Benambra Tailings Management Facility (TMF) Closure and Rehabilitation
Presentation Content

- TMF location and description
- Tailings geochemistry
- Current TMF status and status at closure
- Closure options
- Description of preferred option
  - configuration
  - key issues
- Relevant case studies
  - Australia
  - International
TMF Diversion Drains
Geochemistry of Process Tailings

- Stuart Miller & Associates EGI (1990, 1999)
  - Massive sulphide
  - Extremely high net acid production potential
  - 35% S, NP 40 - 60 kg \(\text{H}_2\text{SO}_4\)/t (dolomite)
  - Net acid production potential 1,000 kg \(\text{H}_2\text{SO}_4\)/t
  - Store permanently underwater
  - Do not expose tailings for more than 80 days
  - acid production after 1 year
  - Final net acid generation (NAG) pH of 2.5 (1.5 years)
700,000 tonnes of tailing produced 1992 - 1996 (Macquarie Resources)

Tailings always submerged, 21 m high dam

Acid generation presently is not a problem

Current water quality close to regulatory criteria

No active rehabilitation undertaken, yet reed beds and frogs are re-colonising the TMF

Local wombats, wallabies, birds and other wildlife seen to inhabit and use facility
Sub-aqueous storage behind 31m high dam
Total tailings contained: 5.7 million tonnes
Pond area: 10 hectares (8 currently)
Tailings grind will be finer than current tailings
Geochemistry same as current tailings
Water Quality

Zn and pH trends in the Benambra TMF

- **Zn (mg/L)**
- **pH**

**Zn**
- 31-Mar-95
- 31-Jul-95
- 30-Nov-95
- 31-Mar-96
- 31-Jul-96
- 30-Nov-96
- 1-Apr-97
- 1-Aug-97
- 1-Dec-97
- 2-Apr-98
- 2-Aug-98
- 2-Dec-98
- 3-Apr-99
- 3-Aug-99
- 3-Dec-99
- 3-Apr-00
- 3-Aug-00
- 3-Dec-00
- 3-Apr-01
- 3-Aug-01
- 3-Dec-01
- 4-Apr-01
- 4-Aug-01

**pH**
- 7.0
- 6.0
- 5.0
- 4.0
- 3.0
- 2.0
- 1.0
- 0.0
Two discharges:
- May-August 1999, 43.3 ML
- Nov 2000-Jan 2001, 52.9 ML

Chemical sampling and biological surveys

Macroinvertebrate surveys could not identify any impacts
# Surface Water Quality Ranges
(November 2000 - January 2001)

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>Conductivity MS/cm</th>
<th>Zinc (T) mg/L</th>
<th>Copper (T) mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upstream</strong></td>
<td>7.3 – 7.9</td>
<td>110 – 240</td>
<td>0.004 – 0.035</td>
<td>0.001 – 0.009</td>
</tr>
<tr>
<td><strong>Water Cover</strong></td>
<td>6.9 – 7.6</td>
<td>1600 – 1900</td>
<td>1.35 – 1.94</td>
<td>0.008 – 0.02</td>
</tr>
<tr>
<td><strong>Downstream</strong></td>
<td>6.9 – 8.0</td>
<td>250 – 480</td>
<td>0.01 – 0.043</td>
<td>0.002 – 0.006</td>
</tr>
<tr>
<td><strong>EPA</strong></td>
<td></td>
<td></td>
<td>0.5</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Current Approved Strategy

- Dry cover (Work Plan 1992)
  - Allow water to evaporate and tailings dry out
  - Spread lime
  - Place impermeable “clay” layer
  - Place waste rock cover
  - Beach inside embankment
  - Topsoil and vegetate

- Work Plan stated that technology may improve over life of project
MEND Research - Canada

- Equally funded by Mining Association of Canada and Natural Resources Canada
- 1988 - present ($CAN17.5 million)
- Over 50 scientific reports and papers. Dry and wet covers.
- “…..permanent water cover remains one of the most effective approaches that can be applied to provide a stable geochemical environment for most sulphide tailings. Additional enhancement is accomplished at some tailings ponds through the use of sub-strata covers over the submerged tailings using oxygen consuming materials to reinforce reducing conditions in the sediments…..” (MEND 2001)
Rehabilitation Options

Potential Options

- Underground disposal, relocation not feasible
- Dry Cover
- Wet Cover
  - Saturated Soil
  - Shallow water cover
  - Naturally generating wetland
Dry Cover

- Dewater TMF and water treatment
- Disturbance of tailings from construction
- Oxidation of tailings is likely during slow construction
- Sourcing of vast amount of cover materials
- Long term erosion of cover material inevitable which opens pathways for exposure and oxidation of tailings
- Maintenance of a capillary break layer is doubtful due to settlement
Wet Cover - Saturated Soil

- Partial Dewatering of TMF and water treatment
- Disruption to tailings from construction
- Specialised construction equipment required
- Survivability of geotextiles
- Slow construction - exposure to weather and storm erosion risk
- Sourcing of cover materials
- Final cover surface is dry and subject to erosion
Wet Cover - Shallow Water Cover

- No need to dewater TMF
- No disturbance or oxidation of tailings
- Resistant to erosion
- No need to source vast amounts of cover materials
- Long term re-creates the original swamp environment i.e. self-sustaining system
- Consistent with MEND conclusions
Wet Cover - Naturally Generating Wetland

- No need to dewater TMF
- No disturbance or oxidation of tailings from construction
- Resistance to erosion
- No need to source vast amounts of cover materials
- Natural replenishment of the organic/sediment from the catchment (5-25mm/year without any organics)
- Re-creates original swamp environment i.e. self-sustaining system
# Water Inflow

## Full Catchment

<table>
<thead>
<tr>
<th>Case</th>
<th>Estimated additional water volume presenting to the TMF per annum (ML)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wulgulmerang Rainfall</td>
</tr>
<tr>
<td>Average Year</td>
<td>260</td>
</tr>
<tr>
<td>Wet Year</td>
<td>531</td>
</tr>
<tr>
<td>Dry Year</td>
<td>64</td>
</tr>
</tbody>
</table>

- Bindi driest year on record (100yrs): +7 ML
- Benambra driest year on record (50yrs): +32 ML
Natural Wetland - Role of Organic Layer

- Is not essential as oxygen barrier but create multiple barrier system. Water is oxygen diffusion barrier.
- Provides oxygen consumption layer below water cover.
- MEND Studies:
  - East Sullivan, Ascot, Eustis and Clinton, Falconbridge, Canada
  - Organic decomposition has:
    - a higher de-oxygenation rate than tailings i.e. preferential consumption of oxygen
    - creates anaerobic conditions at base
    - residues act to physically encapsulate tailings
  - Limited life due to consumption
- Will be consumed over time (up to 30-40 years in exposed areas - expect longer below water).
- Replenishment will occur (demonstrated now in TMF).
Organic Material

- Paper mill belt presses
  - classed as fill material
  - saturated
  - large quantities available
- Sawmill or forestry
  - may be limited supply, requires saturation
- Stabilised sewerage sludge
  - Readily available eg. Carrum
  - Currently rehabilitating Braeside (EPA WA)
PMF Flood Control

- Inlet erosion control

- Spillway discharge

PMF FLOW
Approx. 25 m/s
Approx. 4.2 m/s
Approx. 0.4 m/s

PMF FLOW
Approx. 0.75 m Deep
Approx. 1.4 m/s
Other Issues

- **Quality of long term discharges**
  - current conditions
  - organics
  - self - regulation

- **Minimum water depth**
  - geochemical
  - wave
  - flood erosion
Naturally Generating Wetland: Closure
Naturally Generating Wetland: Intermediate
Naturally Generating Wetland: Long Term
Case Studies of Sulphidic TMF Closures
TMF Case Studies

- Australia
  - Captains Flat
  - Mt Lyell
  - Rum Jungle
  - Rosebery
  - Renison Bell
  - New Zealand
  - Golden Cross

- Canada
  - Equity
  - Quirke
  - Falconbridge
  - Louvicourt
  - Solbec
  - Waite Amulet/Millenbach
  - Sullivan
  - Panel wetlands
  - Les Auriferes Terrain
  - Denison
  - Brenda/Heath steel
  - Spanish American
  - Mattabi
  - Strathcona
  - Stanleigh

- Sweden
  - Saxberget
  - Kristineburg
  - Gaigebert
  - Stekeniokk

- Ireland
  - Lisheen

- Norway
  - Lokkenn

- Peru
  - Lago Junin
Summary of all Case Studies

- Wet cover not feasible in:
  - 50% dry cases
  - 60% saturated soil

- Shallow Water Covers: 48%
- Wetland Covers: 17%
- Organic Covers: 17%
- Saturated Soil: 9%
- Dry Covers: 9%
Captains Flat (ACT) / Rum Jungle (NT)

Captains Flat
dry/saturated soil cover resulted in AD in local Creek

Rum Jungle
Failed dry/saturated soil cover
Mt Lyell - Tasmania

- **Pilot TMF**
  - Tailings pH 7-8 below 1 cm
  - Overlying water pH 4-5 (natural). Average Cu 0.02mg/L, Pb 0.02
  - Appears natural waters mobilising metals
  - Natural vegetation establishment / wildlife

- **Princess Creek >60 metres final embankment**
  - sub-aqueous, lake closure
  - inflows up to 200 L/s
  - Two spillways for long term discharge and flood handling
  - Long term min water cover of 1 metre
  - DPIW&E approval
Rosebery - Tasmania

- Poor water quality from exposed tailings
- Approved closure is free water and wetland
- Found that vegetation establishment inconsistent
- Modified Closure Strategy-
  - lower water to 300-500mm, lime dose, raw sewerage in top pond
- DPIW&E and West Coast Council/National Heritage Council approval
Renison Bell - Tasmania

- Major CSIRO study
- Combined free water wetland
- Creation of organic rich anaerobic surface layer
Lisheen, Ireland

- New mine
- Laboratory and test plots for wetland closure very successful.
- Approved closure is 1 metre slurried peat directly over tailings. Originally proposed limestone layer but not necessary
- Wetland will have free water areas and water level controlled by spillway
- Design based on water and organic material inhibiting tailings oxidation
- BATNEEC - Irish EPA
Golden Cross, NZ

- Mining since 1893, very wet climate
- 9 million cubic metres tailings and waste rock
- Water/wetland cover proposed with spillway to control level
- In areas where tailings exposed a soil cover up to 4 metres thick placed over very soft tailings
- Long term discharge to trout fishery in high quality stream
- Results to date good, excess water will be discharged untreated to Creeks.
Summary

- Dry closure not feasible
- Maintenance of water cover feasible
- International best practice is for permanent water cover
- MEND research program demonstrates effectiveness of permanent water cover closure