Predicting and Managing Waste Impacts through a Holistic and Life-of-mine Geomet Application

Karin Olson Hoal, JKTech Pty Ltd, Brisbane Australia and Colorado School of Mines

John Jackson, JKTech Pty Ltd, Brisbane Australia

David Mulligan and Mansour Edraki, Centre for Mined Land Rehabilitation, Sustainable Minerals Institute, University of Queensland, Australia

U.S. EPA Hardrock Mining Conference: Advancing Solutions for a New Legacy
April 4 2012
SMI – Centre for Mined Land Rehabilitation

The Centre for Mined Land Rehabilitation (CMLR) is a research centre that builds on the strengths of the diversity of backgrounds and disciplines of its staff and postgraduate students to address the environmental challenges of the minerals industry with quality science. Through working closely with industry, governments and communities, we aim to translate research outcomes into practices that will lead to the continual improvement of rehabilitation and environmental outcomes for a sustainable future.

People

- Integrating and involving a diversity of backgrounds to provide knowledge and learning

Partners

- Engaging with industry, government and community for national and global benefit

Programs

- Discovering and delivering research solutions to the resources sector through science

CMLR Updates

- Life-of-Mine 2012
  - Maximising Rehabilitation Outcomes
  - 10 - 12 July 2012, Brisbane

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STAFF PORTAL

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JKTech Pty Ltd

JKTech delivers world class solutions to the mining industry by providing products and services in ore characterization and process improvement within all areas of the life-of-mine cycle including geology, mining, minerals processing and sustainability. As the technology transfer company for the Sustainable Minerals Institute (SMI), JKTech has access to leading edge technologies and methodologies. Our holistic, whole of mine approach allows our consultants to optimise our customers processes which increases throughput and production and lead to a more sustainable project.

To achieve positive outcomes for our clients, JKTech offers a range of products and services including consulting, specialist equipment and software, metallurgical laboratory services, and professional development. JKTech deals with customers around the globe and our clients range from large mining consortia to engineering and technology solutions providers to small businesses within the minerals industry.

**LATEST FROM THE NEWSROOM:**

- PDAC 2012 - March 4-7 - Toronto, Canada
- JKTech offers new testing methodology
- JKTech Today - December 2011

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Mining: Challenges

- Lower grade deposits
- Increasingly inaccessible deposits
- Higher operating costs
- Higher energy costs
- Critical water issues
- Perceptions
Mining: Drivers

Australian Mining Project Expenditure

Geology
- Best investment
- LOM optionality
- Robust and responsive

Process

Infrastructure

Mine

JKAurecon: The link to infrastructure

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Energy

- 6-7% Australia’s energy on comminution
- Mining houses target of 10-20% reduction

<table>
<thead>
<tr>
<th>Activity</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilling</td>
<td>4%</td>
</tr>
<tr>
<td>Blasting</td>
<td>6%</td>
</tr>
<tr>
<td>Ventilation</td>
<td>5%</td>
</tr>
<tr>
<td>Dewatering</td>
<td>2%</td>
</tr>
<tr>
<td>Materials Handling - Electric Eq</td>
<td>6%</td>
</tr>
<tr>
<td>Crushing</td>
<td>10%</td>
</tr>
<tr>
<td>Separations</td>
<td>2%</td>
</tr>
<tr>
<td>Ancillary Operations</td>
<td>40%</td>
</tr>
<tr>
<td>Digging</td>
<td>4%</td>
</tr>
<tr>
<td>Materials Handling - Diesel Eq</td>
<td>17%</td>
</tr>
</tbody>
</table>

BCS, June 2007. Mining industry energy bandwidth study. US Department of energy

(The following slides are Taken from JKMRC/JKTech/CRCORE 2010 presentation)
Mining: Perceptions

On the Nature of Metals (De re metallica) 1556, by Georg Bauer

Lawrence Gipe, “Rosemont Copper Girl,” 2011

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Perceptions

2010 World Economic Forum Report Mining & Metals Scenarios to 2030:
“...not anticipate any technological breakthroughs that would transform key aspects of the industry such as operations, metals and mineral use or energy technologies” for 30 years.
Life-of-mine geomet application

Value

• Locked in variable ore relationships
• Team-based approach
• Integrate data sets
• Operating cost reduction
• Risk mitigation through life of project

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New approaches

- Reconcile extraction with sustainable practice
- Operational state-of-the-art approaches to integrated extraction beneficiation and mineral processing
- Effective prediction
- Environmental and economic impacts
Predict .... Plan .... Manage

PREDICT performance
- Recognize variability and geological drivers
- Model relationships among attributes
- Interpolate throughout mineral deposit

PLAN proactively
- Integrate into mine plan and scheduling
- Reduce uncertainty
- Improve performance

MANAGE impacts
- Understand and control environmental consequences
- Reduce overall project risk
- Recognize financial value through NPV and IRR options
Understanding the variability in the deposit: Identifying the drivers of mining and processing responses
<table>
<thead>
<tr>
<th>Proxies</th>
<th>Indices</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geology, Assays, Equotip, Sonic, NIR</td>
<td>RBTEx, GeMCi</td>
<td>SPI, DWT, RBT</td>
</tr>
</tbody>
</table>

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Met tests for variability vs composites

GeM Ci test
2m core intervals

Crush core at 2.5:1 reduction ratio & Measure Size Distribution

JKFi and MSI

Rotary Breakage Tester

JKCi CRU

JKCi GRD

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Blasting variability for mill

**Blasting scenarios**

- **Base case**
- **Blast S5** - 25ms Delay
- **Blast S1** - Single Hole Delay
- **Blast S2** - 10ms Delay
- **Blast S3** - Higher Powder Factor
- **Blast S4** - 311mm holes & higher

**Throughput (Relative Change)**

- SAG Mill
- HPGR

**Cumulative % Passing**

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Comminution variability by lithology

Plant Throughput

- SAG Plant
- HPGR Plant

- Base case
- Calc-Silicate
- Feldspatic Pyroxenite
- Granofels
- Para Pyroxenite
- Pegmatoids
- Pyroxenite
- Serpentinite

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Spatial understanding

e.g. Equotip

1cm x 1cm grid

(From AMIRA P843)
Spatial 3D domains

1. Grade
2. Distribution of lithology and facies
3. Distribution of weathering and alteration
4. Mineralogy
5. Structural – geotech
6. Spatial distribution of met variables
7. Sampling and analytical precision
Gain spatial understanding of geological controls

Au assay

Au >40% locked in py

clay

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Planning: Attributes into Block Model

Each Model Cell to Contain
• Intrinsic Rock Properties
• Performance Attributes

Performance Parameters

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Predict .... Plan .... Manage

PREDICT process performance
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MANAGE impacts
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Recognize financial value through NPV and IRR options
Back end: Variability and environmental impact

Acid rock drainage:

Predict acid potential and neutralization potential

*mineralogy: total sulfides, carbonates, silicates*

Metal deportment (eg Cd, Sb, As, etc)

Predict where metals are concentrated and liberated

*mineralogy: sulfide species*
Modelling geology and grade

Volcanogenic massive sulphide

Ore Types:
- Gossan
- Massive sulphide
- Stringer sulphide

Cross-cutting dyke

- Ore grade
- SG
- Tonnage
- Value

Knight et al., 2011

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Resource-calculated ore with problematic Cd, As, Sb contents

Is it still “ore”?

Knight et al.
Stable Landforms and Sustainable Substrates

• Effective store-release cover design for containment of waste
• Remediation of problematic soil conditions, Yarraman mine
• Options and strategies for tailings revegetation
• Organic matter in mine rehabilitation and the carbon balance
Water and contaminants in the landscape

- Geochemistry of mine water in monsoonal climates
- Lead pathways study
- Acid mine drainage and geochemistry, Croydon Mine
- Rehabilitation of oilfield brine impacts in an arid environment
Ecosystem Structure and Function

- Restoration of brigalow plant communities on degraded landscapes
- Potential impacts of subsidence on the Newness Plateau, Centennial Coal
- Long-term monitoring and research strategies at North Stradbroke Island
- Sustainability of koala populations in mining environments
Monitoring and Mapping Technologies

- SPOTing long-term changes in vegetation over short-term variability
- Surface conditions of swamps subject to subsidence with high-resolution imagery
- Mapping and validation of strategic cropping land
- Spatial and temporal modelling for vegetation monitoring uncertainty
Mine closure and end-use planning

- Closure strategy for tailings storage facilities
- Risk assessment tools for post-mined line
- Pre-operational rehabilitation research
- Early ore body characterisation for the prediction of acid and metalliferous drainage
Mine closure and end-use planning

- Closure strategy for tailings storage facilities
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- Early ore body characterisation for the prediction of acid and metalliferous drainage
Same approach as for processing:
- Understand the mineralogical and geological relationships
- Locking, exposure to fluids, element deportment, bio-availability
Mineral variability

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Prediction via mineral characterization
### Table 1: Mineral Composition

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dolomite</td>
<td>812.84</td>
</tr>
<tr>
<td>Clay+FeCaMnMg-Sulph/Phos/Carb/Oxide</td>
<td>489.22</td>
</tr>
<tr>
<td>FeCaMgMnZnPb-Carbonate</td>
<td>315.08</td>
</tr>
<tr>
<td>Dolomite/Siderite/Rhodochrosite</td>
<td>283.94</td>
</tr>
<tr>
<td>Dolomite+K-AlSilicate</td>
<td>179.19</td>
</tr>
</tbody>
</table>

### Table 2: Rock Type Distribution

<table>
<thead>
<tr>
<th>Rock Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>36631.63</td>
</tr>
<tr>
<td>Muscovite</td>
<td>10937.76</td>
</tr>
<tr>
<td>Albite</td>
<td>5177.67</td>
</tr>
<tr>
<td>K(Fe,Mg)-AlSilicate</td>
<td>3997.72</td>
</tr>
<tr>
<td>Fe-Oxide/Sulphate+Qtz</td>
<td>3322.72</td>
</tr>
<tr>
<td>Quartz+Fe-(Oxide/Sulphate)</td>
<td>2819.32</td>
</tr>
<tr>
<td>Goethite+NaKCa-AlSilicates</td>
<td>2710.08</td>
</tr>
<tr>
<td>Fe-KAISi-Oxide/Sulphate</td>
<td>2432.14</td>
</tr>
<tr>
<td>Fe-Oxide/Sulphate+Qtz+Clay</td>
<td>2417.03</td>
</tr>
</tbody>
</table>

Application

Brownfields

SEE

Sustainability & Extraction Efficiency

LOM/Long Term Planning

SEE Lite

Greenfields

LOM/Long Term Planning

Short Term Planning Scheduling

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SEE: Sustainable extraction efficiency

• Historical Mine to Mill Results
  – cross-discipline (blast to S/AG Mill) intervention
  – increases mill throughput in the short term

• Geology-Mine-Plant Integration
  – fully integrated predictive optimisation process
  – considers key eco-efficiency attributes
  – enables long-term improvements

<table>
<thead>
<tr>
<th>Metal tonnes</th>
<th>Cost ($/tonne)</th>
<th>Total Energy (kWh/tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (ML/tonne)</td>
<td>Cost ($/tonne)</td>
<td>Carbon Emissions (CO₂/tonne)</td>
</tr>
</tbody>
</table>
### Flexible Circuits

**Energy impact**

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>E, MW</th>
<th>% Energy saving</th>
<th>TOTAL energy with embodied</th>
<th>% TOTAL Energy saving</th>
<th>recovery, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>18.1</td>
<td>0</td>
<td>25.1</td>
<td>0</td>
<td>85.0</td>
</tr>
<tr>
<td>Hybrid</td>
<td>15.8</td>
<td>13</td>
<td>19.3</td>
<td>23</td>
<td>85.0</td>
</tr>
<tr>
<td>Hybrid + coarse upgrade</td>
<td>9.9</td>
<td>45</td>
<td>9.9</td>
<td>61</td>
<td>88.1</td>
</tr>
</tbody>
</table>

**Graph depicting kWh/t and recovery for different scenarios:**

- **Base**
- **Hybrid**
- **Hybrid + coarse upgrade**
More effective project management

Modelled Recovery

Modelled Throughput

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Impacting the cash flow

This illustrates the difference in cash flow predicted from a fully attributed GeM mine planning model versus the mine's traditional ore reserve model. The variation is up to $50m per annum. This information leads to informed rescheduling to maximise value and minimise risk.

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Life-of-Mine 2012
Maximising Rehabilitation Outcomes
10–12 July 2012, Brisbane, Australia

An International Conference on planning, designing and operating mines for creating positive environmental, community and land use benefits

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