OVERVIEW OF HOLISTIC APPROACH TO OIL SANDS TAILINGS MANAGEMENT

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Presentation Outline

- Oil Sands Extraction Process
- Characteristics of Oil Sands Tailings
- Regulatory Requirements for Oil Sands Tailings Management
- Key Elements of Holistic Tailings Management Approach
- Review of Directive 085 Applications
- Conclusions
- Clark Hot Water Extraction process is used
- Bitumen is extracted as froth and waste is disposed as tailings slurry
- Tailings typically consists of sand, clay, silt, other mineral particles, residual hydrocarbons and process affected water
Typical oil sands tailings contain ~15-30% fines (w/w)

~50-55% fines are captured in beach

FT has >5% suspended solids (w/w) and <5 kPa shear strength

FT settles relatively at a faster rate in the initial 2 to 3 year period to reach ~30% solids content

- Reduction in void ratio makes further dewatering and self-weight consolidation very slow
Regulatory Requirements for Oil Sands Tailings Management

- Directive 074 (ERCB 2009)
  - Fines capture and undrained shear strength
  - Suspended in 2014

- Tailings Management Framework – TMF (AESRD 2015) and Directive 085 (AER 2016)
  - Provide opportunity for risk based holistic tailings management approach
  - Specify requirements for managing FT volumes
  - Provide flexibility to the operators for developing site specific tailings management plans
  - Hold operators accountable for managing tailings responsibly
Key Elements of TMF and Directive 085

- TMF sets out targets indicators, triggers and limits

- Ready to Reclaim (RTR)
  - Sub-objective 1 – Deposit’s physical properties are on a trajectory to support future stages of activities
  - Sub-objective 2 – Minimize environmental impacts and ensure self-sustaining ecosystem is established
  - FT must meet RTR status in order to be removed from FT inventory

- Ready for Reclamation (RFR)
  - Identify project areas that are available for reclamation
Challenges Managing Oil Sands Tailings

- Large volume creates containment issues
  - Containment requirement is 0.4 to 0.6 m$^3$/t of processed ore
- Slow self-weight consolidation and dewatering process
  - 976 Mm$^3$ FT inventory in 2013 (AESRD 2015)
- Toxic in nature
  - Risk to environment during and after mining operation ceases
- Closure and reclamation objectives
- Stakeholder’s expectations
- Changing and increasingly stringent regulatory requirements
Key Elements of Holistic Tailings Management Approach

1. Closure and Reclamation objectives
   - End land uses
   - Functional landscape
   - Progressive reclamation
   - Meeting stakeholder expectations
   - Meeting regulatory requirements

2. Tailings characteristics
   - Dewatering
   - Consolidation
   - Physicochemical interaction
   - Water chemistry

3. Tailings technology and treatment plan
   - Fines capture
   - Consolidation
   - Chemical stability
   - Released water quality and quantity
   - Overall environmental impact

4. Tailings deposition strategy
   - TSF design
   - Tailings deposition method
   - Infrastructure layout
   - Water management plan

5. Progressive closure and reclamation plan

6. Performance monitoring and measurement plan

7. Adaptive management

Reclamation and closure
1. Understand Closure and Reclamation Objectives

- Meet regulatory requirements
- Meet stakeholder’s expectations
- Act towards responsible environmental management
  - Set goals for achieving functional landscape and progressive reclamation
2. Understand Tailings Characteristics

- Physical & chemical properties influence closure landform and closure & reclamation schedule

- Consolidation characteristics
  - Bench scale & large scale laboratory testing
  - Commercial software
  - Field consolidation prediction is challenging
  - Choose assumptions carefully and know the model & data limitations
  - Consider full scale field pilot programs
3. Develop Tailings Technology and Fluid Tailings Treatment Plans

- Selected technology must:
  - Reduce FT generation
  - Minimize environmental risks during operation
  - Meet final closure and reclamation objectives

- Must be designed to maximize long-term stability of deposited material:
  - Consolidation behaviour affects closure landform and reclamation schedule
  - Released water quality
  - Overall environmental impact
## Classification of Tailings Technologies

<table>
<thead>
<tr>
<th>Category</th>
<th>Examples</th>
<th>Success Criteria</th>
<th>Challenges</th>
</tr>
</thead>
</table>
| 1. Mixing of coarse tailings stream with fine tailings stream | ▪ CT  
▪ NST | ▪ Segregation | ▪ Availability of coarse tailings  
▪ SFR of ore, etc. |
| 2. Treatment of fine tailings stream | ▪ TT  
▪ ILF with thin lift drying (TRO, AFD)  
▪ ILF with thick lift deposition  
▪ Centrifuge  
▪ Filter press  
▪ Geotubes | ▪ Dewatering and consolidation | ▪ Large deposition areas  
▪ Material transportation  
▪ Capping |
| 3. Water capped deposits | ▪ End Pit Lake | ▪ Development of self-sustaining ecosystems  
▪ Water quality | ▪ Fines re-suspension |
## Tailings Technologies Implemented and/or Proposed

<table>
<thead>
<tr>
<th>Technology</th>
<th>Operator</th>
<th>Deposit Type</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite Tailings (CT)</td>
<td>Syncrude, Suncor, Shell</td>
<td>Fines-enriched sand</td>
<td>Requires coarse sand tailings (competition with dyke construction), mixed performance results, segregation issues</td>
</tr>
<tr>
<td>Non-segregated Tailings (NST)</td>
<td>CNRL</td>
<td>Fines-enriched sand</td>
<td>Requires coarse sand tailings (competition with dyke construction), limited experience, segregation issues</td>
</tr>
<tr>
<td>Inline flocculation (ILF) with thin lift drying</td>
<td>Suncor (TRO), Shell (AFD)</td>
<td>Thin-layered fines-dominated deposits</td>
<td>Proven technology, can achieve desired dewatering performance, large drying areas, material rehandling</td>
</tr>
<tr>
<td>Thickened Tailings (TT)</td>
<td>Imperial Oil (Kearl), Shell</td>
<td>Deep fines-dominated deposits</td>
<td>Challenges with tailings dewatering, ability to cap</td>
</tr>
<tr>
<td>Centrifuge</td>
<td>Syncrude, Shell</td>
<td>Deep fines-dominated deposits</td>
<td>Proven technology, extent of dewatering depends on conveyance method</td>
</tr>
<tr>
<td>End Pit Lake (EPL)</td>
<td>Syncrude, Suncor, Shell, Imperial Oil (Kearl) and CNRL</td>
<td>Water-capped deposits</td>
<td>Pending regulatory approval; commercial demonstration ongoing at Syncrude’s Base Mine Lake</td>
</tr>
</tbody>
</table>

*Additionally CNRL has implemented low fines mine plan to reduce FT generation*
## Alternate / Supplemental Technologies

<table>
<thead>
<tr>
<th>Operator</th>
<th>Tailings Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suncor</td>
<td>- ILF (deep cohesive deposit)</td>
</tr>
<tr>
<td></td>
<td>- Centrifuge</td>
</tr>
<tr>
<td></td>
<td>- TT</td>
</tr>
<tr>
<td>Canadian Natural</td>
<td>- NST enhancement</td>
</tr>
<tr>
<td></td>
<td>- Improvement of MFT spiking</td>
</tr>
<tr>
<td></td>
<td>- Semi in situ MFT treatment</td>
</tr>
<tr>
<td></td>
<td>- NST revegetation</td>
</tr>
<tr>
<td>Shell</td>
<td>- Filter press</td>
</tr>
<tr>
<td></td>
<td>- ILF (deep cohesive deposit)</td>
</tr>
<tr>
<td></td>
<td>- Geotubes</td>
</tr>
<tr>
<td></td>
<td>- Floating centrifuge</td>
</tr>
<tr>
<td>Syncrude</td>
<td>- Accelerated dewatering</td>
</tr>
<tr>
<td>Imperial Oil (Kearl)</td>
<td>- No alternative technologies</td>
</tr>
</tbody>
</table>
4. Develop Tailings Deposition Strategy

- Short-term and long-term containment requirements
  - Tailings and site-wide water balance
  - Beach slope sensitivity analyses
4. Develop Tailings Deposition Strategy (contd.)

- Method of dyke construction
  - Location, topography, future expansion requirements and material availability
  - Adopt “Observational Method”
4. Develop Tailings Deposition Strategy (contd.)

- Selection of tailings deposition method
  - Beaching or sub-aerial deposition
  - Sub-aqueous deposition (under water or under tailings)

- Infrastructure layout
  - Number of deposition points
  - On-spec and off-spec tailings management plan
5. Develop Progressive Closure and Reclamation Plans

- Adopt an iterative process for mining, tailings and closure & reclamation planning
- Periodic status maps depict progression of closure and reclamation goals aligned with mine and tailings plans
- Review TSF closure criteria in consultation with community during operating phase
  - Continuously update tailings management strategy
6. Develop Performance Monitoring and Measurement Plans

- FT inventory must not exceed approved profile
  - Hard bottom – CT09, CPT, etc.
  - Mudline – Sonar survey, density plate, interval depth samples, etc.

- Deposit specific RTR criteria and measurement plans to ensure FT deposits meet RTR status

- Measurement plans to ensure reclamation activities can be initiated
  - Depend on capping method
# Examples of Proposed Ready-to-Reclaim Criteria

<table>
<thead>
<tr>
<th>Operator</th>
<th>Tailings Technology</th>
<th>Sub-objective 1 Indicators / Measures</th>
<th>Sub-objective 2 Indicators / Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suncor</td>
<td>ILF (e.g. TRO)</td>
<td>Clay to water ratio (CWR)</td>
<td>Measures not explicitly defined</td>
</tr>
<tr>
<td>Canadian Natural</td>
<td>NST</td>
<td>Solids content, porewater pressure, effective stress, SFR and consolidation</td>
<td>Soil moisture, type and depth, soil chemistry, upland/wetland vegetation, TSS, salinity and light penetration</td>
</tr>
<tr>
<td>Shell</td>
<td>AFD, CT, TT and Centrifuge</td>
<td>Solids content</td>
<td>Groundwater monitoring and soil &amp; water chemistry</td>
</tr>
<tr>
<td>Syncrude</td>
<td>CT, Centrifuge</td>
<td>Solids content</td>
<td>Groundwater monitoring, deposit water volume &amp; chemistry, fugitive emissions</td>
</tr>
<tr>
<td>Imperial Oil (Kearl)</td>
<td>TT</td>
<td>Solids content</td>
<td>Groundwater &amp; surface water monitoring, water chemistry, stability and erosion</td>
</tr>
</tbody>
</table>

1Directive 085 Application (2016)
7. Adaptive Management

- Flexible decision making tool to deal with uncertainties in tailings technology performance
- Structured and iterative process
- Reduce performance uncertainties over time through monitoring
  - Explore alternatives
  - Predict the outcome
  - Implement alternatives
  - Monitor the outcome
  - Change management based on new knowledge
Tailings management is complex and hence requires a holistic approach.

Must consider:
- Reclamation and closure objectives
- Regulatory requirements
- Long-term containment requirements
- Physical and chemical properties of tailings
- Method of tailings deposition
- Water management plan

Closure and reclamation objectives should be considered at the start of mining operations.
Conclusions (contd.)

- TMF is a positive step towards decreasing liability and environmental risks

- Suitability of proposed indicators for specific deposit types will have to be verified by field measurements over time
  - Continuous improvement / adjustment to site specific RTR criteria
  - Knowledge base will improve as unproven tailings technologies are validated at a commercial-scale over time

- Design, operation and regulatory process should accommodate adaptive management approach

- Other ways such as low fines mine plan should be considered to reduce FT generation
Questions?
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