Acid mine drainage analysis and mitigation of a rehabilitated waste rock dump of Kaiata mudstone from Mt Fred Quarry, Stockton Mine

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Location of Stockton and Mt Fred Quarry

Map by Hamish Pescini
Evolution of a WRD
Evolution of a WRD
Mt Fred Quarry

- Granite quarry
- ~4 Mt of high potentially acid forming (PAF) material backfilled
- ~3.5 Mt Kaiata Mudstone
- 22,000 tonnes of cement kiln dust (CKD)
- 94,000 tonnes of granite
- Backfilled between 2013 and 2015

<table>
<thead>
<tr>
<th>Waste Material</th>
<th>Kaiata</th>
<th>Rehandle</th>
<th>Pond Slop Waste</th>
<th>Road Slop Waste</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tonnes</td>
<td>3,675,000</td>
<td>148,000</td>
<td>77,000</td>
<td>41,000</td>
<td>3,930,000</td>
</tr>
<tr>
<td>Environmental Material</td>
<td>Granite+CKD</td>
<td>Granite</td>
<td>Biosolids+Soil</td>
<td>Biosolids</td>
<td>CKD</td>
</tr>
<tr>
<td>Tonnes</td>
<td>75,900</td>
<td>30,200</td>
<td>18,100</td>
<td>3,200</td>
<td>11,700</td>
</tr>
</tbody>
</table>
Ideal location

• ‘Bathtub’ in low permeability basement rock

• Single
  ➢ Large seep
  ➢ Rock source
  ➢ Backfilling stage

• All material recorded

• Monitored started in 2012

• Parameters monitored;
  ➢ pH
  ➢ Acidity
  ➢ Sulphate
  ➢ Aluminium
  ➢ Electrical conductivity
MFQ construction

- Backfilled in end tipped lifts
- Lifts compacted by machinery driving on it
- 11,700 tonnes CKD dosed on lifts and tiphead
- Final rehabilitation to standard Stockton specifications
  - Reshaped to 18-20° compacted batters
  - 10m benches graded to 1.5% to manage water
  - Diversion drains
  - Compacted 400mm granite : CKD engineered cap
  - 300mm soil : biosolids cover
  - Hydroleeded
  - Planted with native seedlings
- Final rehabilitated footprint – 6.07 ha
Kaiata Mudstone

- Marine mudstone
- Highly friable creating a fine grained deposit
- High compaction – $10^{-7}$ to $10^{-9}$ m/s
- High PAF
- Sulfide S – 1.64 wt%
- Very little to no acid neutralising capacity (ANC)
- Paste pH ~4 and low ANC means no lag to acid production

<table>
<thead>
<tr>
<th></th>
<th>Total wt% S</th>
<th>Sulfide wt% S</th>
<th>MPA</th>
<th>Paste pH</th>
<th>ANC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Range</strong></td>
<td>1.44 – 2.69</td>
<td>1.22 – 2.27</td>
<td>44.1 – 82.3</td>
<td>3.8 – 4.2</td>
<td>&lt;2 – 4.08</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>1.92</td>
<td>1.64</td>
<td>58.7</td>
<td>4.0</td>
<td>-</td>
</tr>
</tbody>
</table>

Weber et al, 2006
Kaiata Mudstone

2 yrs old

2 weeks old
Acidity control

• Saturation by placing maximum PAF material below water table

• Minimisation of oxygen and water ingress
  ➢ Compaction of lifts and reshaped batters
  ➢ Engineered granite cap
  ➢ Soil : biosolid mix cover

• Neutralisation
  ➢ CKD dosing
  ➢ CKD in engineered cap

• Rehabilitation and erosion control to maintain competency of the cap
  ➢ Hydroseeding
  ➢ Seedling planting
CKD

- Cement kiln dust - waste product from the drying process at the local Holcim cement works, which has closed down
- Alkalinity – 650kg CaCO₃ equiv/tonne CKD
- CKD used for both dosing and in the engineered granite cap
- 7,580 tonnes CaCO₃ equiv – dosing
- 6,340 tonnes CaCO₃ equiv – engineered cap
CKD in the engineered cap

- 400 mm 4 : 1 Granite : CKD compacted cap
- Minimisation of oxygen and water ingress
- Neutralisation

- Use of CKD in the cap serves multiple purposes
  - Binding/cementation
  - Fine grained
  - Permeability of $10^{-6} – 10^{-7}$ m/s
  - Neutralisation of any water which does permeate through cap
Acid production from MFQ

\[
\text{FeS}_2 \text{ (s)} + \frac{7}{2}\text{H}_2\text{O} + \frac{15}{4}\text{O}_2 \rightarrow \text{Fe(OH)}_3 \text{ (s)} + 2\text{SO}_4^{2-} + 4\text{H}^+
\]

Pyrite

\[
2\text{CaCO}_3 + 4\text{H}^+ \rightarrow 2\text{Ca}^{2+} + 2\text{CO}_2 + 2\text{H}_2\text{O}
\]

Acid

- 2 mole \text{CaCO}_3 required to neutralise 1 mole of pyrite
- 65,000 tonnes of pyrite
- 14,000 tonnes of \text{CaCO}_3 equiv from CKD
- Equivalent to ~1.8kg \text{CaCO}_3 equiv/tonne waste rock
- Capacity to neutralise ~7% of total acidity
Water quality – 6 monthly load

- Major PAF dumping phase started
- CKD added
- Capping started

Graph showing pH, Al (t/y) and Acidity, SO4 (t/y) over time from 02/2013 to 02/2018.
Water quality – acid load

- Pre-capping – 330 tonnes acid / year
- Post-capping – 115 tonnes acid / year
- Pre-capping – 0.085 kg acid /t waste rock/year
- Post-capping – 0.025 kg acid /t waste rock/year
- ~65% reduction in acidity through the use of CKD and capping of the MFQ
Water quality – April 2013
Water quality – June 2014
Cost benefit analysis

- 215 tonne/yr acid load reduction
- Current active treatment cost - $300/tonne
- Site acid decay rate - 0.62% per annum
- NPV of treatment for 215 t/yr acid load for 100 years - $1.86 M
- Cost to transporting and applying the CKD and granite - $0.85 M
- Value of passive treatment vs active treatment at MFQ - $1 M
Conclusions

• Importance of neutralising agents during dump construction

• CKD dosing was very effective in controlling AMD when used directly on lifts and tipheads

• Granite : CKD capping resulted in steady improvements in water quality

• AMD management of high PAF Kaiata led to a 215 tonnes acid/year decrease

• Passive treatment is estimated to have saved $1M in NPV costs
Acknowledgements

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References

