Sloughing of a tailings excavation slope due to rapid drawdown

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Presentation Outline

1. Introduction and background
2. Description of observed tailings sloughing
3. Slope stability back calculations (i.e., determine conditions that replicate observed slope failure)
4. Prediction of long-term high groundwater level in the tailings
5. Long-term tailings cover stability analysis results
6. Conclusions
Design and construction of a multi-layer soil cover for rehabilitation of two Tailings Management Areas (TMAs) at a former uranium mine.

The soil cover consists of a 0.4 m thick sand/bentonite layer (10% bentonite by weight) beneath a 1 m thick layer of granular material (selected based on a field trial program and option evaluation).

The soil cover is designed to reduce radon gas emissions and infiltration of precipitation into the tailings.
Introduction and Background

- To achieve the desired final topography, the existing tailings surface required excavation and grading prior to soil cover placement.
- The final cover design includes a main drainage channel and swales with erosion protection to safely convey the design storm event.
- After completion of the TMA rehabilitation and soil cover construction, the TMA perimeter dams will no longer be required to function as water retaining structures.
Observed Sloughing

- Sloughing of an excavated tailings slope was observed in the lower swale prior to placement of the overlying soil cover materials.
- The side slope of the tailings excavation that experienced sloughing was 10 horizontal to 1 vertical (10H:1V) and the tailings slope was covered with a temporary non-woven geotextile to control erosion during the construction period.
Observed Sloughing

- Although some erosion of exposed tailings slopes had been previously observed; the large volume of tailings that moved to the base of the swale indicated that sloughing or slope instability was the likely mechanism of the tailings movement.

- During tailings excavation, groundwater seepage was draining into the excavation and precipitation events would cause temporary ponding of water at the base of the excavation, which was then pumped down as part of the active dewatering effort.

- Rapid drawdown of ponded water in the excavation and groundwater seepage into the excavation were inferred to be contributing factors to the observed sloughing.
In the absence of pore water pressure, the Factor of Safety (FoS) of a 10H:1V tailings slope with a $\phi'$ equal to 28 degrees is 5.3 (stable).

Slope stability was carried out for different scenarios to determine groundwater conditions required to replicate the observed sloughing.
Slope Stability Back Calculations

- Horizontal phreatic level equal to the elevation of the swale bottom.
- Minimum FoS for this case is 4.0 (slope is stable).
Slope Stability Back Calculations

- Groundwater table at the excavated tailings (ground) surface.
- Minimum FoS of 2.4 for shallow trial surfaces (slope is stable).
Phreatic level in the tailings 0.5 m above the excavated channel bottom. 

Results in a shallow failure surface (FoS = 0.7) at base of channel (below the water table - similar to observed tailings sloughing).
Phreatic level in the tailings 0.5 m above the excavated channel bottom. Trial surfaces extending above the water table are stable (FoS >> 1). These results indicate that any slumping would be limited to below the ponded water level prior to rapid drawdown.
Potential Long-Term High Groundwater Levels

- The TMA rehabilitation must be stable over long-term post-closure conditions (i.e., check slope stability for high groundwater levels).
- A 3-Dimensional (3D) groundwater model was developed to predict potential long-term high pore-water pressures in the tailings beneath the low permeability sand-gravel-bentonite (SGB) layer (i.e., due to the design storm event and potential rapid drawdown).
- Based on the 3D groundwater modeling results, the predicted maximum groundwater elevation within the tailings underlying the soil cover was calculated to be 352.0 m following the 100 year design storm event.
During a rapid drawdown condition, tailings beneath the low permeability SGB layer could maintain elevated pore water pressure after water drains off the overlying cover; resulting in loss of the resisting force of the overlying weight of water, while elevated pore water pressure remains in the underlying tailings (rapid drawdown condition).

Rapid drawdown conditions were modeled by simulating two phreatic surfaces within different materials in the slope stability model.

The first piezometric surface follows the top of the SGB layer and represents the drained channel. This phreatic surface was applied to the soil cover materials.

The second phreatic surface is assumed to be horizontal at a fixed elevation, representing the high water level in the channel and tailings before rapid drawdown. This phreatic surface was applied to the tailings underlying the SGB.
A sensitivity analysis was carried out for various phreatic surface elevations in the tailings. The figure below illustrates slope stability results for an elevated phreatic surface of 353.2 m (FoS of 1.0).
The minimum FoS for various groundwater elevations were calculated. Based on the 3D groundwater modeling results, the maximum groundwater elevation within the tailings underlying the soil cover (following the design storm event) is 352.0 m. This corresponds to a FoS equal to 2.0 indicating a stable slope following the design storm event.

<table>
<thead>
<tr>
<th>Tailings Groundwater Elevation (m)</th>
<th>Minimum Calculated Factor of Safety</th>
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<tbody>
<tr>
<td>352</td>
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<tr>
<td>352.5</td>
<td>1.6</td>
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<td>1.2</td>
</tr>
<tr>
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</tbody>
</table>
Conclusions

- Slope stability analysis back calculations determined that observed sloughing of an excavated tailings slope was caused by elevated pore water conditions in the tailings likely caused by flooding in the channel followed by rapid drawdown.

- During rapid drawdown, tailings underlying the low permeability sand-gravel-bentonite cover layer could maintain an elevated pore water pressure after the overlying cover drains; potentially resulting in slope instability.

- Slope stability analyses were carried out to check the long-term stability of the cover for rapid drawdown conditions following the design storm.

- The main drainage channel outlet design was modified to include granular filter compatible layers that safely drain excess pore water pressure from the underlying tailings following the design rainfall event.
Thank you!

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