CANMET Mining and Mineral Sciences Laboratories

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Basic Understanding of Water Cover and Applications

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Presentation Outline

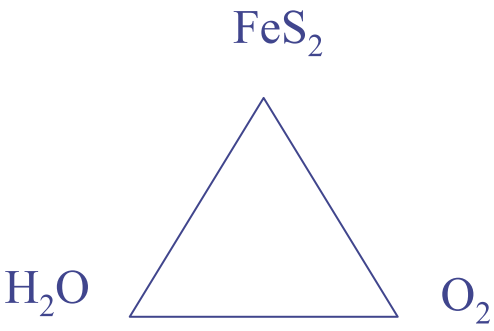
- Acid generation control strategy - need for better covers
- Water cover fundaments
- Performance of water covers:
  - Lab investigations
  - Field sites
- Case histories:
  - Man made impoundments
  - Disposal in natural water bodies

Vegetation Reclamation - Successes/ Challenges

- Successful site remediation
- Surface stabilization, and wind and water related erosion control
- Greatly improved site aesthetics
- Acid rock drainage continues unabated
- Limited growth period and availability of native seed species in the north
- Ongoing effluent collection and treatment required on a long-term basis (perpetuity)
- Sludge collection, disposal and management required

Acid Generation - Control Strategy

- Sulphide minerals, oxygen and water - key ingredients of sulphide oxidation/acid generation problem
- Perpetual collection and treatment strategy unsuitable for long-term management
- Prevention and control measures - best strategy for long-term management:
  - Removal of sulphide minerals - uneconomical
  - Exclusion of air, and hence oxygen – dry and wet covers
  - Exclusion of water or both – dry covers
  - Natural material like till, clay and synthetic liners - oxygen and water limiting
  - Water covers - oxygen limiting

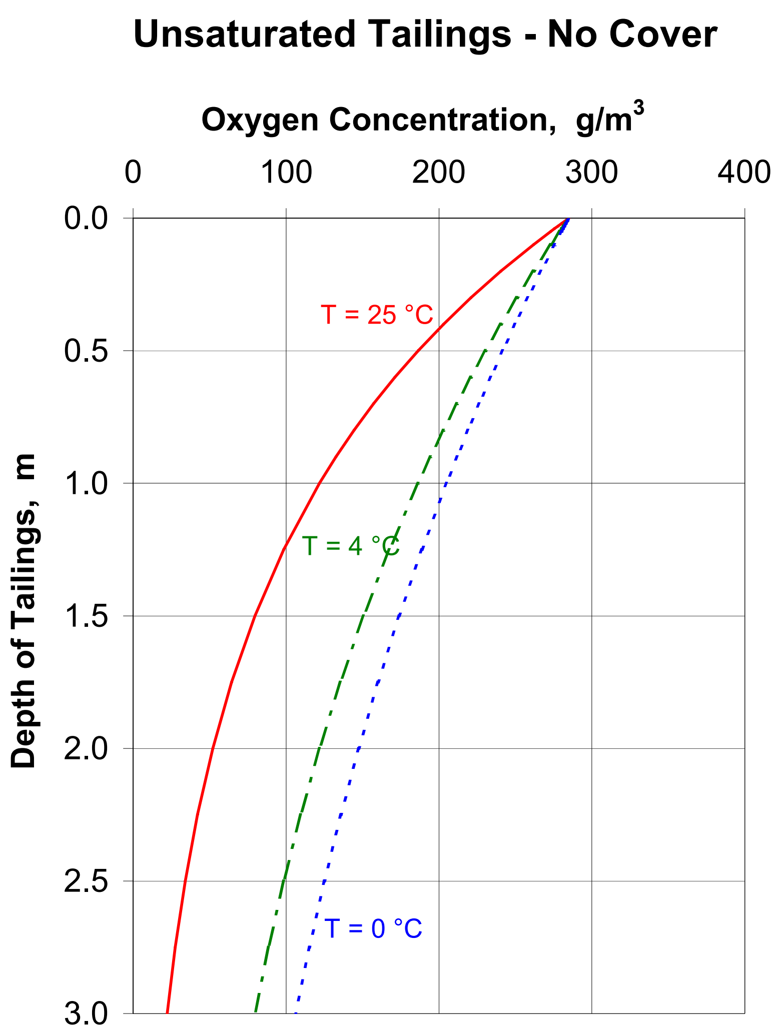


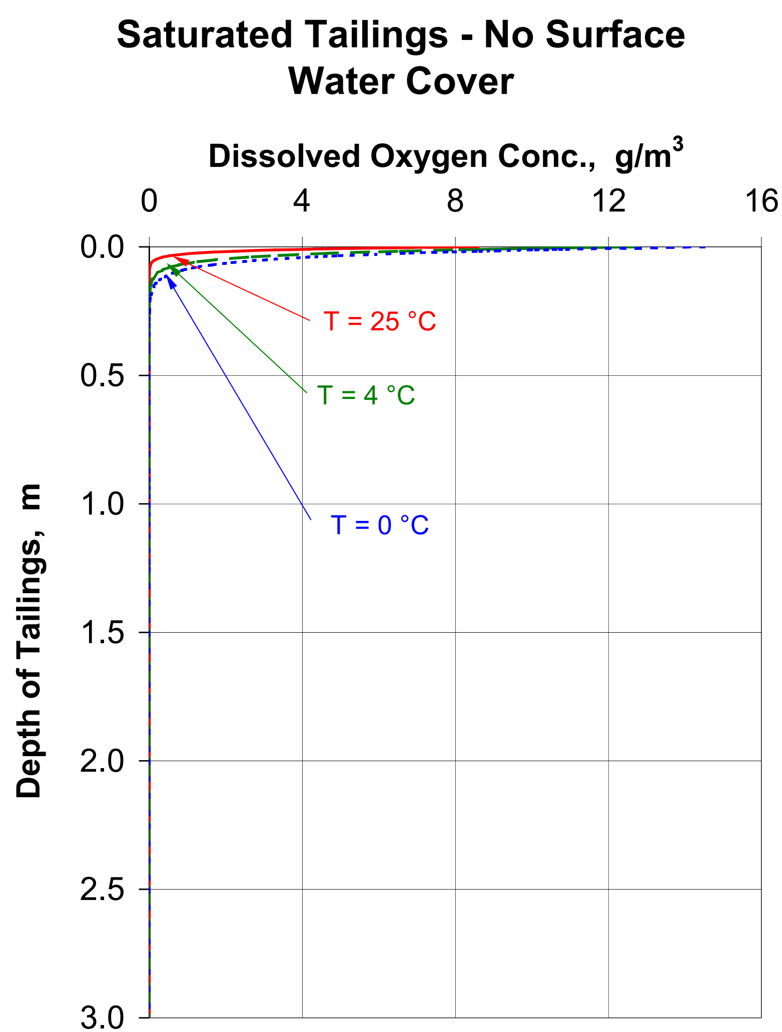
Water Covers - Advantages

- Natural and most economical cover
- Suitable climatic and topographic conditions required
- Low oxygen solubility and diffusivity in comparison to air
- Reduced reactivity at low temperatures

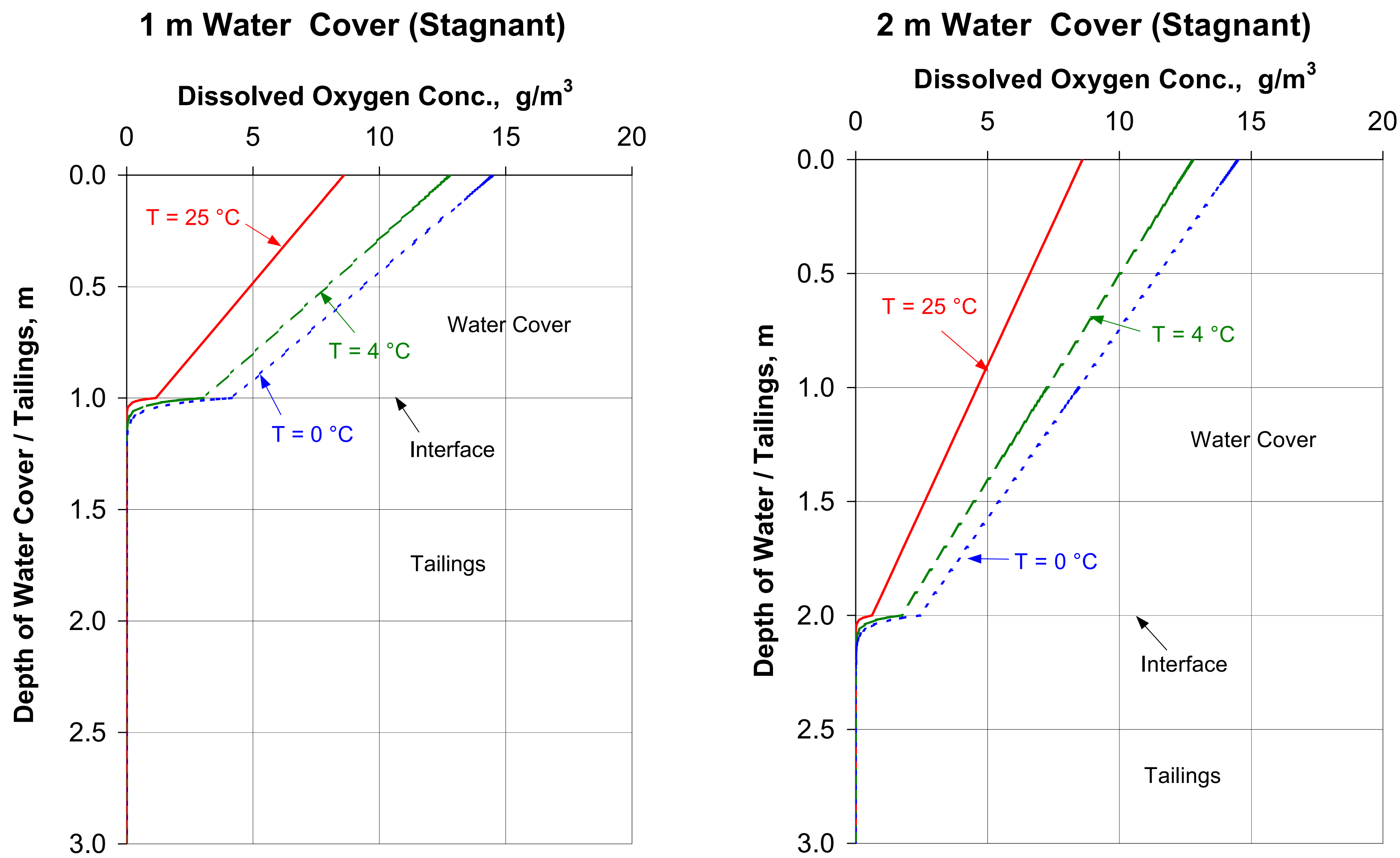
Oxygen Parameters	Water	Air	Ratio water/air
Solubility	8.6 mg/L @ 25 °C	285 mg/L (21.5% v/v)	0.03
Diffusivity	$2x10^{-9}$ m^2/s	$1.82x10^{-5}$ m^2/s	$1.11x10^{-4}$

On Land Vs. Water Cover Oxygen Diffusion Profiles



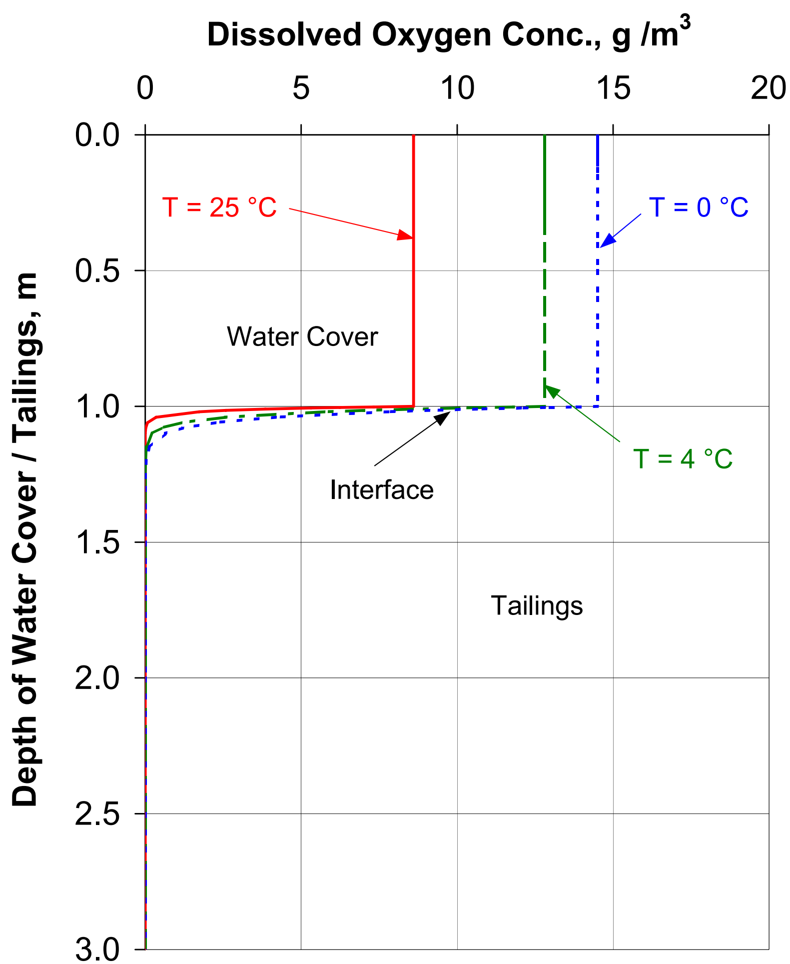


Oxygen Diffusion Profiles Stagnant Water Cover

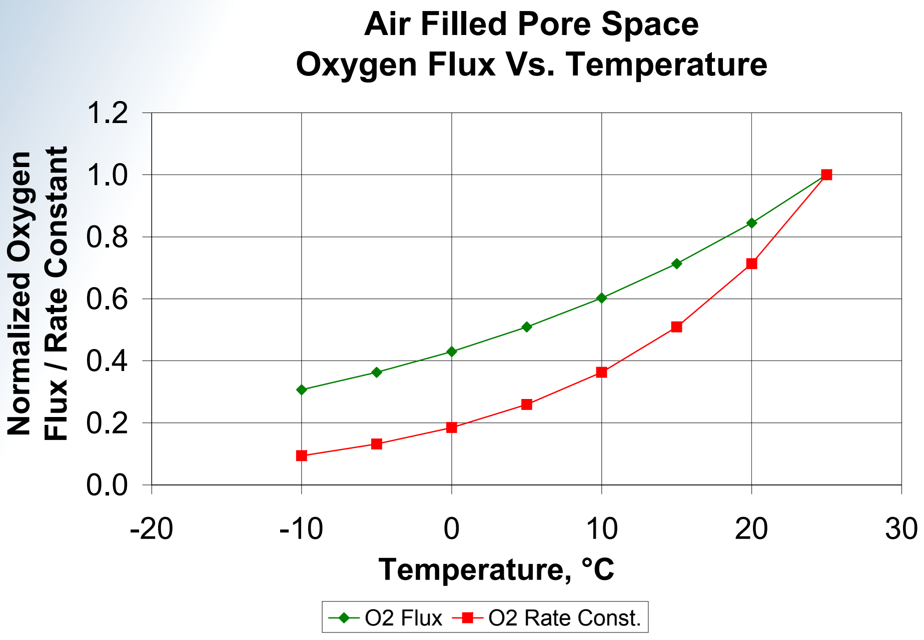


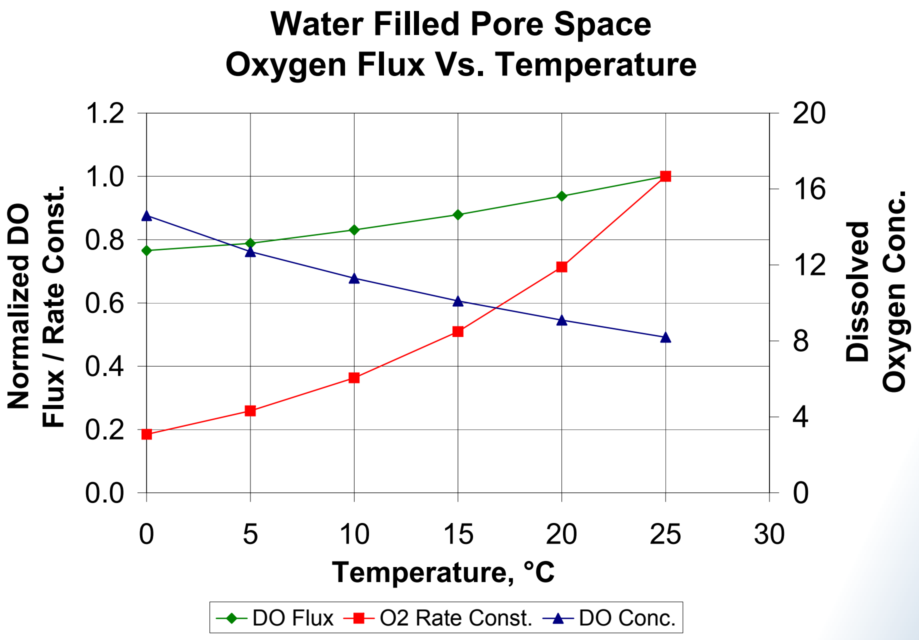
Oxygen Diffusion - Profiles Well Mixed Water Cover

- In most cases, water covers are well mixed and oxygenated during open water conditions
- Oxidation of submerged waste is limited to a shallow, near surface zone
- Oxygen availability in water cover is controlled and limited by the rate of oxygen transfer from air to water at the air-water interface DBL
- No impact of water cover depth unless completely stagnant water during ice cover
- Reduced reactivity and increased oxygen concentration at low temperatures



Dry vs. Water Covers - Temperature Effects



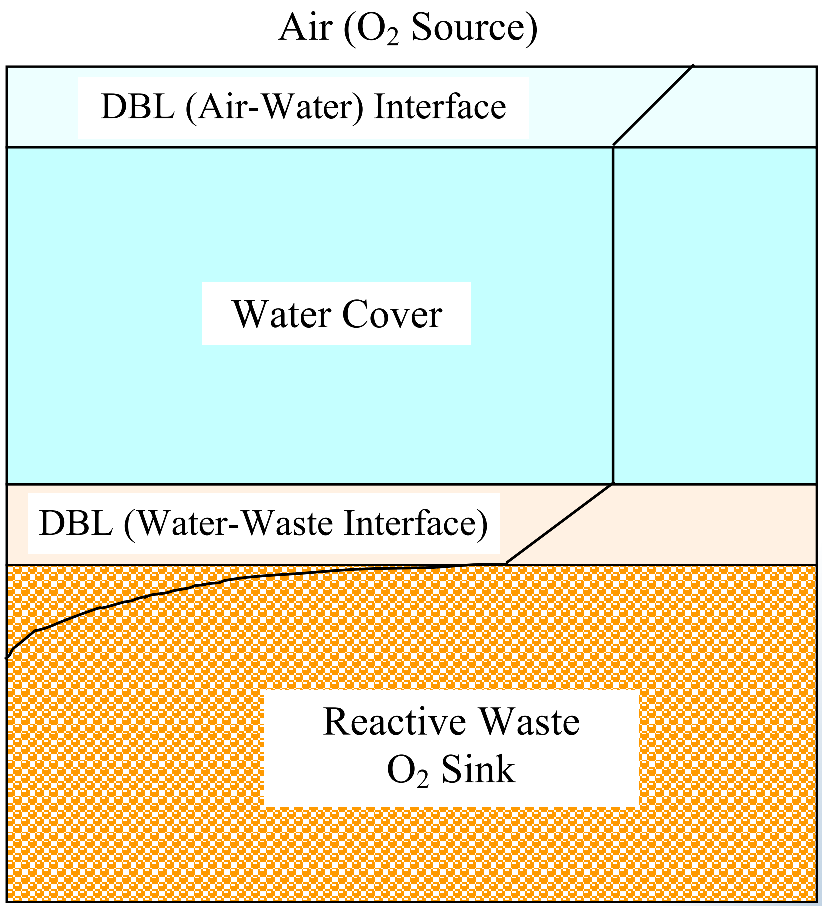


Dry Cover

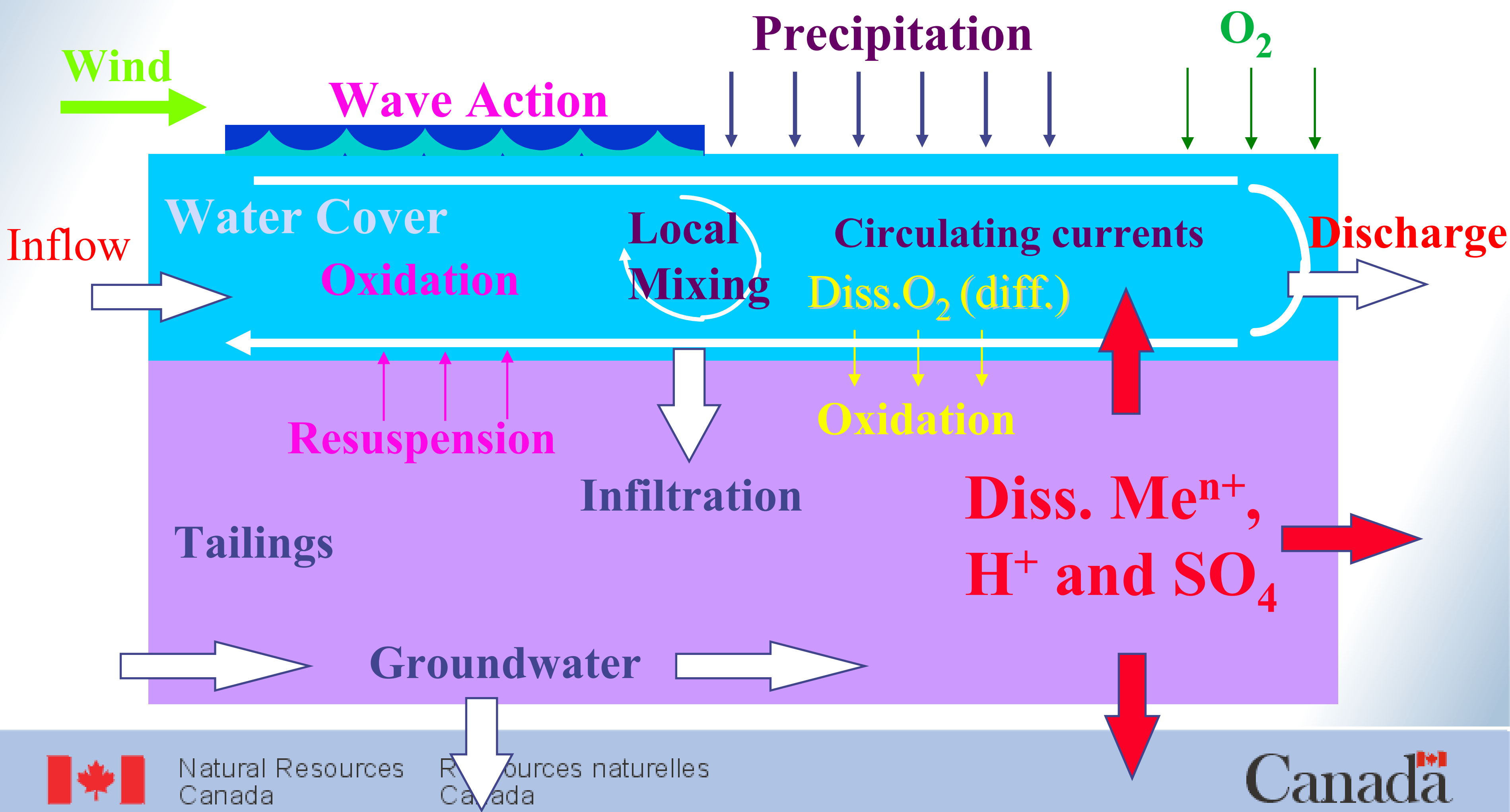
Water Cover

Water Covers Fundamental

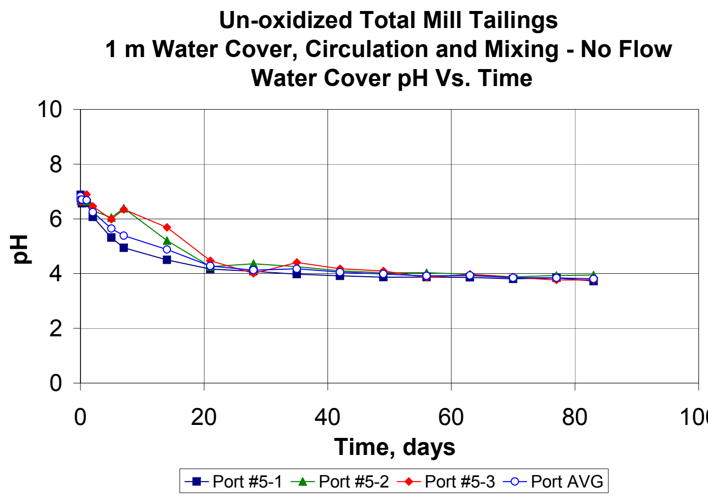
- Water covers are oxygen limiting
- Diffusion barrier to both oxygen from water cover to waste and contaminants from submerged waste to water cover
- Surface oxidation of the submerged waste at the waster-water interface
- Oxygen transfer controlled by Diffusion Barriers Layers (DBL) at the waste-water and water-air interfaces
- Stagnant and well mixed water cover conditions
- Poor mixing and stagnation during complete freeze-up and ice covers

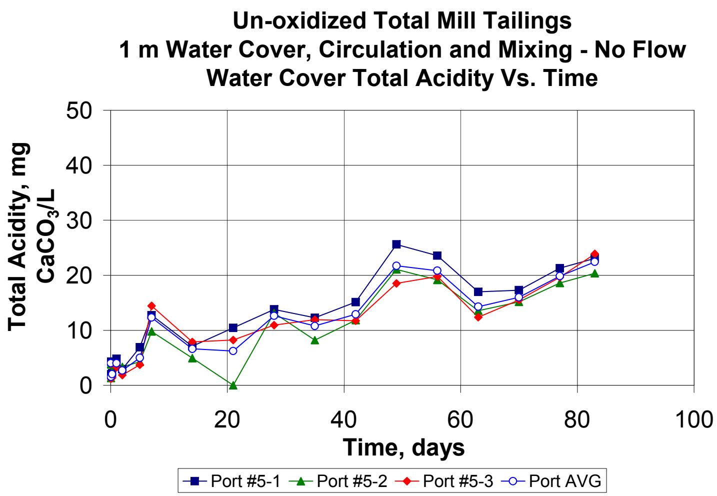


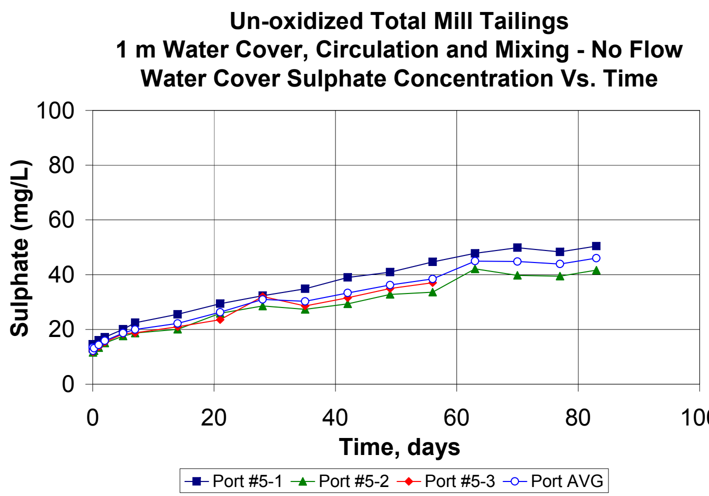
Water Cover - An Interactive, Complex System

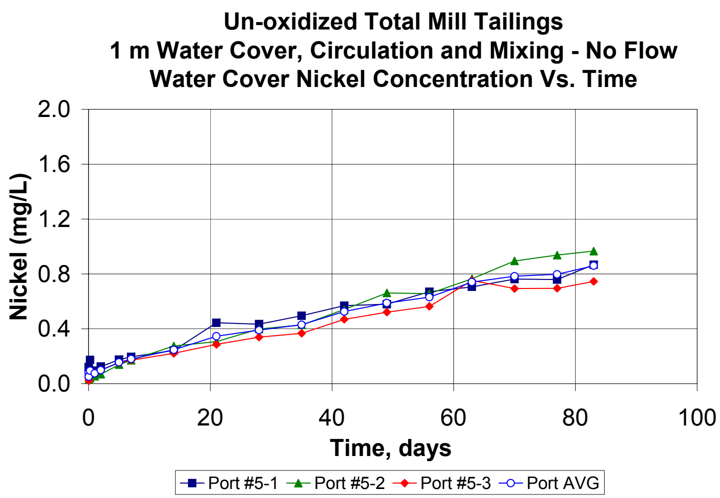


Performance of Water Covers - Laboratory Studies
Surface Water Characteristics









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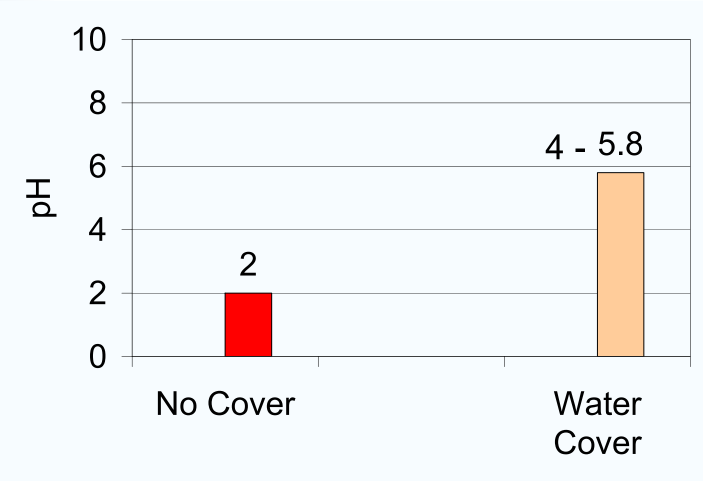
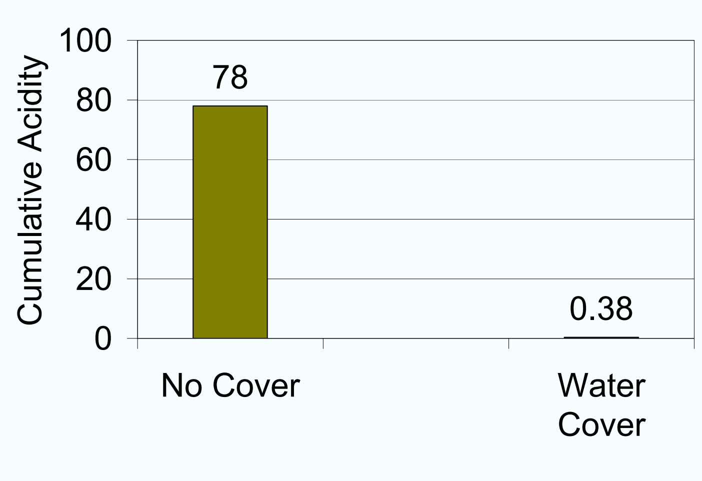
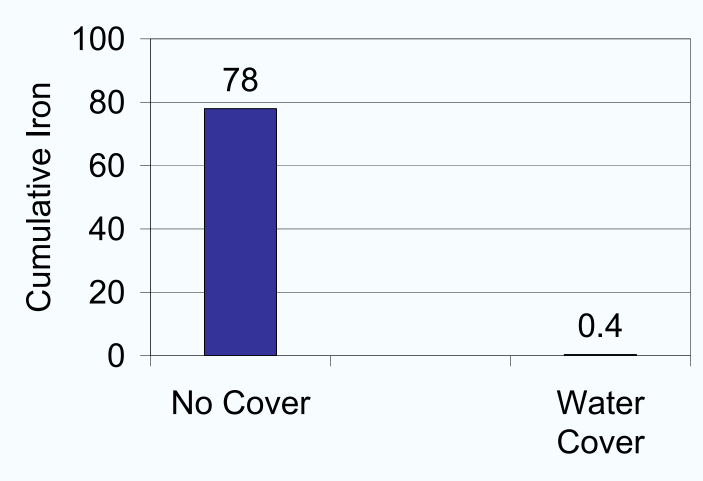
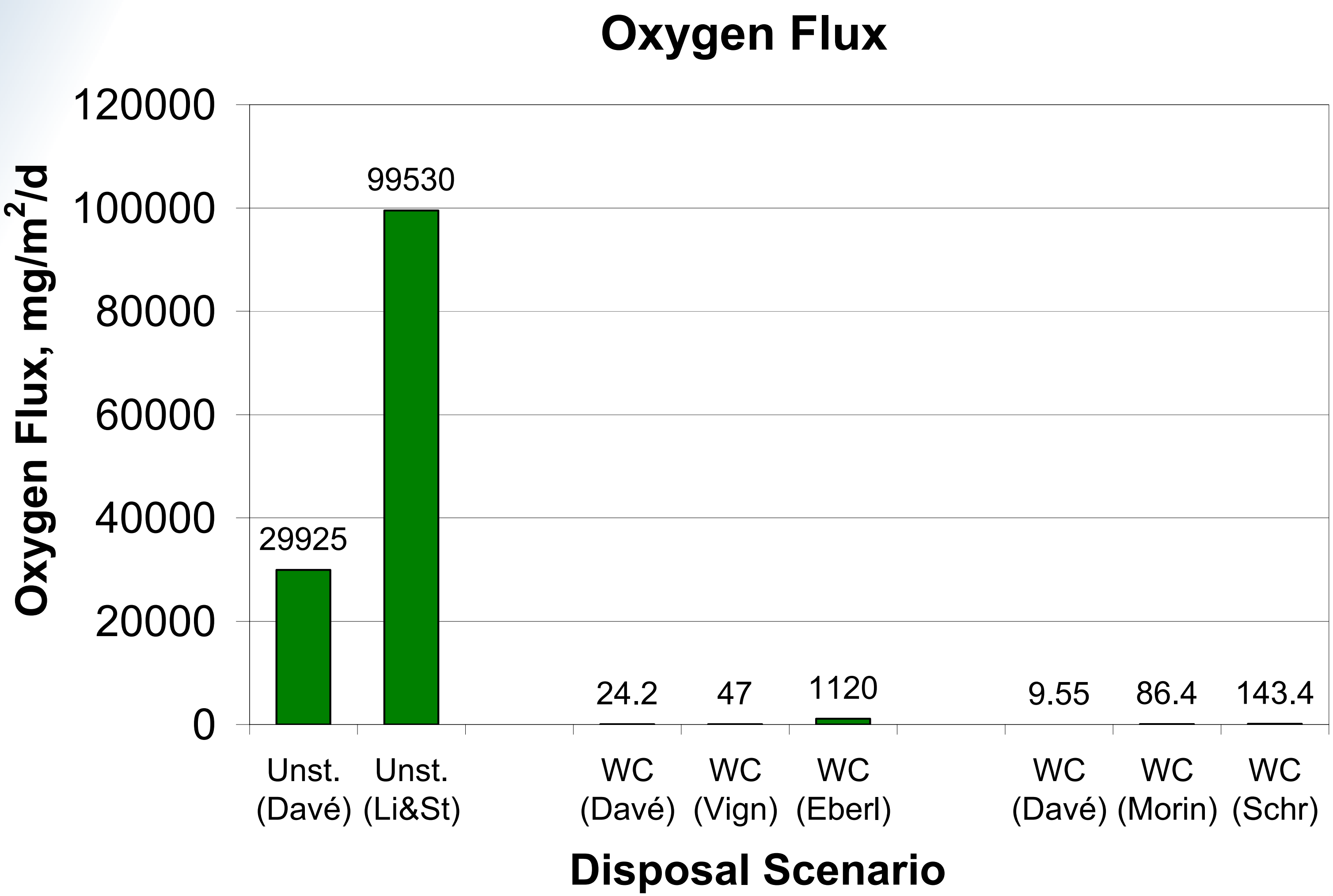






	Control No Cover	Water Cover
Acidity	100	0.48
Total Iron	100	0.51

Performance of Water Covers – Oxygen Flux



Performance of Water Covers – Man Made Impoundments

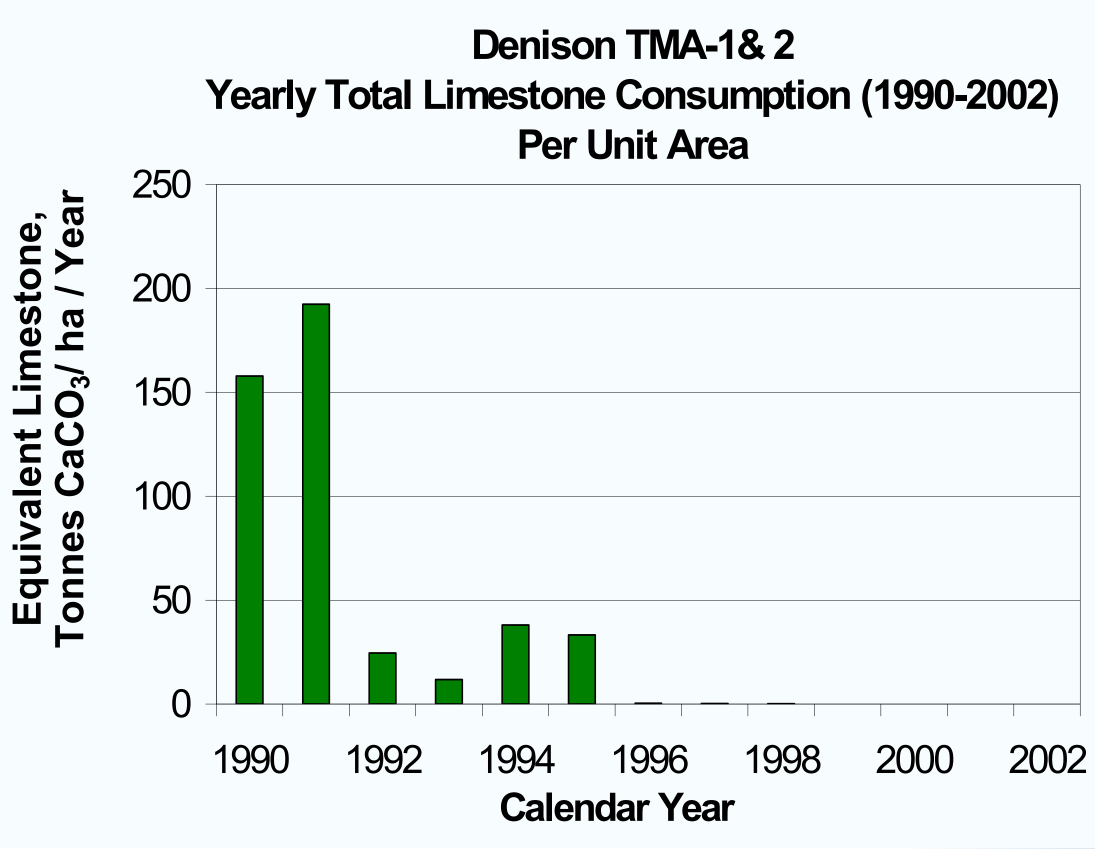
- Four sites: Denison, Panel, Quirke and Stanleigh TMAs, Elliot Lake, Ontario, Canada
- Low ore grade (~0.1% U) - mine closer in early to mid 1990s
- Highly acid generating pyritic uranium tailings, ~ 5-10% pyrite
- Acid-leach milling process, no available alkalinity
- Extensive field sites having in-situ shallow water covers, minimum 1 m water depth
- Site rehabilitation during 1992 to 1999
- All sites on care and maintenance

Water Cover Site - Denison TMA

- Mine operation from 1957 to 1992
- 63 M tonnes of acid generating pyritic U tailings; 5-7% pyrite
- Two tailings management areas (TMA-1 and TMA-2); combined area 290 ha; separate single elevation water covers
- Decommissioning activities 1993 to 1996; impervious containment dams; reinforcement 1993; designed precipitation run-off facilities
- Tailings dredged; single elevation water cover provided and maintained by natural run-off from containment area catchment basin
- In situ lime addition and periodic effluent treatment

Performance of Water Covers - Denison TMA

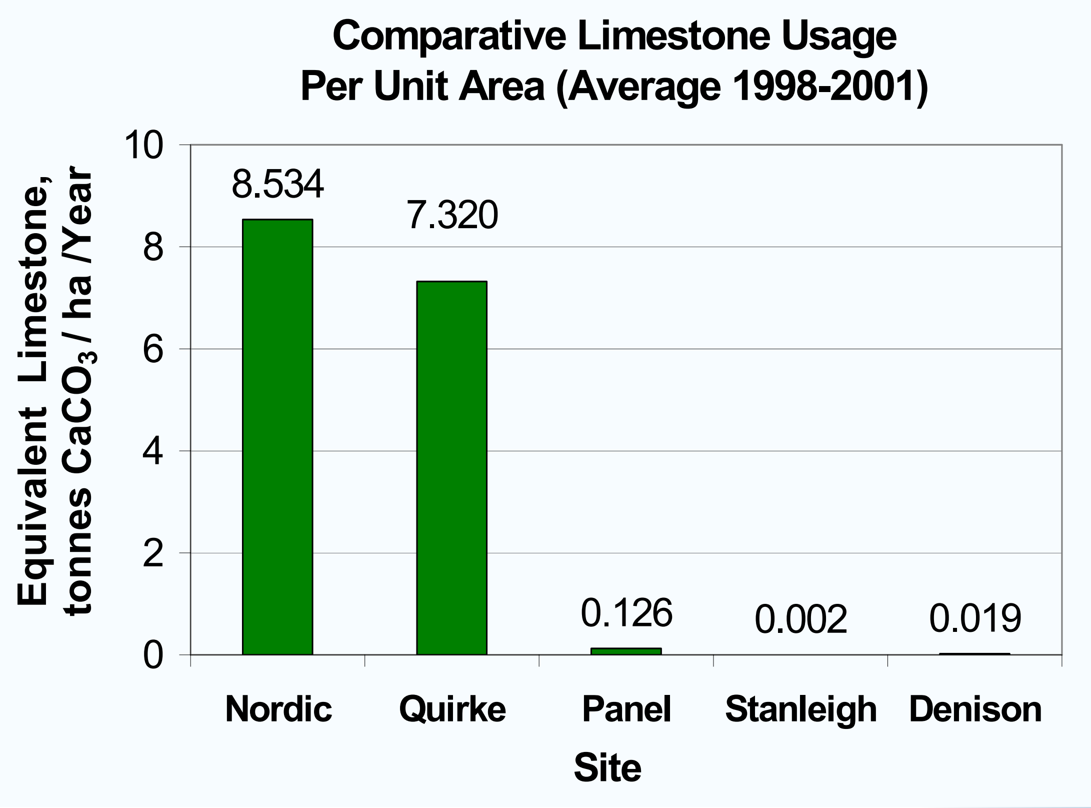
Year	Total $CaCO_3$ Equivalent (tonnes/year)	Total $CaCO_3$ Equivalent (tonnes/ha/year)
1990	42,779	157.858
1991	52,119	192.320
1992	6,636	24.487
1993	3,201	11.813
1994	10,288	37.963
1995	9,024	33.300
1996	74	0.275
1997	59	0.218
1998	18	0.065
1999	1	0.002
2000	1	0.002
2001	2	0.006
2002	0.16	0.001



Water Cover Sites – Man Made Impoundments

Performance of Water Covers
Water Cover / Revegetated TMAs

Site	Total $CaCO_3$ Equivalent (tonnes/year)	Total $CaCO_3$ Equivalent (tonnes/ha/year)
Denison	5.07	0.019
Quirke	1405.40	7.320
Panel	15.54	0.126
Stanleigh	0.68	0.002
Nordic	1117.91	8.534

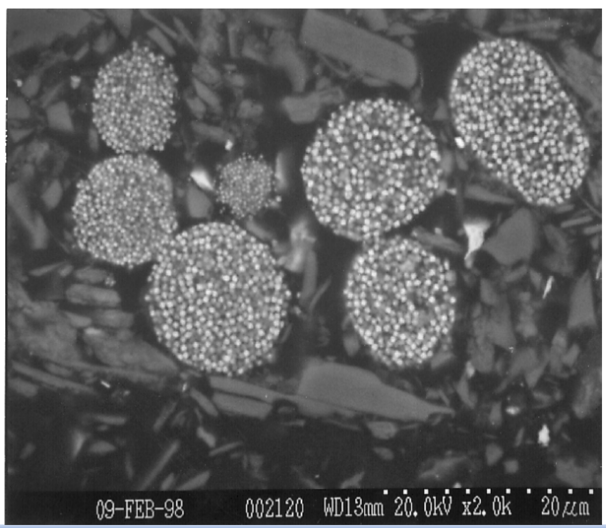


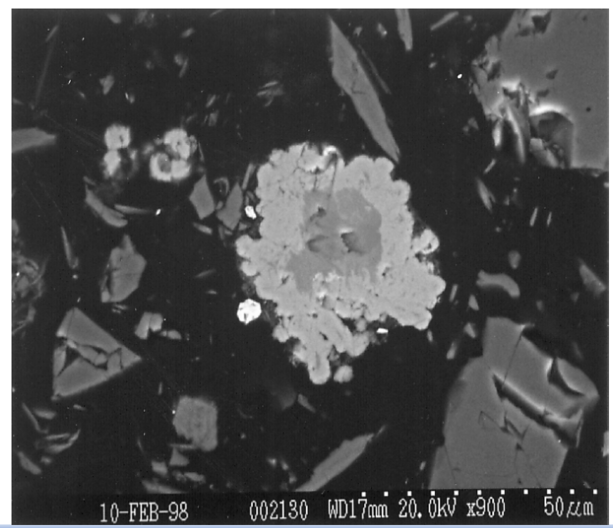
In-situ Water Covers - Performance Summary

- Shallow water covers are effective
- Oxygen penetration typically less than 1cm
- Field sites performing well as per design specification; water cover maintained at near neutral pH conditions
- Acid generation rate at Denison TMA has reduced to less than 0.03% and 0.15% of pre-water cover operating and during site rehabilitation
- In comparison to the revegetated Nordic/Lacnor site, acid generation rates at Denison, Panel and Stanleigh TMAs have decreased to less than 1.6%
- Flushing of the previously generated acidity and oxidation reaction products at the Quirke TMA are resulting in its high alkali demand comparable to that at Nordic TMA

Water Covers on Reactive Tailings

Framboidal pyrite





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Water Covers – Man Made Impoundments

Water Covers – Man Made Impoundments

Summary Water Covers – Man Made Impoundments

- Suitable for both existing and new waste management sites
- Design for closure for new sites; waste oxidation could be minimized
- Integration of local topography and biota
- Water quality could be maintained in-situ to meet discharge standards; downstream treatment could be minimized
- Designed for maximum probable precipitation events and extreme draught conditions
- Incorporation of minimum water cover depth and/or wave breakers to control wind-wave induced erosion
- Medium to high risk associated with the long-term maintenance of water retention dams and flow structures; large footprint in case of catastrophic failure
- Impact of global warming on water cover depth and retention

In Lake or Submarine Disposal

Selected Underwater Disposal Sites

<u>Lakes:</u>

- Buttle Lake BC, Westmin
- Benson Lake BC, Cominco
- Mandy Lake, MB, HBMS
- Anderson Lake, MB, HBMS
- Garrow Lake, NWT
- Lake Superior, MAN, US, Coastal Bay, Reserve Mining
- Vale Inco VBN, Doris North

<u>Submarine Disposal:</u>

- Vancouver Island, BC, Fjord, Island Copper
- Alice Arm, BC, Fjord, Amax
- Tilt Cove, Bay Verte, NFLD
- Jorden River, BC, Coastal Bay, Sunro Mine

In Lake Disposal – Mandy Lake, MB

Disposal in Natural Water Bodies

- Minimal or no risk of catastrophic failure
- Most suitable for long-term geotechnical and chemical stability
- Suitable for small headwater or isolated water bodies
- Economically attractive and predictable technology
- Least impacted by climate change
- Water body is sacrificed during the operating phase; habitat compensation may be required
- Special ministerial permission is required and local stakeholders concurrence may be necessary
- Post operational site recovery is relatively quick, but the original habitat and biodiversity may be permanently impacted

Summary

- Availability of suitable and site specific waste management technologies
- Low maintenance closure and walk away options are desirable over long-term perpetual treatment
- Ecosystem integration and holistic waste management approach

Thank you - Merci