CASE STUDIES - OPEN PIT DESIGN USING WHITTLE 4D

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ABSTRACT

Case Studies in Open Pit Design Using Whittle 4D will be discussing the following four examples:

- OPTIMIZATION OF PROCESS PLANT DESIGN USING WHITTLE 4D AS A SIZING TOOL

  In this case, the home office and project team had different views of the size of the final project. The home office wanted to reduce the size of the project to reduce capital expenditure, while the project team suggested a larger project. Whittle 4D was used to determine Net Present Value and Internal Rate of Return using the Whittle scheduler (FDAN) to schedule many alternatives, and calculate the NPV and return for each alternative.

- COMPARISON OF PIT OPTIMIZATION METHODS: LERCHS-GROSSMAN VS FLOATING CONE

  Many pits are developed based on floating cone economics. A comparison of methods in one large gold mine resulted in the stripping ratio of the pit being reduced by 10% in the Whittle 4D optimization as compared to the floating cone optimization.

- PIT OPTIMIZATION TO DETERMINE IF A NEW MILL IS JUSTIFIED

  A large heap leach gold and silver mine needed to determine if a new mill was justified. The planning and scheduling would take several man months if completed without pit optimization and scheduling software. Whittle 4D software proved to be very effective in providing optimized pits and a mine schedule in a short time frame.

- PIT OPTIMIZATION TO DETERMINE HOW TO MINE AND SIZE:

  Open pit optimization determined where the underground operation should start, and whether the material should be processed by milling or heap leaching.

  One of our clients asked for help in determining where the pit should end and a new underground operation start. We used Whittle 4D to help determine where the pit should end and where to go underground. In addition the operation needed to determine how to process the material.

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INTRODUCTION

Mine Development Associates (MDA) is a consulting firm based in Reno, Nevada, with a second office in Tucson, Arizona. MDA currently employs 7 mining professionals, and started offering consulting services in 1987. We have been using Whittle 3D and 4D since 1990 and have completed over 20 projects with the software. We have used data that was output from SURPAC, MEDSYSTEM, DATAMINE, and VULCAN interfaces in the Whittle software.

CASE STUDY 1:
OPTIMIZATION OF PRODUCTION CAPACITY

MDA was requested to resolve a question of start-up production capacity for a proposed copper heap leach operation anticipated to produce 160,000 tonnes of copper per year. A feasibility study had been completed for this size operation that started in higher grade material resulting in changes in the ore tonnage throughout the life of the project. The client wanted to study different production rates varying between 40,000 tonnes of copper per year and 160,000 tonnes of copper per year, in 40,000 tonne increments. This resulted in production of between 20 and 40 million tonnes of ore per year for the 160,000 tonne Cu case. In addition, lowering the initial year or two production capacity and raising the production rate in the first several years of the operation were evaluated in several combinations. The main objective of this study was to determine if the capital cost of the project could be lowered, or delayed, without severely impacting the overall economics.

The model was in MEDSYSTEM software and contained over 650,000 blocks. At the time this work was completed, both the Whittle conversion program for MEDSYSTEM and the Whittle option to schedule by tonnes of copper were unavailable. MDA converted the model to SURPAC and used the Whittle conversion in SURPAC, rather than to write a new conversion for the MEDSYSTEM model.

The model was imported to SURPAC and a Whittle 4D model was prepared. The model contained alluvium and several rock-types, which required several sub-regions to define the slope. The processing costs included components for cost per tonne processed and per pound recovered. In addition, the cost of mining increased as the pit increased in depth due to the increased haul cycles. The model was reblocked by Whittle FDRB to add the variable mining cost, and reduce the size of the model to just over 150,000 blocks. The original 20 x 20 x 15 meter model was converted to a 40 x 40 x 15 meter model. This reduced the run time from 2 days on a 386-33 to about 2 hours without significant changes in the pits.

The optimization was completed in several phases. In the first phase, the pits were optimized between U.S. $0.20 and $1.20 per pound copper prices. This optimization resulted in a number of relatively small phases, however, two pits were too large for scheduling, with about ten years of ore in one pit. This is not an uncommon problem in a disseminated deposit with similar grades over a large area. Even with changes in copper price of $ 0.00001, the pit was difficult to split up. We finally achieved reasonably sized pits from which to schedule production by continuing to lower the change in copper price. In this case, this pit should have pit phases designed more for operational considerations than economics, as the pit optimization was telling us that the economics would be about the same.

The next step was to choose the pit phases from which to schedule production. Now the Whittle FDOP will handle up to 100 optimum pits based on varying metal price, however, at this time 50 was the limit. We have always used the maximum number of pits for FDOP to increase the number of choices for design of pit phases. In this case our pit phases were chosen from several FDOP runs based on the client's desire to limit each phase to no more than two or three years of production. By designing pit phases in this fashion, stripping is delayed until it is necessary and areas of higher-grade material are mined in succession. MDA used the Whittle FDPR program to produce bench maps of the FDOP pits and choose pit phases to schedule mining. The initial 10 pit phases were chosen and the remaining ore was grouped into the final pit.

Production schedules were produced using Whittle FDAN. At the time this project was completed, FDAN did not schedule production based on metal production so we wrote a Fortran program to take the FDAN spreadsheet output in 2 million ton increments and schedule annual production based on metal production. Varying the cutoff grade also improved the project economics. MDA completed the four production rate options at 6 different cutoff grades, which enabled us to put schedules together using variable cutoff grades. Options of starting with lower production rates and later expanding to higher rates were also evaluated. I haven't counted the number of Whittle FDAN runs we completed probably close to 50, and they all were completed fairly quickly, the most lengthy being 3 minutes.

Finally, MDA designed all the pit phases in SURPAC, summarized the grade and tonnage in each pit, and converted the pit designs and Whittle results files into MEDSYSTEM. Production schedules were produced from the pit phases that included the ramp system. This project was completed in about one month. Figure 1 is a graph of the NPV of the project vs copper cutoff grade. As the size of the project was increased, lower cutoff grades could be justified. The effect of varying the cutoff grade is not as significant as varying the production rate. The study also concluded that the production rate proposed as a maximum was not the optimum, and could be increased to improve NPV.

CASE STUDY 2

COMPARISON OF FLOATING CONE RESULTS

A large operating gold mine requested that MDA complete a Whittle 4D pit optimization to compare with their internal floating cone calculations. The model large, covering an area of 8000 feet by 8000 feet and 2000 feet in elevation. The object of this study was to compare the results of the Lerchs-Grossman pit to a floating cone evaluation.

The model contained about 1.5 million blocks and was a MEDSYSTEM model. It was fairly complex, containing 8 ore categories and two processing methods. This evaluation was also completed prior to obtaining the Whittle/MEDSYSTEM conversion program. The model was converted to a SURPAC model.

The model was reblocked to reduce the size to about 400,000 blocks. The mining cost was constant for the upper benches, but was variable for the remaining benches. Five different pit slopes were used in the evaluation. The Whittle FDOP evaluation took about four hours to complete on a SUN IPX.

The client had been mining for several years and had not evaluated their deposit using Lerchs-Grossman methods. The result of the evaluation was a final pit with a stripping ratio that was reduced by about 10% compared to the previous floating cone final pit.

CASE STUDY 3

IS A NEW MILL JUSTIFIED

A large operating heap leach gold and silver mine requested that MDA complete a Whittle 4D evaluation to determine if a proposed mill was justified. The deposit included some high-grade material that could be treated in a gravity mill. If the new mill was justified, additional sulfide ore could be processed over the life of the operation, thereby increasing reserves.

The grade model was in MEDSYSTEM format model that contained about 2.5 million blocks. The block dimensions were 25 ft x 25 ft x 25 ft. The model contained both gold and silver grades so it was necessary to convert the grades to an equivalent gold recovered grade, in terms of the mill option. There were nine ore types present in the model, classified by oxidation state and quality of the resource estimate. Two methods of processing material were checked. The model was converted to a Whittle model file using the Whittle 4D interface for MEDSYSTEM. The model was reblocked to reduce the size to 624,000 blocks.

Since the evaluation was done to evaluate adding a mill or not, the pit was optimized twice; once assuming heap leaching only, and once assuming both heap leaching and milling. The optimization was completed for gold prices between U.S. $ 200 per ounce and U.S. $ 500 per ounce, and resulted in 100 incremental pits. The FDOP runs took between 9 and 12 hours on a 486-66 computer. The incremental pits were inspected using FDPR to plot the bench plans and we produced initial schedules using FDAN. The incremental pits were chosen to simulate pit phases and to schedule fairly small increments of about 1/50 of annual production. By using this fairly small increment we were able to adjust the number of benches one pit phase leads to the next pit phase to avoid periods of very high stripping, and short ore supply. The pit phases spanned 1.5 to 3 year phases each.

We next scheduled production for the life of the mine for the two options and compared the economics. In this case, although the mill case added considerable "ore", the return on investment was higher with the heap leach case only. Figures 2 through 5 illustrate the results of the study.

CASE STUDY 4

WHERE SHOULD THE PIT STOP AND THE UNDERGROUND START?
HOW IS THE MATERIAL PROCESSED?
WHAT PRODUCTION RATE IS BEST?

MDA completed the mining portion of a feasibility for a proposed new gold mine in South America. MDA was requested by the client to complete detailed mine planning for the deposit. As part of this evaluation we provided three pit optimization runs for this nearly vertical deposit:

- heap leach; only open pit
- mill; only open pit
- mill; open pit and underground operation

MDA constructed the model using SURPAC and it contained 222,040 blocks. The blocks were 10 meters x 10 meters x 6 meters. The model contained six ore types and 4 waste rock types and the pit slope was dependent on rock-type. The model was converted to a Whittle model file using internal SURPAC routines. The deposit appeared as though it was leached at the surface, as the grade of the deposit increased with depth, until the sulfides were reached.

The model was optimized utilizing three separate parameter files to learn about the economics of the deposit. The first optimization was based on a heap leach operation, the second based on a milling operation with open pit mining only, and the third a milling operation with open pit and underground mining. The FDOP optimization runs were completed on a Pentium computer in 1-2 hours. For comparison, runs were also completed on a Sun Sparc 20 in about 5 minutes.

The first evaluation concerned how to process the material, and at what production rate. Using FDAN we completed a production schedule for all three options at two different production rates. It should be noted that only the open pit portion for the open pit and underground option was used to obtain a production schedule. The schedules were input to a detailed spreadsheet and a net present value and rate of return was generated for each option and production rate. Both the mill open pit only and open pit with underground options produced considerably more ounces and improved NPV compared to the heap leach option. The mill option and higher production rate was chosen for detailed planning.

Next came the question of how to develop the mine, as open pit only or open pit combined with underground mining. The open pit and underground option included the underground development cost. The result of the evaluation was that the high-stripping material was removed from the pit with the underground option which improved the cost per ounce and economics of the pit, and minimized equipment requirements for the pit. A graphical representation of the results is shown in Figures 6 through 8.

CONCLUSIONS

MDA has used the Whittle 3D and 4D package on over 20 different projects. The software has been an excellent product for MDA, and has provided our clients with quick and realizable solutions for:

- An optimized family of pits (with estimated slope with ramp systems) with tonnage and grade to use as a template for the final pit and phase design of new and existing mines.
- A production schedule that, without too much effort, is close enough to an achievable schedule that allows very quick decisions to be made based on a number of economic scenarios.

The FDAN program provides MDA and our clients with a method of quickly evaluating project economics and developing targets for detailed production scheduling. A number of questions can be quickly evaluated including: 1) what production rate, 2) how to process material, 3) is a new mill justified? And numerous "what if" scenarios.

The Whittle final pit is close to the designed final pits. In general it contains about the same amount of ore but less waste (1-10%) than the actual final design due to the shape and location of the final ramp system. We usually start our pit design several benches above the Whittle pit bottom, because the pit is usually small at this point. The ramp system develops quickly and can take up considerable room, which causes excess stripping. After the final pit has been designed in detail with the ramp system located, rerunning Whittle FDOP can help achieve the best results. Unless the mine is in operation and has a current final pit design, the locations of the pit ramps are not known, and the slope with the ramp system can only be estimated. Whittle is an excellent product, but you still need a pit designer that is able to see the proper way of laying out ramp systems, and is willing to keep trying to improve the final pit design. Small changes in final design can produce considerable savings. Economics is the name of the game.

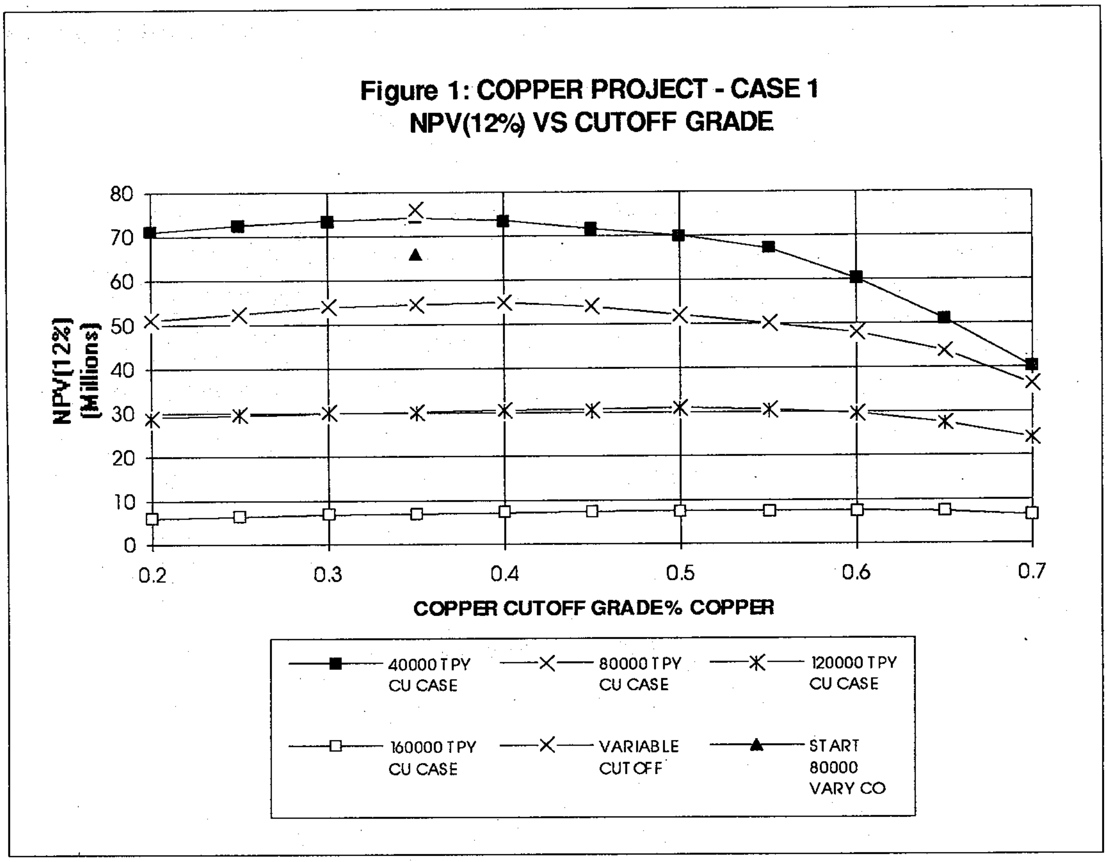


Figure 1: COPPER PROJECT - CASE 1
NPV(12%) VS CUTOFF GRADE
NPV(12%) (Millions)
80
70
60
50
40
30
20
10
0
0.2
0.3
0.4
0.5
0.6
0.7
COPPER CUTOFF GRADE% COPPER
40000 TPY CU CASE
80000 TPY CU CASE
120000 TPY CU CASE
160000 TPY CU CASE
VARIABLE CUTOFF
START 80000 VARY CO

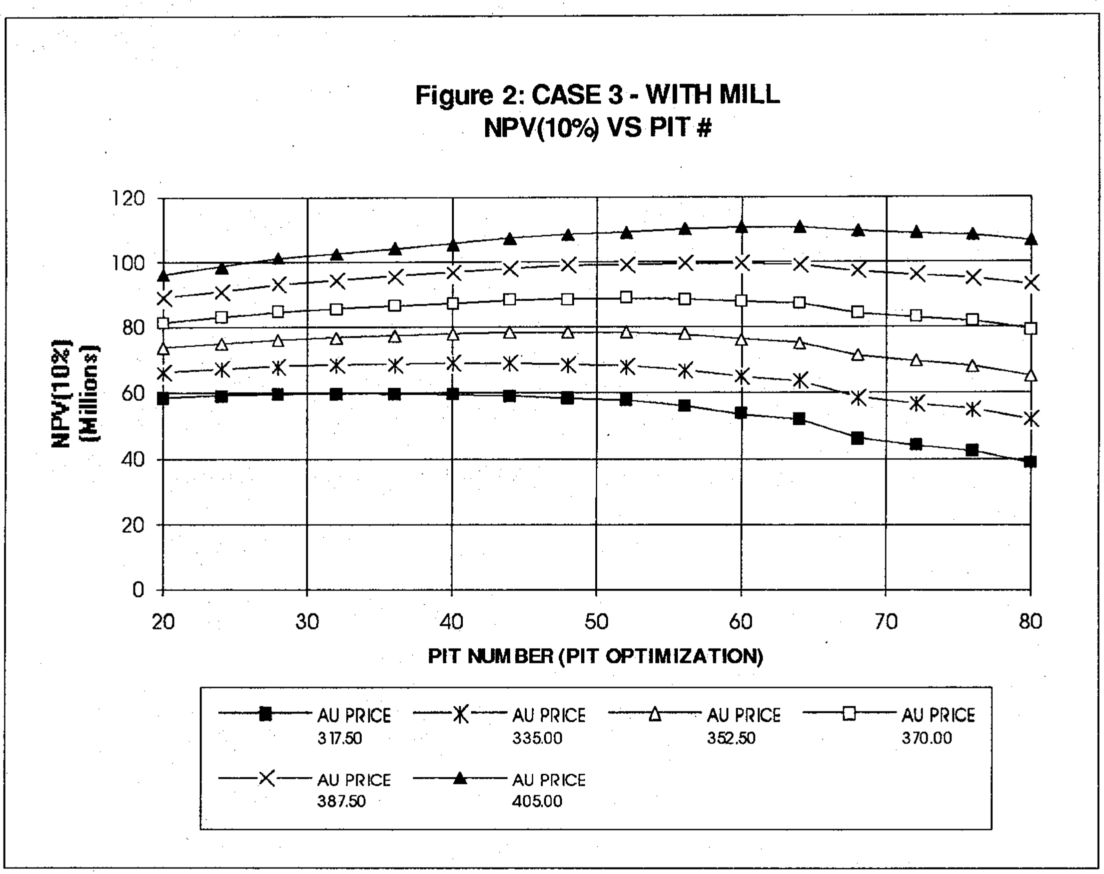


Figure 2: CASE 3 - WITH MILL
NPV(10%) VS PIT #
NPV(10%) (Millions)
120
100
80
60
40
20
0
20
30
40
50
60
70
80
PIT NUMBER (PIT OPTIMIZATION)
AU PRICE 317.50
AU PRICE 335.00
AU PRICE 352.50
AU PRICE 370.00
AU PRICE 387.50
AU PRICE 405.00

Figure 3: CASE 3 - WITHOUT MILL
NPV(10%) VS PIT #

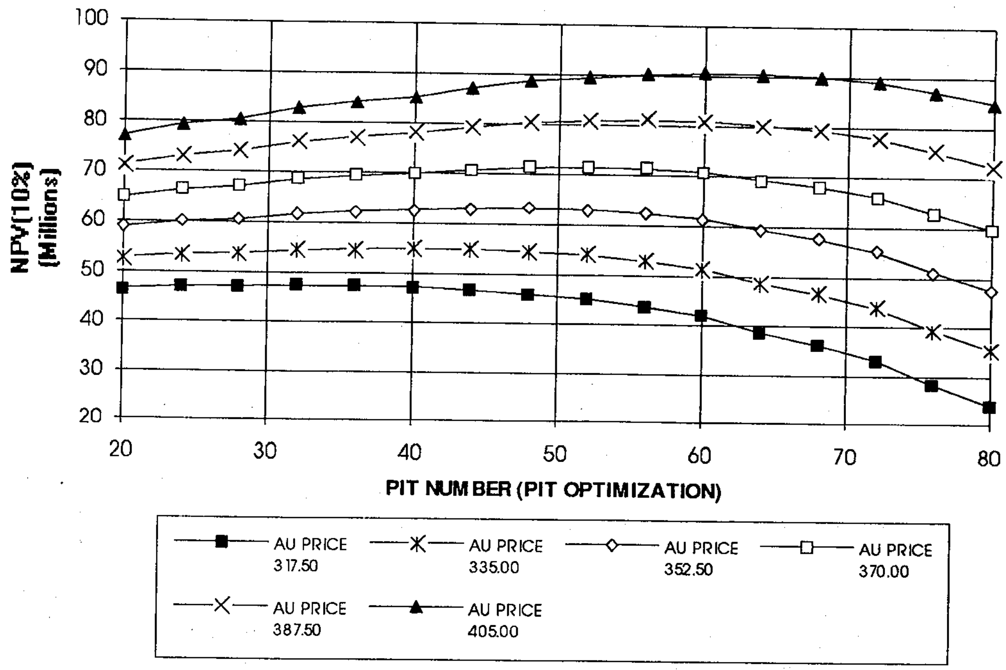
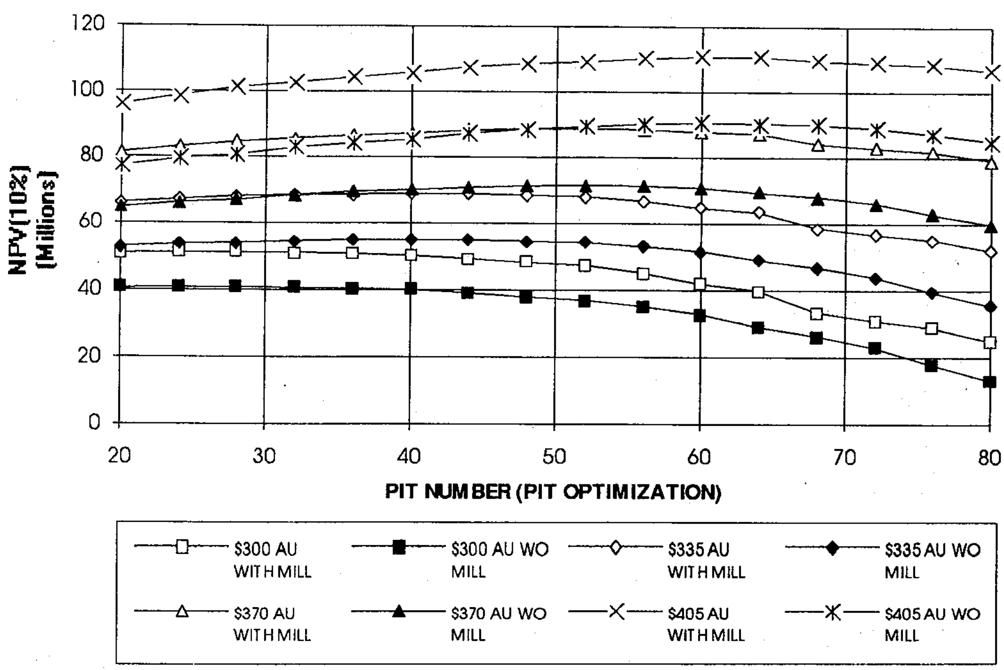


Figure 4: CASE 3 - ALTERNATIVE COMPARISON
NPV(10%) VS PIT #



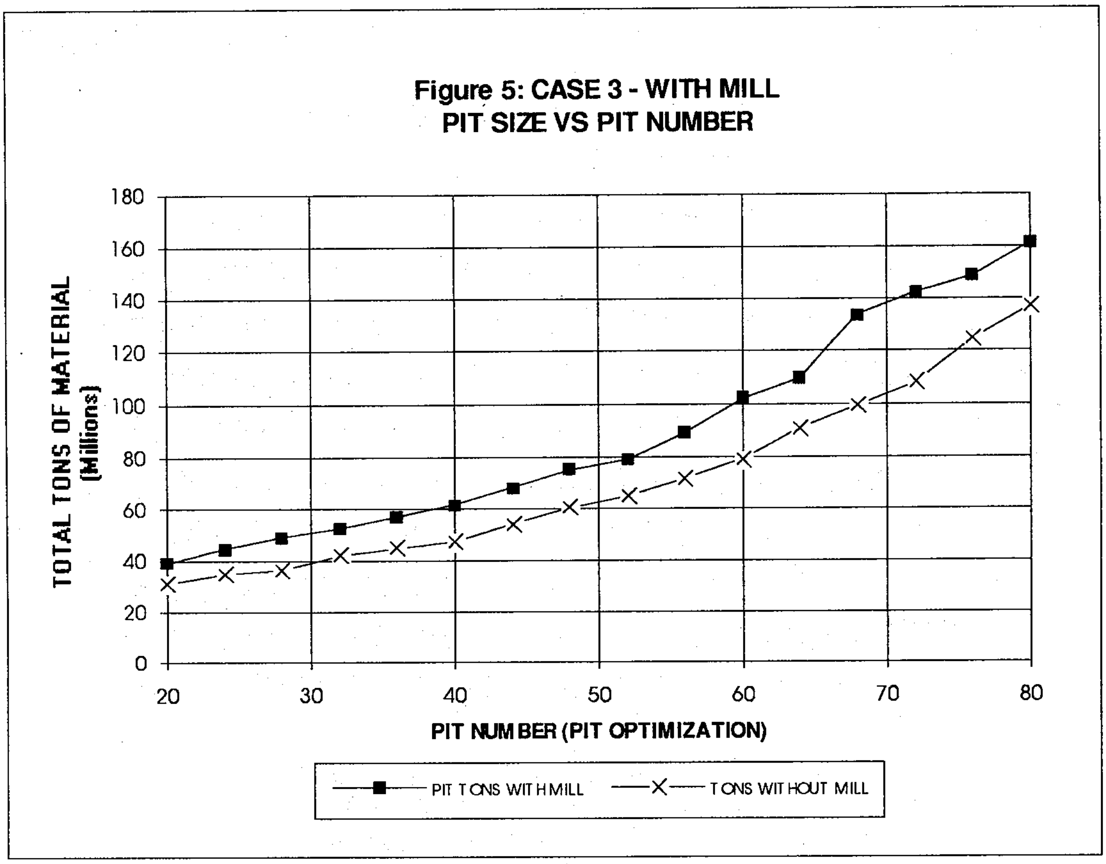


Figure 5: CASE 3 - WITH MILL
PIT SIZE VS PIT NUMBER
TOTAL TONS OF MATERIAL (Millions)
0
20
40
60
80
100
120
140
160
180
20
30
40
50
60
70
80
PIT NUMBER (PIT OPTIMIZATION)
PIT TONS WITH MILL
TONS WITHOUT MILL

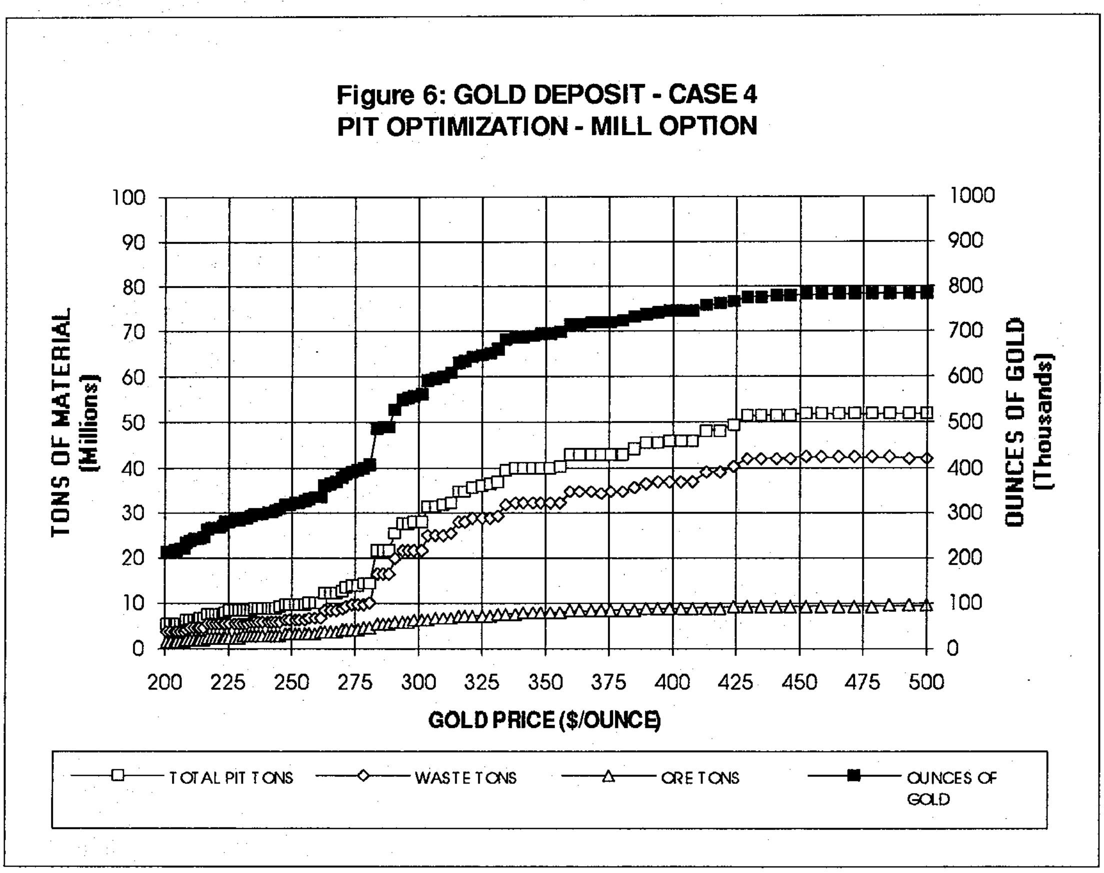


Figure 6: GOLD DEPOSIT - CASE 4
PIT OPTIMIZATION - MILL OPTION
TONS OF MATERIAL (Millions)
OUNCES OF GOLD (Thousands)
0
10
20
30
40
50
60
70
80
90
100
1000
900
800
700
600
500
400
300
200
100
200
225
250
275
300
325
350
375
400
425
450
475
500
GOLD PRICE ($/OUNCE)
TOTAL PIT TONS
WASTE TONS
ORE TONS
OUNCES OF GOLD

Figure 7: GOLD DEPOSIT - CASE 4
PIT OPTIMIZATION - HEAP LEACH OPTION

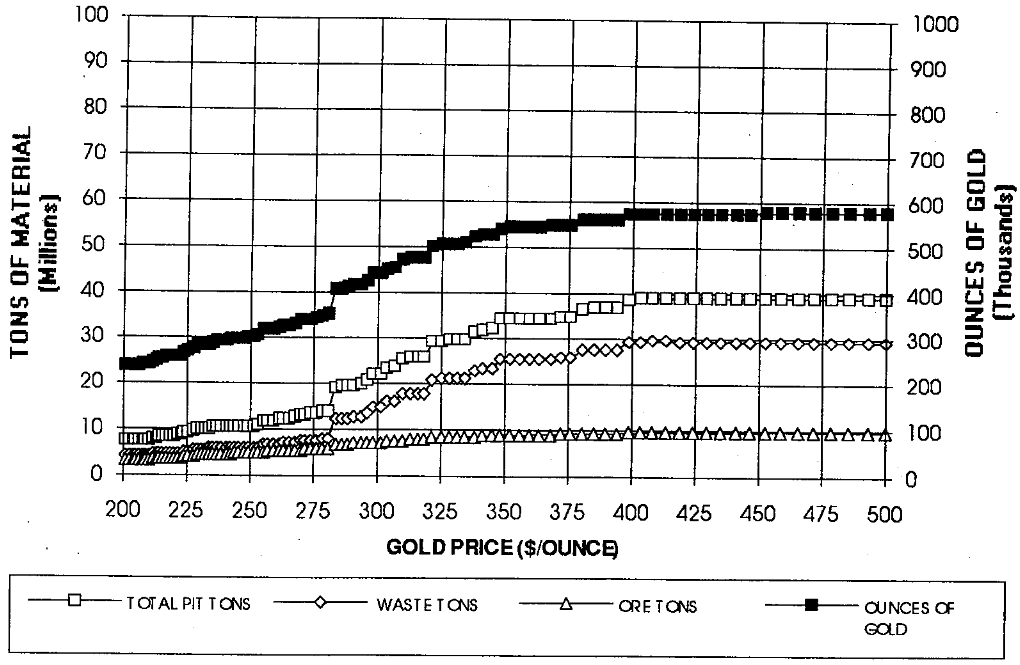


Figure 8: GOLD PROJECT CASE 4
PIT OPTIMIZATION WITH UNDERGROUND