Integrated Mine Waste Management and Closure Services

– Mine Waste Cover Systems – Meeting Long-Term Performance Expectations

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Presentation Discussion Points

- Some Context
- Let’s Discuss…
  - Functionality
  - Objectives
  - Criteria
- What are the Expectations for Cover Systems
- What are the Challenges with Cover Systems
- Discussion Points for Moving Forward
Context – the Issue

- Groundwater and Surface Water
- Sulphide Mineral
- Water Transport
- Gas Transport
  - Advection
  - Diffusion
- Example:
  - Net Percolation Rate?
- Example:
  - Oxygen Ingress?
Context for Cover Systems

- Cover systems span a continuum of objectives:
  - Revegetation, reclamation
  - Erosion and Sediment Loss / Transport
  - Strict Control / Management of Water and/or Gas
  - Transport for Geochemical Objectives

Less “Engineered”

More “Engineered”
Cover System Alternatives

Erosion Protection

Reclamation / Revegetation

Moisture Store-and Release and Enhanced S&R

Saturated Layer

Capillary Break

Barrier Type ($k_{sat} \leq 1 \times 10^{-7}$ cm/s)

- CCL
- LLDPE
- GCL
- GCLL
- BGM
- Frozen

Dr. Lee Barbour
Cover System Functionality

- But... What do all these Cover System “Types” have in Common in terms of Functionality?
  - A growth medium that “stores-and-releases” water through evapotranspiration; and
  - Runoff during certain times of the year.
**Cover System Functionality**

- **Diversion** – a layer of the cover system may be constructed from materials with a sufficiently low hydraulic conductivity so as to limit downward percolation of rainfall or snowmelt and ‘release’ water as surface runoff or interflow.

- **Store-and-release** – infiltrating water is stored within the rooting zone of the cover so that it can be subsequently released via evapotranspiration (ET). In these types of covers, the objective is to minimize deep percolation by returning most of the infiltrating waters from storage to the atmosphere via ET.
“In Tune” w/ your Setting?
“In Tune” w/ your Setting?

Rum Jungle – Constructed ~ mid-1980s
“In Tune” w/ your Setting?

Rum Jungle – Constructed ~ mid-1980s

NP Criteria (5%)
“In Tune” w/ your Setting?

El Sherana – Constructed ~ 2009

O’Kane et al, 2011
“In Tune” w/ your Setting?

O’Kane et al, 2011
Cover System Functionality

Managing Oxygen
Cover System Functionality

Managing Oxygen

• 1m Water Cover:
  • $O_2$ ingress is
    ~ 1 mol/m$^2$/year
  • Oxygen diffuses through water
    ~ 10,000 slower than air
  • Must maintain very high saturation conditions for low $O_2$ diffusion
    • At least 85% if not 90% saturation throughout year
    • ~ 1 mol/m$^2$/year

Aachib (2002)
Gas flows upward and out the top surfaces of stockpiles when it is lighter than the surrounding air

- Less $O_2$, more $H_2O_{\text{vapour}}$ \textit{in pore-air}, $T_{air}$ \textit{lower} than $T_{in}$

\textit{Phillip et al., 2009}
**Cover System Functionality**

Managing Oxygen

- Gas Transport
- Advection
- Diffusion
- Require Low Air Permeability
  - Cover System?
  - Wet Conditions?

Phillip et al., 2009

Gas flows downward and out the toe of stockpiles when it is heavier than the surrounding air

- Increase in CO$_2$ in pore-air, $T_{air}$ **higher** than $T_{in}$
Cover System Functionality

Equity Silver Mine

Morin et al., 2010
Cover System Functionality

Equity Silver Mine

Morin et al., 2010
Cover System Functionality

Equity Silver Mine

Morin et al., 2010
Cover System Functionality

Whistle Mine

Ayres et al., 2012
Cover System Functionality

Whistle Mine

Oxygen Ingress:
- Internal and cover gas monitoring
- \(~ 1 \text{ mol/m}^2/\text{yr}\)

Ayres et al., 2012
Continuum of Performance

- Performance exists as a continuum
- Common qualifiers across all climates differing in nominal values.
- Understanding site specific climate important for setting realistic performance criteria.

Climate is our First Filter
Advancing our Approach…

The Average Does Not Exist

Must Include Seasonality
Advancing our Approach….

“Site-Specific”… Includes Micro-Climate Effects

Rendering courtesy of Justin Straker
Advancing our Approach…

“Site-Specific”…
Includes Climate Change Effects

- Not just an increase/decrease in temperature
- Not just an increase/decrease in precipitation
- Influence of climate change on seasonality
  - Change in growing season (onset and length)
  - Change in snowmelt timing
- Base case of predicted performance…. include climate change effects
  - Sensitivity on alternate climate change scenarios
Expectations of Cover Systems?

- Challenging to demonstrate benefits
  - Or rather magnitude of benefits
  - Implications for water management (quantity and quality) and water collection/treatment systems

- This challenges attributed to:
  - Dynamic variations of loading
  - Difficulty with Predicting:
    - Influences on acidity/element loading
    - Time period for post-closure costs
  - A discount rate for net present value (NPV) calculations agreed to by all stakeholders
  - Uncertainties associated with all processes (values) used for pre-closure, closure, and post-closure costs estimation at project startup and during operations
Expectations of Cover Systems?

Equity Silver Mine

All due to Cover System?

- GW inflow from watershed?
- Oxygen?
- Storage and flushing of oxidation products

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**Morin et al., 2010**

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**NOTE:** Flows bypassing Main ARD Pond in May and June 2002 included. After 1994, the Southern Tail flow is included in the Main Pond flow which increases the Main Pond flow by approximately 10%.

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**GW inflow from watershed?**

**Oxygen?**

**Storage and flushing of oxidation products**
## Do we Appreciate the Subtleties?

### 6% discount rate

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<th>Direct Water Treatment (Base Case)</th>
<th>Simple Soil Cover</th>
<th>Complex Soil Cover</th>
<th>Geomembrane Cover</th>
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### 2% discount rate

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Key Points Moving Forward

- **Cover system technology** has *advanced* significantly in the past 10 to 20 years
  - Database of performance monitoring is *increasing*
  - Mining industry is *gaining confidence* with its ability to properly design and implement cover systems
  - Greater *understanding* for the need to develop site-specific holistic designs influenced by site climate conditions, hydrogeology, geochemistry, materials, etc.
  - Vastly improved *numerical modelling* tools to enhance our understanding for performance
  - Do we appreciate the *subtleties inherent* with our typical *tools* to inform *decisions*?
Thank You!

O'Kane Consultants Inc.
Habitat for Humanity Initiative – El Salvador