Boliden Aitik Mine Closure Planning: Overview of the Mine and the Overall Closure Planning Project

Nils Eriksson (nils.eriksson@boliden.com)

The project has been developed mainly by:
Boliden Mineral AB, Boliden, Sweden
Enchemica LLC, Loveland, Colorado, US
Lorax Environmental Services Limited, Vancouver, BC, Canada
O´Kane Consultants Inc., Saskatoon, Canada
Sweco Environment AB, Sundsvall, Sweden
MINES
SMELTERS
HEADQUARTER

*25th ANNUAL BRITISH COLUMBIA-MEND ML/ARD WORKSHOP – Vancouver, BC, November 28 and 29, 2018
Aitik

- One of the world’s most productive open-pit copper mines
- Copper, gold and silver
- Large volumes and rational methods
- Milled tonnage 2017: 39 Mton
- Employees: 700
The main closure components include:

- 700 ha of waste-rock storage facilities of which 400 ha contain PAG waste-rock while 300 ha contain NAG waste-rock.
- 1700 ha tailings facility.
- 3 km long, 1 km wide and 525 m deep Aitik open pit.
- Salmijärvi pit which is 1 km long, 0.7 km wide and 270 m deep.
After closure water will ultimately flow from the site to the Lina River, which forms part of the N2000 Kalix & Torne river system.
Complex system

Complex system to analyse at any given time – even more so when predicting future behaviour and results of planned closure measures – with e.g.:

- Multiple sources
- Multiple recipients/discharge points
- Numerous operational and closure alternatives
- Evolution over time

We need:

- Systematic approach
- Solid conceptual models
- Performance based closure objectives
Performance based closure objectives

In performance-based design:

• closure measures that make up the closure scenario are selected based on predictions of impact to the recipient environment.

• the relationship between closure measures and predicted impacts to the environment can be quantified by numerical analysis.

This provides an opportunity to develop site-specific performance-based design criteria based on quantification of the acceptable loadings to the recipient environment.
How good is good enough?

• Mine closure has many objectives
• Mines with potential ARD problems: often recipient water quality issues are in focus – the case in Aitik
• The overall closure objectives will be set by what is considered as acceptable recipient water quality

Climate scenario

- Legal requirements
- Recipient flow and quality

Acceptable discharge flow and quality

- Site layout and properties
- Material characteristics
- Management options
- Closure options and performance

•25th ANNUAL BRITISH COLUMBIA-MEND ML/ARD WORKSHOP –
Vancouver, BC, November 28 and 29, 2018
Recipient water quality objectives

• The European WFD and N2000 implemented into Swedish legislation

• N2000 – extreme burden of proof in order to obtain environmental permits "beyond reasonable scientific doubt"

• EQS for water bodies set by HVMFS 2013:19, up-dated 2015-05-01

<table>
<thead>
<tr>
<th>Substance</th>
<th>Annual average concentration (µg/l)</th>
<th>Maximum concentration (µg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cd</td>
<td>≤ 0,08 (class 1)</td>
<td>≤ 0,45 (class 1)</td>
</tr>
<tr>
<td></td>
<td>0,08 (class 2)</td>
<td>0,45 (class 2)</td>
</tr>
<tr>
<td></td>
<td>0,09 (class 3)</td>
<td>0,6 (class 3)</td>
</tr>
<tr>
<td></td>
<td>0,15 (class 4)</td>
<td>0,9 (class 4)</td>
</tr>
<tr>
<td></td>
<td>0,25 (class 5)</td>
<td>1,5 (class 5)</td>
</tr>
<tr>
<td>Ni</td>
<td>4 bioavailable concentration</td>
<td>34 bioavailable concentration</td>
</tr>
<tr>
<td>Pb</td>
<td>1,2 bioavailable concentration</td>
<td>14</td>
</tr>
<tr>
<td>As*</td>
<td>0,5</td>
<td>7,9</td>
</tr>
<tr>
<td>Cu</td>
<td>0,5 bioavailable concentration</td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>3,4 total concentration Cr&lt;sup&gt;VI&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>U*</td>
<td>0,17</td>
<td>8,6</td>
</tr>
<tr>
<td>Zn*</td>
<td>5,5 bioavailable concentration</td>
<td></td>
</tr>
</tbody>
</table>

*above background
Used evaluation methodology

- Development of conceptual and quantitative models for each risk object.
- Site investigations and supporting studies to obtain good input data to the models.
- Development of common 200 year climate scenario for all models which affects performance and recipient conditions.
- Evaluation of cover performance for waste-rock facilities (WRF) and tailings management facility (TMF) under selected climate scenario and design.
- Geochemical modelling of leachate water quality and flow over time for the WRF and TMF as a function of waste characteristics and cover performance under selected climate scenario.
- Modelling of Open Pit (OP) filling, pit geochemistry, discharge water quality and flow under selected climate scenario and planned closure measures.
- Modelling of resulting recipient water quality and flow under selected climate scenario and the modelled load from the closed Aitik site over time.
- Modelling of bio-available concentrations and evaluation of results against EQS.
- Failure Modes and Effects Analysis (FMEA)
Methodology

Climate

WRD

TMF

Salmijärvi - OP

Aitik - OP

Myllyjoki

Leipojoki

Vassara

Lina

- Site investigations
- Hydrogeology
- Cover performance
- O2-transport
- H2O-transport
- Geochemistry
- Leachate Q & C
- Pit filling period
- Overflow discharge rate
- Physical evolution of water column
- WQ predictions of water column
- Resulting recipient flow and quality
- Recipient impact
- Compliance to objectives (EQS)
Other inputs:
- Groundwater
- Direct precipitation to pit lake surface

Tailings Facility Runoff/Seepage

PAG Waste rock Runoff/Seepage

Pit Wall Runoff

Runoff from Natural Ground

NAG Waste rock Runoff/Seepage

Treated Effluent (55 years)

Pit Overflow after 55 years

Pit Overflow after 100 years
Conceptual Model for Flows and Chemical Loads for Closure Conditions in Aitik

FLOW RATE MONITORING LOCATION
5XX

WATER QUALITY MONITORING LOCATION
5XX*

WATER QUALITY PREDICTION COMPARISON POINT

Leipojoki River downstream of S01 discharge and upstream of Vassara River

Vassara River downstream of Leipojoki River and S01

Lina River upstream of Confluence with Vassara

Lina River downstream of all Aitik discharge

Reclaimed TMF

G-H Dam Seepage

Potential future flows (seepage and surface runoff) from reclaimed WRSF

Reclaimed Waste Rock
Conclusions

• Regulatory environmental quality standards (EQS) for water bodies are available to use as overall performance-based closure objectives in Sweden.

• These EQS provide the opportunity to evaluate the overall requirements for the integrated closure of the Aitik mine.

• An iterative and systematic approach was developed to evaluate the integrated effect of different closure options and to develop a base-case closure scenario that fulfils water quality objectives in the recipient.

• FMEA performed in order to identify risks and to further guide & improve closure planning
Thank you!