Model to Metal Reconciliation: Delivering on Promises

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Purposes

- Improve reliability of business plans
- Comply with Reserve reporting requirements
- Explain of business plan variances
- Continuous improvement
- Identify issues at critical points
- Build a more profitable business

The need for reconciliation

Reconciliations should be consistently monitored over time.

Even a successful predictive approach can deteriorate due to changes in geology, ore type, sampling procedures, grade control methods, mining methods, milling controls, personnel, etc.

Lack of systematic reconciliation means that there are no controls <u>to monitor the predictions, and to moderate expectations</u>

This may result in non-optimal use of the resource, pressure on the mining team, profit objectives not being met and unhappy shareholders.

Outcomes of a robust reconciliation system

Recognition of trends can provide insight into how the current predictions may become realized during future production

It is useful to know that the mill is receiving the predicted ore at a lower than expected grade, even while there is still uncertainty as to whether this is due to problems with:

- ore reserve (due to data, interpretation or estimation)
- grade control (due to similar errors plus ore loss and dilution)
- mining (due to deviations from the plan), and / or
- milling (due to sampling errors or losses)

Similarly it is useful to know that production is exceeding predictions since this may mean the grade control process, the mine plan and the revenues are all suboptimal.

Basic reconciliation procedures

A simple scientific approach should enable a robust reconciliation method to be quickly developed. The essential steps are:

1. Establish an audit trail for all data
2. Agree to report results routinely in a consistent format and ensure that there are cross-functional reconciliation meetings in place to discuss results and develop action plans
3. Collect and tabulate the data
4. Report variations based on consistent volumes (bench by bench, stope by stope) or periods (monthly, quarterly, annually)
5. Graph the variations (or factors) for each parameter to determine trends
6. Analyse and explain the differences
7. Alter the input parameters systematically to reduce future reconciliation differences

F1, F2 and F3

Mine call factors and mill call factors have been used in many mines without any clear systematic definition.

Harry Parker (2012) has provided a solution to many of the reconciliation problems, since by his definitions…

Relationship between factors

$$F1=\frac{\text{GRADE CONTROL (PRODUCTION)}}{\text{ORE RESERVE (PREDICTION)}}$$

and

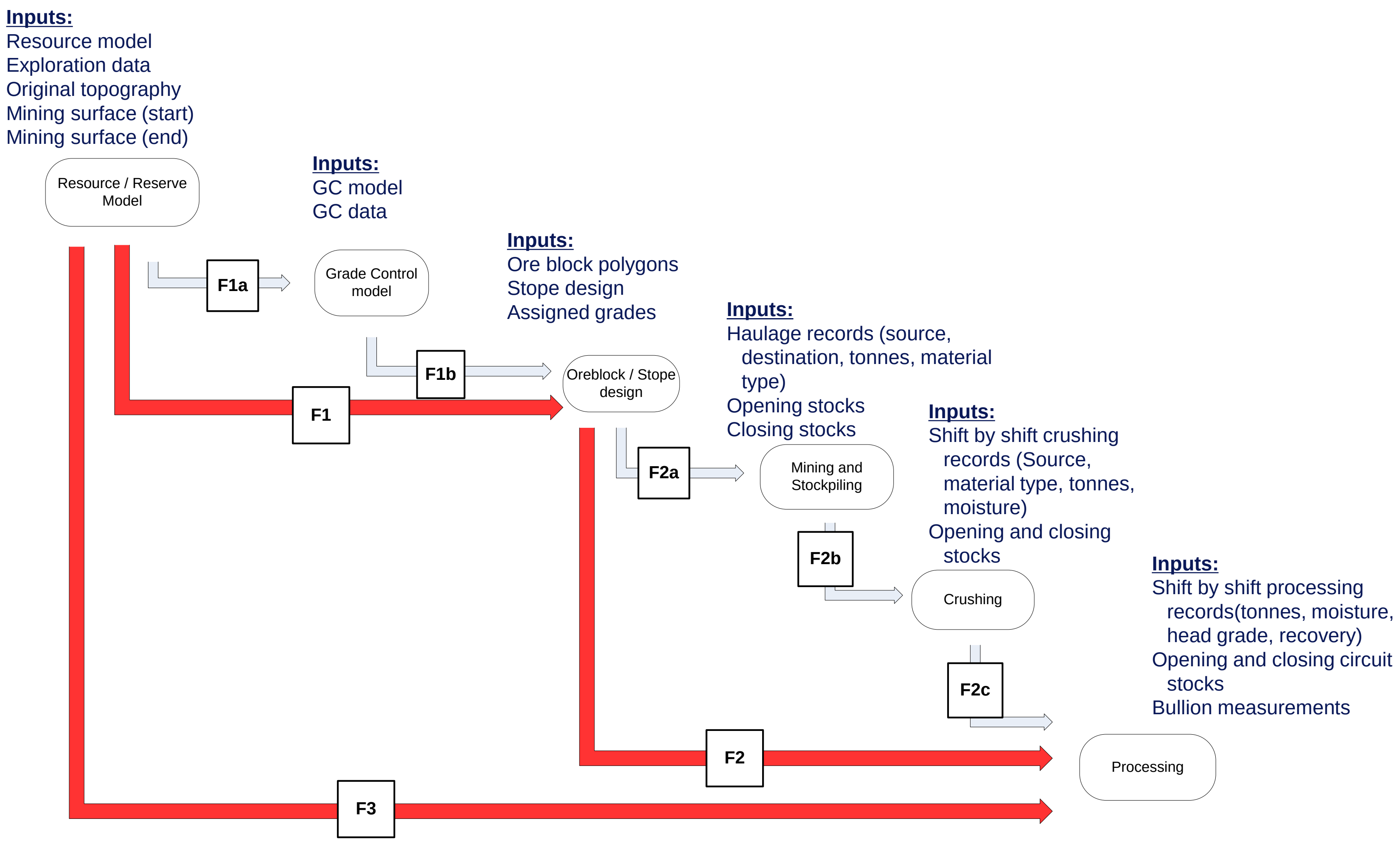
$$F2=\frac{\text{MILL (PRODUCTION)}}{\text{GRADE CONTROL (PREDICTION)}}$$

and

$$F3=\frac{\text{MILL (PRODUCTION)}}{\text{ORE RESERVE (PREDICTION)}}$$

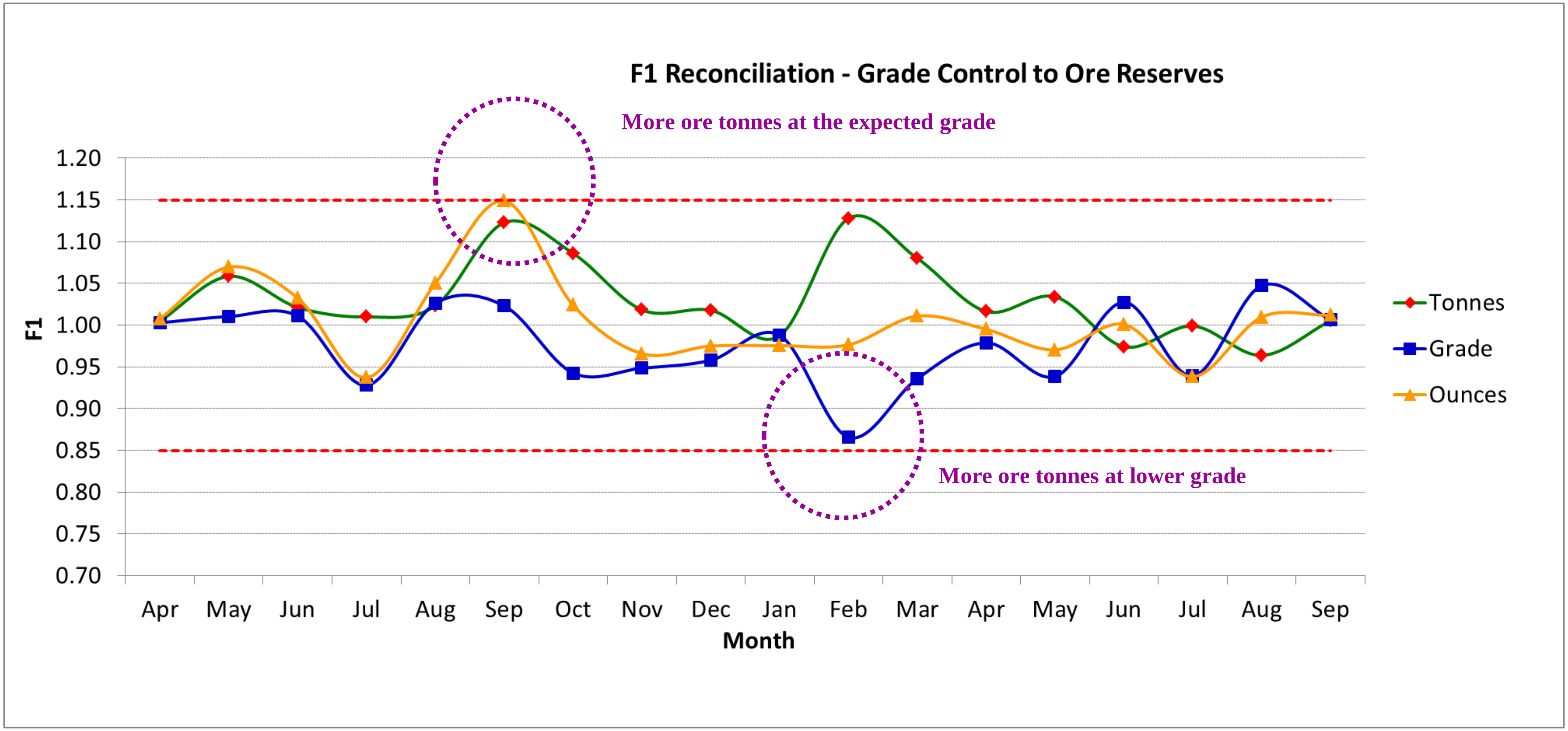
Therefore $F3 = F1 * F2$.

Inputs to the Reconciliation Factors



Shaw, W.J., Weeks, A., Khosrowshahi, S., Godoy M. 2013. Reconciliation – Delivering on Promises. 36th APCOM Applications of Computers and Operations Research in the Mining Industry, Porto Alegre, Brazil

Example of an F1 reconciliation



Mine plan compliance

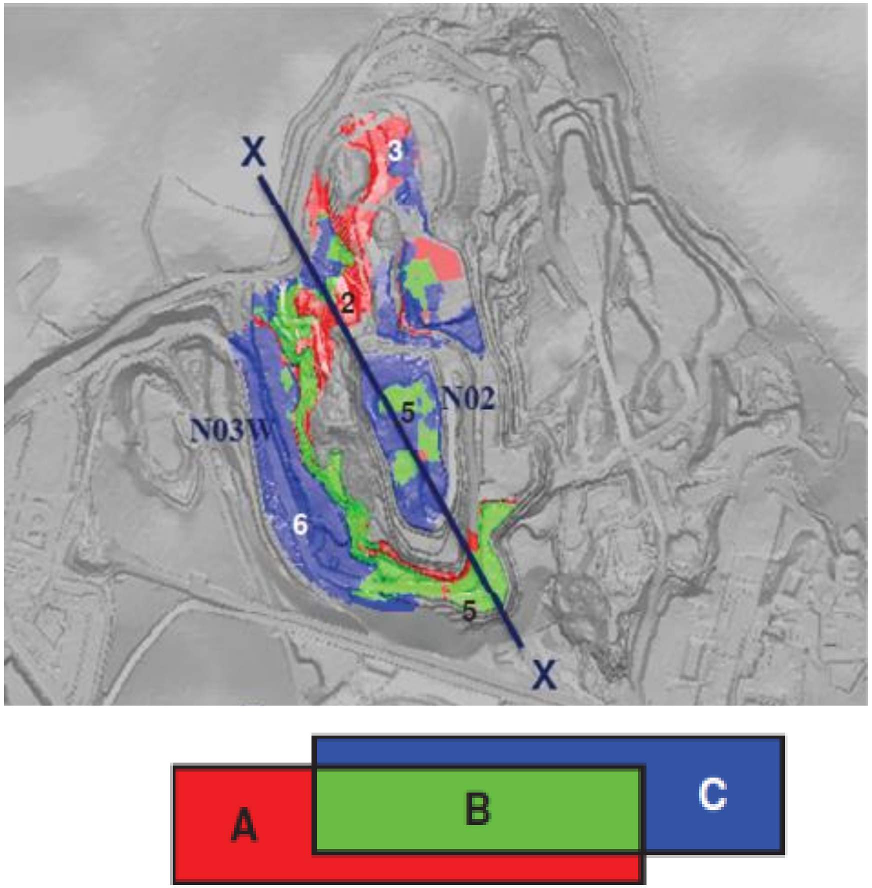
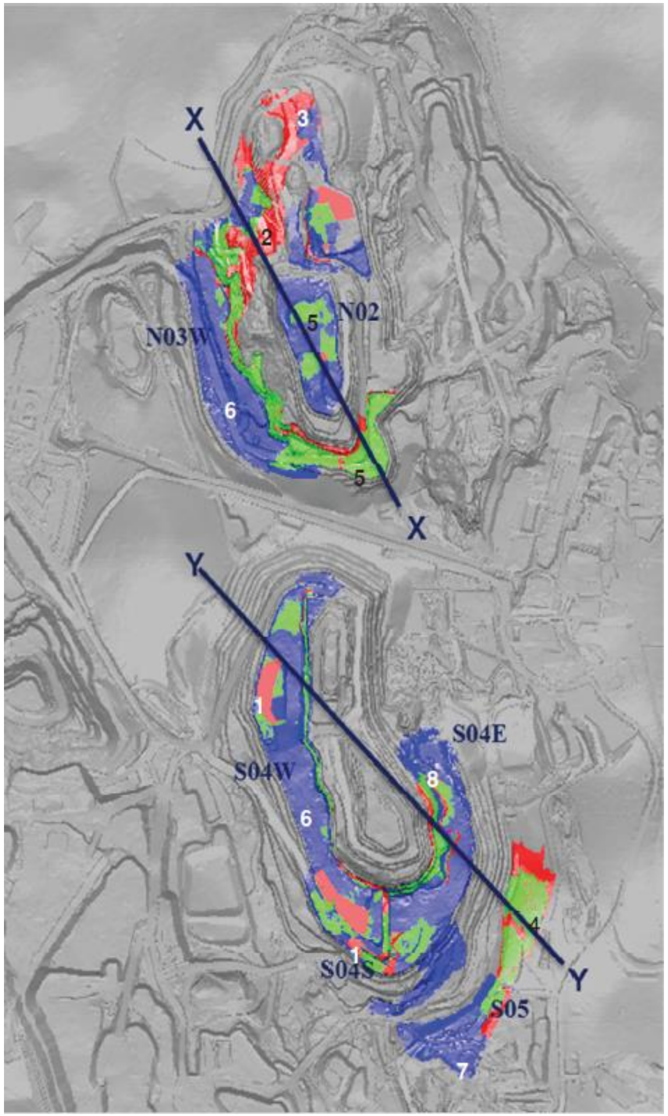
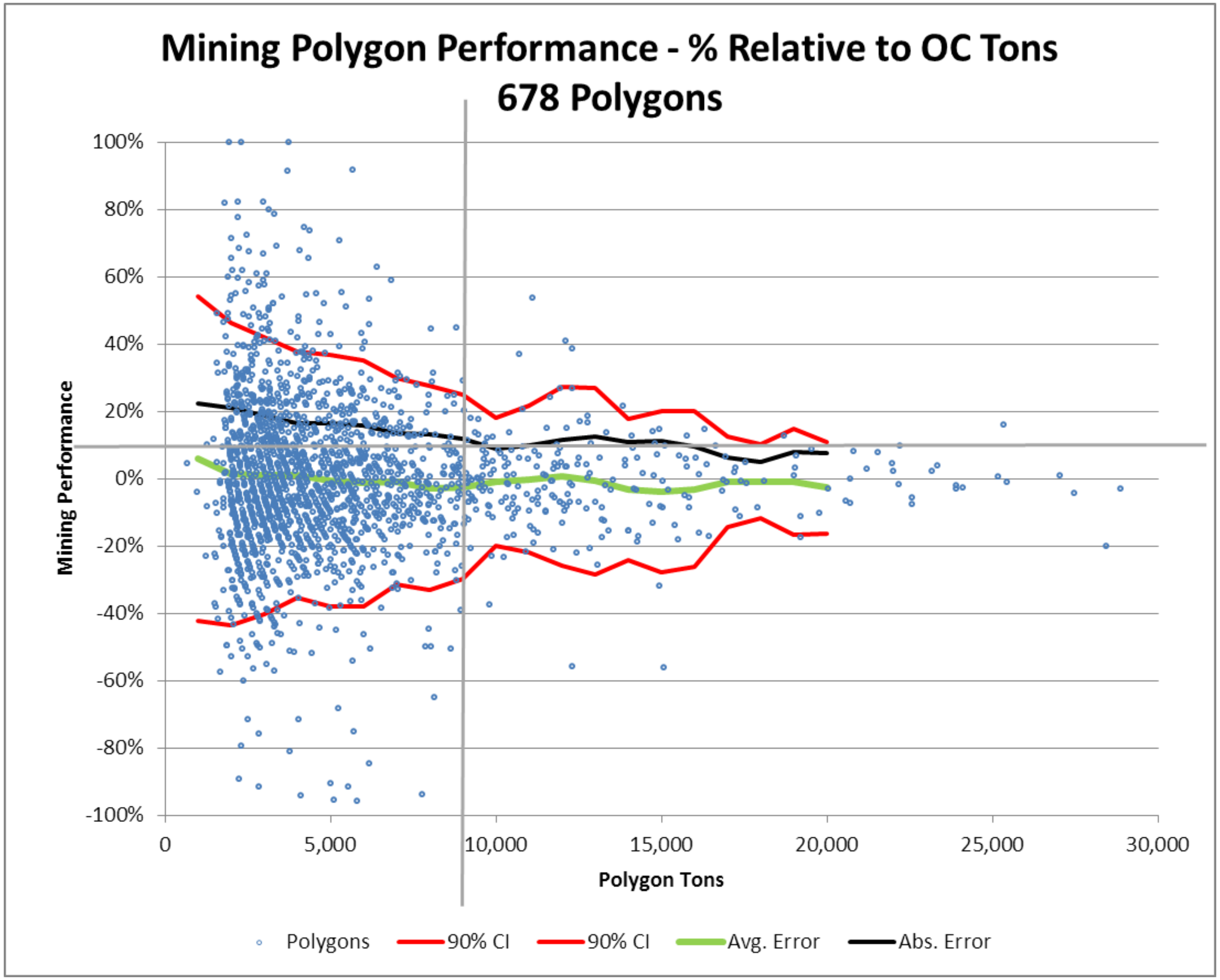


Figure 8-1 - Schematic As-mined vs. As-planned Mined Areas

A = Area in 2013 Business Plan but NOT in ACTUAL MINING (Behind Plan)
B = Area in 2013 Business Plan AND in ACTUAL MINING (In-Plan)
C = Area in ACTUAL MINING but NOT in 2013 Business Plan (Outside Plan)



Polygon Compliance



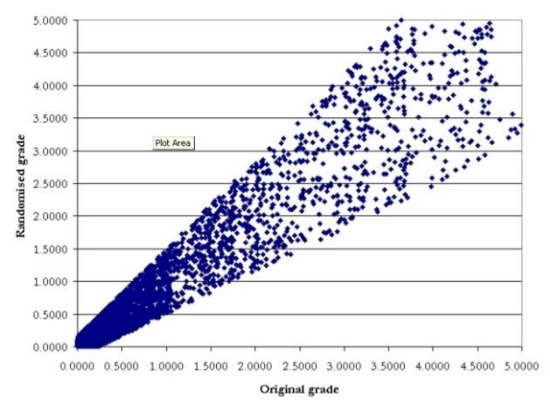
Advantages of a good reconciliation process

Once problems have been highlighted solutions can be considered. Typical examples are:

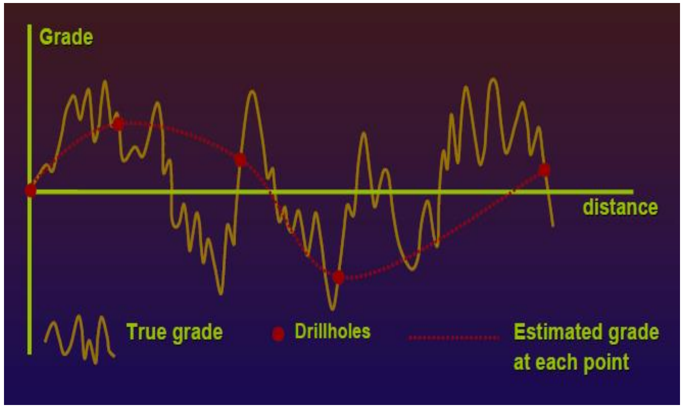
Problems	Solutions
Cannot achieve reserves	Compare mapping x geological model
Tonnage is too high	Examine moisture content
Tonnage is too low	Examine bulk density
Mill has less ore than mining	Check stockpiles and weightometers
Mill has lower head grades	Check circuit sampling and tailings.

Possible contributors to F1 variances

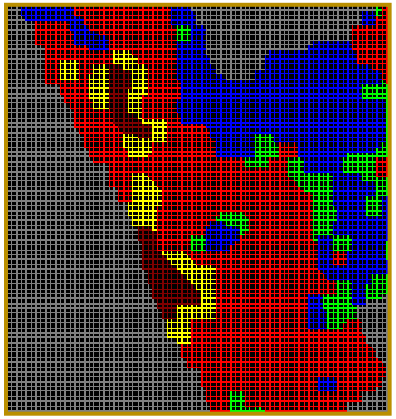
Sampling errors



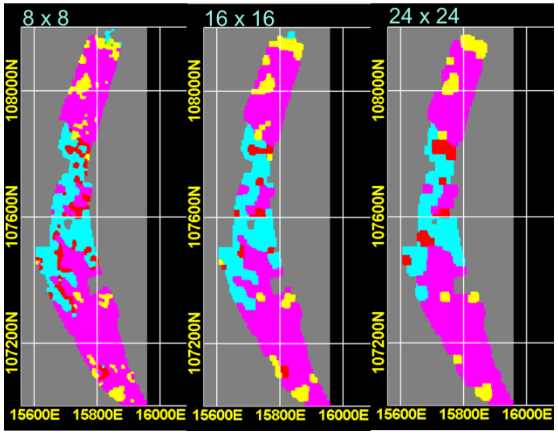
Estimation errors



Boundary definition



Mining selectivity

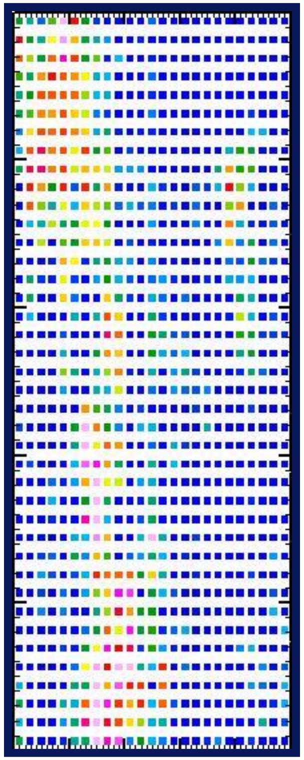


Blast movement

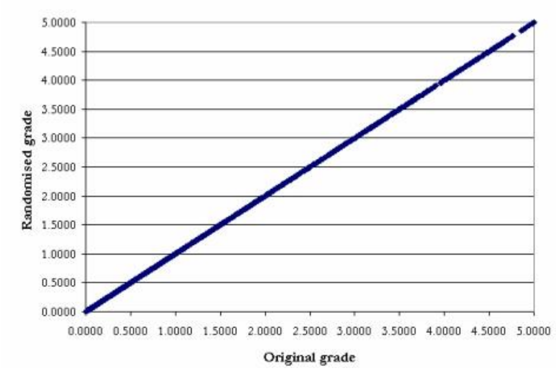
These are collectively termed Ore Control Effect

Traditional ore control process

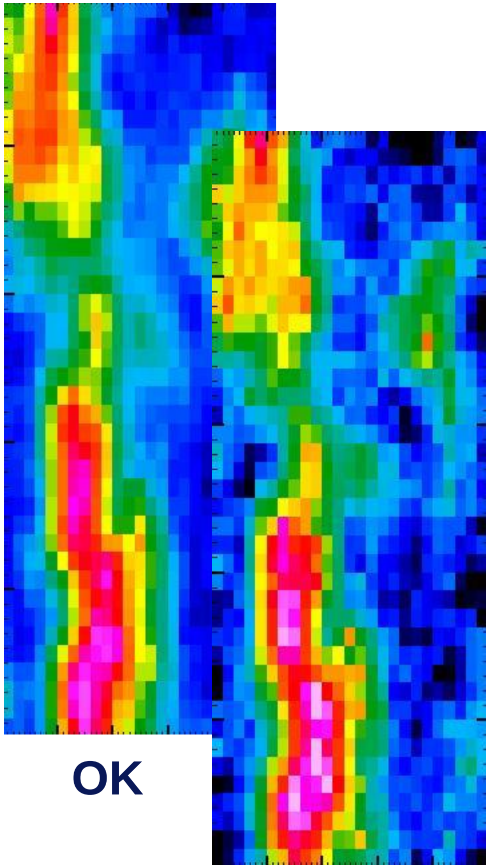
Grade control data



Error free data is assumed



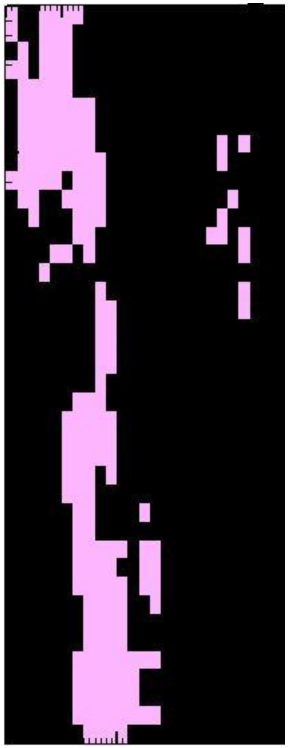
Grade Estimation



OK

ID2

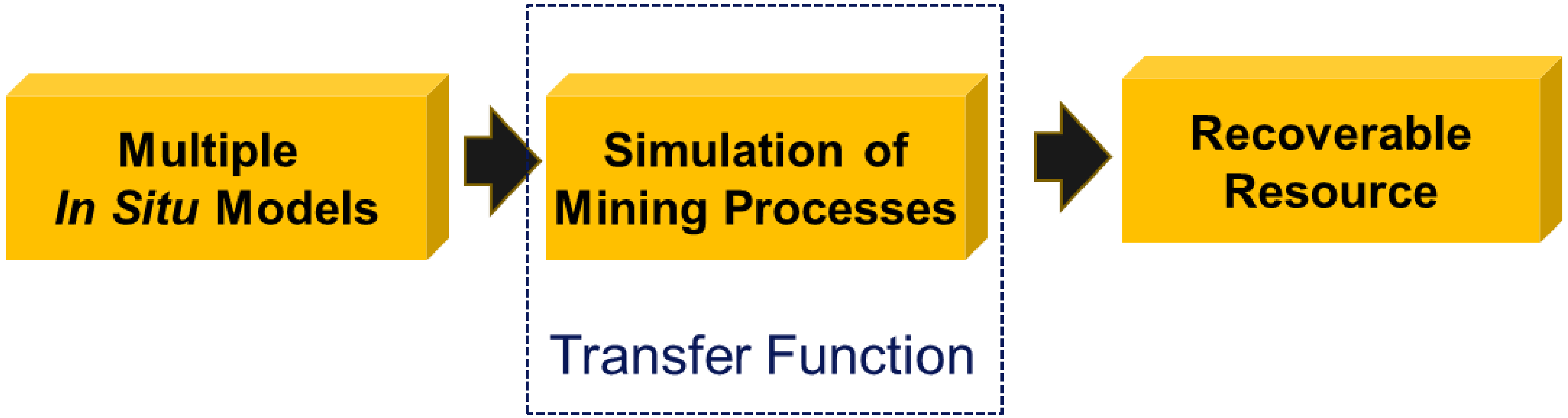
Digline generation assuming error free estimates



A methodology to assess and minimize reconciliation variances

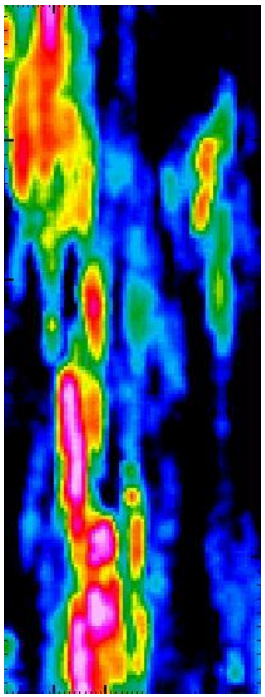
Using high resolution conditional simulations of an orebody the mining operation can be modeled. Simulated orebodies can be sampled using various grade control strategies and these notional grade control samples used to predict outcomes.

In particular, the Chain of Mining (CoM) method (Shaw and Khosrowshahi, 2002) can be used to assess how sampling, grade control, mining selectivity and blasting practices impact reconciliation variances. This should be a significant consideration in converting Resources to Reserves.

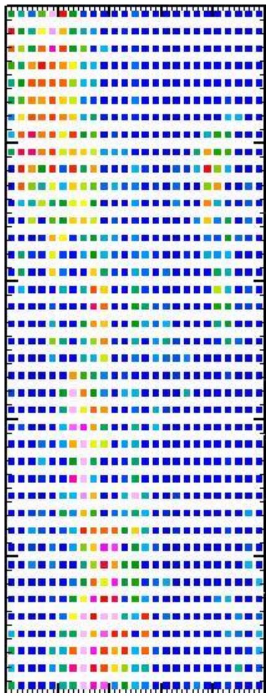


The Chain of Mining method

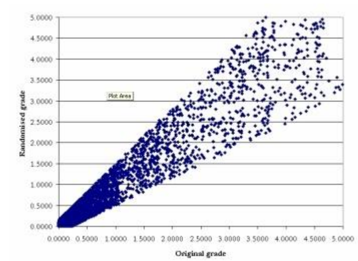
Reference



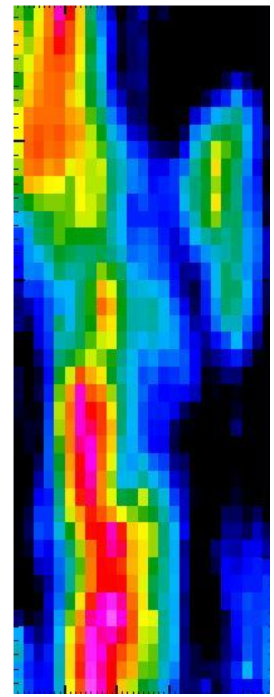
GC Data



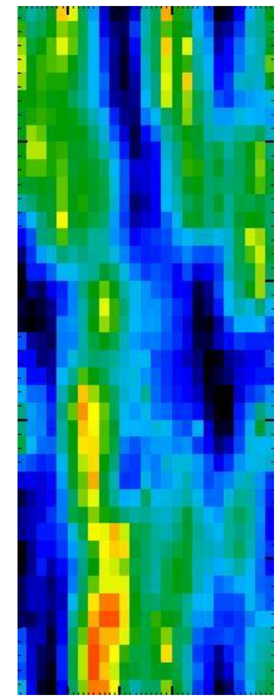
Sampling Errors



Digline Optimization

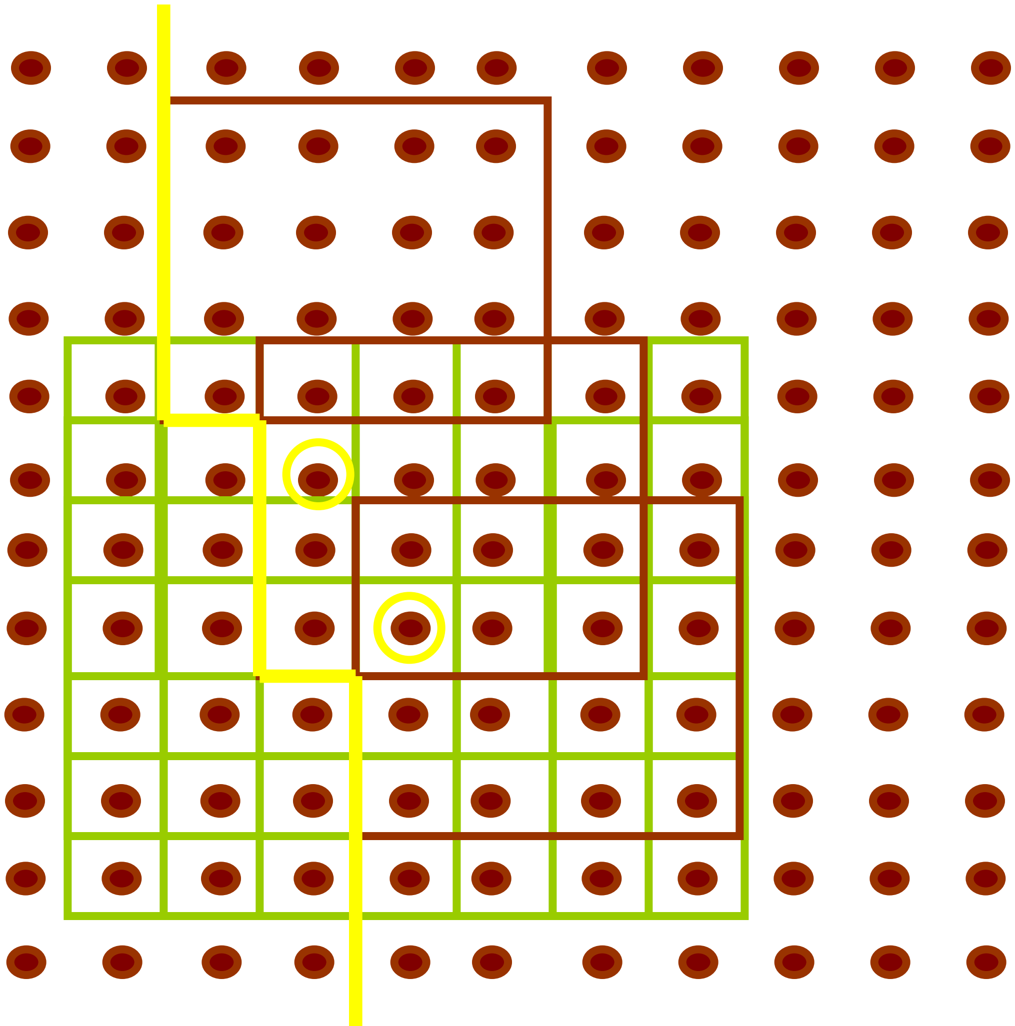


Blasting

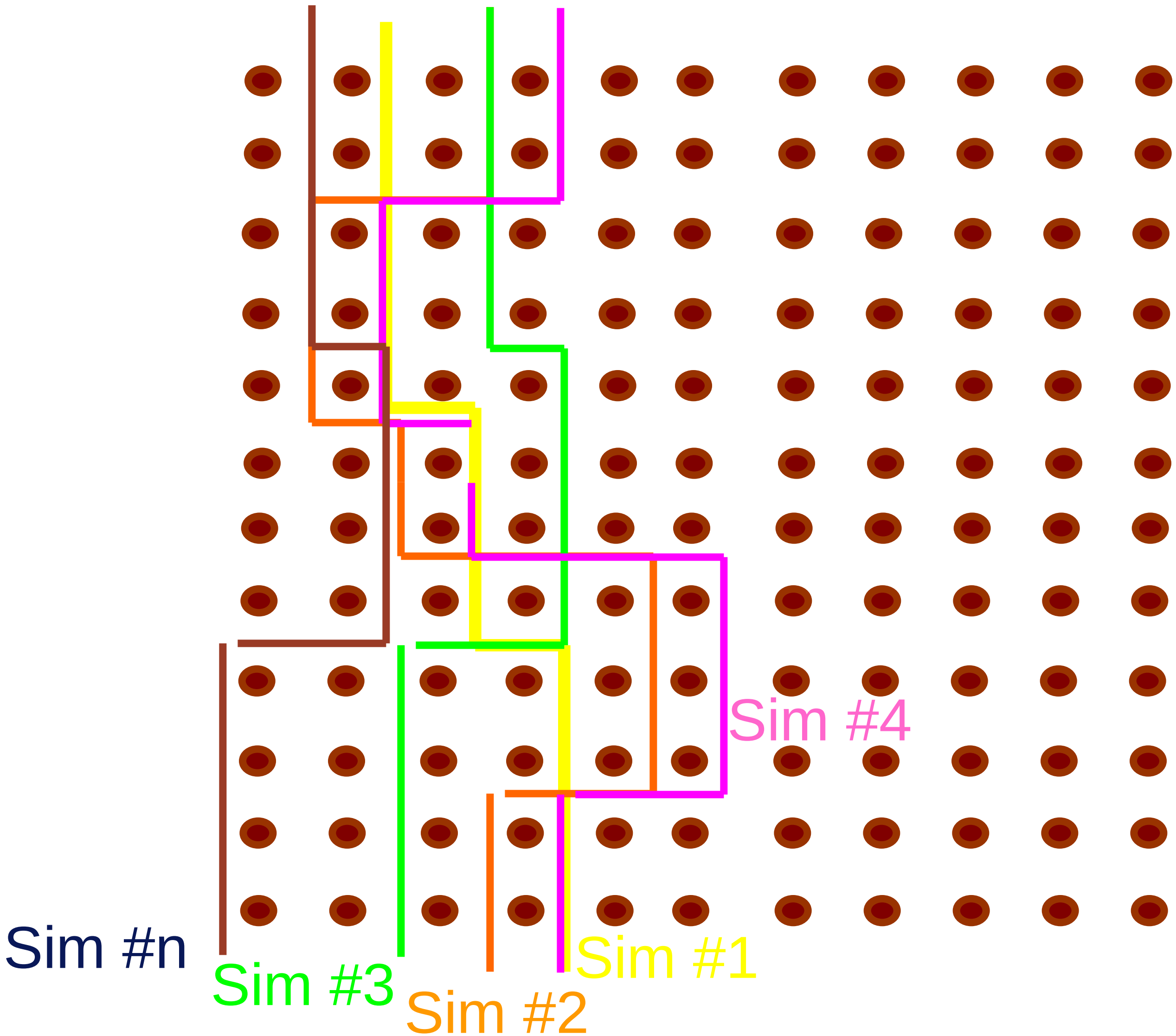


CoM produces recoverable resource models of tonnes and grade which can be used to assess risk.

Dig-line optimization

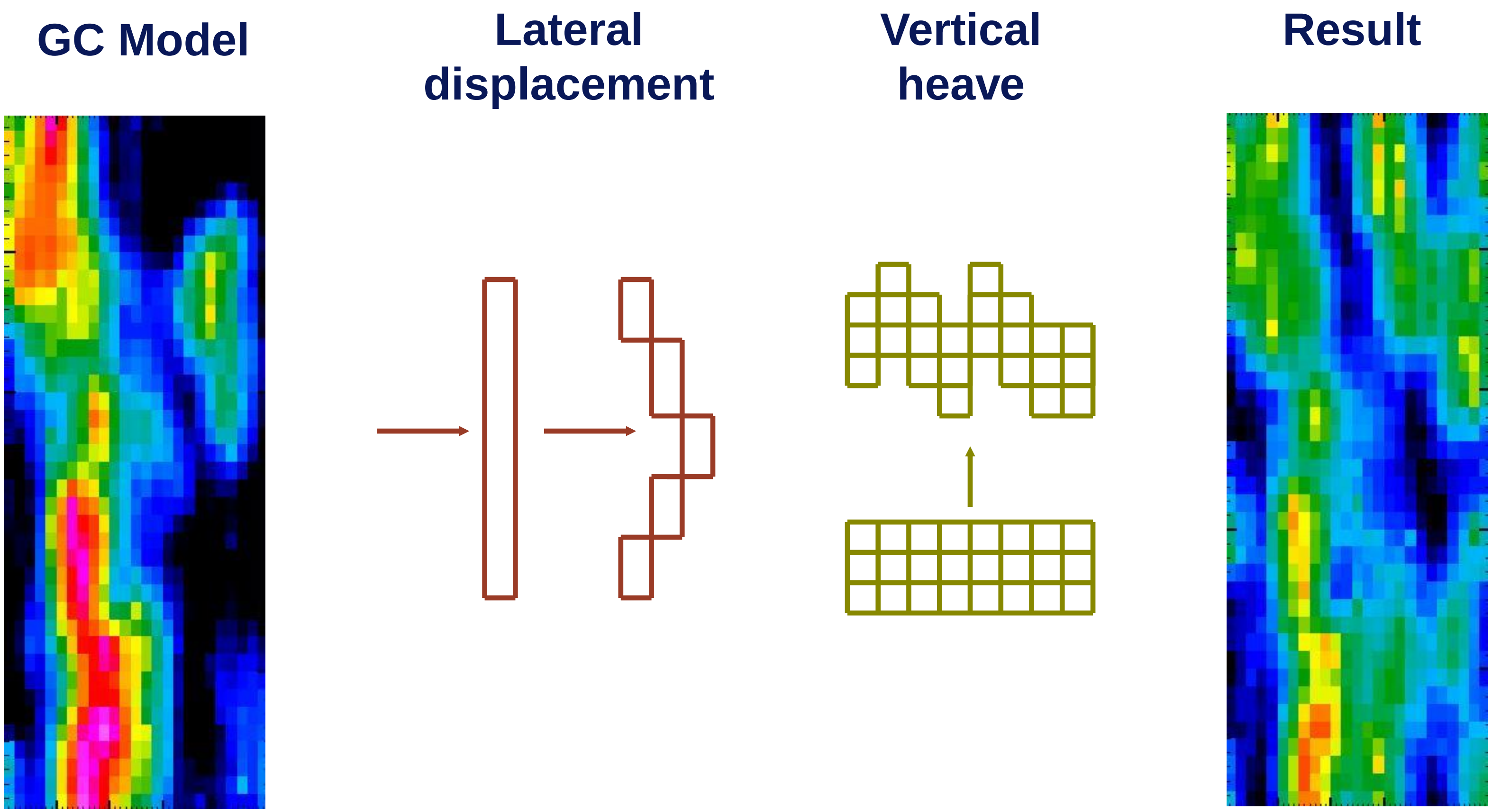


Dig-line optimization



Collection of boundaries produce probability of boundary of mining

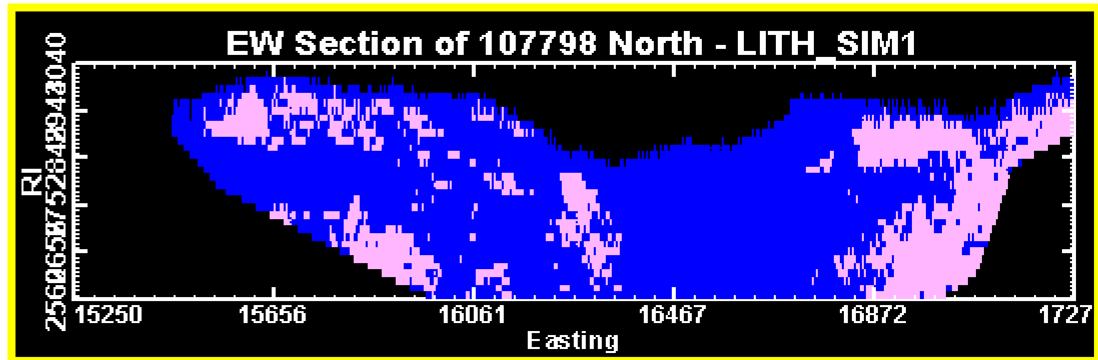
Modelling the impact of blasting

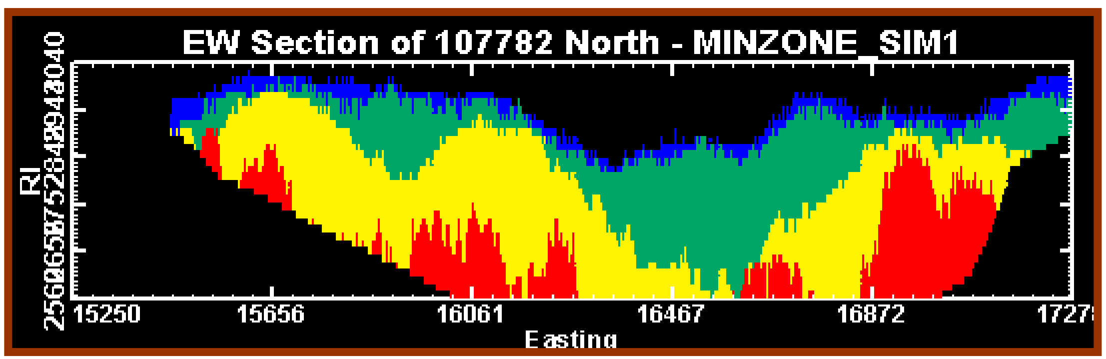


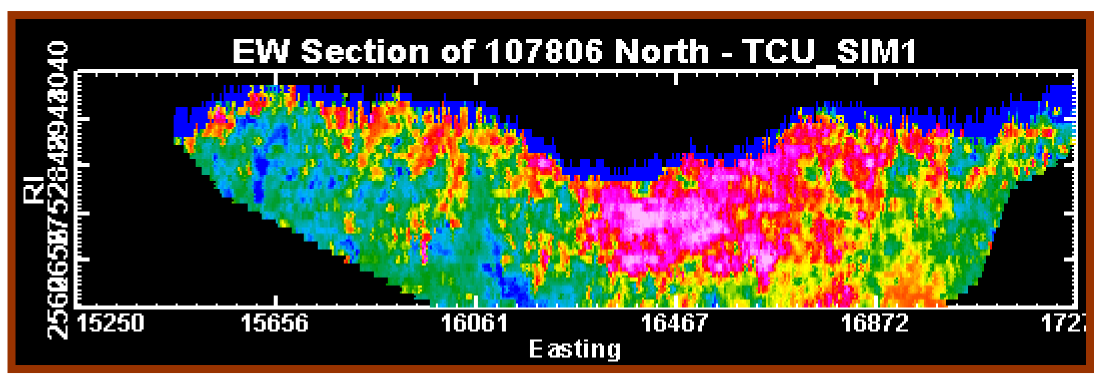
Case Study: Escondida

Khosrowshahi, S., Shaw, W.J. and Yeates, G., 2005, Quantification of risk using simulation of the Chain of Mining - a case study on Escondida Copper.

Simulated models

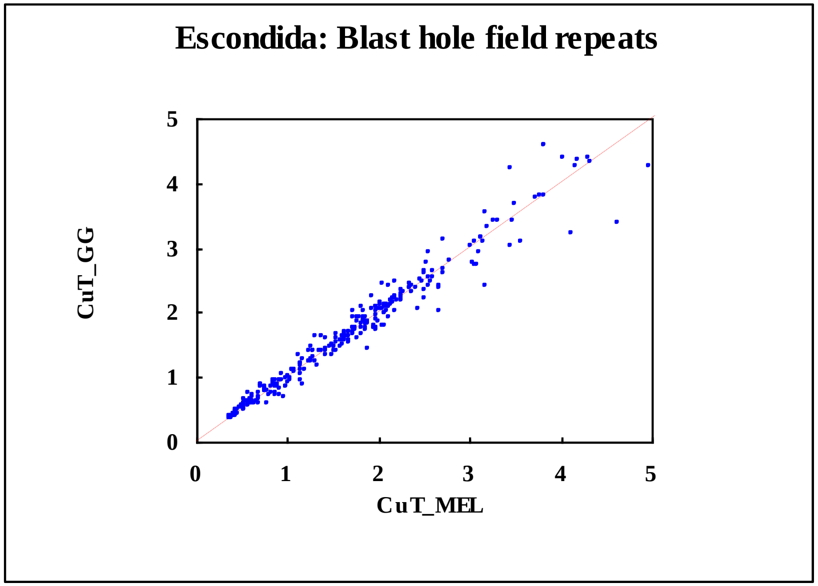






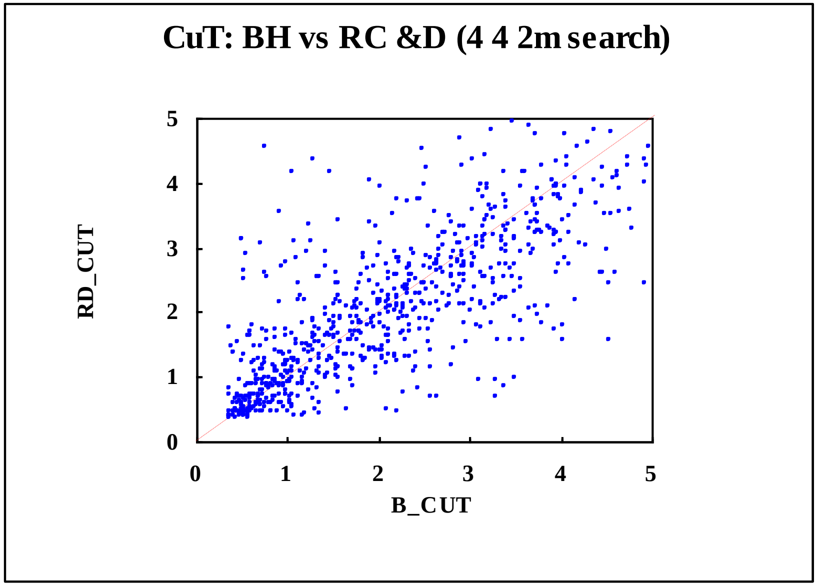
Sampling error

Low sampling and assaying precision error



Precision of 9.2% demonstrated by 289 field repeats

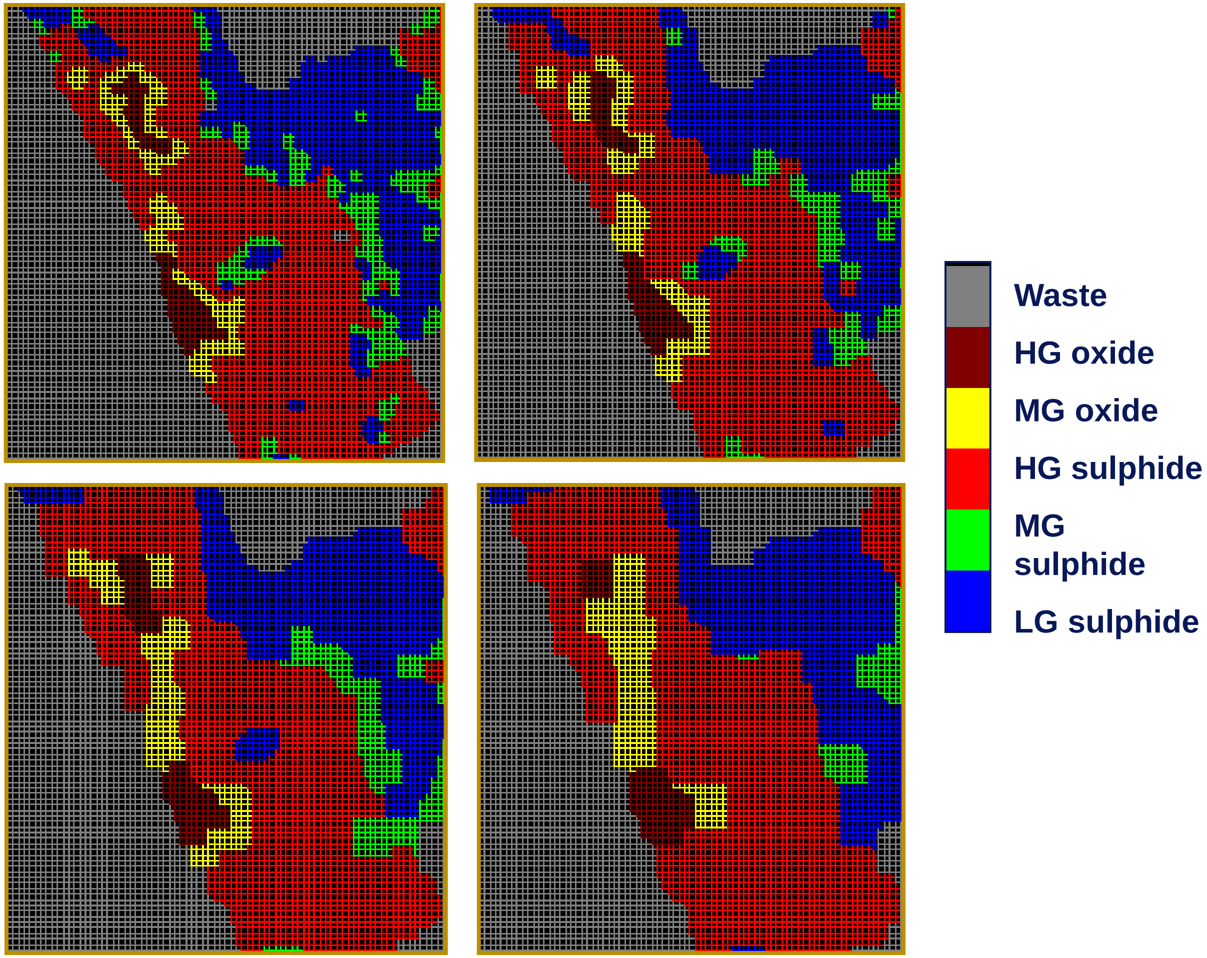
High sampling and assaying precision error



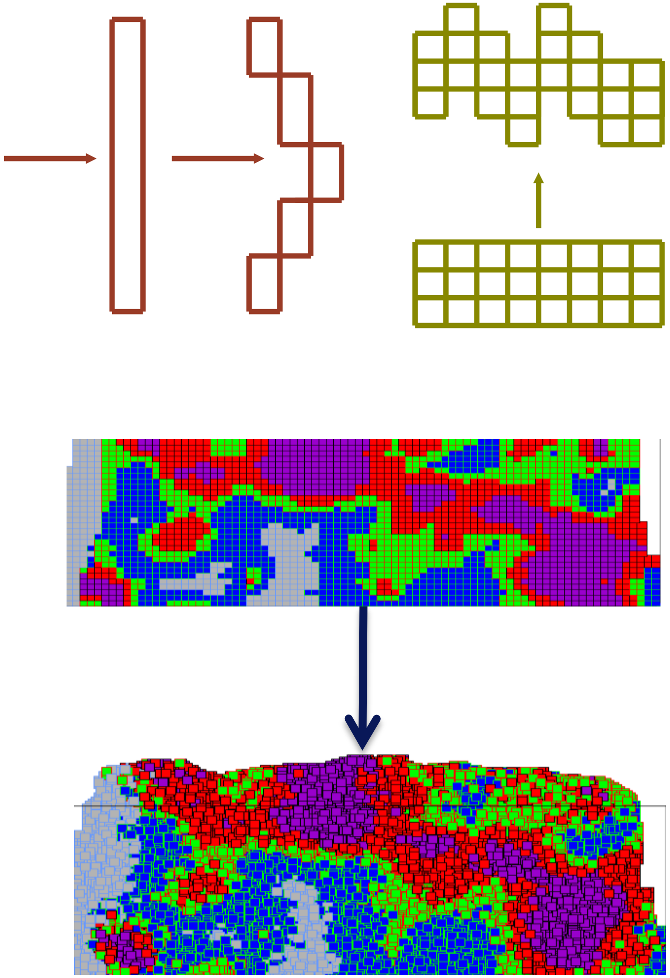
Precision of 40.9% demonstrated by 633 paired Blast Hole and Resource Hole samples

Mining Selectivity

Impact of different selectivity on digline optimization

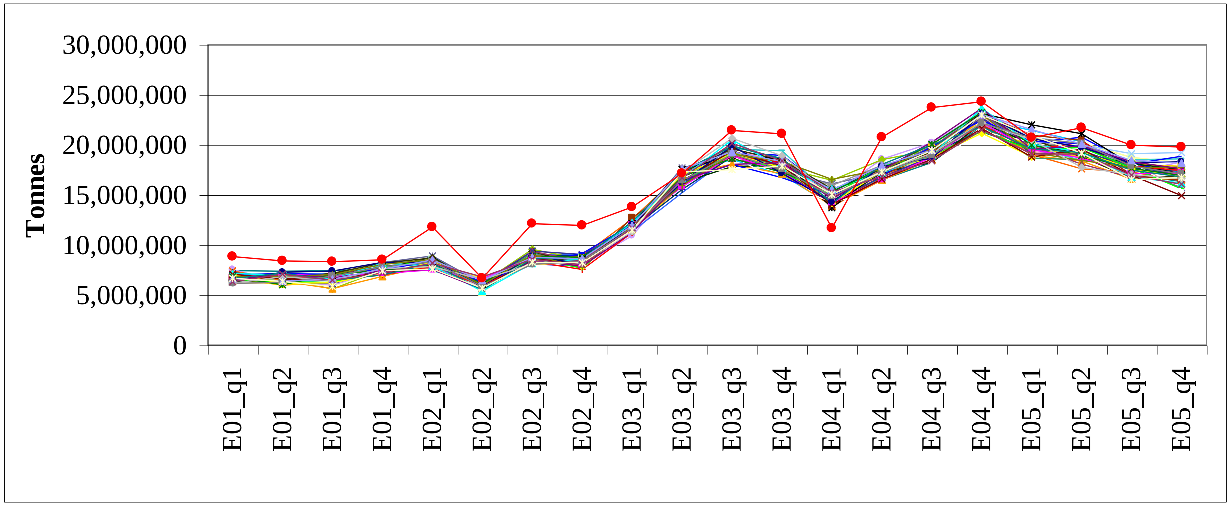


Blast movement modeling



Results

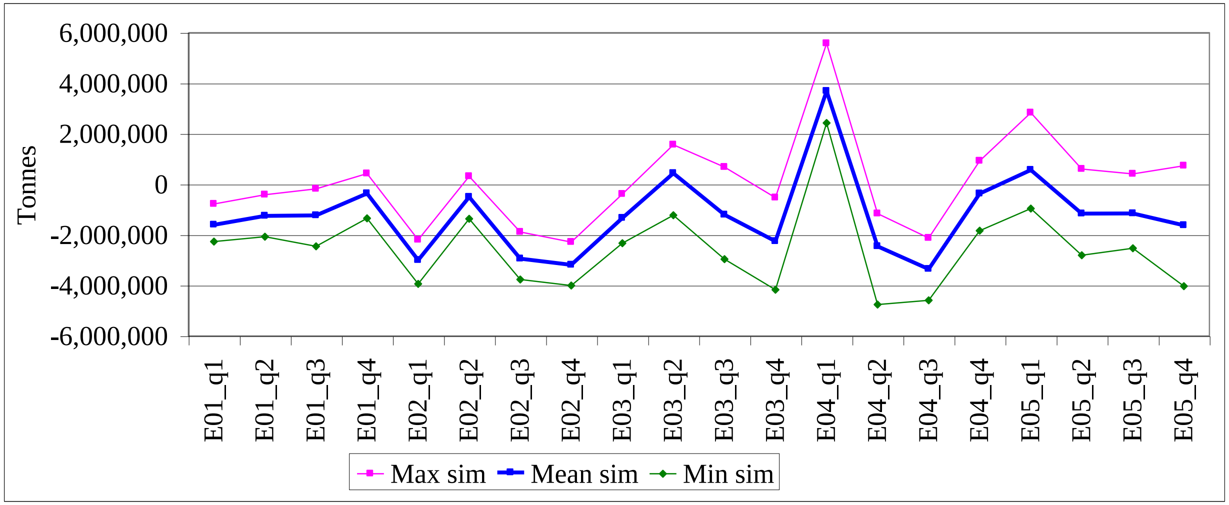
Analysis of risk for Tonnes by Quarters for 5 year plan



CoM case:

8 x 8 m

High Sampling error



Conclusions

A robust reconciliation system enables:

- The total mining operation to be seen in context
- Major problems and sources of error to be identified
- Both underestimation and overestimation to be critically monitored improvements to be tested and evaluated
- Reporting to management and communication to shareholders to be clear and consistent

Conclusions

The Chain of Mining method…

- Is a uncertainty based method to evaluate recoverable reserves and production expectations
- Allows for reliable predictions of mining outcomes
- Provides estimates that include the impact of ore control and mining practices
- Implicitly uses local orebody morphology to define ore loss and dilution