Cover Systems and Landforms for Closure of Mine Waste Storage Facilities – Practical Insights with a Focus on Saskatchewan

Brian Ayres, M.Sc., P.Eng.

SMA Environmental Forum – October 17-18, 2018, Saskatoon, SK

Our vision

We strive to be the premier engineering solutions partner, committed to delivering complex projects from vision to reality for a sustainable lifespan.

Mine Waste Storage Facilities (MWSF)

Varying Landforms:

- Ponds of finer, wetter tailings
- Stockpiles of coarser, drier tailings
- Stockpiles of waste rock

Varying Landform Attributes:

- Geochemistry … reactivity, solubility, etc.
- Geotechnical … grain size, strength, etc.
- Geometry … footprint, height, slopes

Varying External Factors:

- Climatic conditions (seasonal)
- Hydrogeological setting

From a closure / reclamation perspective …

✓cover system design will be influenced by numerous factors

✓detailed site characterization is paramount

SNC·LAVALIN

MWSF Cover System Technology – Evolution over Time

- Mine reclamation started in earnest in 1970s
- Early designs based on landfill liner designs, with unrealistic expectations of performance
- Cover system technology advanced with considerable research since early 1990s
    - MEND (2004) – Cover design manual
    - MEND (2007) – Macro-scale focus
    - MEND (2012) – Cold regions focus
    - INAP (2017) – Global focus

Fundamental Changes in Cover System Technology over Past 40 Years:

- Improved software to numerically simulate cover system performance
- Advancements in modelling methodology
- Much greater appreciation for evolution of cover materials / systems
- Field performance monitoring – evolved from small test plots, to larger-scale field trials, and now watershed-scale focus
- Overall design … more emphasis on how cover system integrates w/ final landform

SNC·LAVALIN

Objectives and Design Functions of MWSF Cover Systems

Objectives:

- Support agreed-upon end land use
- Minimize degradation of receiving environment post-closure

Most Common Design Functions:

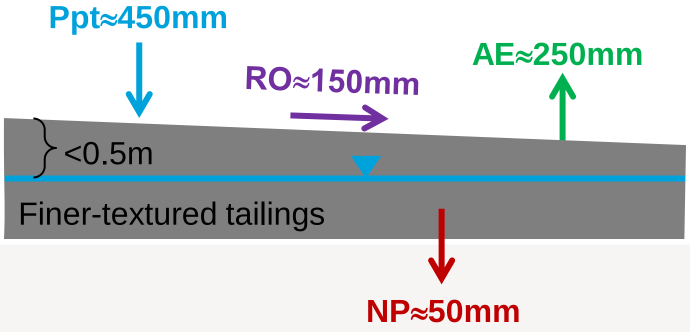
- Waste isolation (“keep clean water clean”)
- Re-establish vegetation and ecosystems
- Control wind and water erosion of waste material
- Limit influx of oxygen to reactive waste material
- Limit net percolation of meteoric water through the waste

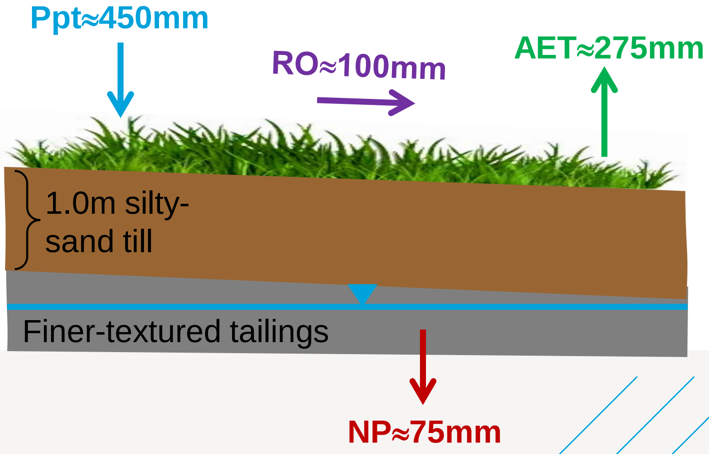
SNC·LAVALIN

Example where a Cover System Increased Net Percolation Rates compared to No Cover Scenario


Tailings Impoundment at a Legacy Mine Site in Northern SK

	Cont. Runoff	Cont. Seepage	Total Potential Cont. Flow
No Cover	150mm	50mm	200mm
1m Till Cover	0	75mm	75mm





SNC·LAVALIN

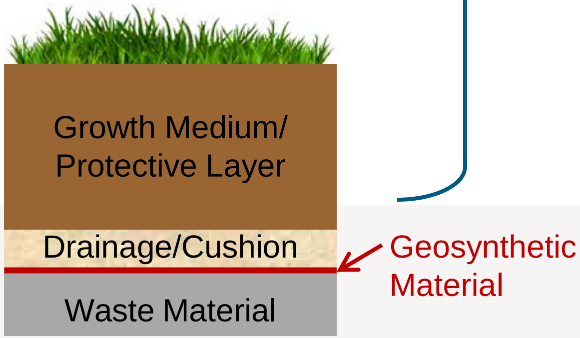
Cover System Design Alternatives

Moisture Store & Release (S&R)

Enhanced S&R

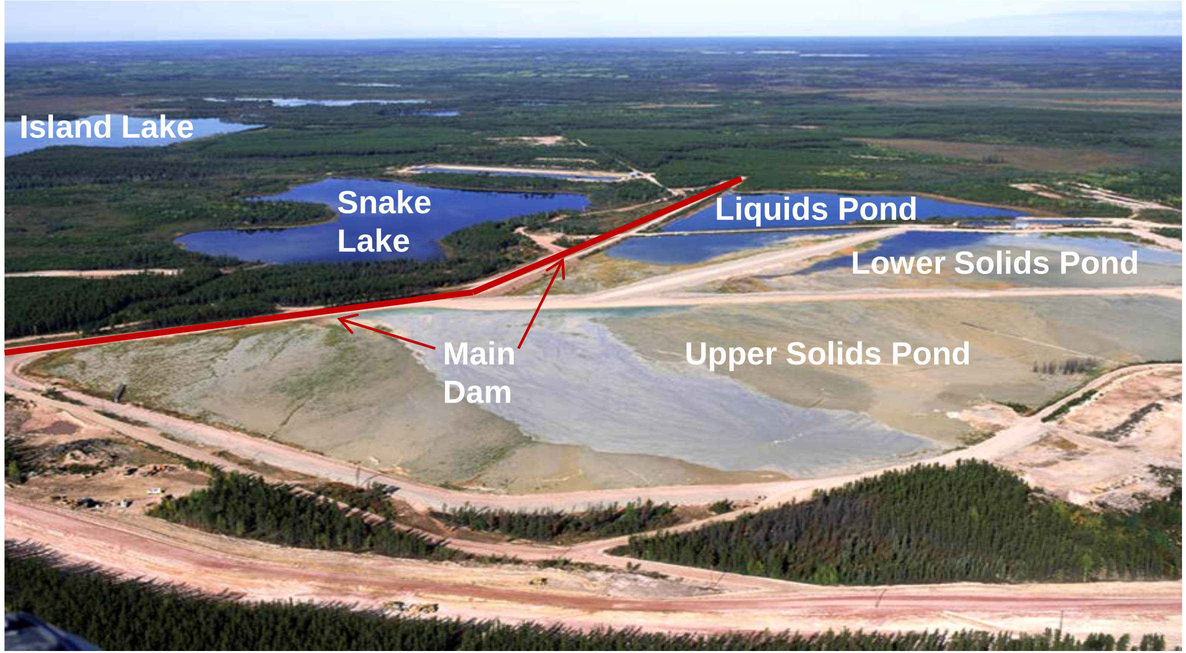
Barrier Type

Covers w/ Geosynthetics



Can all of these alternatives function over the long term under SK's extreme climatic conditions?

Case Study – Cluff Lake Tailings Management Area (TMA)



(Source: COGEMA 2001 Cluff Lake Project Comprehensive Study Report)

- TMA received ~2.67 Mm^3 (~80 ha) of uranium tailings between 1980 and 2002
- Main Dam – till-bentonite core down to bedrock

Major Concerns for Closure:

1) Ra-226 and Uranium source terms
2) Proximity to sensitive aquatic receptor
3) Limited cover materials … local sandy till (~15% fines)

SNC·LAVALIN

Case Study – Cluff Lake Tailings Management Area (TMA)

- Initial thinking was a cover system w/ compacted sand-bentonite layer would be needed to limit net percolation and radon gas emissions

(Photo courtesy of M.D. Haug)

- Concerns arose about the longevity of a barrier-type cover design in a cold region over a tailings deposit

(Photo courtesy of Orano Canada)

- Through detailed site characterization and analyses, COGEMA demonstrated that a 1.0 m till cover (min.) would be acceptable
- Reclaimed TMA performing as-designed

SNC·LAVALIN

Example of Enhanced Moisture S&R Cover System

(Source: Ayres et al., 2013)

- Compacted waste rock overlain by 1.0 m silty-sand till
- Claude waste rock pile at the former Cluff Lake Mine (Orano Canada)
- B-zone waste rock pile at Cameco's Rabbit Lake Mine

SNC·LAVALIN

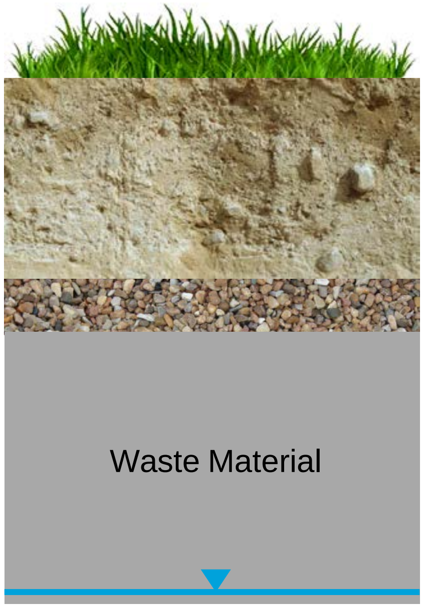
Cover Systems with Capillary Break Effects (CCBE)

They work great provided …

- Appropriate textural contrast between adjacent layers
- Capillary break layer remains in a drained state

How can we ensure a CCBE performs as intended over the long term?

- Increase thickness of overlying water storage layer
  … especially on long slopes
- Use CCBEs where the water table is deeper



SNC·LAVALIN

Cover Systems with Geosynthetics

(Source: www.agru.at/en/products/lining-systems/)

(Source: www.titanenviro.ca)

Which Product is Right for Your Site?

- Chemical compatibility w/ waste & cover pore-waters?
- Texture of sub-grade material?
- Length of construction season?

(Source: www.passel.unl.edu)

Key Cover Design Aspects:

- Lateral drainage / diversion capacity
- Geotechnical stability
- Serviceable lifespan of geomembrane

Cover System Construction Considerations

Over-Compaction of Growth Medium Layer

- Decreases water storage capacity and limits deeper root development
- Winter construction or use lighter equipment

Revegetation Method

- Higher seed germination rates w/ drill seeder

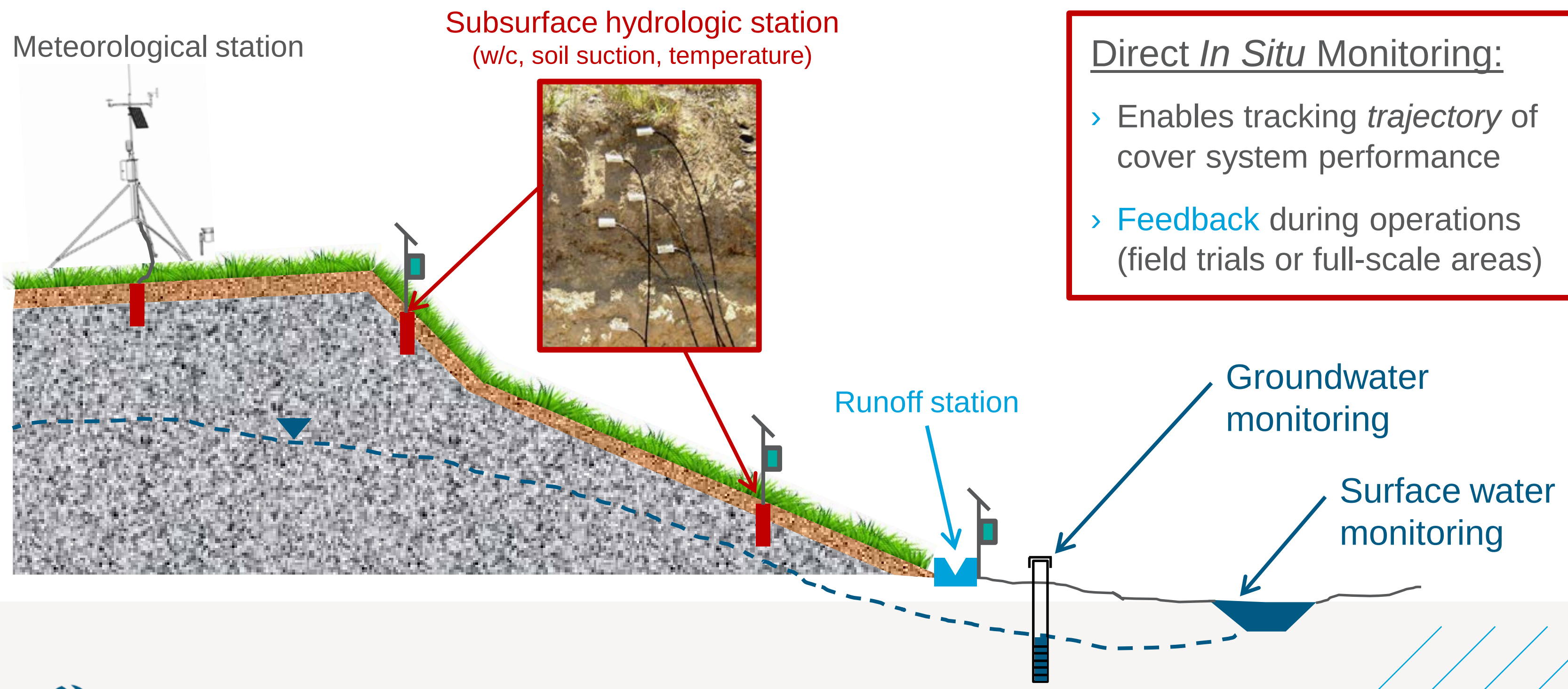
Potential for Material Segregation

- Gap-graded materials prone to segregation
- Place in thinner lifts, doze for homogeneity

Adequate construction QA/QC!

SNC·LAVALIN

Performance Monitoring of Reclaimed Mine Waste Landforms



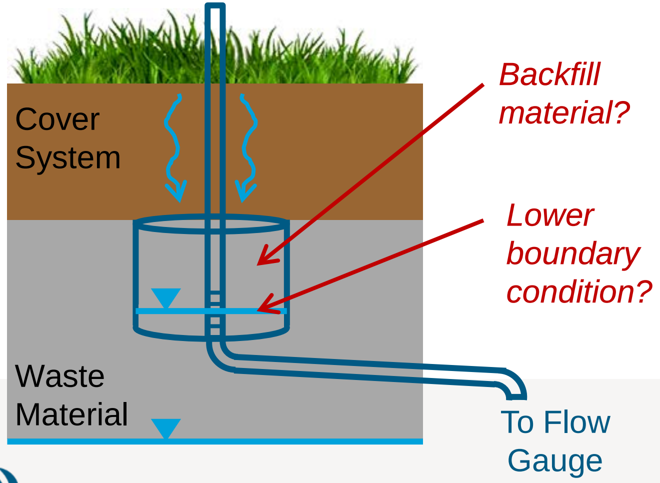
Direct *In Situ* Monitoring:

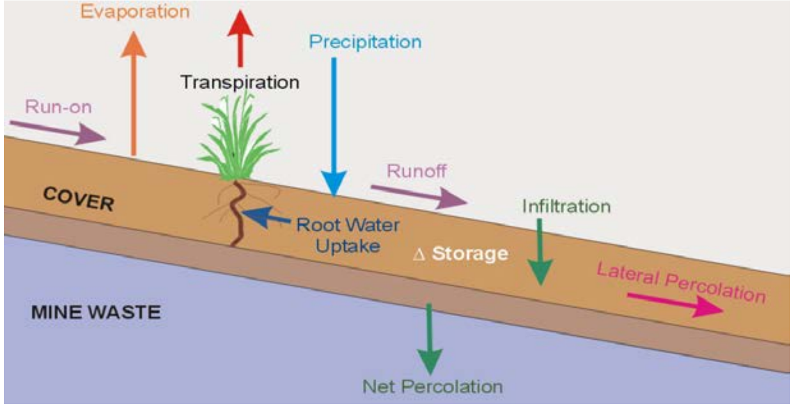
- Enables tracking *trajectory* of cover system performance
- Feedback during operations (field trials or full-scale areas)

SNC·LAVALIN

Quantifying Net Percolation Rates

- Key input for numerical assessments of contaminant transport
- Simple parameter for stakeholders to understand





(Source: MEND, 2007)

Gravity-drainage Lysimeters …

- Conceptually simple, but proper design, installation, and operation can be challenging

SNC·LAVALIN

Traditional MWSF Reclaimed Landforms vs. Natural Landforms

Traditional MWSF reclaimed landforms:

- uniform shapes w/ linear slopes
- drainage courses highly engineered, typically along contours
- artificial revegetation designs

(Source: www.miningfocus.org)

Natural soil-mantled landforms:

- variety of shapes w/ non-linear slopes
- drainage courses meandering and follow natural drop lines
- vegetation dependant on hillslope hydrology and incident solar radiation

(Source: https://www.nrcs.usda.gov)

SNC·LAVALIN

Geomorphic Approach to MWSF Landform Reclamation Design

- Emulate the natural landscape that is in equilibrium w/ local climate, soils, vegetation
- Incorporate “forms” that fit the “function”
- Incorporate diversity to promote resiliency, leading to a sustainable ecosystem

Is there a <u>business case</u> to build landforms with a more natural appearance?

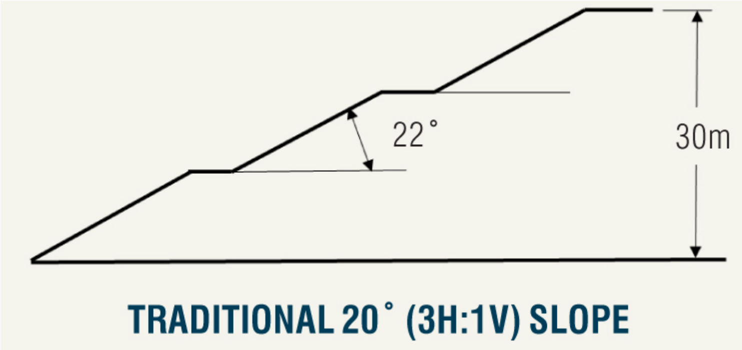
1) Reduced maintenance liability post-closure
2) Earlier transfer to custodial care
3) Public relations value (e.g. AB oil sands)

Reclaimed Tailings Pond 1 at Suncor, AB (www.nps.gov)

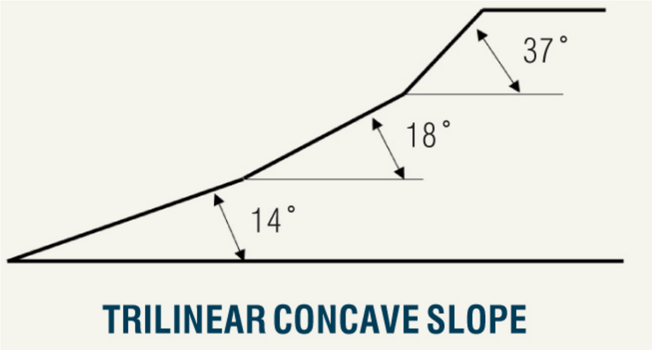
Reclaimed Slurry Pond, Indiana (www.in.gov/dnr/)

SNC·LAVALIN

Geomorphic Approach to MWSF Landform Reclamation Design



(Source: www.ausimmbulletin.com)



(Source: www.ausimmbulletin.com)

- Benched slope profiles are prone to failure over the long term
- Concave slopes are more stable than linear slopes

Cameco's Rabbit Lake BZWRP Reclaimed Landform (2010)

(Source: Ayres et al, 2005)

SNC·LAVALIN

Surface Water Management

Why is this important?

- **Gully erosion** and re-established surface water drainage courses are greatest physical risk to reclaimed landforms (McKenna and Dawson, 1997)
- Erosion gullies have a high visual effect
- Erosion can lead to increased contaminant loading

(Source: www.dailymail.co.uk)

Key Design Aspects for MWSF Reclamation:

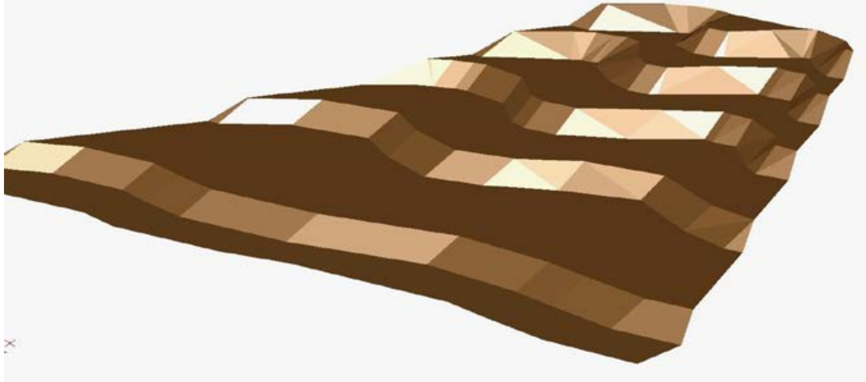
- Incorporate climate change into design storm event
- Clearly defined catchments w/ high drainage density
- Limit drainage channels / outlets on north-facing slopes

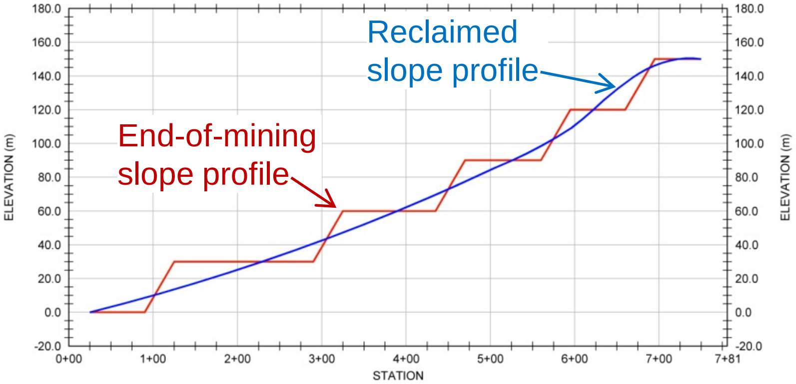
(Source: www.emnrd.state.nm.us/)

SNC·LAVALIN

MWSF Landform Design w/ Closure in Mind

"Contour-Terraced Stockpile" *(Ayres et al., 2006)*





- Facilitates curvilinear slope profile and creation of ridges and swales at closure

SNC·LAVALIN

Key Take-Away Messages

- Various cover system design alternatives exist, but simple yet robust designs are preferred for SK's climatic conditions
- Use appropriate landforms to support design functions of mine waste cover system

(Source: www.westmoreland.com/)

(Photo courtesy of Orano Canada)

- Reclaimed mine waste landforms will evolve over time … design for this fact
- A business case exists for building mine waste landforms with a more natural appearance

SNC·LAVALIN

List of References

Ayres, B., Dobchuk, B., Christensen, D., O'Kane, M. and Fawcett, M. 2006. Incorporation of natural slope features into the design of final landforms for waste rock stockpiles. *In* Proc. of 7th International Conference on Acid Rock Drainage, St. Louis, MO, USA, March 26-29.

Ayres, B., Landine, P., Adrian, L., Christensen, D., and O'Kane, M. 2005. Cover and final landform design for the B-zone waste rock pile at Rabbit Lake Mine. *In* Proc. of 4th International Conference on Uranium Mining & Hydrogeology, Freiberg, Germany, September 11-16.

Ayres, B., O'Kane, M., Barber, L, Hiller, D, and Helps, D. 2013. Performance of an engineered cover system for a uranium mine waste rock pile in northern Saskatchewan after six years. *In* Proc. of Northern Latitudes Mining Reclamation Workshop and CLRA Conference, Whitehorse, YT, September 9-12.

Ayres, B. and O'Kane, M. 2013. Design, construction, and performance of closure cover systems for spent heap leach piles – a state-of-the-art review. *In* Proc. of 2013 Heap Leach Conference, Vancouver, BC, September 22-25.

COGEMA. 2001. Cluff Lake Project Decommissioning Comprehensive Study Report.

INAP (International Network for Acid Prevention). 2017. Global cover system design technical guidance document. September.

McKenna, G., Scordo, E., Shuttleworth, D., Straker, J., Purdy, B., and Buchko, J. 2011. Aesthetics for mine closure. In Proc. of Mine Closure 2011, Volume 1, Lake Louise, Canada. Australian Centre for Geomechanics, Perth, pp. 603-612.

McKenna, G. and Dawson, R. 1997. Closure planning practice and landscape performance at 57 Canadian and US mines, draft. July.

MEND (Mine Environment Neutral Drainage). 2004. Design, construction and performance monitoring of cover systems for waste rock and tailings. Report no. 2.21.4, July.

MEND (Mine Environment Neutral Drainage). 2007. Macro-scale cover design and performance monitoring reference manual. Report no. 2.21.5, July.

MEND (Mine Environment Neutral Drainage). 2012. Cold regions cover system design technical guidance document. Report no. 1.61.5c, July.

SNC·LAVALIN

Our values are the essence of our company's identity. They represent how we act, speak and behave together, and how we engage with our clients and stakeholders.

SAFETY

We put safety at the heart of everything we do, to safeguard people, assets and the environment.

INTEGRITY

We do the right thing, no matter what, and are accountable for our actions.

COLLABORATION

We work together and embrace each other's unique contribution to deliver amazing results for all.

INNOVATION

We redefine engineering by thinking boldly, proudly and differently.

SNC·LAVALIN