Stress testing mine plans

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Do you have this problem?

- **Uncertain commodity prices**
- **Increasing operating costs**
- **Uncertain capital costs**
- **Plant not performing to expectations**
- **Grades not as predicted by block model**

What should I do?

mineplanning 2009 Mine Planning Workshop
November 19→20, 2009. Torremayor Hotel, Santiago, Chile.

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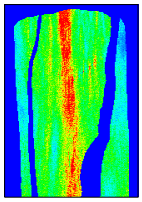
Carry on as normal!

Smoothed Ore Body Model

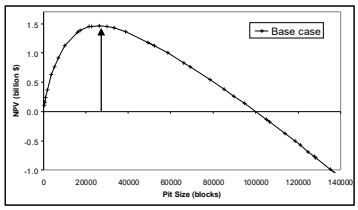


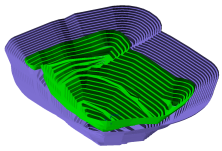
Open Pit Optimiser

$1.3/lb Cu
80% recovery
$2.5/t mining cost
$8.50/t processing

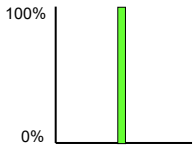
Assume fixed costs and prices

Find the maximum NPV pit for a fixed discount rate eg 10%





Design + schedule



Expected NPV

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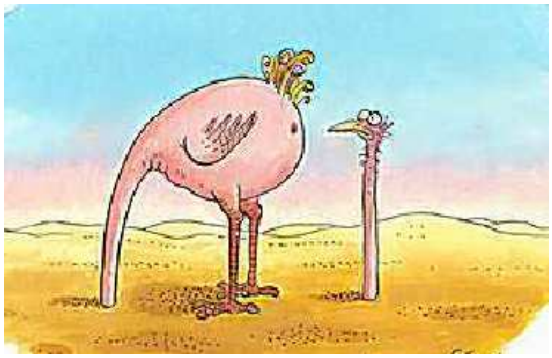
In other words…



Bury your head in the sand and hope for the best!

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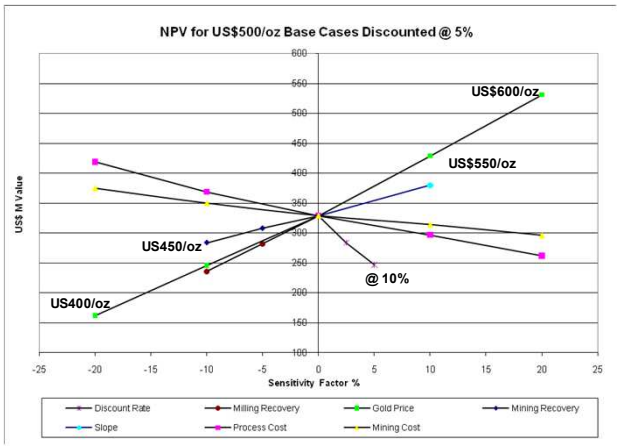
Sensitivity Plots



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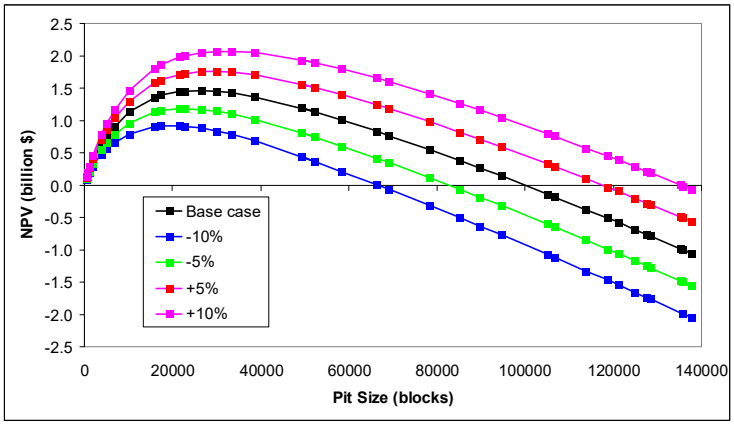
Sensitivity to Metal Prices



NPV of nested pits with alternate fixed metal prices

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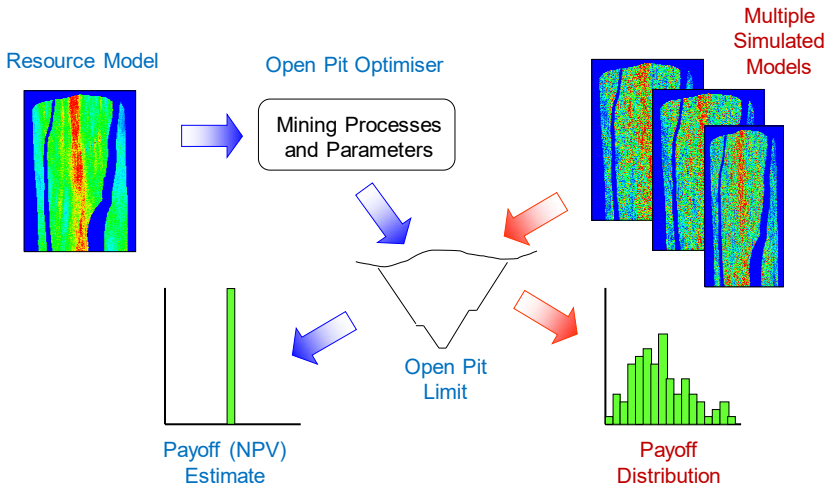
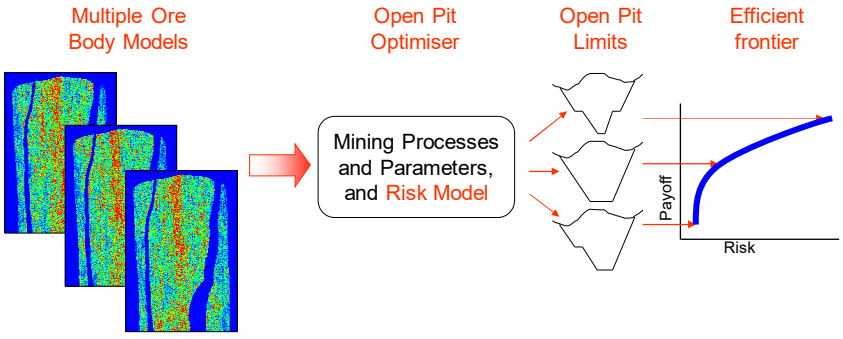
Traditional Open Pit Risk Analysis with Simulations

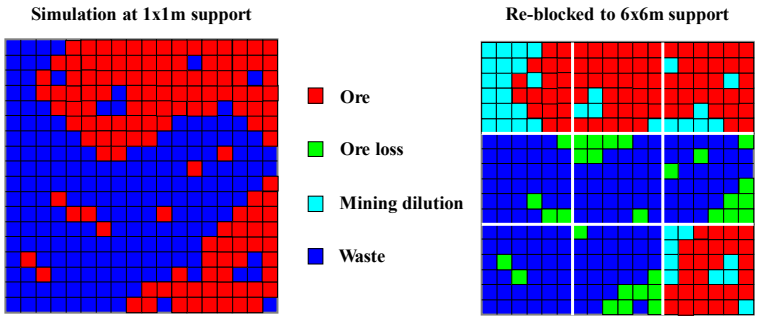


Incorporating CS + risk models



The efficient frontier provides the best possible trade-off between expected payoff (NPV) and downside financial risk

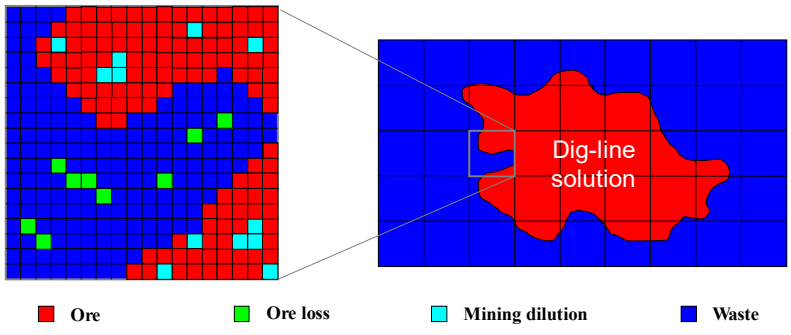
Re-blocking Simulations to Mining Support



Re-blocking to SMU dimensions may introduce significant ore loss and mining dilution

Re-blocking using dig-lines

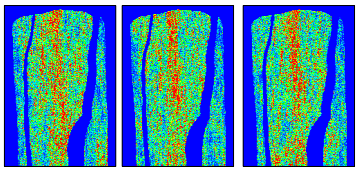
Explicitly Consider Equipment Constraints



Incorporates local ore loss and mining dilution for any block dimension

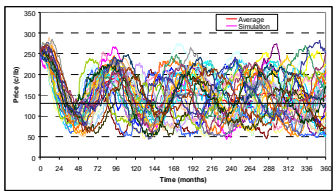
How do we account for...?

Multiple Ore Body Models



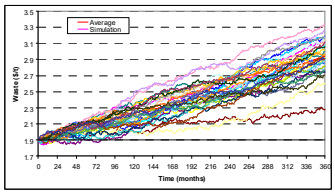
Equally probable with true spatial variability

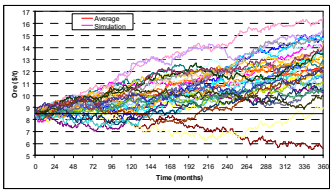
Possible Cu prices over 30 years



Start with today's price and allow for mining cycles with mean reversion to $1.30/lb

Mining and processing costs that grow over time





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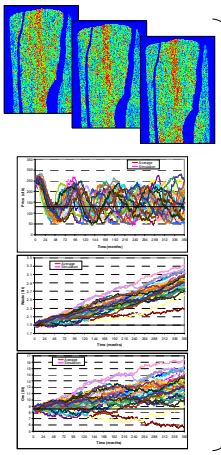
Proposed framework

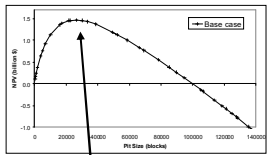
Probabilistic Models

Open Pit Optimiser

Open Pit Limit(s)



Mining Processes and Parameters, and Scheduler



Still the maximum NPV pit?

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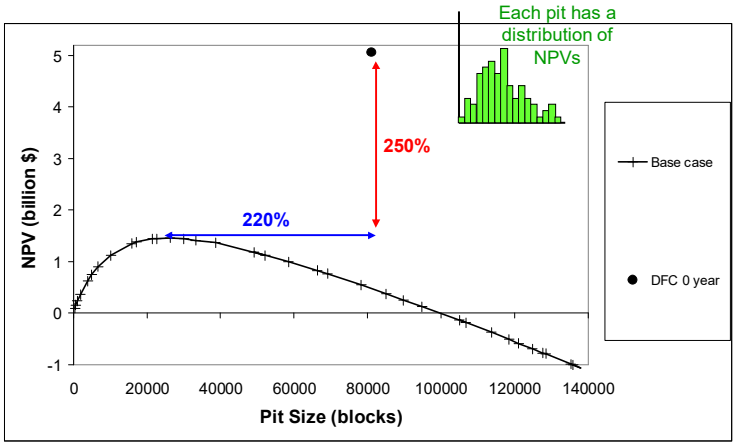
Direct NPV result



As the scheduler is embedded in DFC, then it is a 1 step process to find the maximum NPV pit

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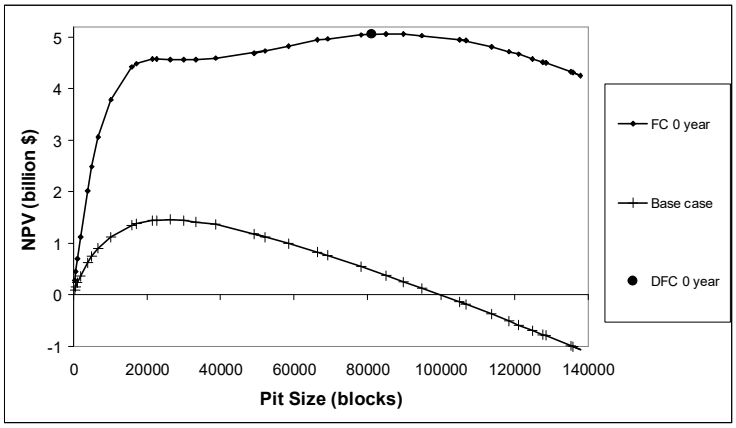
Direct NPV result



The nested pits can be post processed with the same probabilistic models

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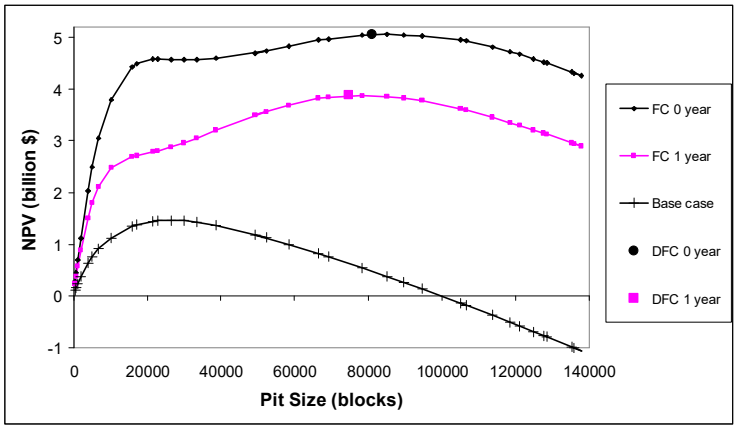
Direct NPV – 1 Year delay



Time dependent variables permit investigations of alternate investment timings

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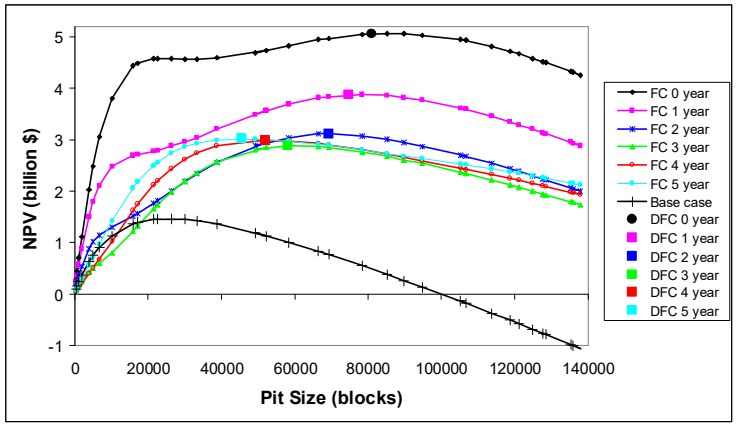
Direct NPV – 1-5 Year delays



Should we delay investment?

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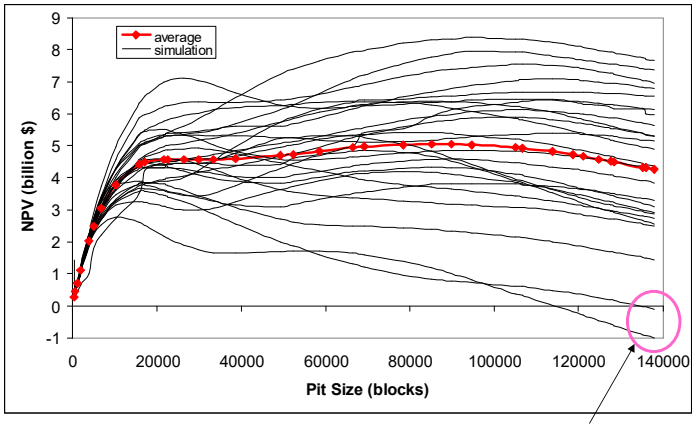
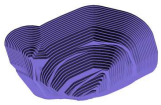
Is the downside risk acceptable?

Results of 25 simulations of possible grade models, commodity prices, mining and processing costs, metallurgical recovery on a series of nested pits

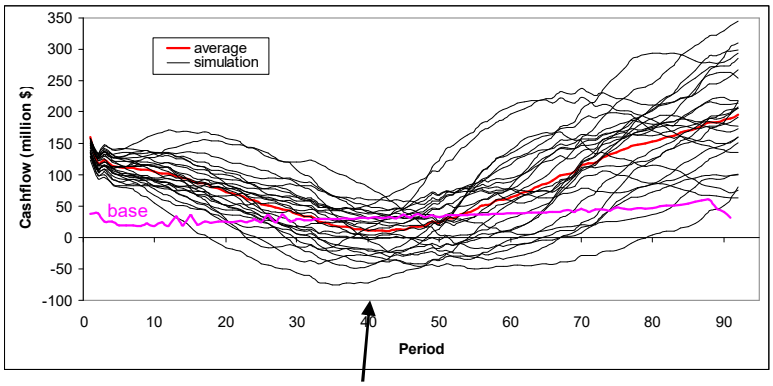


8% chance of –ve NPV

Stress test your mine plan!



Possible financial outcomes for each period using Monte Carlo simulation techniques



Should we forward sell, plan for a shutdown or change the mine plan to avoid potential losses?

The future?

All uncertainties need to be modeled stochastically

- Geology
- Grades
- Commodity prices
- Mining and processing costs
- Recovery (geometallurgy)
- Mining cycle
- Discount rate
- Capital costs
- Exchange rates
- Throughput (geometallurgy)
- Dilution and ore loss
- Smelter costs
- etc

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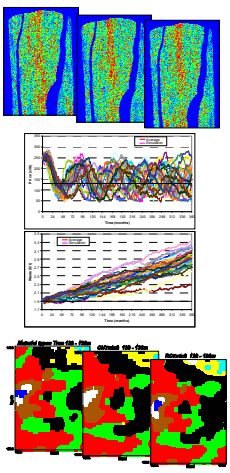
Possible future framework?

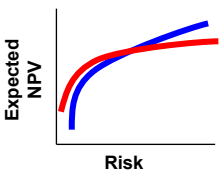
Probabilistic Models



Open Pit Optimiser

Mining Processes and Parameters, Scheduler, Capital Constraints and Risk Model

Open Pit Limits



Best pit to account for uncertainties, capital constraints, and risk tolerance

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