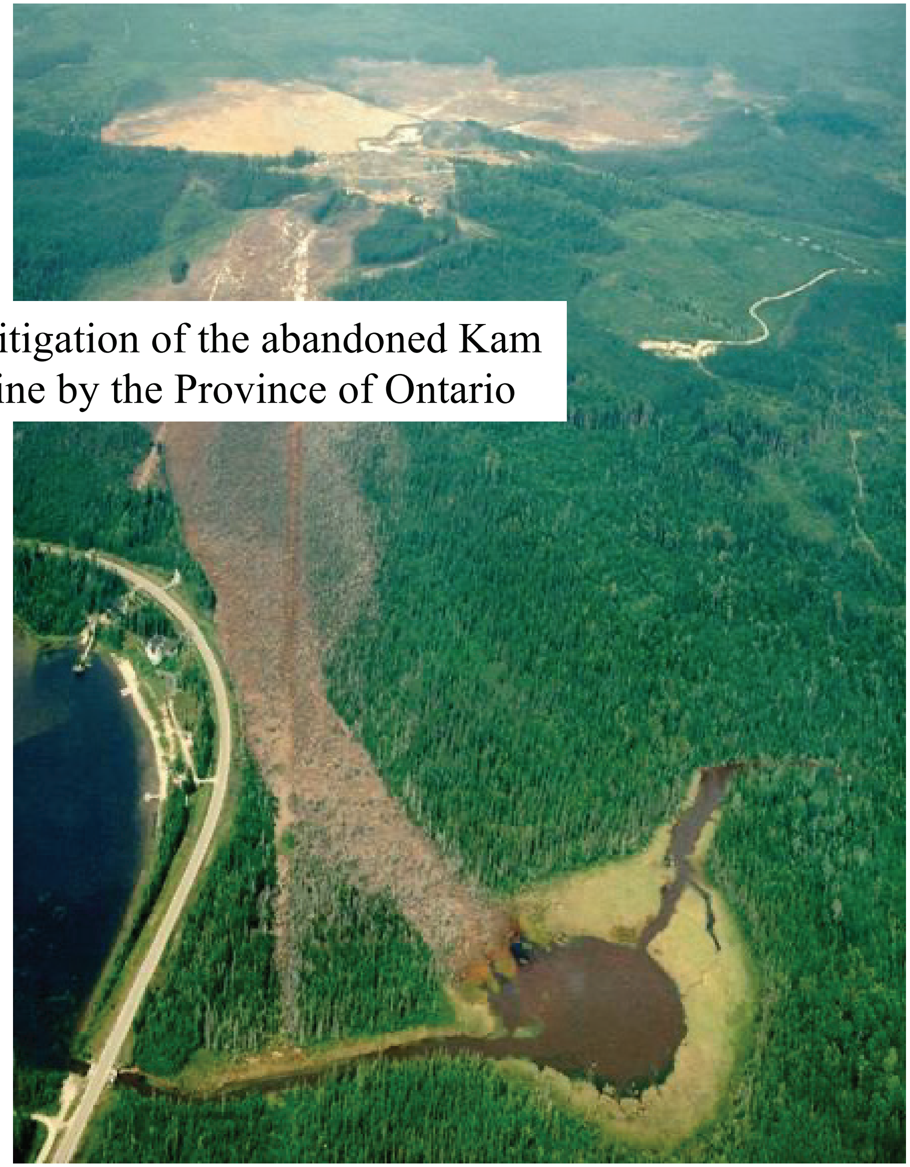
Dry Cover Systems

Collect and Treat Drainage

Conclusions

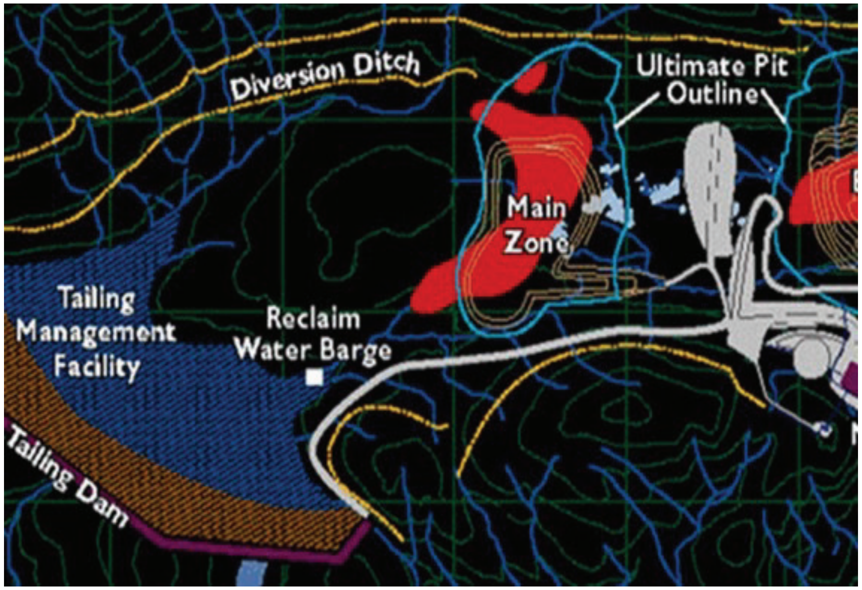
General Principles and Factors to Consider





Prior to mitigation of the abandoned Kam Kotia Mine by the Province of Ontario

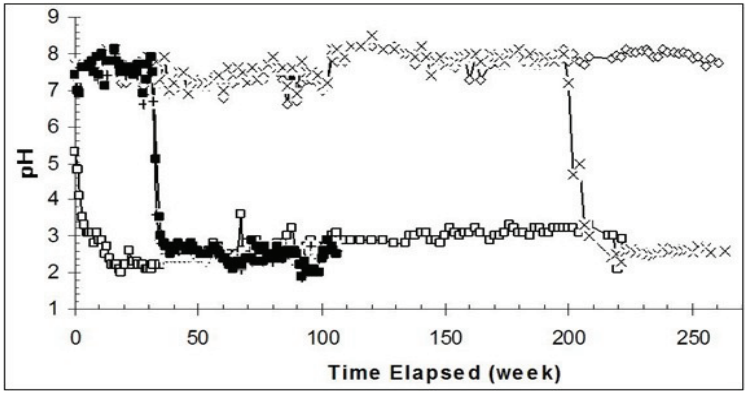
If not properly mitigated, ML/ARD produced by mine tailings can result in widespread impacts to aquatic and terrestrial resources and prohibitively expensive remediation costs.



Since the 1990s, BC has required detailed ML/ARD prediction and mitigation showing how mines will proactively prevent potential ML/ARD impacts.

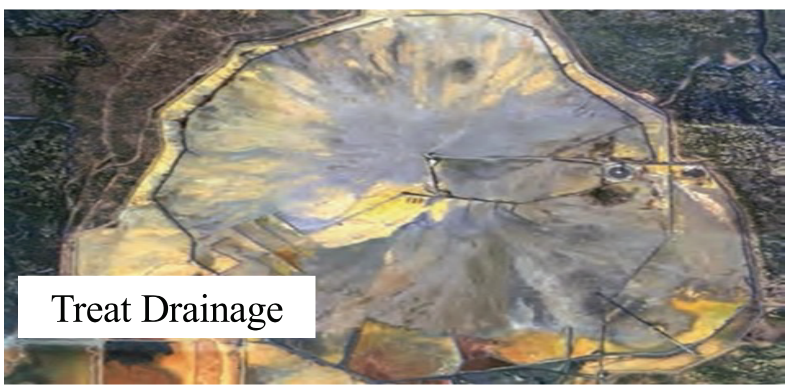
Performance objectives for ML/ARD mitigation include:

- physical containment,
- discharge limits,
- receiving environment objectives, and
- post-mining land and water use.



Mitigation requirements for constructed tailings storage facilities (TSF) will depend on:

- predicted ML/ARD of the tailings and other stored materials,
- properties of the storage facility,
- site conditions, and such as climate,
- community and government requirements.



Reliably, Pro-actively

ML/ARD mitigation failure is unacceptable and unsustainable and mitigation plans must reliably, pro-actively achieve their performance objectives.

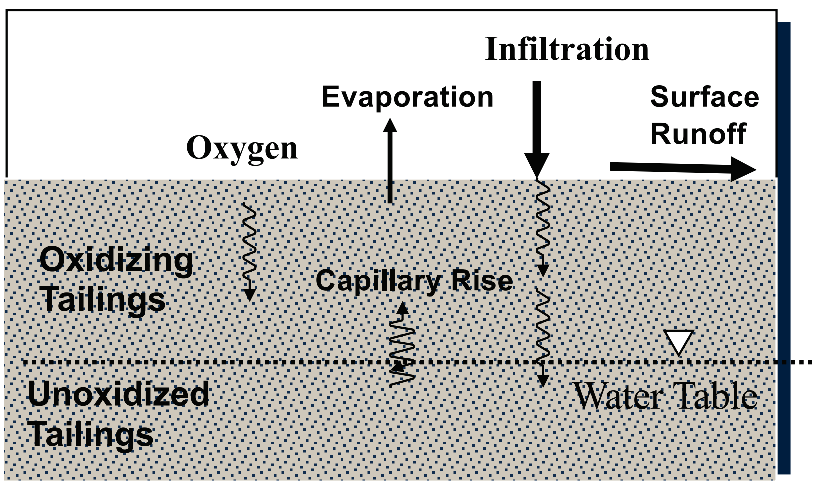
Reliability is a key component of both sustainability and cost-effective success.

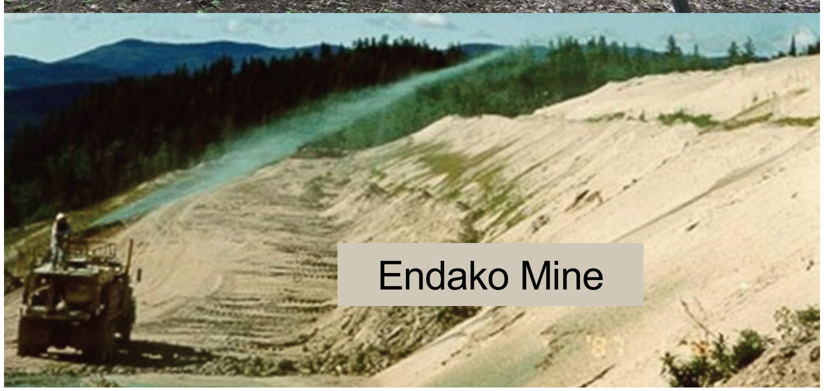
Proponents must demonstrate of the capability of mitigation plans to reliably, pro-actively achieve their performance objectives

Proactive prevention of failure requires addressing all potential failure mechanism.

Proactively addressing all potential failure mechanisms requires being well informed about a large number of complex properties and processes.

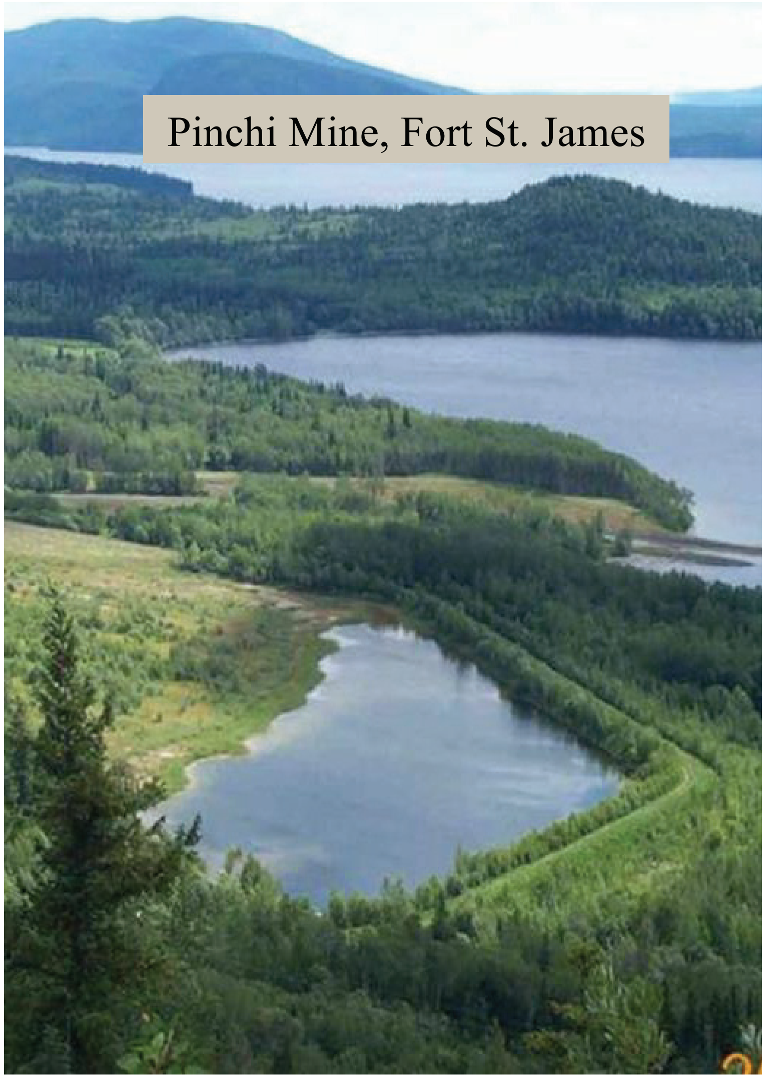
This requires a multidisciplinary team and practitioner and community and indigenous input and knowledge.





While the primary focus is on drainage discharge, prevention of wind erosion is also important.

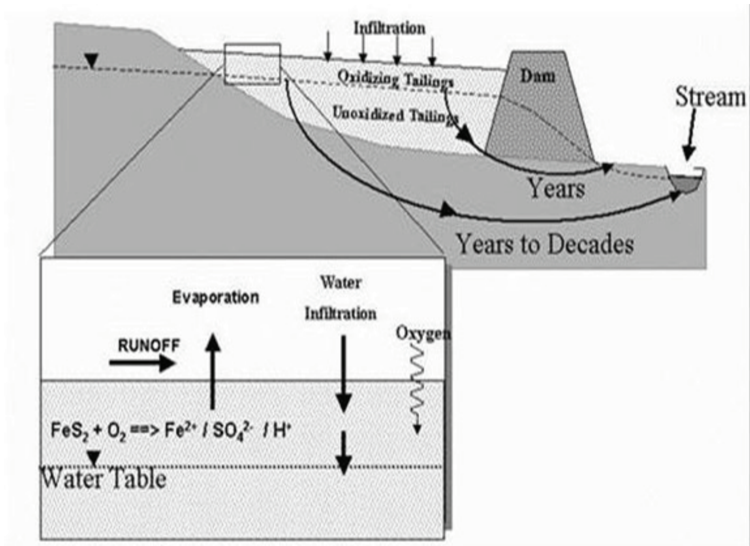
Finding ways to prevent wind erosion of exposed dry tailings is a challenge at many sites.



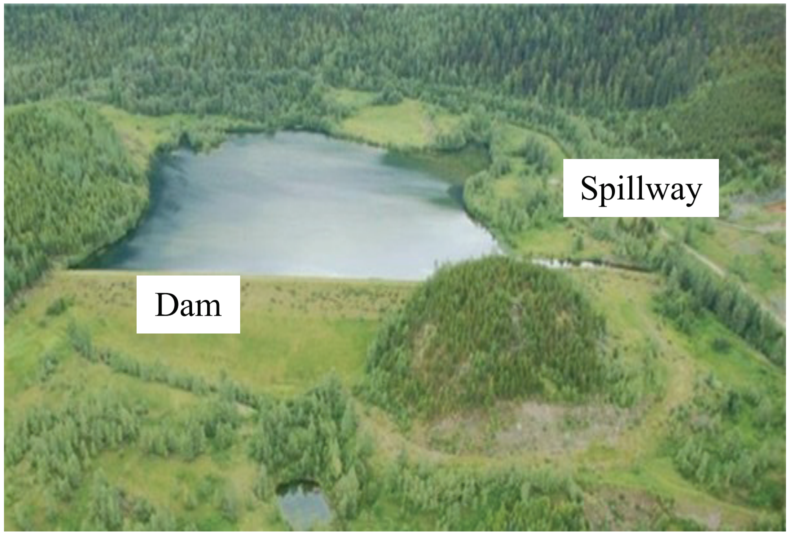
Site-Specific

Every mine and its geological and environmental conditions are unique so while there are generic ML/ARD requirements, there is no universal, successful everywhere ML/ARD mitigation method.

The best practice is not a single technology, but a methodical, comprehensive well-informed process for developing a mitigation plan that successfully addresses all site-specific needs, conditions, and risks.



Developing site-specific understanding is onerous but costs are minimal compared to the costs of failure when site-specific information needs were not adequately addressed.



Mitigation structures and equipment requiring **continual operation and maintenance** includes dams, ditches, drains, covers, spillways, pipes, pumps, power sources and treatment facilities.

Consequently, most forms of ML/ARD mitigation require operation and maintenance for the foreseeable future.

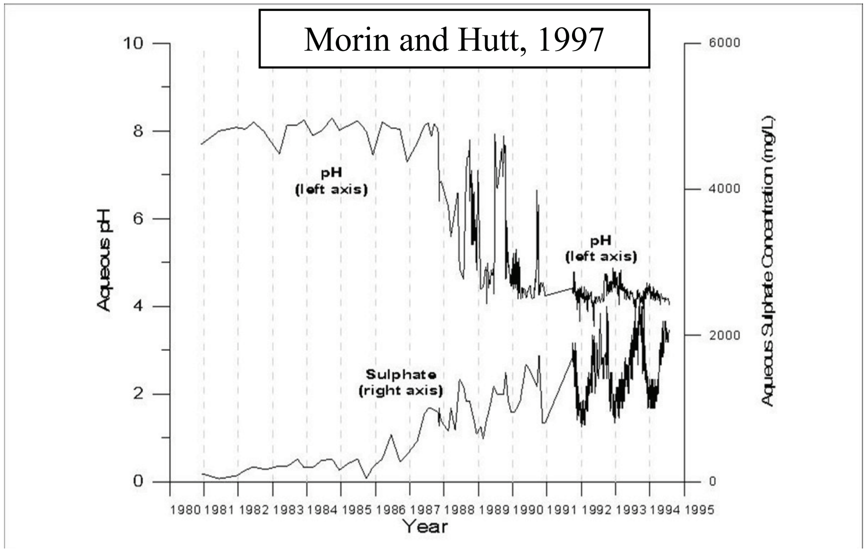
Some mitigation components may require periodic replacement.

Climate change is increasing the frequency of harmful events.

To sustain future performance, mitigation measures must be capable of functioning during and after all future harmful climate events.

One way to prevent failure due to extreme events and upsets is to provide additional capacity and backup equipment and facilities.

Backup spillways will prevent dams from overtopping if diversions fail or primary spillways are blocked.



Changing TSF Conditions

A major mitigation challenge is safely managing changing conditions.

All landscapes continually undergo change; but reactive geologic materials and engineered landforms make mine sites particularly dynamic.

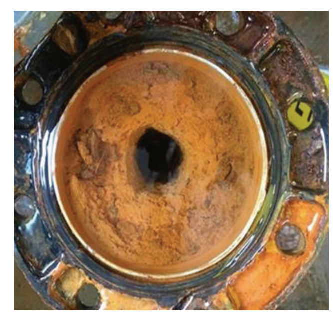
Monitoring needs to:

- provide early warning of deleterious changes and
- trigger corrective actions.

Constructed TSFs may undergo changes as a result weathering, erosion, solute leaching and precipitation, and biological activity.

The objective of **chemical stability is** misleading and should be replaced by the objectives of **achieving acceptable chemical conditions**.

TSFs need to be designed and managed so that physical changes also do not adversely affect their physical stability.



Threats to TSFs from beaver dams include:

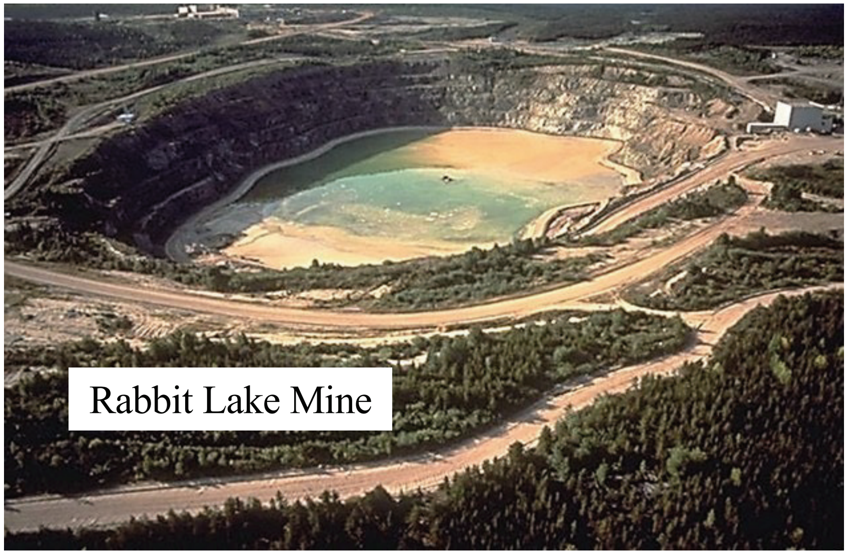
- adversely changing the water balance,
- blocking a spillway or diversion,
- flooding dam foundations and
- breaking upstream during large runoff events and releasing flows that exceed the capacity of a spillway or diversion.

A beaver dam flooding the foundation of the tailings dam in the foreground.

Mine planning should **assess the feasibility of whether desulphurization or other forms of storage** can be used to decrease the need for storage in the TSF.

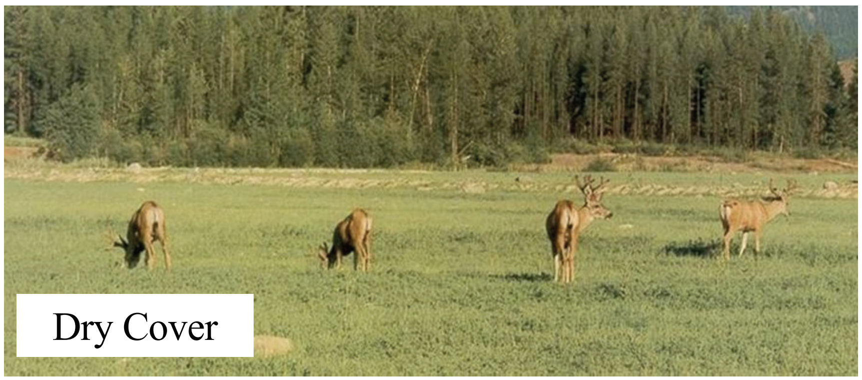
Desulphurization requires:

- suitable mineralogy,
- facilities for rapid onsite analysis and
- mitigation of the residual higher sulphide tailings.



The need for constructed tailings storage facilities can be decreased by storing tailings in completed pits and underground workings.

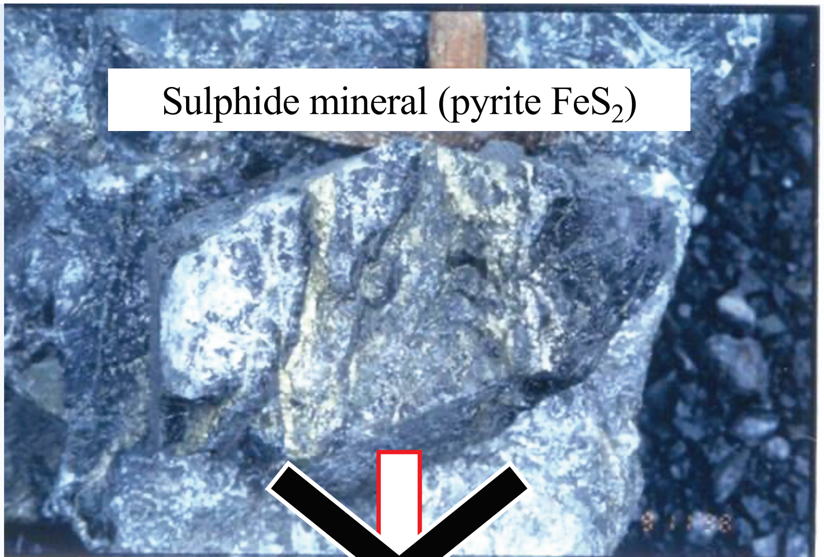
55% of the Louvicourt tailings were used as paste backfill in the underground mine. The remaining 45% were stored underwater in the tailings impoundment.



The three most widely used forms of ML/ARD mitigation are:

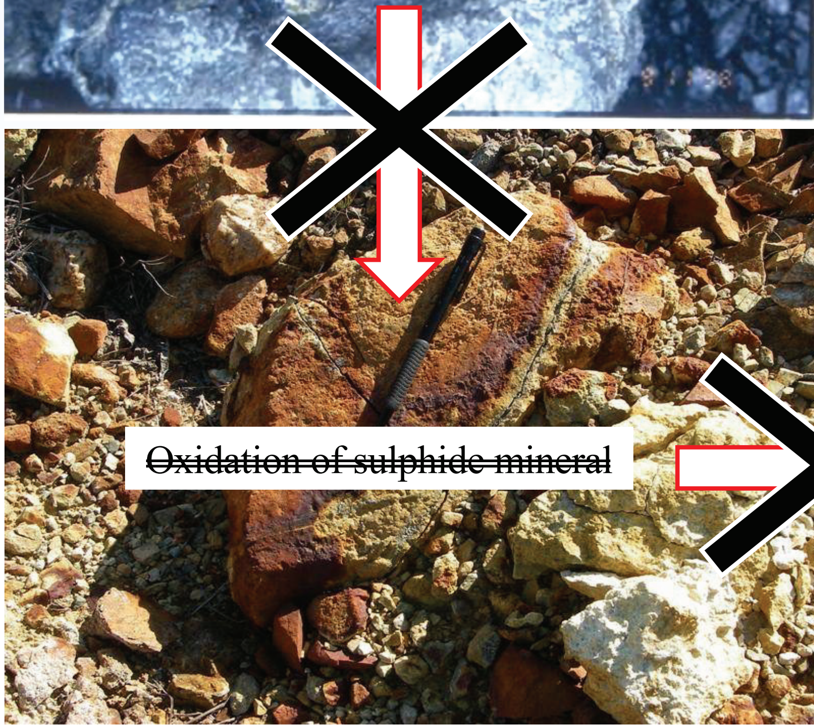
- subaqueous storage,
- dry covers and
- collect and treat drainage.

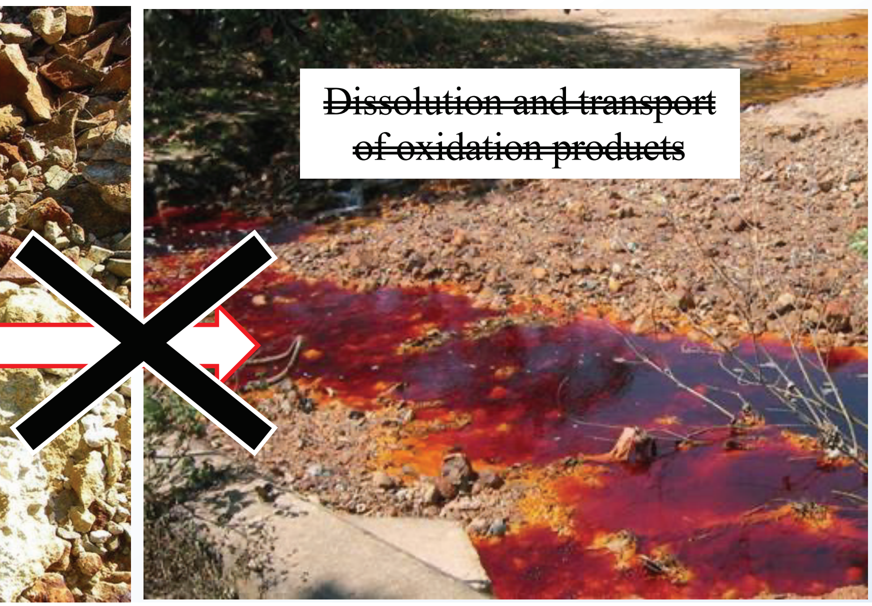
Subaqueous Storage



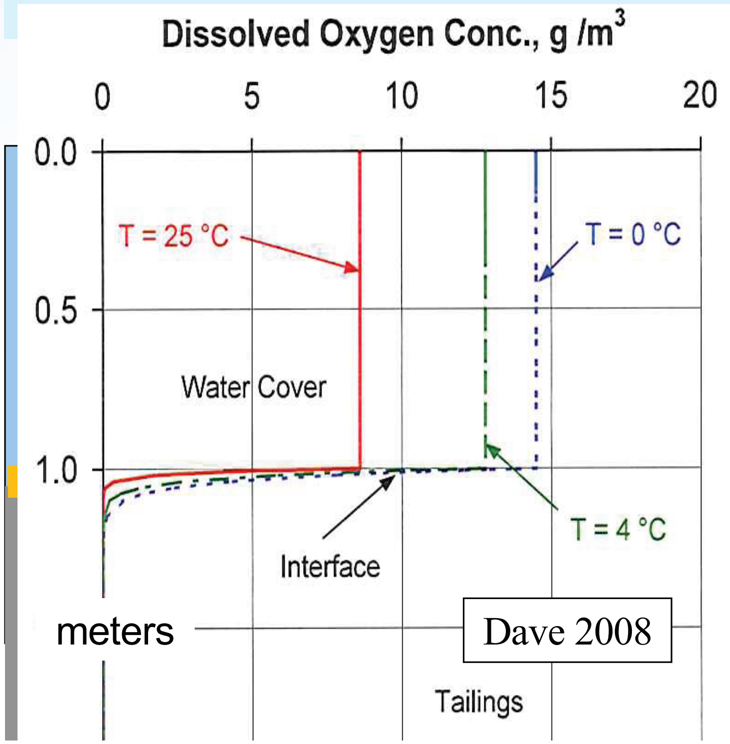
Most sulphide minerals are relatively insoluble in water at neutral pH.

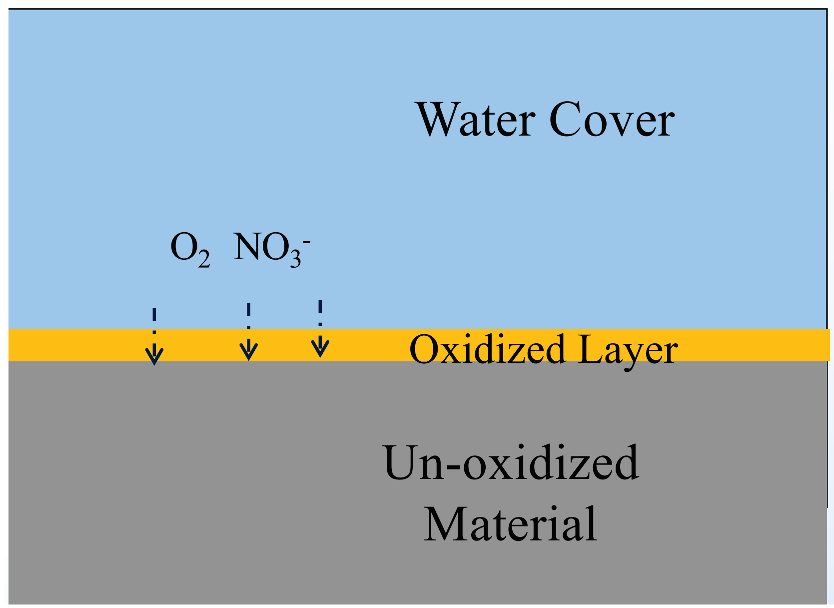
By minimizing oxidation, subaqueous storage minimizes dissolution and the creation of deleterious drainage.



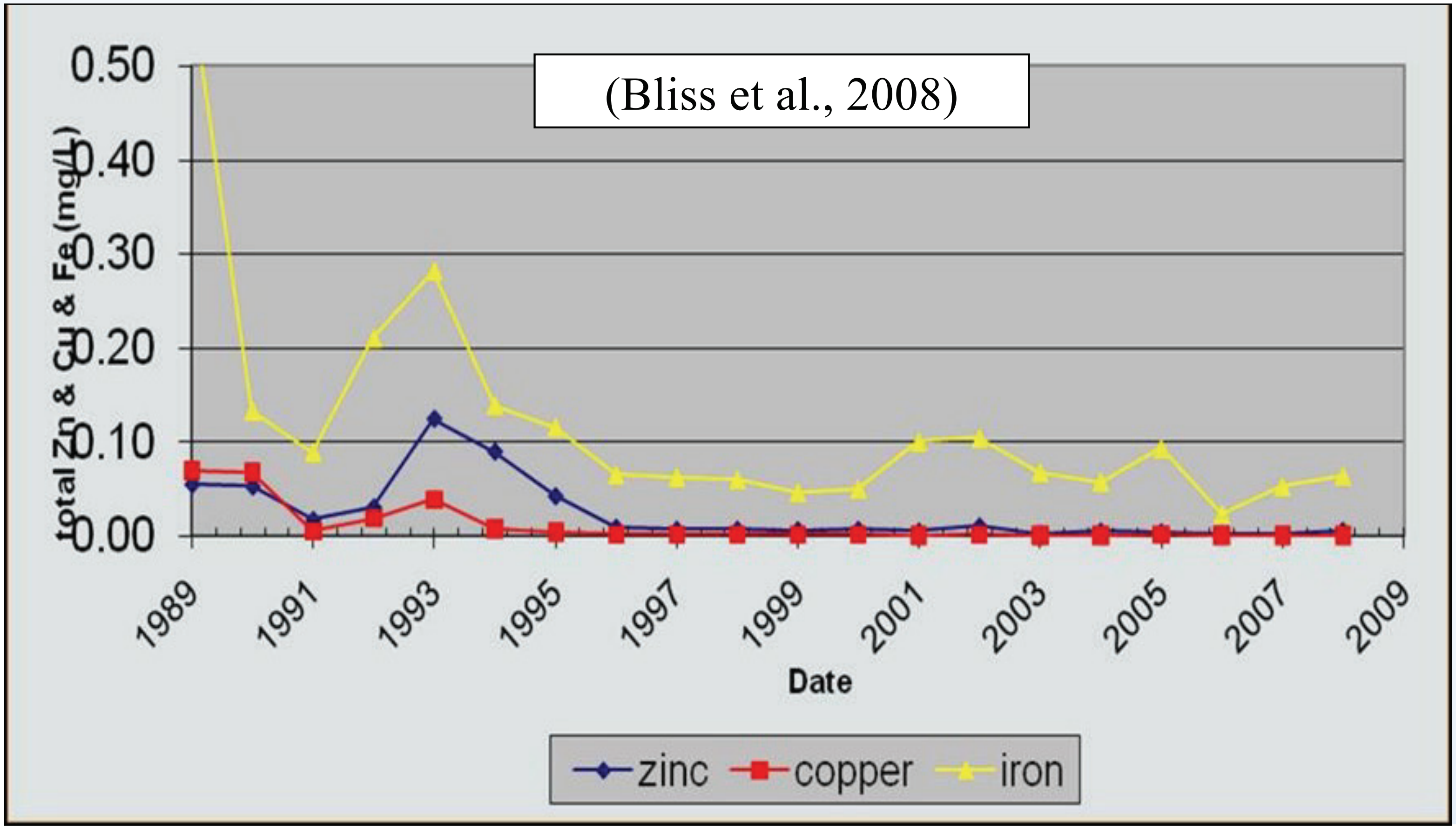


Studies of tailings indicate sulphide oxidation is limited to a few millimetres or centimetres below the tailings-water interface.





If tailings are largely insoluble and flooded soon after deposition, soon after the mine closes solute concentrations meet discharge water quality criteria.



There are numerous examples where subaqueous storage produces drainage that is good enough for direct discharge to the environment.

Drainage treatment may be needed if:

- ore contains soluble minerals soluble under disposal, tailings are allowed to oxidize prior to flooding, or
- process water contains reagents, such as cyanide, or by-products of processing, such as thiosalts.

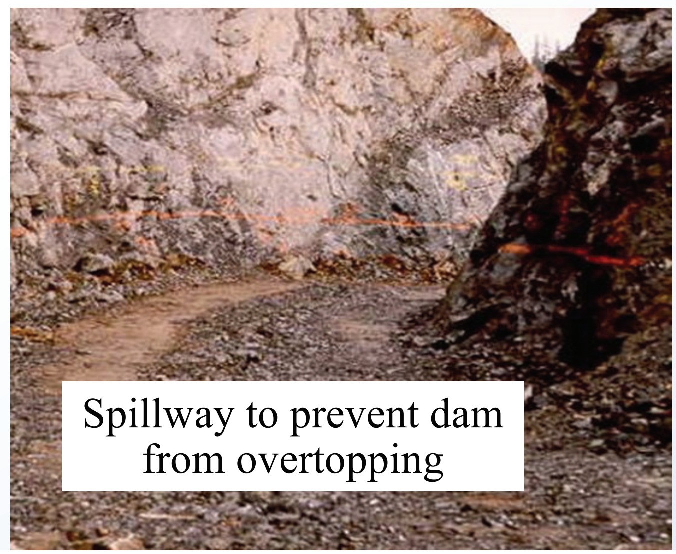
The main drawback of TSFs with dams is the catastrophic the environmental consequences and potentially loss of life if a major dam failure releases water and entrained tailings.

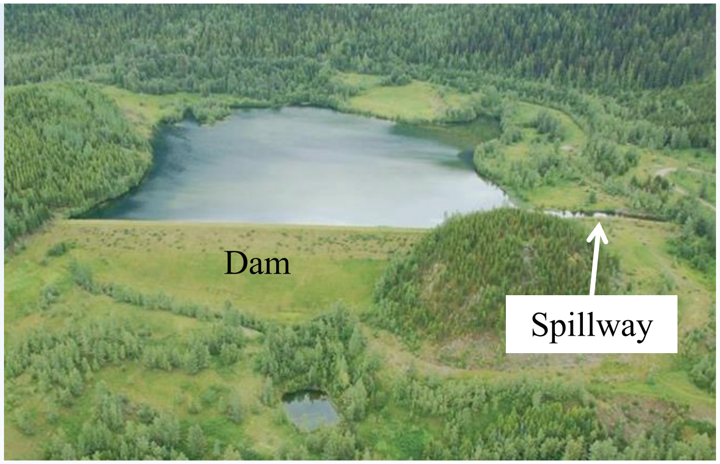
Dam failures result from poor practices and <u>not</u> gaps in our understanding or ability or unpredictable conditions and events.

Requirements to prevent dam failure include:

- detailed geotechnical, seismic and hydrogeological knowledge,
- design, construction and operating procedures that ensure the TSF is resilient to erosion, floods and earthquakes,
- additional capacity and backup equipment and facilities to withstand extreme events and upsets,
- proactive monitoring and maintenance of dams, spillways and drainage diversion, and
- financial security commensurate with future costs.

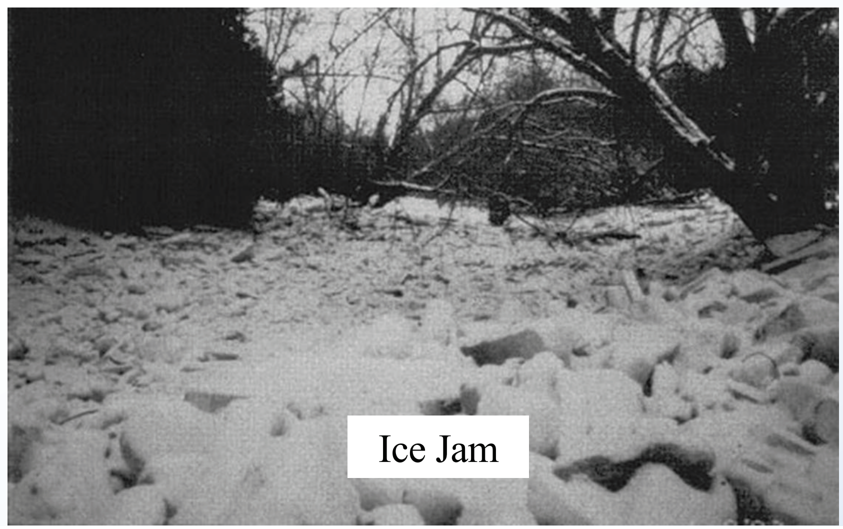

Vegetated soil cover to prevents dam erosion


Spillway to prevent dam from overtopping

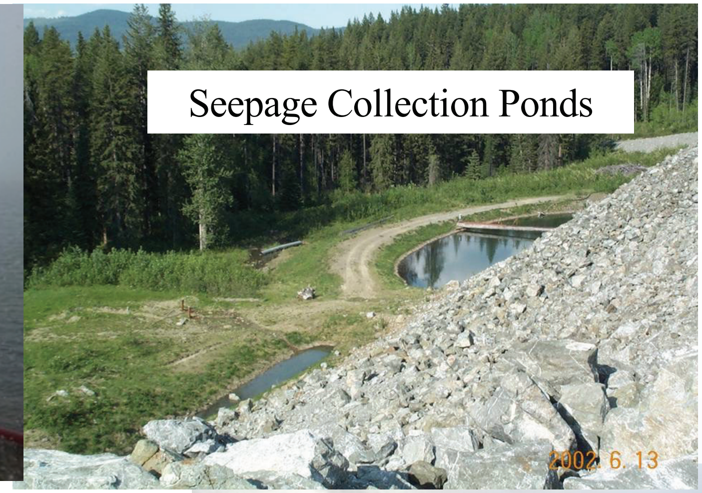


Spillways must be big and strong enough to convey the probable maximum flood.

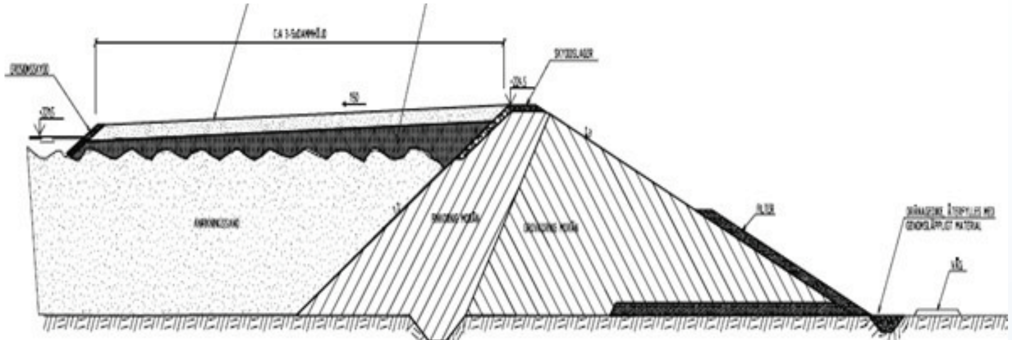
Monitoring and maintenance is required to ice jams, mass wasting, beaver dams, and woody debris from blocking the spillway.

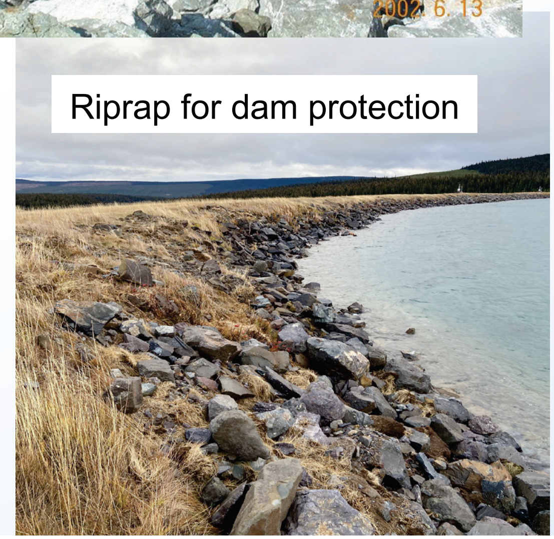


Other requirements of constructed subaqueous TSFs are mitigation of erosion, detailed dam monitoring, seepage collection ponds, and beaches or rip rap to protect dams from waves.



Beach for dam protection (Lindahl 2008)



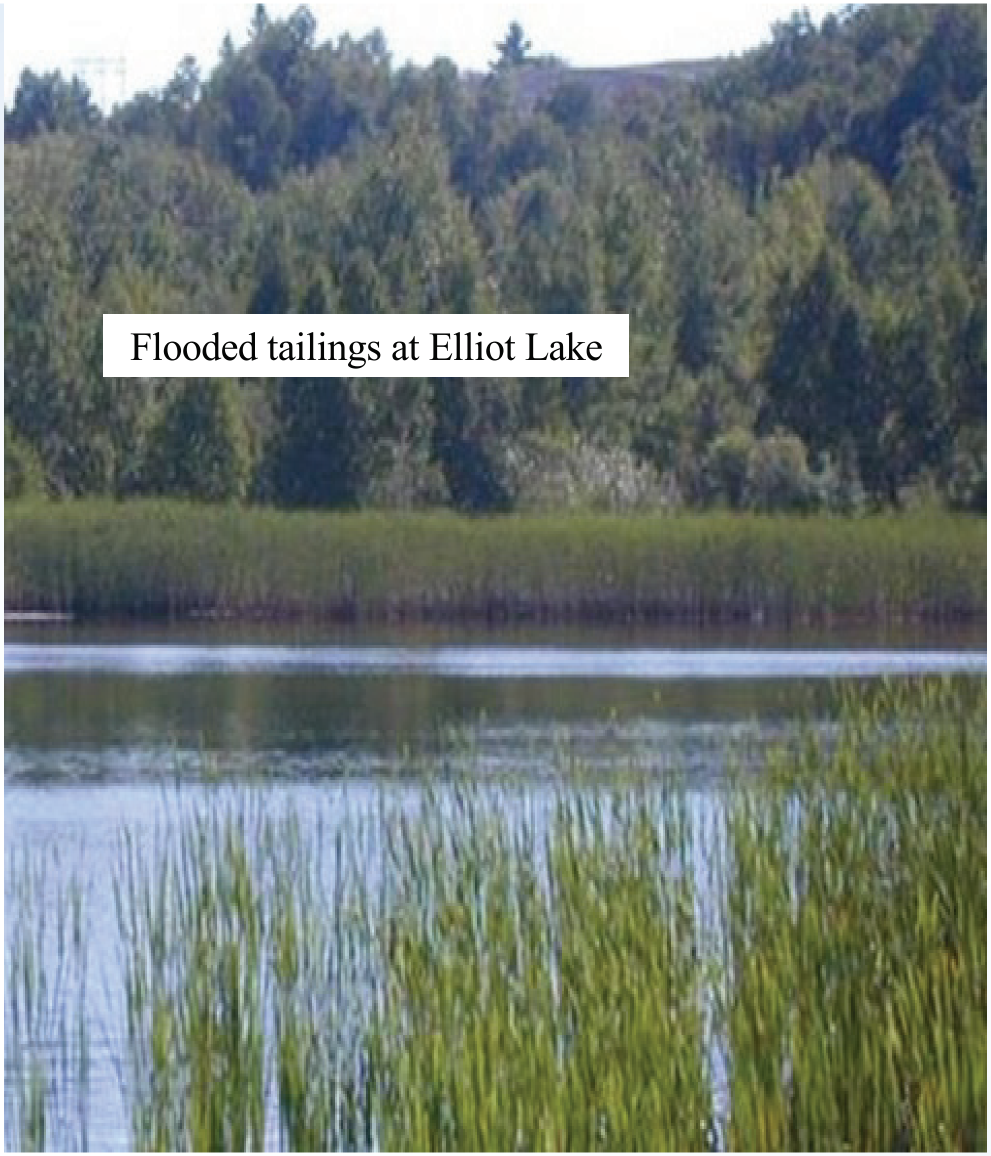


Design objectives for the water cover are sustaining flooding during a long drought and preventing waves and ice moving tailings onto beaches.

Based on generic calculations of wave action, Louvicourt set a minimum water cover depth of 1 m.

Consequences of a dam failure depend in part on the volume of water.

The water required for a drought may be decreased if there is alternative source of water such as a pit lake.



The required depth to prevent waves moving tailings can be decreased with baffles, berms or aquatic vegetation.

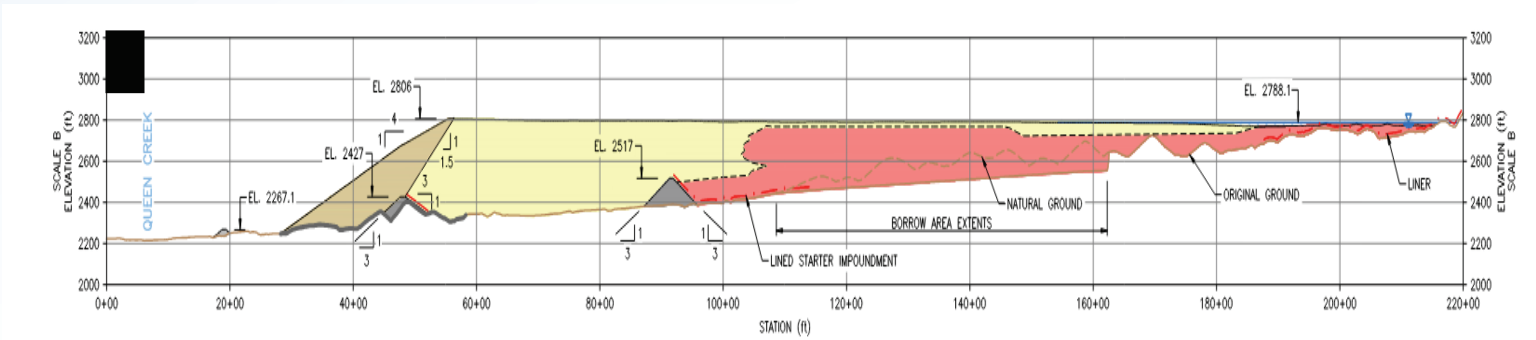
Several sites replaced their water cover, in whole or in part, with a saturated mineral or organic soil or desulphurized tailings.

Saturated soil cover at the Snip Mine

Saturated cover of desulphurized tailings at the Huckleberry Mine

Saturated 2m cover of wood waste at the East Sullivan Mine in PQ (Germain et al. 2009)

PAG tailings can be flooded in a TSF without water retaining dams by deposition beneath the elevated water table of silt tailings in the center or at the lower end of the impoundment (figure from Kate Patterson, KCB).



Conclusions

Flooded tailings at Elliot Lake

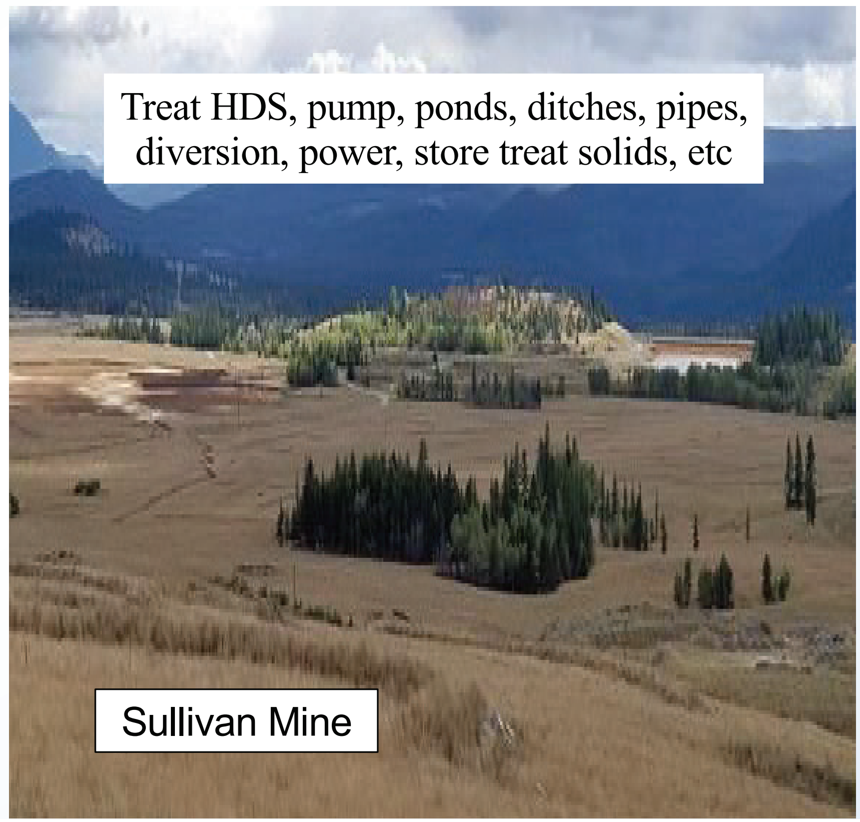
Flooded tailings impoundment
at the Louvicourt Mine

Geochemical advantages of subaqueous storage **may** include:

- almost complete prevention of sulphide oxidation and minimal metal release and
- less uncertainty regarding long-term performance compared to dry covers and drainage treatment, the other major forms of mitigation.

Geotechnical oversight should ensure information and work required to prevent dam failure.

Mitigation performance is better, and operation and maintenance requirements and costs are far smaller for subaqueous TSF's than TSFs with dry covers and drainage treatment.



Gaps in knowledge and practices that need to be addressed are:

- future ecological health and productivity,
- diagenesis of treatment residues co-disposed with tailings, and
- future governance to ensure indefinite maintenance of TSF dams.