VBOC - A **Value Based Ore Control** Model

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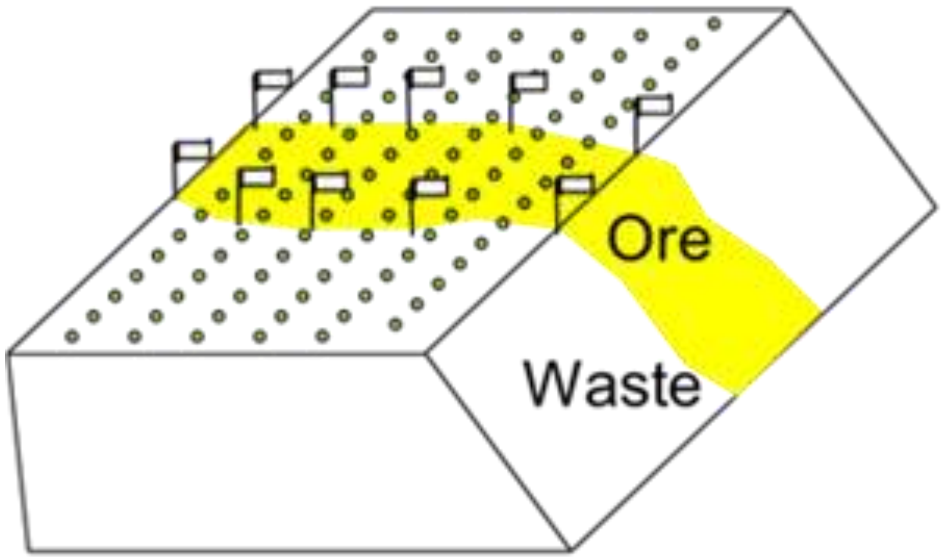
Standard Ore Control

The standard ore control practices in most open pit metal mines are based primarily on cut-off grade estimates of in-situ rock.

Consists of delineating ore waste boundaries based on blasthole grade values.

Ore or waste boundaries are blocked out based on economic cut-off grade.



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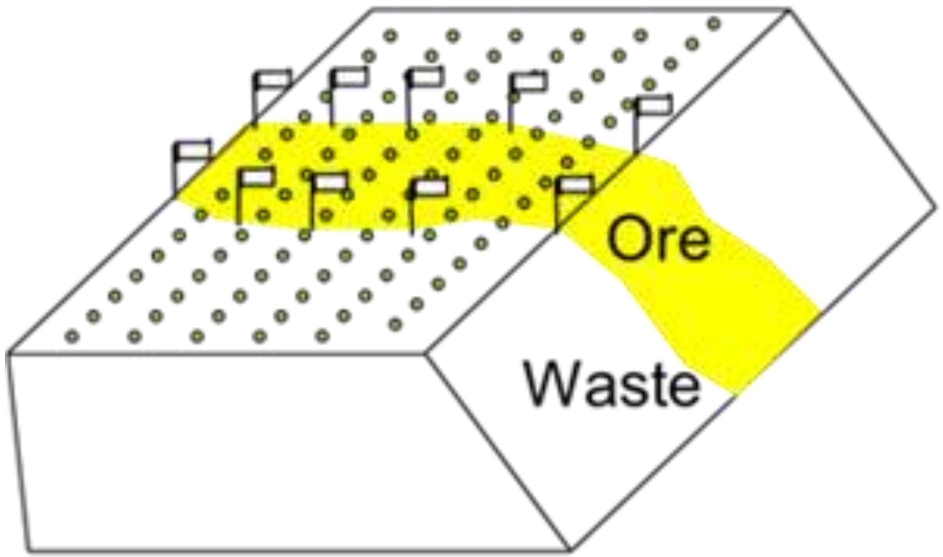
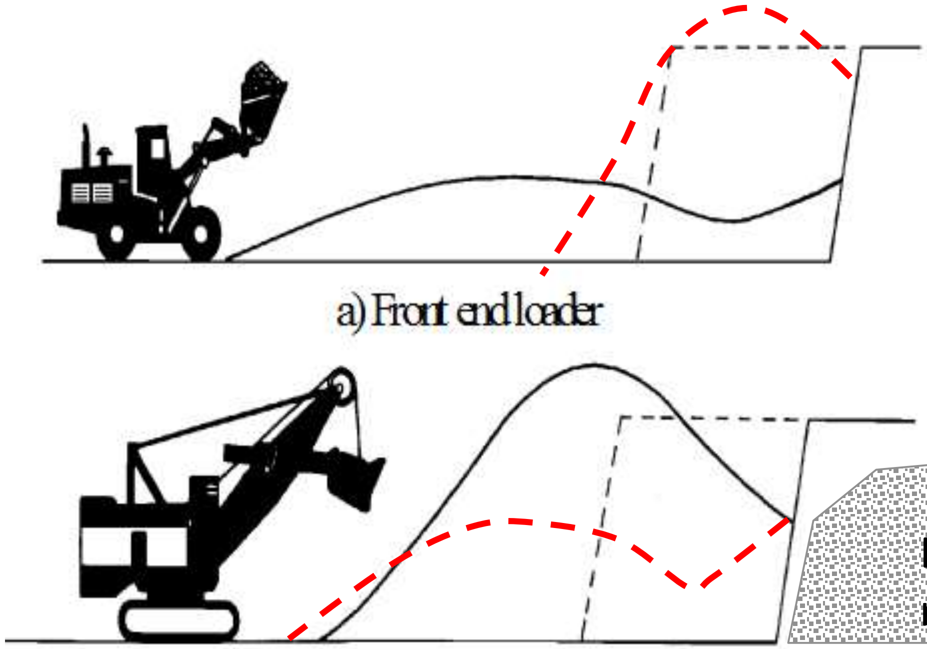


BUT

Value ≠ Grade

Value = f(Grade, TPH, Recovery and Costs)

Impact of Blasting on Value of Muck Pile

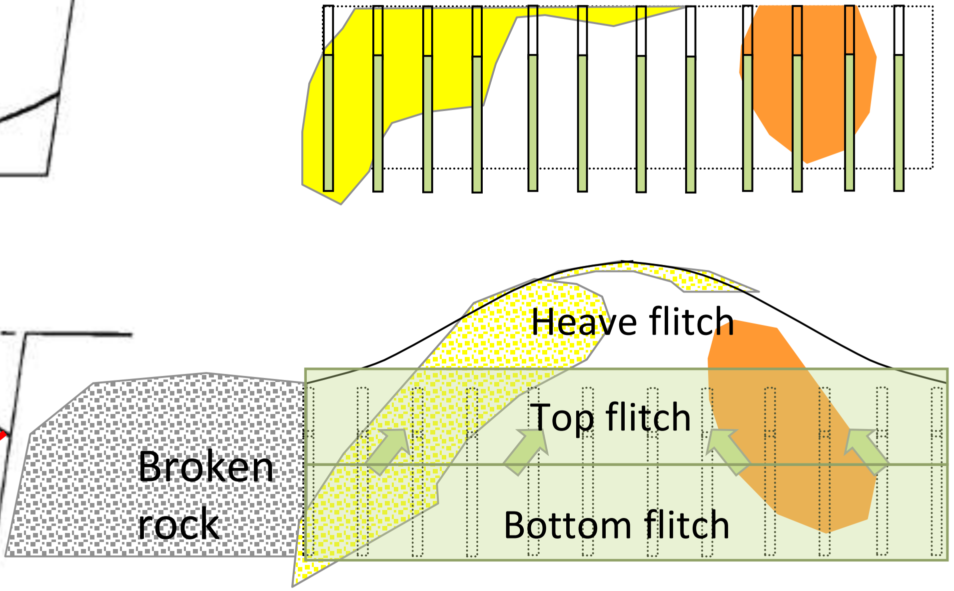


a) Front end loader

b) Shovel

Digger productivity

Dilution & ore loss



Blast movement impacts excavator productivity, ore loss, dilution and overall mine economics

Fragmentation has a direct influence on the performance of mining production equipment, crushers and grinding mills

Feed **size** and **hardness** are the most significant drivers for SAG/AG mill performance

Value of parcel of rock within a blasted muckpile is dependent on the feed characteristics such as grade, fragmentation and hardness

Value Based Ore Control Model - VBOC

VBOC integrates blasting and processing models to estimate the value of rock in an open pit production blast muckpile in a reasonable time frame so that digging decisions can be made based on value rather than just grade.

Estimates the **Value** of post blast material based on:

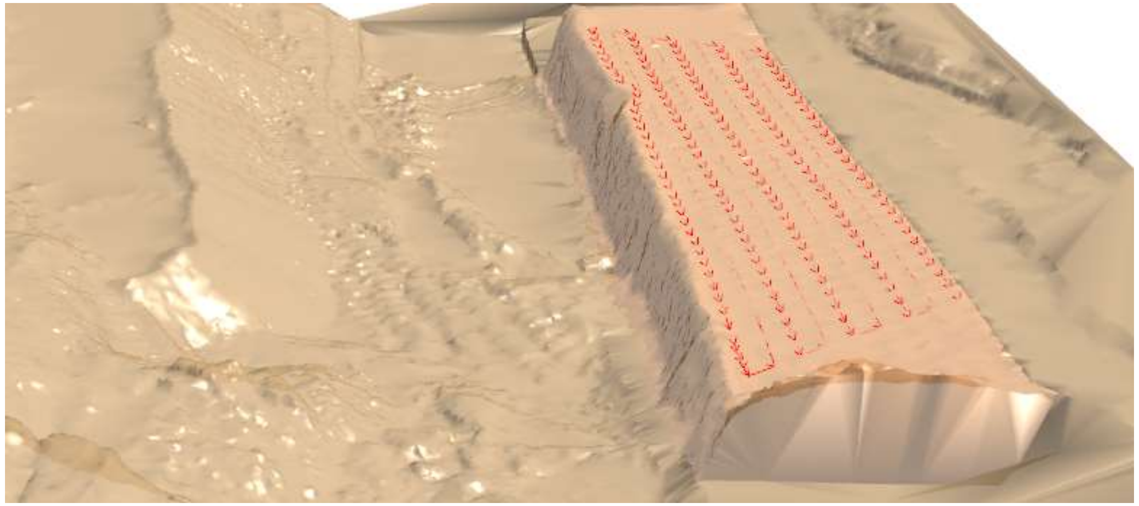
- Grade
- Particle size distribution
- Mine productivity
- Mill throughput and recovery

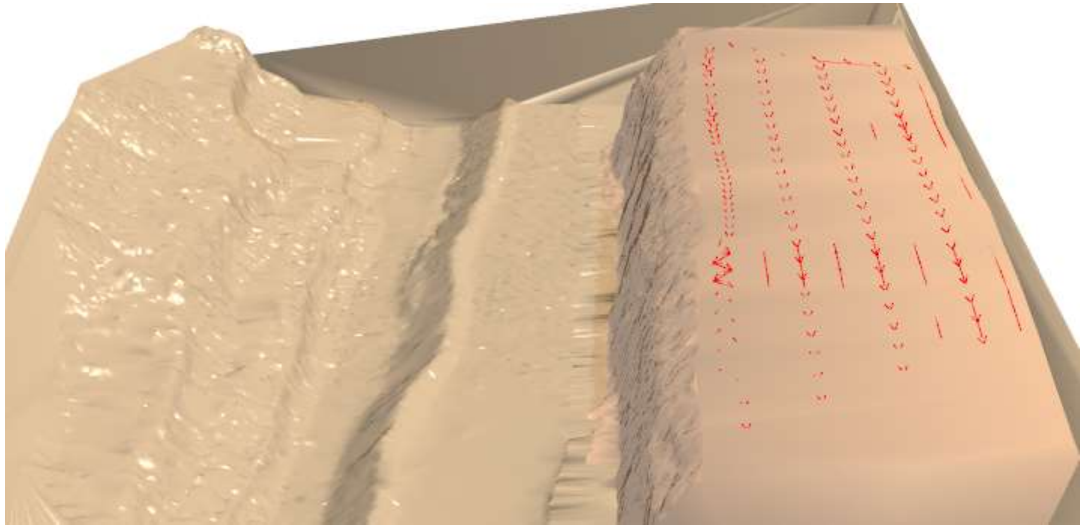
The tool has **three main models**:

1. A model to estimate blast movement and resulting muckpile profiles, ore loss and ore dilution
2. A model to estimate fragmentation within the muckpile
3. Models to predict the throughput and recovery within the muckpile

Key Features of VBOC

- 3D, Multi hole and variable rock properties
- Predicts post blast properties of a muck pile – shape, fragmentation, dilution, ore loss
- Track any property stored in the block model in post blast muckpile
- Uses rock hardness parameters same as metallurgists and estimates downstream process throughput, recovery, metal output and finally value of muckpile
- Can use the actual mine surfaces and actual drill & blast parameters
- Designed as an operational tool to make day to day decisions
  - Simulate production blasts on a regular PC within 2 hours
  - Part of mine work flow uses existing systems to import and export data





Blast Movement Model (Picorelli et.al. 2018)

Initial velocity vector for each block within the blast is estimated based on:

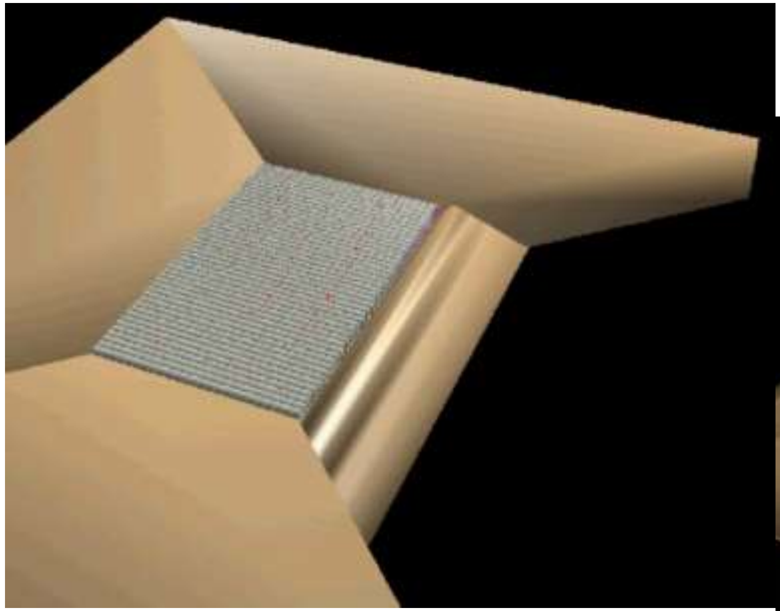
- Energy vector in each block,
- Timing and
- dynamic confinement conditions of that block.

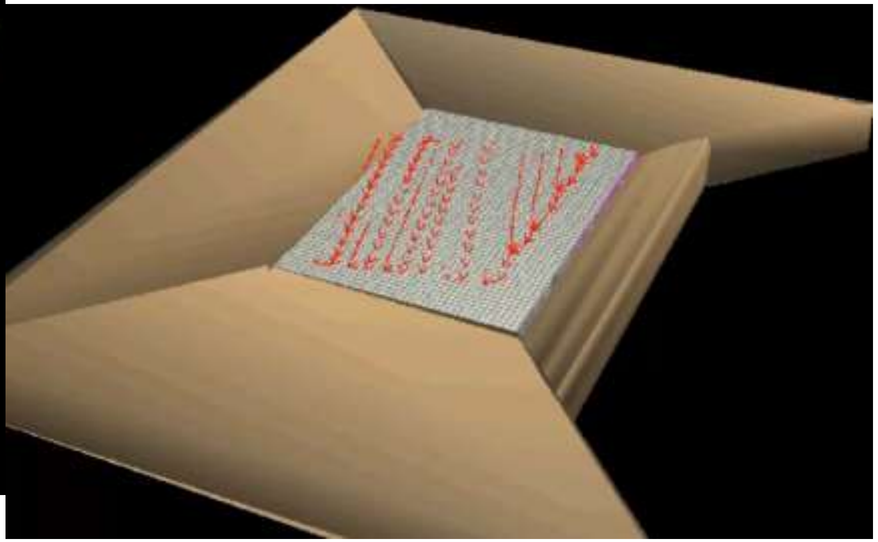
Uses a commercial physics engine software to simulate block interactions using the rigid body dynamics.

A properly calibrated model can predict the overall blast movement of a blast with reasonable accuracy.

Example:

- Large open pit gold mine
- Two blasts were monitored
- Different blast designs, powder factors, initiation patterns and free face conditions
- Blast instrumented with BMMs
- Post blast muckpile profiles were surveyed using laser scans





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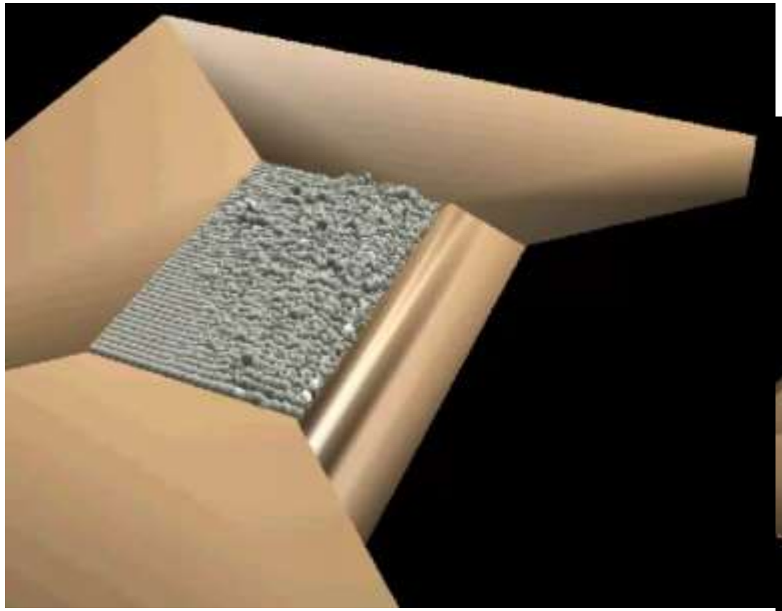

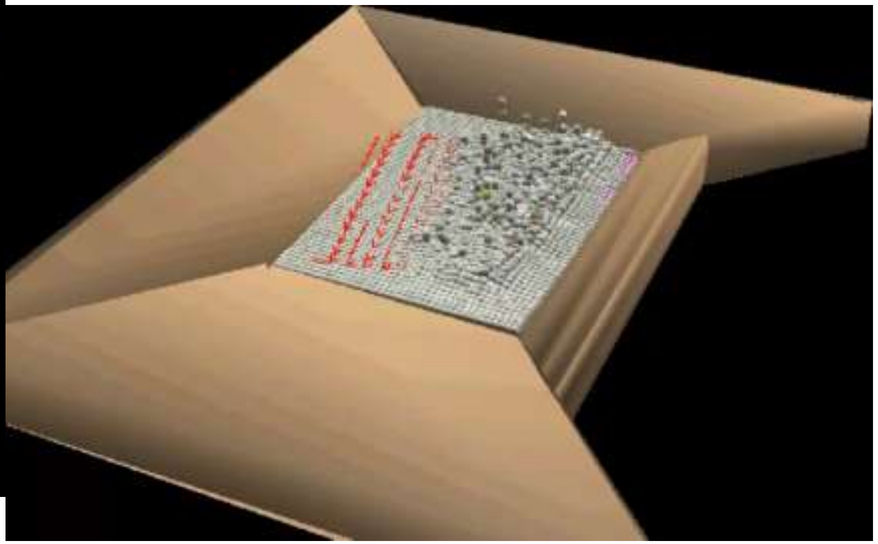

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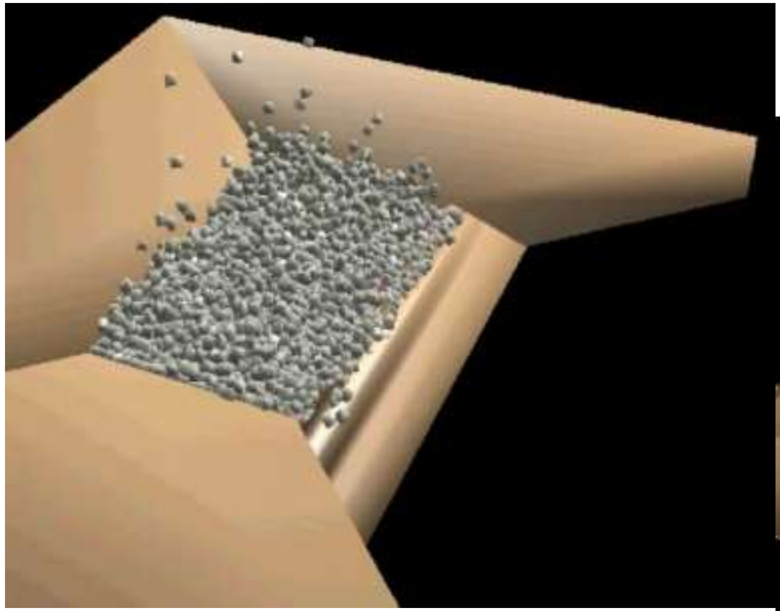

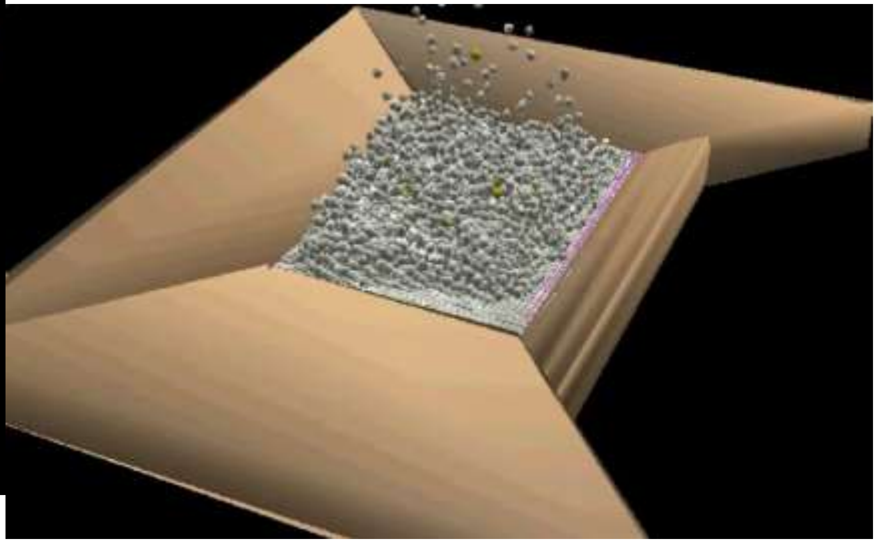

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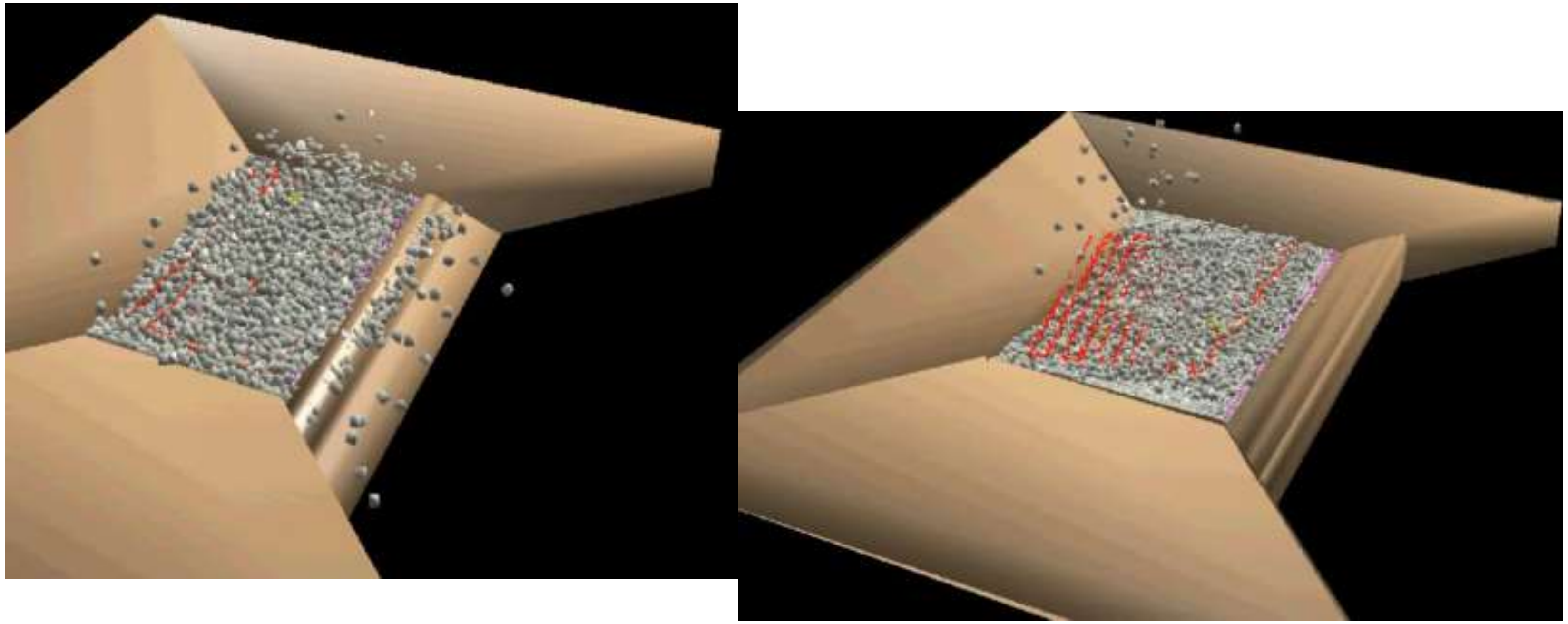
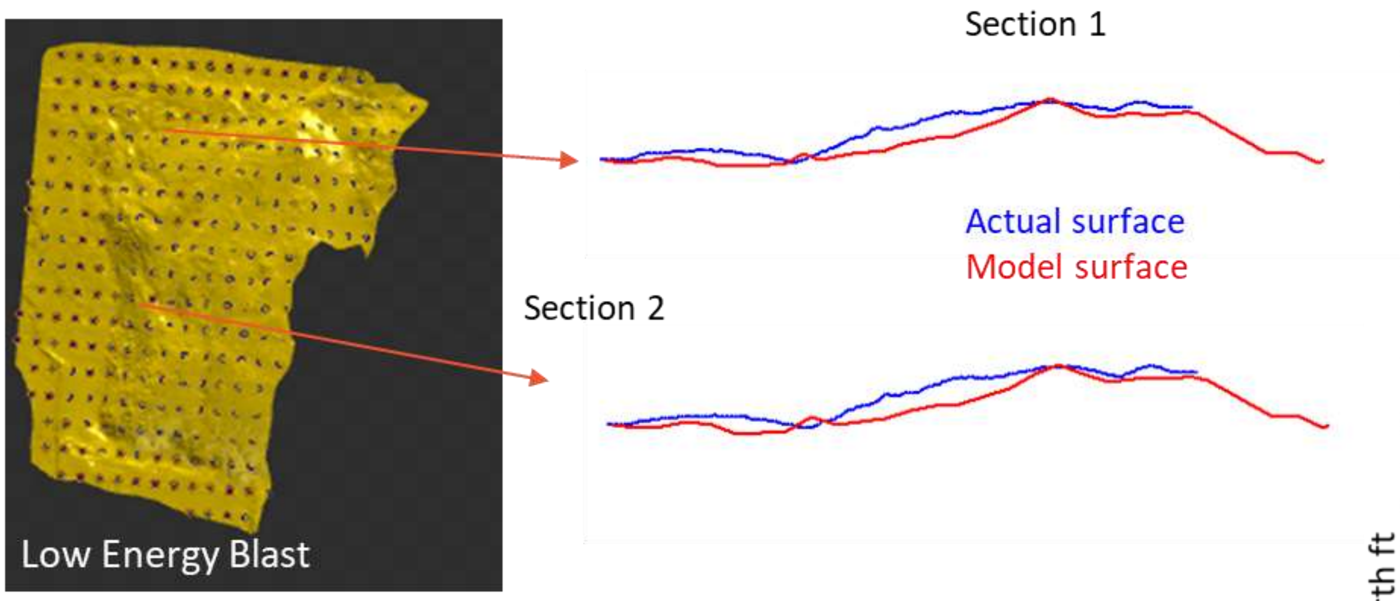
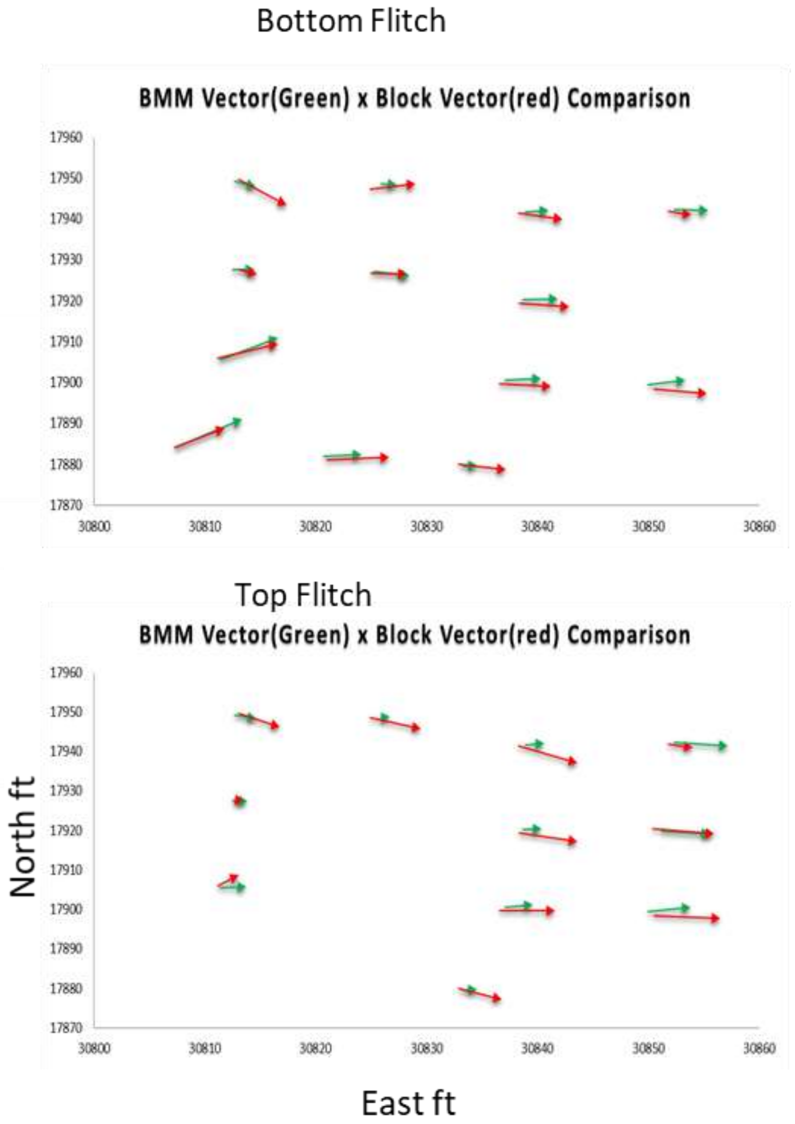


Blast Movement Model - Calibration

The post blast muckpile surface data from laser scans and BMMs data from the low energy blast was used to calibrate the model

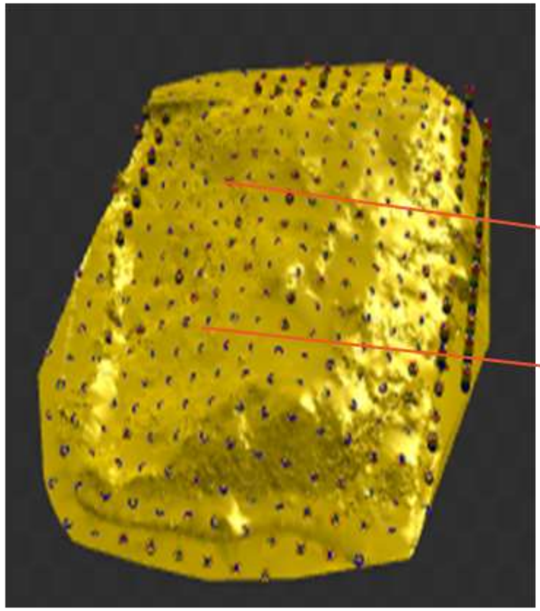


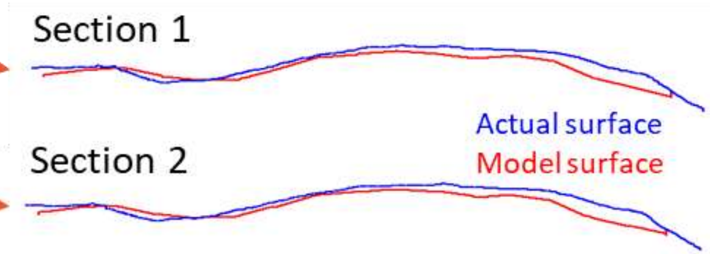


	Average BMM estimate (m)	Average Model estimate (m)
Low energy blast (PF ~0.4 kg/m^3)		
Top flitch	1.17	1.49
Bottom flitch	1.53	1.85

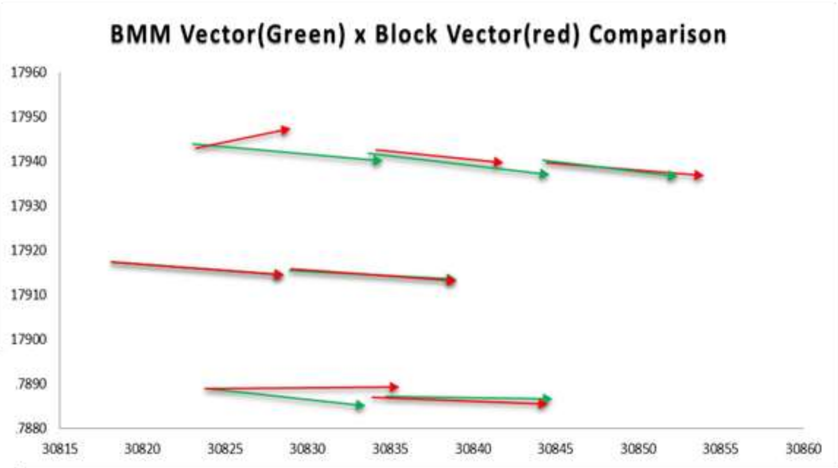
Blast Movement Model - Validation

The calibrated model is then used to estimate the muckpile surface profiles and internal movements of blast 2 with higher powder factor

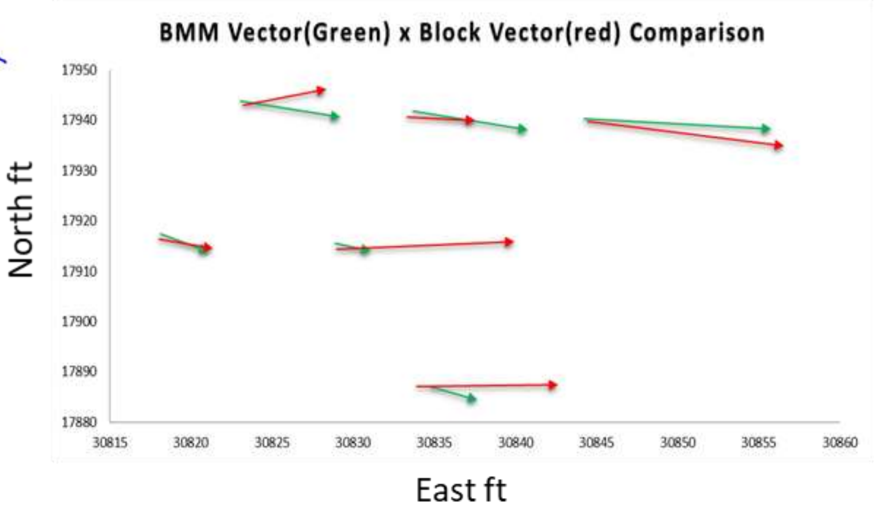




Bottom Flitch

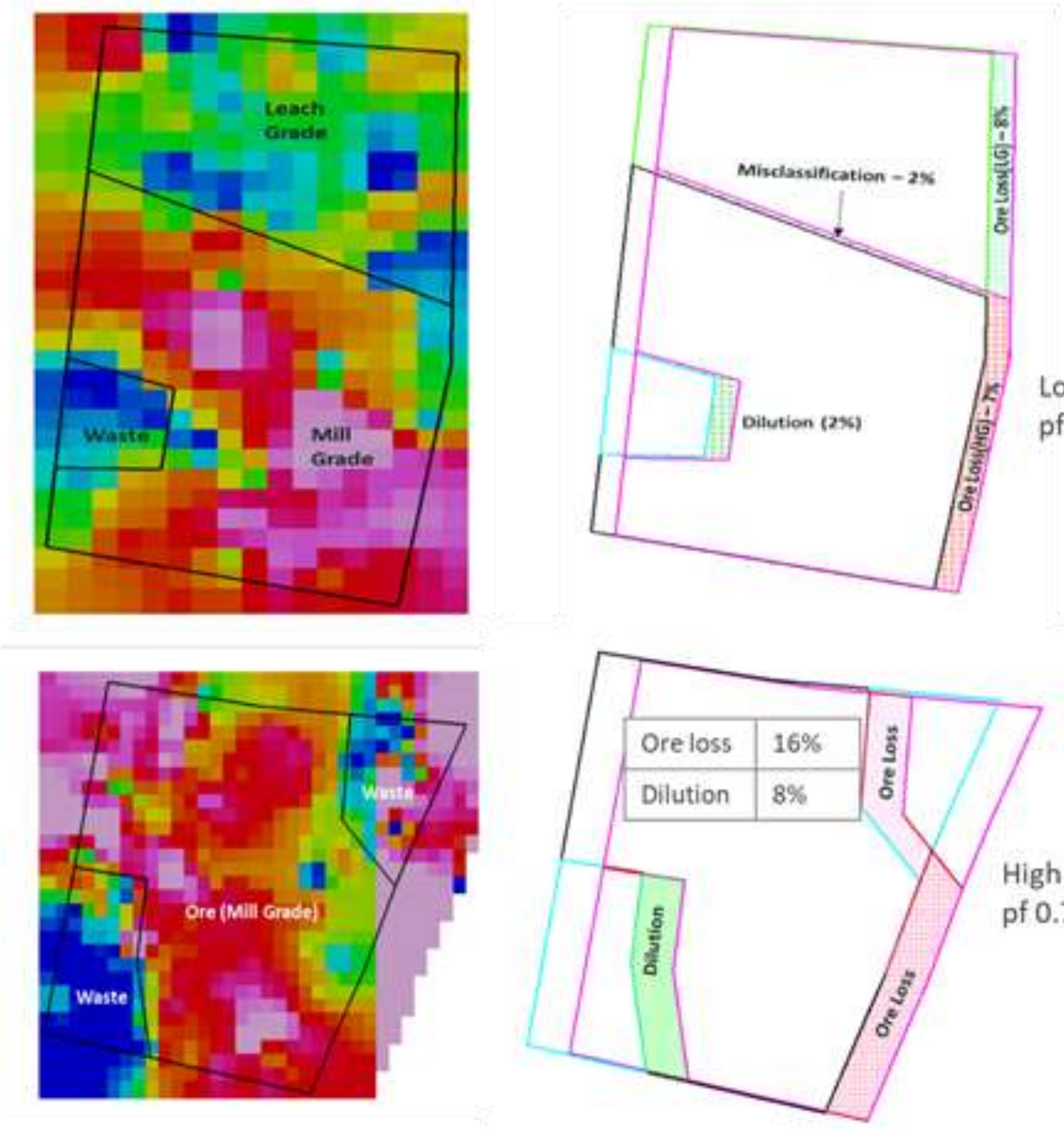


Top Flitch



	Average BMM estimate (m)	Average Model estimate (m)
High energy blast (PF ~0.7 kg/m^3)		
Top flitch	3.32	3.01
Bottom flitch	2.26	2.39

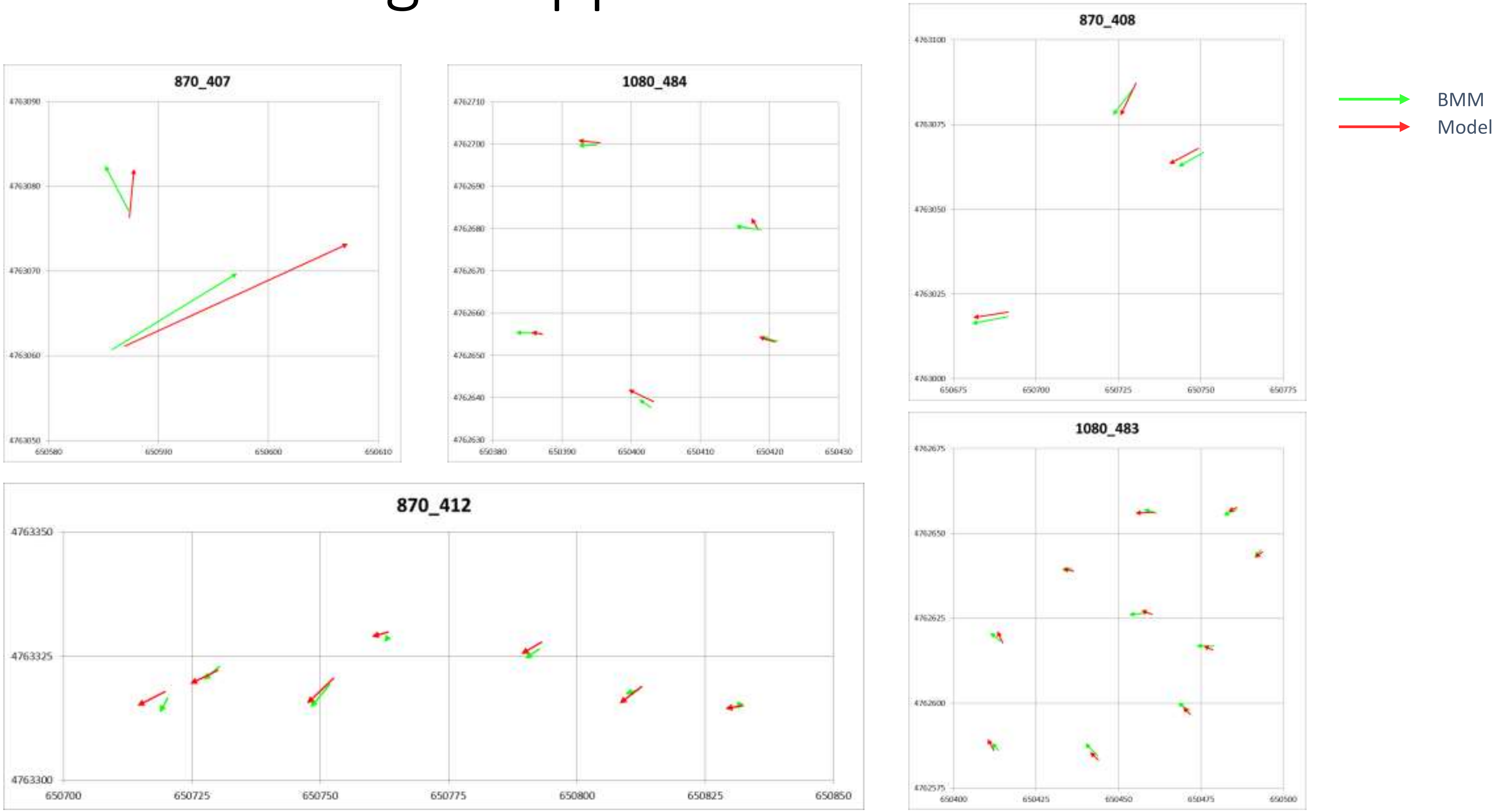
Ore loss and dilution estimates



Low energy blast
pf 0.4 kg /m^3

High energy blast
pf 0.7 kg /m^3

Data from a large copper mine



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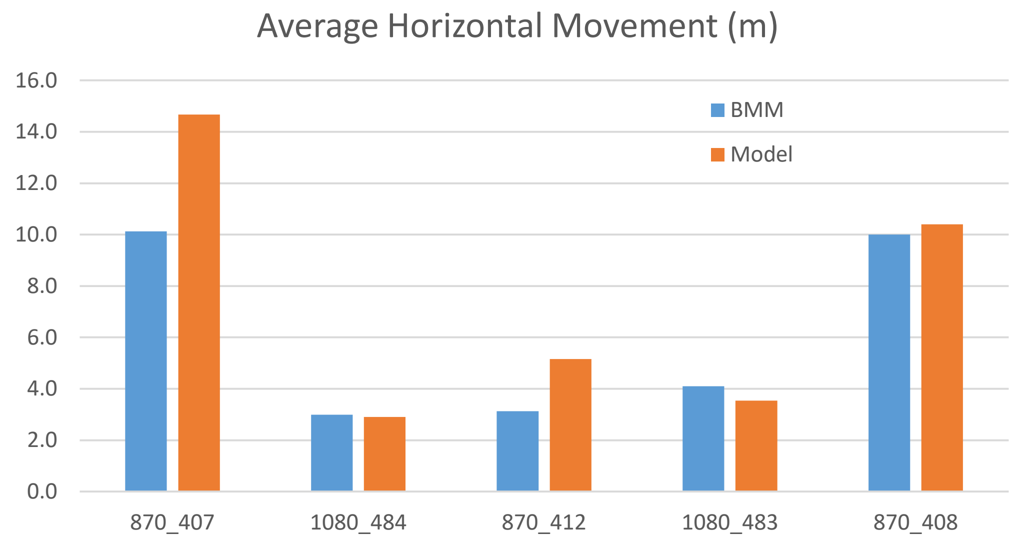
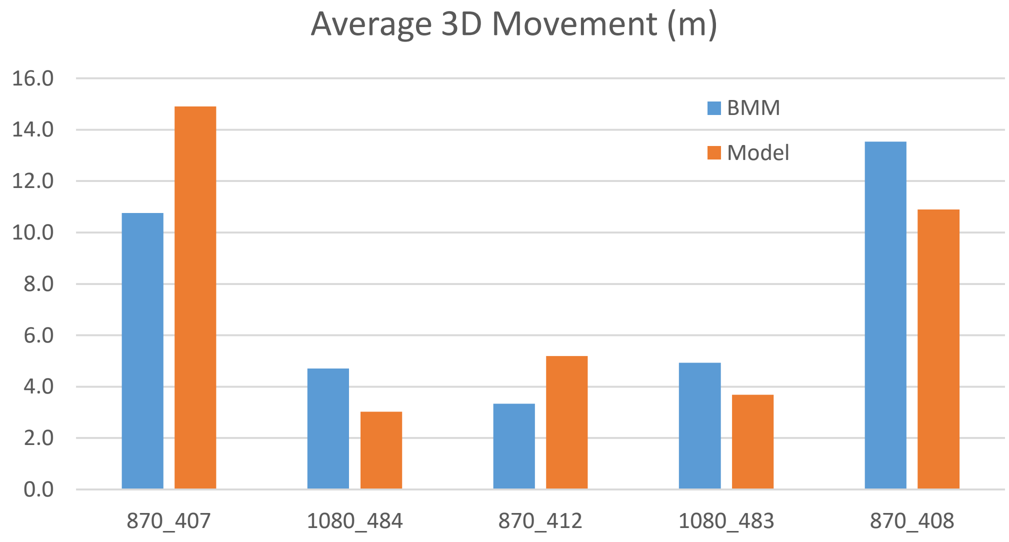




BLAST FRAGMENTATION MODEL

The blast fragmentation model used in this tool uses the comminution theory similar to the crushing and grinding model developed at the JKMRC.

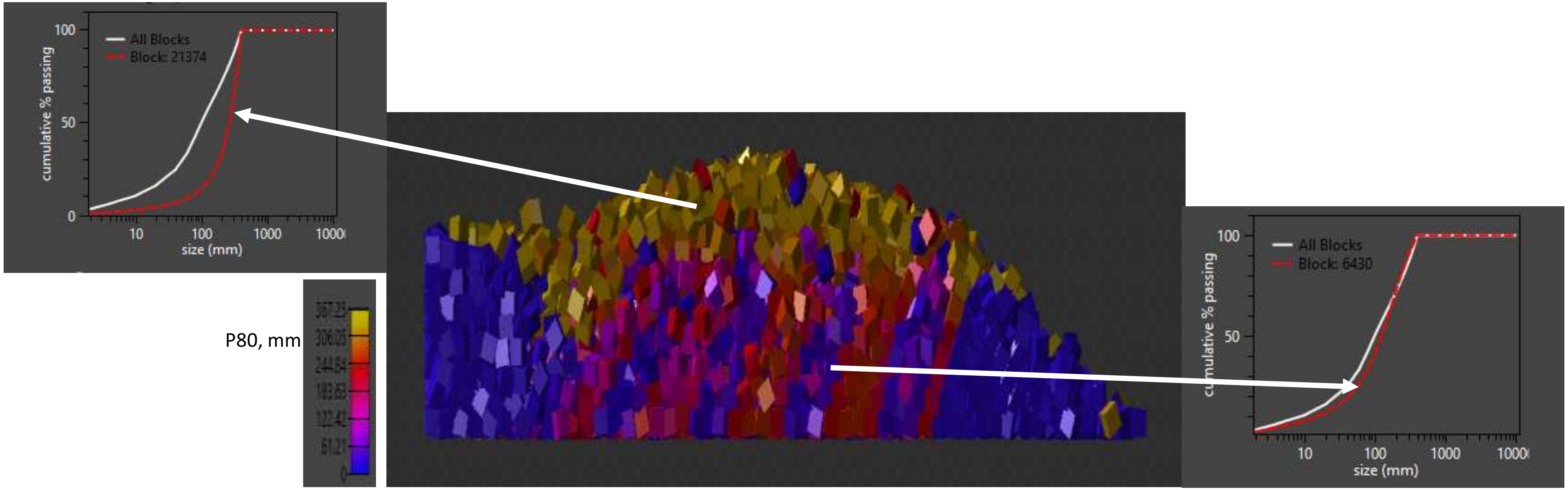
Fraction of energy used in fragmenting the rock is called the fragmentation energy (E_f)

E_f = f(rock properties and explosive detonation characteristics)

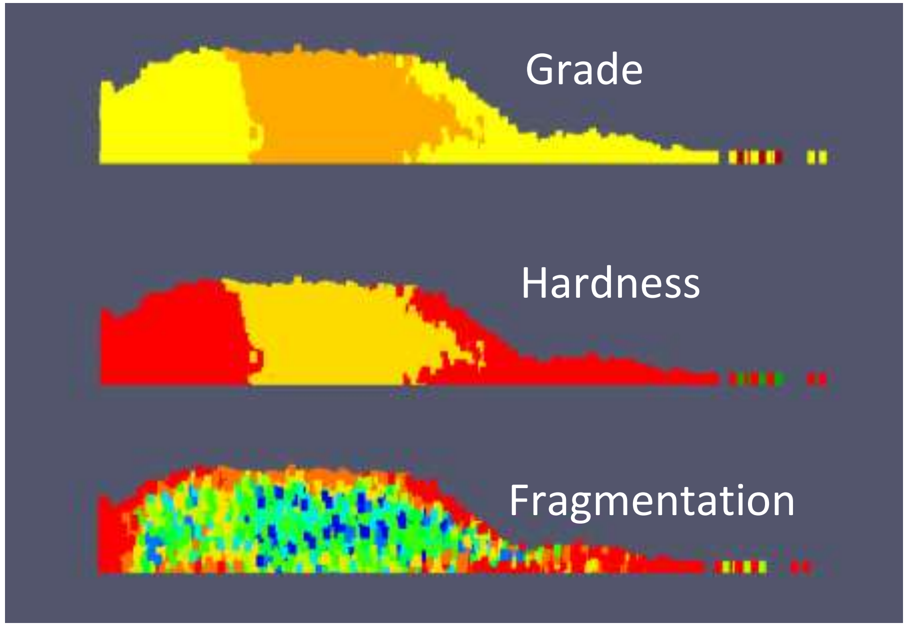
$$t_{10} = Kc \times Ks \times A\,[1-e^{(-b \times Ef)}]$$

Where,

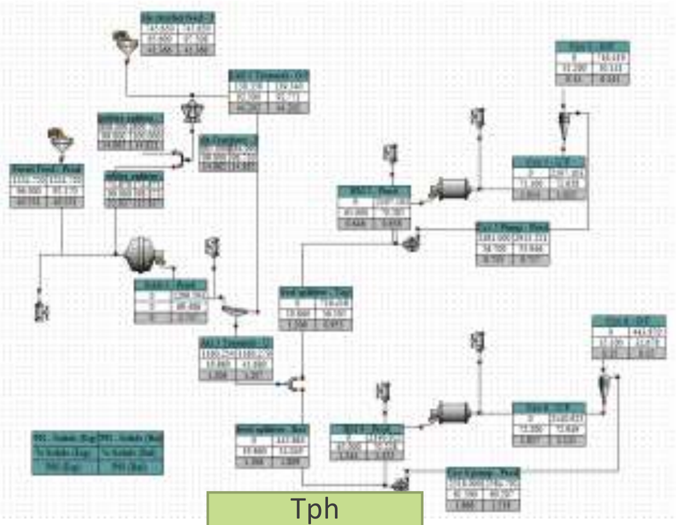
t_{10}:	percent passing 1/10th of the initial size in each block
A & b:	breakage parameters of rock in each block derived from the drop weight test.
Kc & Ks:	model parameters to account the effect of size and confinement conditions in each block



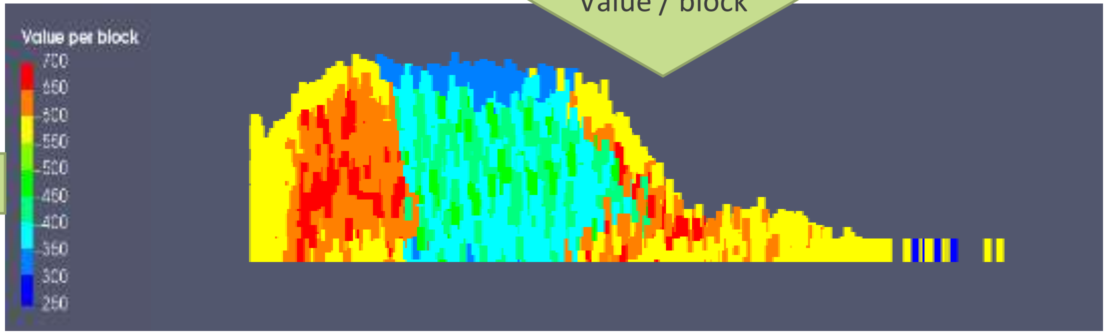
Throughput and Recovery Prediction Models



Downstream Process Models



Tph
Recovery
Kwh/t
$/t
Value / block

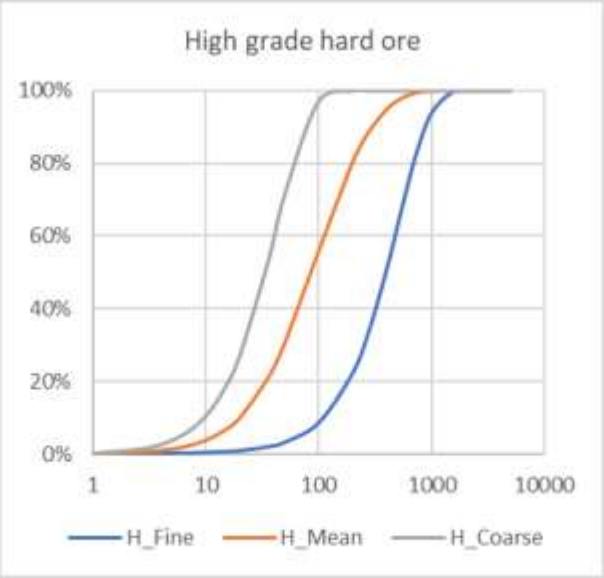


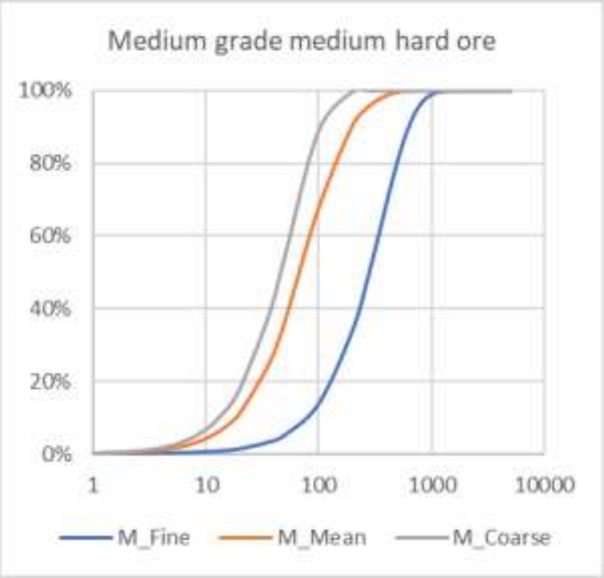
Value Based Ore Control Methodolgy – Example

This example considers an open pit bench consisting of two different ore types.

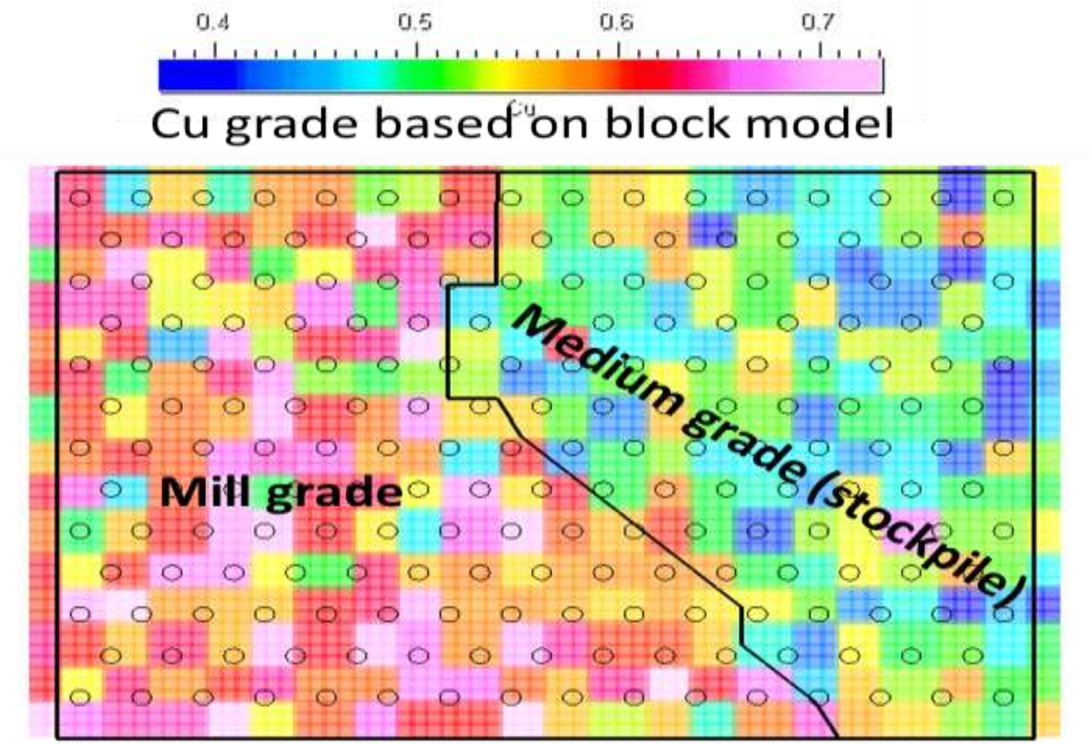
	% Cu	Axb	Ta	BWi
High Grade, hard ore	0.6	33.3	0.47	18.5
Medium grade, medium hard ore	0.5	49.3	0.39	13.5

Fragmentation Estimates

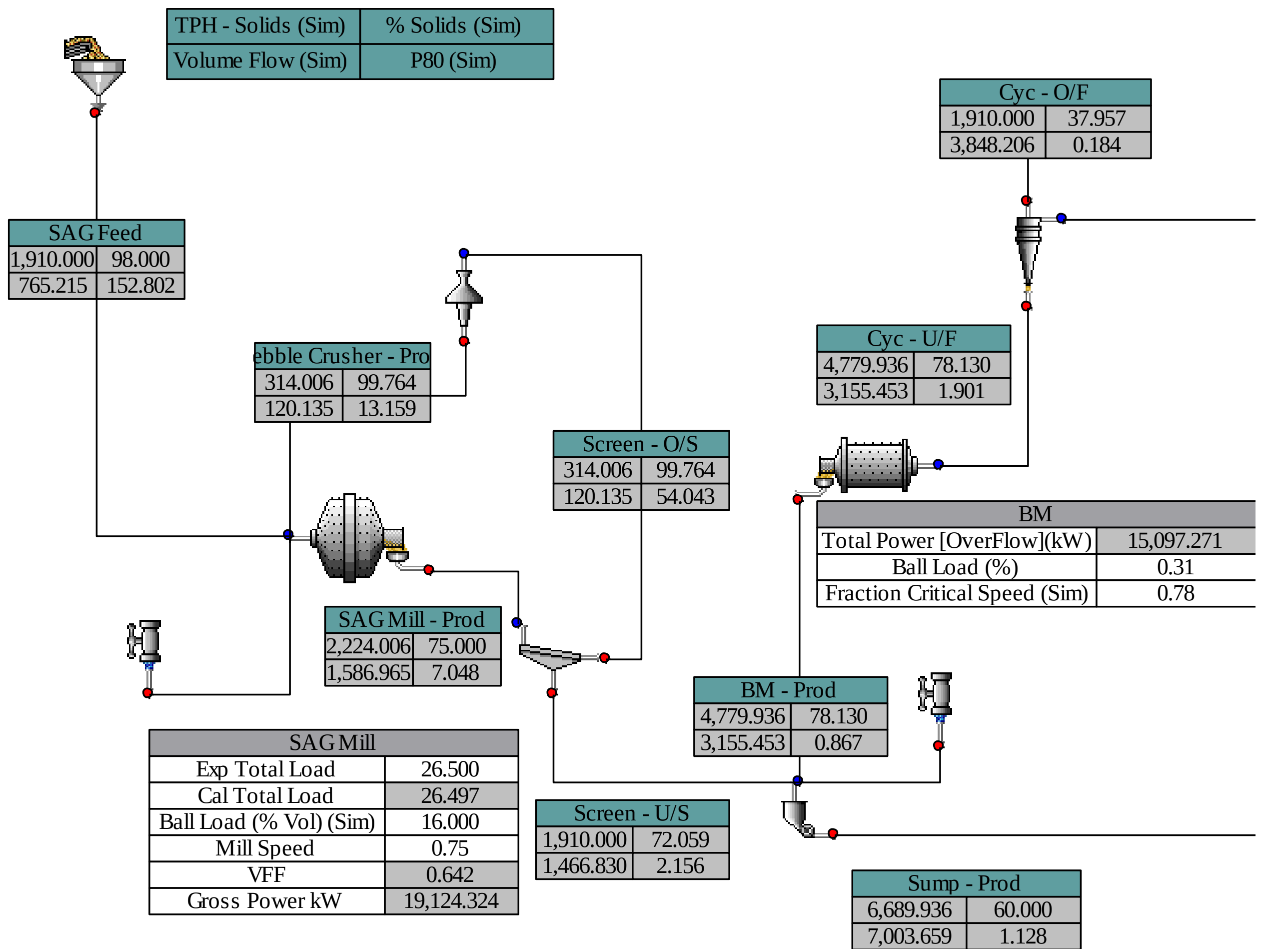


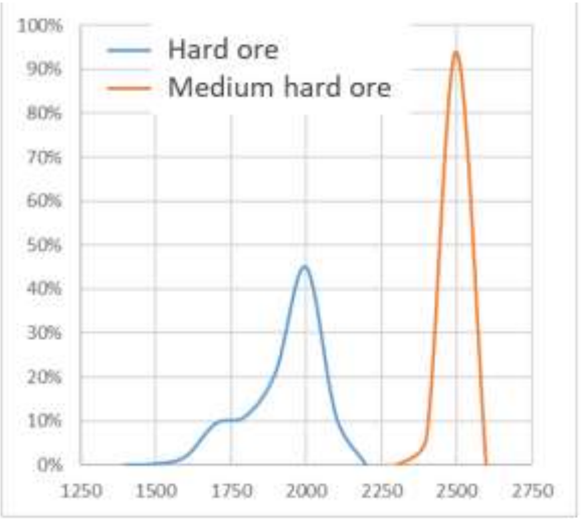


Cut off grade = 0.55%Cu

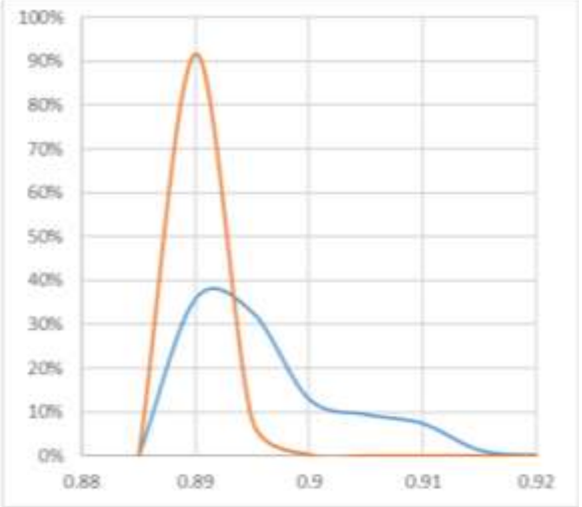


Throughput and recovery estimates





Throughput tph



Recovery

	Cu (%)	P80 (mm)	Throughput (tph)	Recovery (%)	Power consumption (kwh/t)	Metal output (tph)
High grade, hard ore	0.6	0.206	1,882	89	19.5	10.13
Medium grade, medium hard ore	0.5	0.239	2,449	88	14.9	10.93

Metal output vs Grade

Applying standard grade control methodologies:

Cut off Grade = 0.55%Cu

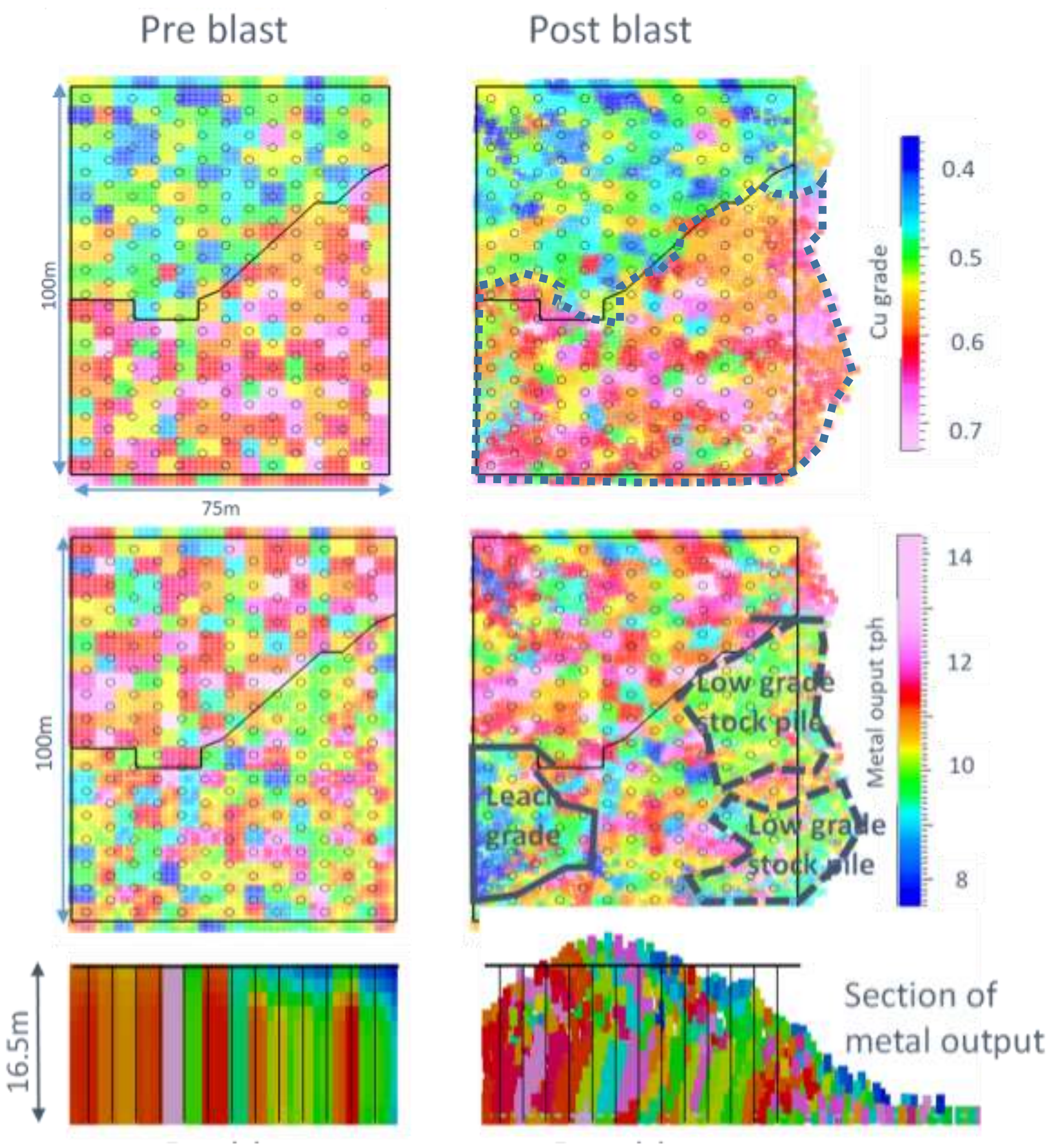
If we apply metal output as criteria based on value,

such as:

>10 tph metal output = Mill feed

<10, >9 tph metal output = Low value stockpile

<9 tph metal output = Leach feed



Conclusions

- Standard ore control in most mines is based on insitu cut-off grade estimates leads to sub-optimal digging decisions
- Value of ore within a muck pile depends on its post blast grade, throughput and recovery, which in turn depends on the hardness and particle size distribution.
- The proposed value based ore control (VBOC) tool integrates blast movement and fragmentation models with processing models to estimate the value or metal output of post blast material.
- Blast movement part of the tool has been tested in the field and proven to be reasonably accurate to manage blast induced ore loss and dilution.
- Fragmentation and process models are still being tested and requires more field cases to make it robust and to make an operational tool for field mining engineers.
- The model can estimate the value of blast muck in 3D hence it is possible to integrate the model outputs with the excavators to make digging decisions based on value of the ore in a bucket rather than just grade.