Advances in Fluid Fine Tailings Measurement and Management in the Athabasca Oil Sands

Dale Kolstad, P.E., P.Eng
Barr Engineering Company
Outline

- Introduction to Oil Sands & fluid fine tailings (FFT)
- FFT inventory measurement & quantification
- FFT reduction & reclamation strategies
- Closing Commentary
Canadian Oil Sands

- Canadian Oil Sands region roughly equal in size to Florida (~ 142,200 km²)
- Three regions – Athabasca, Cold Lake, Peace River
- 3% mineable, 97% in-situ
- Mining operations started in 1967 (Suncor predecessor)
- Currently ~ 20% of mineable area has been cleared or disturbed

https://en.wikipedia.org/wiki/Oil_sands
Geology of the Athabasca Oil Sands

- Bitumen deposits located in the McMurray Formation
  - a layer of shale, sandstone, and oil-impregnated sands
  - formed during the Cretaceous period
  - up to 150 m thick
  - underlies the Clearwater Formation, a layer of marine shale and sandstone
  - overlies a layer of shale and limestone (Devonian)

Conly et al. 2002, Hein et al. 2000
Mined Bitumen Process

- Fluid Fine Tailings (FFT) generated from flotation and froth treatment
- Dispersed silt and clay particle mass varies; on average 17% by mass of the solids in the tailings streams

Alberta Research Council
http://www.albertatechfutures.ca/Corporate/History/AlbertaResearchCouncil.aspx
The FFT problem & regulation

- 80 km² (20,000 acres) of tailings basins and growing
The FFT problem & regulation

- FFT is like ......
- Defined as >5% solids by mass and <5 kPa shear strength
  - performance reporting requirements for fluid tailings volume
  - management plans for reclamation

FFT Inventory Measurement and Quantification

- **Top:** mudline
  - Sonar, Density Plate, Interval Depth Sampling

- **Bottom:** ‘hard bottom’
  - Drop Sounding, Cone Penetration Test (CPT)

- **Volume**
  - 3D modeling software

---

FFT Inventory Measurement and Quantification

- **Importance**
  - Escalating requirements (and penalties) for tailings volume profiles beyond ‘threshold’ limits

- **Challenges & Opportunities**
  - **Current Procedures**
    - Cost of Annual Pond Surveys
    - Inconsistent and Inaccurate Measurement & Quantification
  - **Future Procedures and Innovation**
    - Electronic Pond Monitoring Systems?
    - Pipe Measurement Prediction of FFT Generation Rate?
fft reclamion

- Progressive and ‘ready to reclaim’ materials within 10 years of mine end of life
- Future landscape integration
- Holistic approach
- Net environmental effect

McKenna et al Shear strength and density of oil sands fine tailings for reclamation to a boreal forest landscape.pdf
Portfolios of Tailings Technologies

- Reduce during mining or extraction
- Process differently
- Deposit differently
- Address the water (wetscape)
- Reclaim the ‘soil’ differently

https://jegreenword.wordpress.com

https://beta.theglobeandmail.com/report-on-business/
Portfolios of Tailings Technologies

- Recent study commissioned by COSIA
- 25 commercial stage technologies
- 76 potentially viable technologies in consideration

Table 2-1: Master Technology List Summary Table

<table>
<thead>
<tr>
<th>Category</th>
<th>Commercial</th>
<th>Prototype</th>
<th>Pilot Industry</th>
<th>Pilot Third-party</th>
<th>Research Industry</th>
<th>Research Third-party</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mining</td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>2. Extraction</td>
<td>1</td>
<td></td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>3. Tailings Processing</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>29</td>
</tr>
<tr>
<td>4. Deposition</td>
<td>11 (1)*</td>
<td>2</td>
<td>9</td>
<td></td>
<td>5</td>
<td>2(1)*</td>
<td>31</td>
</tr>
<tr>
<td>5. Water Treatment</td>
<td>3 (6)*</td>
<td></td>
<td>8</td>
<td></td>
<td>2</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>6. Reclamation</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>32</strong></td>
<td><strong>7</strong></td>
<td><strong>28</strong></td>
<td><strong>6</strong></td>
<td><strong>13</strong></td>
<td><strong>15</strong></td>
<td><strong>101</strong></td>
</tr>
</tbody>
</table>

*Numbers in parenthesis represent technologies not currently being investigated for oil sands but used in other mining areas.

Modeling for Tailings Deposition & Performance

<table>
<thead>
<tr>
<th>state</th>
<th>processes/phenomena</th>
<th>applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active filling</td>
<td></td>
<td>Enhancing fines capture, deltaic capping, etc.</td>
</tr>
<tr>
<td>Young Ponds, FFT</td>
<td>Newtonian flow</td>
<td>Selective placement of thickened/treated tailings.</td>
</tr>
<tr>
<td>interval</td>
<td>non-Newtonian flow</td>
<td>Reducing segregation and generation of FFT, improved dewatering,</td>
</tr>
<tr>
<td></td>
<td>sedimentation</td>
<td>basin planning (deposition location, timing, thickness)</td>
</tr>
<tr>
<td></td>
<td>‘gelled’ bed</td>
<td>Tailings volume reduction, strength development &amp; stability, ready to reclaim</td>
</tr>
<tr>
<td></td>
<td>clay aggregation</td>
<td>– with sand cap for example</td>
</tr>
<tr>
<td></td>
<td>creep</td>
<td>Predicting volume reduction, need for treatment: rate and quality</td>
</tr>
<tr>
<td></td>
<td>‘deposit’</td>
<td>of water release, residual bitumen migration</td>
</tr>
<tr>
<td></td>
<td>consolidation</td>
<td>Integration in reclamation plan, landform evolution with time</td>
</tr>
<tr>
<td>Old Ponds, Treated</td>
<td>soil</td>
<td></td>
</tr>
<tr>
<td>Tailing Deposits</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sand Capping for Tailings Deposit Reclamation

- In Situ remedy – legacy tailings
- Successful in soft sediment capping
- Advanced research in Oil Sands
- Failure modes investigation; scale up from flume to basin

Placement of caps on soft and fluid tailings Langseth, Jim; Luger, Dirk; ... Contributor, Tailings and Mine Waste Conference (2015 : Vancouver, B.C.)
Tailings Consolidation & Drying

- Ex Situ Remedy – legacy tailings
- Dredge → chemically treat → deposit → consolidate & dry
- Effectively generates ‘trafficable waste’ – soft ground strategies
- Land (footprint) and cost intensive – multiple ‘touches’

Kolstad et al Field pilot performance results for flocculated fluid fine tailings under three depositional variations.pdf
Tailings Co-Disposal (Mixing)

- Ex Situ remedy – legacy tailings, new tailings
- Exploit available ‘free water capacity’ of stripped materials
- Pilot stage in Oil Sands
- Effectively generates ‘trafficable waste’ – soft ground strategies
End Pit Lakes/Water Capped Deposits

- Demonstration pit lake (base mine lake) and DPL project
- Various sizes – and depths – with different contents, vegetation treatments and drainage approaches
- Lake functionality, ecological metrics, and timelines

http://www.cosia.ca/pit-lake-research

- Resuspension of tailings (turbidity)
- High dissolved solids - salts
- Low nutrients
- Biologically uninhabitable tailings
- Bitumen resuspension
Closing Commentary

- Large investments – totaling over 1 billion dollars (CAD) – has been made in tailings reduction and reclamation to date

- Industry committed to continuous improvement and technology development - no ‘silver bullet’ technology; opportunities for innovation and technology advancement remain

- Effective measurement and quantification necessary to demonstrate progress toward reclamation and closure

- Collaboration and landscape integration between mine sites is critical

- Sustainable development required to gain/retain public acceptance (social license)
Thank you


http://www.greenpeace.org/canada/en/Multimedia_u/Photos/Forests/Boreal-forest/Boreal-Forest-Alberta-Canada/