Hydro-geotechnical analysis of a thickened tailings deposit in Northern Canada, via UNSATCON

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Outline

- Musselwhite mine
- Experimental study
  - Hydro-geotechnical properties
  - Column test
- UNSATCON simulation
  - UNSATCON --- a new software
  - Column test simulation
  - Field simulation
- Implications & Conclusions
**Musselwhite mine**

<table>
<thead>
<tr>
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<th>Musselwhite mine</th>
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<tbody>
<tr>
<td><strong>Production (guidance for 2017)</strong></td>
<td>265,000 ounces</td>
</tr>
<tr>
<td><strong>Gold Reserves (proven and probable)</strong></td>
<td>1.85 million ounces</td>
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<tr>
<td><strong>Gold Resources (inferred)</strong></td>
<td>1.17 million ounces</td>
</tr>
</tbody>
</table>

- **Per year**
  - 400 mm evaporation
  - 700 mm precipitation

![Musselwhite mine image](image-url)

![Musselwhite mine map](image-url)
Musselwhite mine

✓ Deposition: 3,000-5,500 TPD

Tailings beach profiles – north survey line

Discharge dyke north limb

Day 1

Day 365

Discharge dyke south limb

Horseshoe shaped dyke (Kam et al. 2011)
Geotechnical gravimetric water content

54-45% moisture content

Winter data

Summer data

Musselwhite mine
Physical problem solved

Initial deposition

Evaporation

New deposition

Deformation

Drainage

Evaporation

Evaporation

Drainage

Drainage

Drainage

SSM (Fredlund et al.)

Modified SSM (Zhang&Lytton)

BBM (Alonso et al.)

GCM (Wheeler et al.)
Use of UNSATCON-ML

Examples of optimizing deposition scheme
(The speaker's thesis)

Denser profile after 10 years of deposition
Hydro-geotechnical properties

- **Tailings’ basic properties:**
  - LL 21.5 %; PL is 12 %; Gs = 3.27
- **SWCC (Soil Water Characteristic Curve)**

![Graph showing SWCC and tailings properties](image)

- **Column test**
  - Compressibility and permeability

![Column test setup](image)
Hydro-geotechnical properties

Column test
Compressibility and permeability

Ultrasonic displacement Sensor & Webcam

Model T5
Bottom Drainage via a porous stone
Comparison between UNSATCON prediction with measurement:

From the geotechnical perspective, no reason to increase the underflow density pass the segregation threshold.
Selected analyses In the field

Single deposition per year

- Winter
  - 2 m/yr
  - 2.5 m/yr
  - 3 m/yr

- Summer

Two depositions per year

- Summer
  - 2.5 m/yr
  - 3 m/yr

Over 3 years
Profiles recording the deposition process from UNSATCON

(1) Degree of saturation
(2) Void ratio
(3) GWC
Overall void ratio over time

Natural time scale

- 2.0 m/yr-S
- 2.0 m/yr-W
- 2.5 m/yr-S
- 2.5 m/yr-W
- 3.0 m/yr-S
- 3.0 m/yr-W

Over all average void ratio

Time (days)

0 200 400 600 800 1000 1200

log time scale

- 2.0 m/yr-S
- 2.0 m/yr-W
- 2.5 m/yr-S
- 2.5 m/yr-W
- 3.0 m/yr-S
- 3.0 m/yr-W

Over all average void ratio

Time (days)

0.01 0.1 1 10 100 1000 10000

Winter

Summer

Winter

Summer
Void ratio over 3 years -- UNSATCON Prediction

- **Void ratio of 1st layer**

  1st layer void ratio

  - 2.0 m/yr-S
  - 2.0 m/yr-W
  - 2.5 m/yr-S
  - 2.5 m/yr-W
  - 3.0 m/yr-S
  - 3.0 m/yr-W

  3rd layer void ratio

  - 2.0 m/yr-S
  - 2.0 m/yr-W
  - 2.5 m/yr-S
  - 2.5 m/yr-W
  - 3.0 m/yr-S
  - 3.0 m/yr-W
Water content over 3 years -- UNSATCON Prediction

- Water content

**Overall GWC**

- 2.0 m/yr-S
- 2.0 m/yr-W
- 2.5 m/yr-S
- 2.5 m/yr-W

From Kam et al. (2011)
Biannual deposition

- **Sr = 0.9, w = 18%**

### GWC

- 2.0 m/yr-S
- 2.0 m/yr-S (2 layers per year)

### Void ratio

- Average void ratio vs. time (days)

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Shunchao Qi & Paul Simms  
Case study of a thickened tailings deposit with UNSATCON  
1/31/18
Conclusions

- Void ratio (deformation) is insensitive to the range of rise rates and deposition times examined in this paper;
- Degree of saturation ($S_r$) is sensitive to the deposition parameters;
- Therefore, if a site has tailings with potential for acid generation, deposition management can mitigate this risk.
Acknowledgements:

Funding for development of UNSATCON

Thanks & Questions
Testing UNSATCON

- **Testing – Drying box test: 5 layers**
  - By Daliri et al. (2016) at Carleton University
  - Material: hard rock tailings

**Diagram:**
- **Layer 1** and **Layer 2**
- **Elevation (m)**
- **Void ratio**
- **Time increase**
- **Irrecoverable volume change modeled using method in Zhang & Lytton (2009)**
- **Pore water pressure (kPa)**
- **GWC**
- **Time (days)**
To be revised
Void ratio over 3 years -- UNSATCON Prediction

- **Void ratio of each layer**

  1st layer void ratio

  ![Graph showing void ratio over time for the 1st layer](image1)

  - 2.0 m/yr-S
  - 2.0 m/yr-W
  - 2.5 m/yr-S
  - 2.5 m/yr-W
  - 3.0 m/yr-S
  - 3.0 m/yr-W

  2nd layer

  ![Graph showing void ratio over time for the 2nd layer](image2)

  3rd layer

  ![Graph showing void ratio over time for the 3rd layer](image3)
Deposition parameters influence on desaturation