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# **ECONOMIC CHANGE AND PIT DESIGN**

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## **ABSTRACT**

Utilising Whittle Four-D software a selection of cases can be optimized to define the physical extent for the base, optimistic and pessimistic pits in a changing economic world. Setting ranges rather than single values for each of the parameters required will allow for easy definition of the possible scenarios. Identifying the 'stable' and 'unstable' wall segments within the pits will then allow a flexible pit design to be formulated. Subsequent scheduling of the various scenarios can be evaluated and implemented if there is a change in the economic conditions affecting the mining operations.

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## **INTRODUCTION**

"Nothing is more certain than change", a common quotation, well known to the mining industry.

How does a company cope with changing conditions? Management styles have changed dramatically to accommodate changes in strategies and economic conditions. Pits are seen to be static in design and incapable of rapid change. This leaves the miner in a position where, once the pit has started, he is committed to follow the excavation schedule. Minor variations are possible within the designed pit, for example by changing the cut-off grade, mill feed tonnes can be increased or decreased. Profits consequently fluctuate as prices vary. If we could predict the future, than pits could be designed to optimize that economic window current for the pit life. However, predicted metal futures tend to be erratic in their accuracy. Commonly, corporations explain their varying fortunes on the changing metal prices, hoping that next year the tables will turn and this year profits will be recouped.

Ideally, a pit design that could incorporate changes to suit the economic climate would be better than a static one.

We recognise the problem, what is a possible solution?

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### IDENTIFYING THE STAGES

The following sequence is suggested as an approach to allow for more flexible pit designs.

- 1) Define a range of values to each variable used during the pit optimization, notably the variables producing the greatest differences in results.
- 2) Select the current base case and also the most optimistic and pessimistic case values for three optimization runs.
- 3) Run the three optimizations.
- 4) Check the resulting pit shells against the geological model for inconsistencies.
- 5) Where required, rectify the parameters to the optimization or the block model and re-run the optimization.
- 6) Identify the 'Stable' and 'Unstable' sectors of the pit walls.
- 7) Design the pit and possible cutbacks or contractions that may be required to take advantage of a change in the economic climate.
- 8) Schedule the pit for today's economic scenario, and also develop alternative schedules if the pit has to be expanded or contracted.

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### DEFINING THE RANGES

Whittle Four-D uses many parameters to assist in defining the final 'optimum' pit. It is advantageous to discuss a check list of the various parameters so as to identify the range of values that maybe applicable.

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### THE ORE BODY MODEL

#### • BLOCK MODEL

Critical to a good optimization is the ore body model that is to be used. Defining the correct spatial relationship of the mineralisation is the skill of the interpreter and can dramatically influence the shape and depth of the resulting pit. If an alternative interpretation is possible it may be useful to optimize both and identify areas where the pits are concurrent. This may allow a test pit to be designed that will assist confirmation of one of the interpretations.

- **ORE**

Consideration in classifying the ore types should be given to metallurgical characteristics, penalty elements present, mining habits, statutory requirements, geological and geostatistical subdivisions. All contribute to the correct valuation of the parcel during optimization.

- **WASTE**

Bulk densities need to be correctly assigned to the block model as the waste is the largest volume to be mined and as such has a direct impact on the costs, which are calculated as unit tonnage costs in the Whittle optimization. Defining differing waste categories ( such as 'Scraper Dirt' or 'Free Dig') will assist in allocating specific costs rather than using a global value.

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## MINING

- **PIT WALLS**

Geotechnical consideration of the batter angles, batter heights, berm widths and haulage road widths will influence the overall pit slope angle and affect the amount of waste to be removed. Selecting a maximum and minimum configuration of potential wall slopes will influence the overall profits from a pit. If steeper slope angles are used then a possible 'catastrophe cost to rectify pit wall failure' may be worthwhile to consider. It may be cheaper to have steeper walls and allow for wall failures, as clean-up costs and mill feed delays, than to excavate the larger volume. 'In wall ramps' as declines parallel to the pit wall with regular entry points into the pit also have advantages and could be used as an alternative scenario.

- **MINING DILUTION AND RECOVERY**

Selecting the correct equipment for excavation of the ore body to complement the style of mineralisation will directly affect the mining dilution and recoveries. Several approaches are possible to allow for dilution and mining recovery by the optimization. 'Dilution skins' can be applied during the ore body modelling stage. However this assumes that the mining characteristics of the ore body are known. Whittle allows a global value to be applied to add dilution and subtract extraction losses. This implies that the ore body has a regular geometry and all styles of mineralisation present have similar mining characteristics. Ore body characteristics related to contact style, attitude and geometry should be weighted against the mining equipment's adaptability, bench heights and excavation orientation to determine the range of dilution and extraction loss values

- **MINING RATE**

Extraction rates will be determined by equipment selection which will influence the time required to complete the excavation to be matched against the processing rate for an overall scheduled subsequent Net Present Value (NPV) resulting from the operation. Ore body configuration and mill requirements often determine the equipment and subsequent cost flow-on. However, consideration of the equipment size and subsequent extraction rate, dilution, and extraction losses against a change in NPV may also influence the choice of equipment.

**• COSTS**

Determining a range of unit mining cost values to reflect the changes in ground conditions, equipment size and excavation rates can readily be set-up on a spread sheet and evaluated. Selecting the current base, then the most pessimistic and optimistic cases as inputs to the optimization, will define the limits of possible economic changes.

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**PROCESSING**

Processing costs include all costs associated with 'Ore', which not only include the treatment costs for different ore types but also specific mining tasks related to its extraction, administration and time costs if applicable. The processing method, costs, recoveries and rates can all be estimated for the three cases. Alternative methods using different technology or scaling up the operation should not be excluded and can be part of the most optimistic scenario.

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**FINANCIAL**

Financial modelling of the operation needs to have as much emphasis as the geological model. Both influence the final shape of the optimum pit and resulting cashflows produced from the operation.

**• PRICE**

Establishing the range of potential prices can be disheartening, as expert opinions can vary widely. However as we are trying to establish ranges for the various scenarios ( current, pessimistic and optimistic cases ) a spread of values has a distinct advantage over a single estimate. Four-D handles price variation easily by setting up the MCostM values which are to be used for the optimization and analysis.

**• DISCOUNT**

Similar to fluctuations in price, forecasts of discount rates can vary widely. By establishing ranges, the various cases can be evaluated and the appropriate pit shells extracted from the results file.

**• COSTS**

Costs for mining and processing have been discussed and the ranges for each can be set up as alternative scenarios.

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**RUNNING THE OPTIMIZATION**

Establishing the economic ranges rather than individual values for each of the critical parameters in the optimization process establishes the potential extent of the changing economic world. History, experience, or a range of expert opinions can all assist in establishing this frame of reference. We are more likely to be within the ranges than to be correct on a single set of criteria.

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From the preceding work a table can be generated with all the ranges of values.

Creating the tabulation of the parameters and values.

| Interpretation      | Model A | Model B                         |             |
|---------------------|---------|---------------------------------|-------------|
| Pit Slopes          | Model 1 | Model 2 ( include catastrophes) |             |
| Price               | Base    | Optimistic                      | Pessimistic |
| Cost Mining         | Base    | Optimistic                      | Pessimistic |
| Cost Processing     | Base    | Optimistic                      | Pessimistic |
| Dilution            | Value 1 | Value 2                         | Value 3     |
| Mining Recovery     | Value 1 | Value 2                         | Value 3     |
| Processing Recovery | Value 1 | Value 2                         | Value 3     |

A set of values can now be selected to run the optimizations for the base, optimistic and pessimistic cases and each of these can also have a 'worst', 'best' and 'scheduled' case generated from the results file. Utilising Whittle Four-D, either all scenarios can be run and evaluated to define optimum pits for each scenario, or just the three cases ( base, optimistic and pessimistic ) can be run to allow a rapid evaluation. Selecting the largest and smallest of the optimized pit shells will identify the physical extent of the parameter values used and hopefully the real world. Further assistance can be from the FDUT programme which gives statistics on individual shells and pits.

Selected pit shells can now be extracted from the results file and imported back into the general mining package for further work.

### CHECKING THE OPTIMIZED PIT SHELLS

Optimization can only evaluate the information supplied and not make any judgement as to the validity of the data, so it is important to check the output shells after the optimization. Following are common faults to be checked.

Crating is the feature where the pit is 'sucked' down to a single block, which invariably is a high grade interval in a drill hole. The validity of the high grade intersection must be investigated. Depending on the modelling technique the data might not be correctly represented and should be corrected in the block model.

Pit base orientation should be checked so that it reflects the correct strike of the ore body. It has been noted during multiple cases studies that an incorrect model interpretation is reflected in the optimum pit output by having a series of craters instead of a continuous basal zone.

Orientation of the major walls should be parallel to the dominant regional foliation. If the pit walls cut across the dominant regional foliation, instability in the pit walls occurs and wall failure can be expected. Re-orientating the pit wall to be parallel and convex to this direction will aid stability to the pit.

Exploration drilling is often designed to intersect the mineralisation, and not check the footwall of the ore zone. Geological contacts and structures that may be in the pit wall on the footwall side should be investigated. Commonly the ramp is on the footwall side of the mineralisation which is the least known geologically and can be a source of problems.

If problems are identified then they need to be corrected before proceeding to the selection of the pits.

### **IDENTIFYING THE 'STABLE' AND 'UNSTABLE' SECTORS OF THE PITS**

As most 'ore bodies' are not homogeneous there tends to be a clustering of pits that have common boundaries. It is this tendency to form clusters that can be used to identify and design logical cut-backs which can be utilised when there is a change in the economic climate. Generally pits tend to be nested asymmetrically with common or near common boundaries, which is to our advantage.

Common or nearly common walls can be identified and used as 'stable' final walls or interim walls in a pit design. This approach allows the following features to be identified and used during the actual pit design.

1. Exit position of the final ramp.
2. Basal position of the final ramp.

Experience has demonstrated that it is advisable to commence a pit design at a level above the final floor. This will allow for some adjustment in the basal portion of the pit after the 'ore body' is better understood ( generally the final pit base in the optimization is a crater formed by a high grade value ), although a temporary design has to be included in the initial design phase.

3. Take off positions for cut-backs or contractions occur with the 'unstable' sectors and can be of two types:

Staged cut-backs as part of the base case ( to approach the 'Best' case NPV )

Economic cut-backs which would become effective with a change in the economics of the pit. Strategic design of the pit to allow for expansion or contraction should be incorporated into the ramp layout and identification of wall segments that will be stable for the entire pit life or form part of an interim wall.

Approaching the pit design with the aim of 'planning for change', rather than this being the 'final design', will identify features which influence the expansion or contraction of the pit.

### **SCHEDULING THE PIT**

Utilising the 'Pit List' facility in FDRB which export and import of individually designed pits to be converted into result files, a custom made design can be converted into a results file for further analysis in FDAN. This will allow the 'base case pit' as well as the optimistic and pessimistic pits to be given individual 'shell numbers' which can then be used during further analysis.

## CONCLUSION

Using ranges of values for the various parameters required for pit optimization will allow the identification of a base, optimistic and pessimistic economic scenario. Optimizing the three cases using Four-D and importing the results back into the general mining package will identify the physical extent for the various pits. Identifying the 'stable' and 'unstable' wall segments will assist in formulating a flexible pit design which can be implemented if there is a change in the economic conditions affecting the mining operation.

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