ADDING $MILLIONS TO MINE VALUES

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ABSTRACT

Two of the most powerful tools available to our industry have been used to show how multi-million dollar improvements can be made to mine values. Whittle Programming's FOUR-D pit optimization software and RTZ's OGRE (Optimal Grades For Resource Exploitation) basically show us how to mine smart. A common basis for these optimizers is to take advantage of the time value of money; thereafter each package addresses unique cost and revenue issues.

FOUR-D is able to calculate the best size of pit as costs or revenues change. This package calculates a marginal cutoff but does not address the advantages of optimizing the cutoff grades or of stockpiling low grade material. It is considered that the FOUR-D optimum pit provides the fundamental outline within which we must mine smart.

OGRE is able to calculate optimal grades for resource exploitation by indicating the best possible NPV for a defined resource. It does not address the fact that as parameters change, so should the pit size. For any defined reserve inside an optimized pit with a reasonable life span, say more than 4 years, it is considered that OGRE can show how best to mine smart by adopting optimal cutoff grade and stockpiling policies.

Studies show that by taking advantage of the important synergism between these two optimizing packages, the value of mining operations can be improved by tens of millions of dollars. Some real case examples are given here.

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OGRE

• INTRODUCTION

OGRE determines a cutoff and stockpiling policy based on the maximization of the present value of a defined ore reserve. To achieve this, the program applies two basic principles.

The first principal is that at any time in the mine life the cutoff grade is determined by current and future:

- grade distribution of the reserve (a reserve with a larger proportion of low grade ore relative to high grade ore may dictate lower cutoffs in the early stages of mining and vice versa);
- capacities of the processing stages;
- mining, milling and marketing costs and
- product price.

The second principle is the use of time discounting of money or Net Present Value (NPV) as a basis for comparing different circumstances. The optimum is the cutoff grade combination which returns the highest NPV.

An important consideration in the determination of cutoff grade is the 'opportunity cost' of mining. Here OGRE assesses the cost of mining and milling higher grade ore at the expense of lower grade which may overlie the higher grade material. This may suggest stockpiling of lower grade material. Optimum policies can be determined for a range of conditions including varying price, costs, recoveries, mine, mill and market capacities, stockpiling and other financial considerations. OGRE presents itself as a powerful tool in the evaluation of different planning strategies and early feasibility planning.

• ASSUMPTIONS

To best illustrate the use of OGRE as a planning tool in determining cut-off grade, optimum throughput and stockpile policy, a simple example is used. Consider an operation defined by the following parameters:

- **Ore reserve grade/tonnage relationship**

In this simple example only one block has been used to define the entire reserve. To achieve greater accuracy it is possible to break reserves into as many as 50 blocks, each with their own grade/tonnage relationship. Individual blocks may represent annual plans or individual benches of a planned pit. Ore reserves data in this format allows the effect of varying cut-off grades on the tonnage of ore and feed grade to be determined.

GRADE TONNAGE RELATIONSHIP			
From g/t	To g/t	Tonnes (millions)	Grade g/t
0.00	0.50	46.5	0.00
0.50	0.75	0.76	0.69
0.75	1.00	0.66	0.82
1.00	1.25	0.65	1.16
1.25	1.50	0.53	1.31
	>1.50	3.69	3.12

- **Variable costs**

  Mining$1.00/t
  Processing $12.00/t
  Rehandle $1.00/t

- **Fixed costs ($millions)**

	Y1	Y2	Y3	Y4	Y5	Y6
Admin	3.25	3.20	3.20	3.15	3.05	3.05
Capital	0.75	0.75	0.75	0.80	0.80	0.80

Variable costs are kept constant over the life of the mine while fixed costs have been varied with respect to time. OGRE allows all costs to be declared as constant or variable with respect to time.

- **Price and recovery**

  $575/oz gold, 90% recovery

• CUT OFF ANALYSIS

Results of an analysis of the optimum cut-off policy using OGRE are shown in Figure 1. Implementing a declining cut-off policy from 1.2 g/t to 0.9 g/t results in the best NPV. This example assumes no stockpiling takes place and presents rationalisation for 'highgrading' operations in the early stages of mining and argues for treating stockpiles later. The value of implementing such policies is calculated.

Informed boards of mining companies could now sell this idea on to informed shareholders. We recognise the difficulty in persuading owners to accept lower ounces produced per annum as mine life extends.

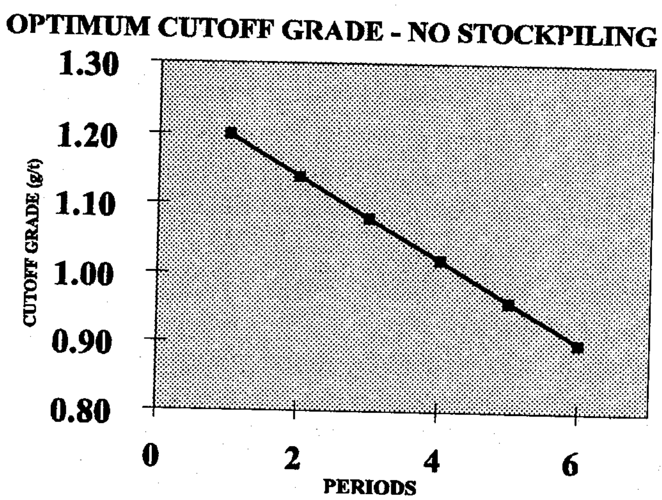

Figure 1

• THROUGHPUT ANALYSIS

In another example, assuming fixed mill capacities of 0.25 mtpa, 0.5 mpta, 1.0 mpta and 1.5 mpta, a range of production capacities has been examined. These are determined by the size of appropriate mining equipment along with the impact upon NPV of the rates of mining. Optimal cut-off grades are used but no stockpiles are kept . Figure 2 refers. For each of the four ore processing rates, different total movement mining capacities are analysed. This means that at times the mill will be constrained and unable to proceed while waste is being mined. At other times waste mining will be reduced since ore will be abundant.

The advantages of greater throughput are clearly evident, with initial changes in both plant and pit capacities yielding significant changes to NPV. These improvements reduce as capacities are further increased and mine life is shortened to a point where the time value of money has little influence.

Although the NPV continues to improve with the increasing scale of the operation, risk and the 'law of diminishing returns' become dominant factors in the decision-making process. The optimum pit/mill capacity becomes a trade-off between financial exposure and the logistics involved with moving larger volumes and the economic benefits to be gained.

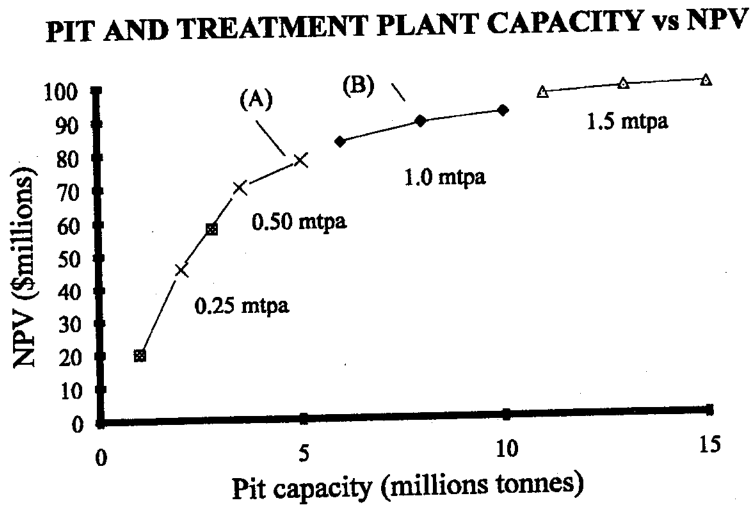

Figure 2

In this example, the option to mine and mill ore using a pit/plant capacity of 5 mpta and 0.5 mpta respectively (Case A) or to increase capacities to 10 mpta and 1.0 mpta respectively (Case B) has been considered. An additional capital expenditure of $15 million is also assumed. In the first case, assuming no stockpiling is carried out, the throughput will result in an NPV of $78 million.

The second option results in an NPV of $92 million, representing an improvement in NPV of $14 million. If additional capital costs associated with the expansion are $15 million, the latter option is economically not viable. However, if capital costs were $12 million dollars, then a decision must be made as to whether the increased financial exposure is offset by the increased value of the project.

- **STOCKPILE ANALYSIS**

The optimum cut-off grade policy indicates a general decline in cut-off grades throughout the life of the mine. It is evident that treating higher grades in the earlier years and deferring lower grades until the latter years will improve the value of a mining project. As a result, the material which lies between the highest cutover grade and lowest cut-off grades clearly lends itself to being stockpiled and processed later. The result is a further improvement in the value of the project.

To illustrate the concept of improving values by stockpiling, consider a project with a pit capacity of 11 mtpa and a mill throughput of 1.0 mtpa without stockpiling. The value of the project is $96 million. Figure 3 refers.

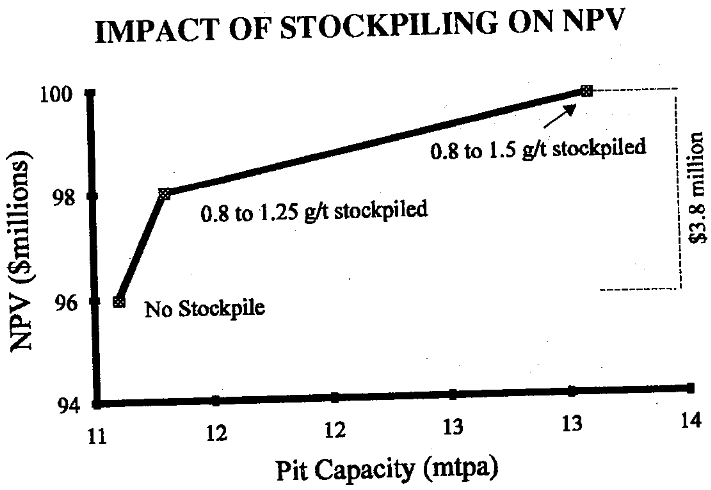

Figure 3

Consider two stockpiling options:

- Cut-off at 0.8 g/t with cut-over at 1.25 g/t (stockpile 0.8 g/t to 1.25 g/t)
- Cut-off at 0.8 g/t with cut-over at 1.50 g/t (stockpile 0.8 g/t to 1.50 g/t)

Ore above the cut-over is sent directly to the mill where all costs and revenues are calculated. The cost of mining material above the cut-off but below the cut-over is calculated to determine the cashflow for the period. Rehandling of the stockpiles occurs once all the reserves have been mined unless the ore production is constrained by waste. Then the stockpile is treated. Stockpile cashflows are calculated based on rehandle and processing costs and an NPV is calculated using the appropriate discount rate. Figure 3 shows that the NPV of the project can be improved by $3.6 million if the right stockpile policy is employed.

In this instance one stockpile only is examined. However, it is possible to consider up to four stockpiles at different cutovers and this may be appropriate for larger mines. In addition, start-up balances with a stockpile can be analysed in conjunction with reserves.

FOUR-D

• INTRODUCTION

FOUR-D enables the generation of a series of nested optimal pits where each successive outline is for a slightly higher product price than the previous one. This is done for a range of prices, from the lowest for which anything at all can profitably be mined, to the highest chosen to consider. These pits are then interrogated at base case costs and prices to establish their value. Selection of the optimum pit may be based on the company's philosophy of mining.

FOUR-D uses time discounting of money and provides two mining sequences for use in selection. The best case mining sequence mines the nested pits bench by bench, starting and completing the smallest pit then the next largest pit, and so on. The worst case mining sequence (the common method of mining) mines out to the optimum pit outline bench by bench. The best case mining returns a higher NPV due to the increased cash flow in the earlier years by mining internal pits with lower strip ratios and higher profitability.

In reality it is usually possible to schedule one or more pushbacks into the mining sequence. This should return an NPV which lies somewhere between the best and worst case. It is then necessary to determine whether to

- maximize mine life (ore tonnes) and select the best case pit (but with a lower NPV),
- to mine without any pushbacks in which case the worst case pit should be selected, or
- to choose a pit between the two.

If sub-optimal pits contain significantly more ore for a marginal decrease in NPV, it may be considered worthwhile to mine those pits to gain life for the project.

• ASSUMPTIONS

Varying throughput rates of 1.0mtpa, 1.5 mtpa, 2.0 mtpa and 2.5 mtpa have been considered with concomitant savings due to economies of scale. Assumed parameters include:

PIT OPTIMIZATION ASSUMPTIONS		
	Mining Costs $/t	Processing Costs
1.0 mtpa	$1.00	$13.60
1.5 mtpa	$0.99	$13.30
2.0 mtpa	$0.98	$13.10
2.5 mtpa	$0.98	$13.00

• OPTIMUM PIT SIZES

The following incremental results were indicated for worst case schedule pits:

FOUR-D OPTIMIZATION RESULTS			
	Ore Tonnes added (millions)	Mine Life (years)	NPV added ($millions)
1.0 mtpa	0.00	8	0
1.5 mtpa	2.60	7	20
2.0 mtpa	3.12	6	35
2.5 mtpa	3.64	5	46

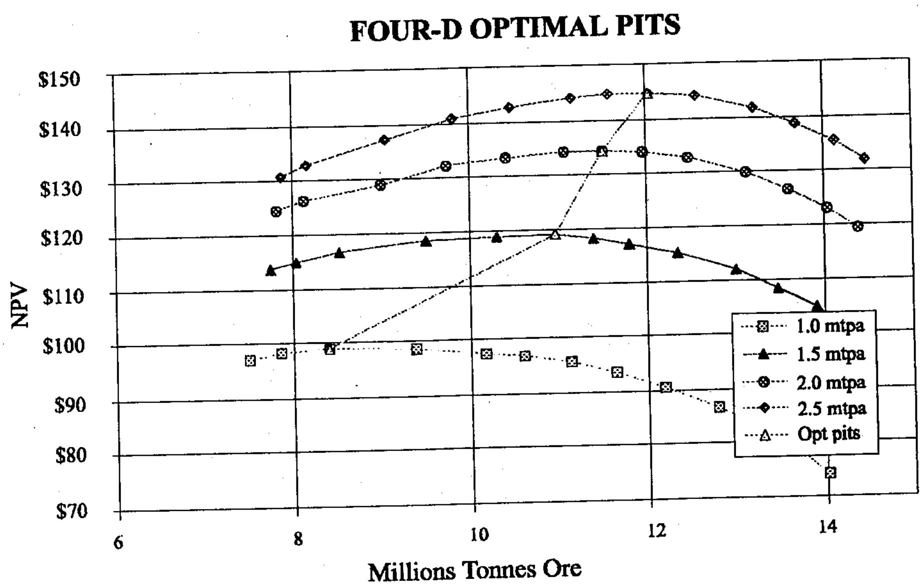

Figure 4

This shows the advantages that increased throughput has on the value of a mine. It is significant to note that the improvements are decreasing with mine size. It is worth $20 million to increase from 1.0 mtpa to 1.5 mtpa but only $9 million to increase from 2 mtpa to 2.5 mtpa. Figure 4 refers.

• ADDING VALUE TO THE OPTIMUM PITS

The advantage with FOUR-D software is that it allows the impact of reduced costs on pit size to be considered. That is, lower costs result in larger pits and vice versa. However, the package does not optimize cutoff grade with respect to the theory of declining cutoff grade with time. As a result, the

NPV resulting from FOUR-D can be improved if cutoff grades are optimized. OGRE on the other hand allows an optimal cutoff strategy but analyses one pit only and hence does not allow for increasing pit sizes with declining costs.

Complete analysis requires each optimum pit to be subjected to OGRE type optimization. Only the smallest (1.0 mtpa) pit has been subject to this and the results have been conservatively extrapolated to larger pits. For scheduling purposes, the smaller pit has been divided into 5 stages and each stage has been expressed as a grade-tonnage relationship as described for the earlier example.

The difference between optimization runs at fixed cutoffs (simulating FOUR-D) and at variable cutoffs with stockpiling show:

OGRE OPTIMIZATION INCREMENTAL RESULTS

($ millions)

	NPV variable COG	NPV fixed COG	NPV added
1.0 mtpa	17	0	17
1.5 mtpa	32	19	13
2.0 mtpa	40	31	9
2.5 mtpa	46	39	7

The OGRE runs assume stockpiling of marginal material until the pit was depleted. This low grade ore is then processed at the end of the mine life. This is not an unusual series of events. What is different however is the cutover grade that was calculated as optimum. Cutovers were 1.4 g/t in year 1, declining to 0.8 g/t in the final mine stages.

For fixed cutoffs, the improvements in increased processing rates are similar to those shown by the FOUR-D analysis. However the pit size, unlike the FOUR-D pits, has not changed, so a lesser improvement is indicated at higher throughput rates. These values are used as a base value from which to calculate possible improvements for each rate if variable cutoffs were practised.

Here the synergism of the optimizers is evident; an initial FOUR-D derived pit containing enough ore for 8 years could have its value improved by $17 million if an optimal cutoff policy was practiced for that pit. By mining at an additional 0.5 million tonnes per year, the same pit could have an improved value of $32 million.

The improvements from a fixed cutoff policy are $17 million and $13 million for the 1 mtpa and 1.5 mtpa respectively. As can be expected, the advantages of optimizing cutoffs decreases as the time span for mining decreases.

The results of adding value to the FOUR-D pits is shown in Figure 5.

THE OGRE/FOUR-D SYNERGISM

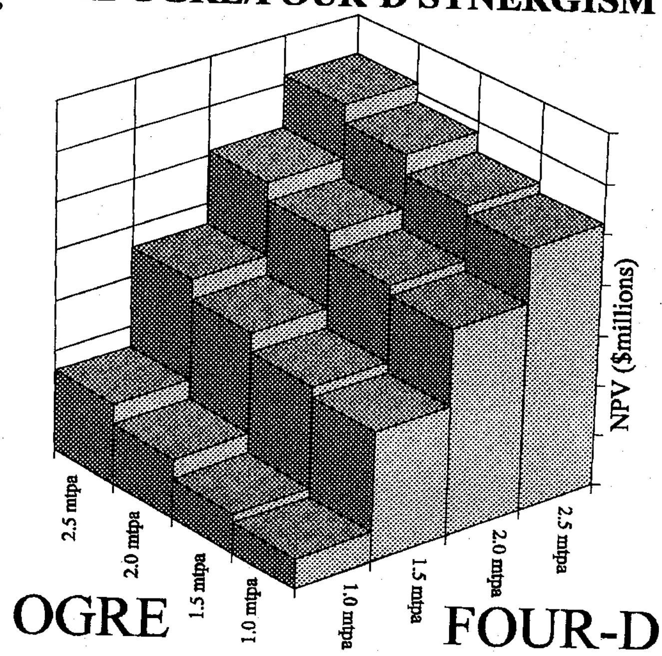

Figure 5

CONCLUSION

Although the figures used in these examples cannot be definitive, they do indicate the order of magnitude of the difference in value between various cutoff grade, stockpiling and throughput scenarios. The assumptions made are simplistic, with costs changing marginally for changes in capacity. With more detailed costing it would be expected that the differences will be more pronounced.

However, it is shown how the rigorous application of FOUR-D and OGRE as planning tools help make the appropriate capacity/cutoff/stockpile policy decisions. These are clearly multi-million dollar decisions and the costs and efforts of a detailed analysis are easily justified.

The practical implementation of such policies may be more difficult to achieve. Apart from accurately defining ore at the specified cutoffs, it would take an enlightened board of directors to accept that the annual production of ounces may decline from year one. Provided they are reminded that the first years are set artificially high to ensure the maximum value is achieved, this may be a policy that will add considerable value to the Australian mining industry.

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