A SENSITIVITY ANALYSIS OF PRE PRODUCTION CAPITAL EXPENDITURES ON SOUTH AFRICAN GOLD MINES

Gregory Arnold Blaylock

A project report submitted to the Faculty of Engineering, University of the Witwatersrand, Johannesburg, in partial fulfillment of the requirements for the degree of Master of Science in Engineering.

Johannesburg, 1989

DECLARATION

I declare that this project report is my own, unaided work. It is being submitted for the Degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other university.

Gregory A. Blaylock

15th day of February 1989.

ABSTRACT

With mining industry costs escalating at present rates it becomes necessary to evaluate and control pre-production capital expenditures if new mining ventures are expected to make a profit. Establishing a base case and model comprised of a new deep level gold mine gives potential mining projects a guideline for projection of capital expenditure.

A new gold mine initiated in 1985 and scheduled to begin producing in 1990 was chosen as the model. The model is broken down into six major categories according to share of total pre-production capital expenditure. These categories are shafts, development, reduction plant, services, housing and general. An analysis of current progress compared with the initial feasibility study reveals a 59% increase in estimated pre-production capital expenditure (in real terms) over what was initially planned.

Major reasons for the enormous increase in pre-production costs include geological variations, planning discrepancies, higher escalation factors and changes in exchange rates.

ACKNOWLEDGEMENTS

I regret that I am unable to directly acknowledge my employer due to confidentiality of actual capital expenditures incurred while developing a new gold mine. Information was made available to me without hesitation, along with permission to print, but with the understanding that no reference be made to its origin. Shaft designations, development headings and other identities have been changed to preserve the integrity of everyone involved.

The capital invested in the mining industry, for the purposes of this research project, originates from a single mining house and is subject to a unique corporate philosophy.

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LIST OF SYMBOLS AND TERMS

CAD	Computer Aided Design
CAPEX	Capital Expenditure
c.f.m	cubic feet per minute
CIP	Carbon-In-Pulp
CSS	Central Statistical Service
F/W	Footwall
H/W	Hangingwall
IPC	Intermediate Pump Chamber
I.S.S	Initial Shaft System
Kv	Kilovolt
Mb	Megabyte
Ml	Megalitre
mm	millimetre
MPa	Mega-Pascals (pertaining to the uniaxial compressive strength of a rock type)
MTC	Minimum Tax on Companies
Mva	Mega volt amp
Mw	Megawatts
PC	Personal Computer
R'000's	Thousands of Rands
S.V	Sub-Vertical (pertaining to shafts)

1 INTRODUCTION

Within the Republic of South Africa the escalating costs of bringing a modern gold mine into production has limited the development of new mines. However, because gold mining revenue has been effectively protected with a counteractive effect by the depreciation of the Rand against the U.S. Dollar, many groups and mines are investing capital at increasing rates to explore and exploit new ore reserves.[1] Many new mining ventures are anticipated but the amount of capital invested in real terms, due to current economic conditions, is actually on the decrease[1]. It is estimated that between 1985 and 1990, the period covered by this project report, a total of R11 914 800 000 will be invested as capital in both new and on-going mining operations.[1] High grade deposits, those averaging 6.0 g/t or better with adequate tonnage, are not frequently discovered and investors are wary of lower grade marginal deposits.

Time and again underestimation of pre production capital expenditures results in a project either closing down or requiring a fresh injection of capital. For example, underestimation of pre-production capital expenditures on a new platinum mine in 1988 eventually led to lower share prices and an inevitable take-over.

It is easy to point fingers and say how badly a job was done. The difficult part is recommending and implementing solutions, or preventing the problem from occurring in the first place. Within this project report several critical areas are extensively analysed. The purpose of this research project is not to criticise mine management but to estimate what it costs to bring a new underground gold mine into production and to make a positive contribution by illustrating the sensitivity of pre-production capital expenditures.

1.1 Definition of Pre-Production Capital Expenditure

For the purpose of this research project pre-production capital expenditure begins when the decision to go ahead with a project has been made and actual construction on the [illegible] area begins. *It is* assumed that exploration costs, freehold acquisition and similar expenses are common to every mining venture and as such can be considered sunk costs which for the purpose of this analysis can be excluded from pre-production capital expenses. Pre-production capital expenditure ends when the mine begins generating revenue via constant milling of ore.

1.2 Goals of Pre-Production CAPEX Analysis

Accurate estimation of CAPEX (CAPital EXpenditure) is vital to the *economic* success of any business, and mining is no exception. Most investment decision methods are based on estimated *cash flows with a* minimum real rate of return expected before the decision to proceed with a project is made.

An accurate estimation of the amount and timing of pre-production CAPEX does not guarantee the success of a mining project. It does however afford investor confidence that the project will begin producing on schedule and within the CAPEX budget allocated, according to the expected rate of return. Because the typical mining venture takes 7 - 10 years to reach production, risks are high. The investment may not be returned for another 5 years.

Once money is spent on shaft sinking and underground development it is gone forever. There is no resale value to be considered.

2 DESCRIPTION OF THE MODEL MINE

A classical sensitivity analysis requires a base case or model. Various components of this model are then altered, either individually or in groups, to determine the relative importance of the components and sensitivity of the project as a whole. Usually the sensitivity is reflected by changes in rates of return.[2] For purposes of this project report rates of return, most affected by early variations in a cash flow, are not the measure of success. From a pre production point of view, success is achieved by bringing the mine into production on schedule and within budget.

The model in this case is a new gold mine scheduled to come into production in 1990. Pre-production CAPEX is broken down into individual elements to determine which element affects the pre-production CAPEX programme most. In this case the total estimated CAPEX is divided into six major categories of shafts, development, reduction plant, services, housing ar general. Increased spending in real terms rangi. from 13.47% in the case of shafts to 127.91% in the case of development, resulted in the total project CAPEX operating 59% over the initial feasibility CAPEX forecast.

2.1 Statement on Available Data

An exercise of this sort requires access to confidential information closely guarded by the mining house undertaking the project. While not an industrial secret, early estimates of the amount of money to be spent financing a new mine should be accessible only to government, directors and top management. Careless statements regarding over or under spending for a new mine may have significant impact on the share value of the mine in question. Information on the progress of the project and the CAPEX spent becomes available to shareholders annually via the usual annual reports. The CAPEX information analysed in this research project is original data obtained from a new gold mine under construction in the Republic of South Africa. No direct reference is made to the origin or destination of money spent. Potentially identifying labels have been changed but figures quoted for pre-production CAPEX spending are real.

2.2 History of the Model Mine

In 1985 it was decided to go ahead with an expansion scheme on an existing mine which would eventually double the mill tonnage from 180 000 to 360 000 mill tons per month.[3] The lease for the extension was already secured and preliminary borehole results indicated adequate grade and tonnage to warrant an expansion, but these results were not good enough to justify an independent mining operation.[3] The cost of starting a new mine from scratch are obviously higher, a point which is emphasised in this project report.

An initial feasibility study was completed which is the starting point for the expansion project and for this research project. The new mine extension is being developed from an existing operation but has all the attributes of an independent mine and will be treated as such, with the exception of tax and timing implications.

2.2.1 Initial Feasibility Study

In the initial feasibility study undertaken in 1985 an estimated capital expenditure flow sheet was done over the expected life of the mine. Table 2.1 summarises the intended spread of capital expenditures and revenue over the life of the proposed expansion project. Unless otherwise stated all years are financial years ending June 30. According to this study the cost to bring the mine into production at 60 000 tons per month was put at R 415 532 000 (Dec 1985 terms).[3] Over a period of years this production rate was to increase to 180 000 tons per month. Costs associated with this increase in production are considered on-going capital expenditures and not pre-production capital expenditures and therefore are not part of this project report.

Table 2.1 CAPEX and Revenue for Life of Project

(R 000)

Year	Progressive Capital Expenditure Sub-total	Incremental Capital Expenditure	Incremental Revenue
1990	415 532	415 532	-------
1993	539 744	124 212	677 641
2004	1 044 105	504 361	8 554 475
2033	1 481 355	437 250	69 517 580

From a common sense point of view the initial construction period is critical to get the mine into production. Here however, we see that 28% of the total projected CAPEX for a 48 year project is incurred within the first six years (1985 - 1990) during which time no revenue is being generated. The initial feasibility study cash flow, summarised in Table 2.1, is misleading because while CAPEX figures were given in December 1985 terms, revenue figures were calculated with an escalating gold price. A complete cash flow analysis is necessary to determine the overall viability of a new mining project but pre-production capital expenditures should be evaluated more extensively than any other money spent. Future capital spending and working costs are part of a complete analysis but are of no concern if the mine never comes into production. Accurate estimation of costs in the economic environment of today is essential for success.

2.2.2 Current Progress

Expansion is in progress by the sinking of a surface main shaft, surface ventilation shaft, a sub-vertical shaft and a service shaft. Development to these shafts from the adjoining mine allows the expanded division to come into production in a relatively short period of time. Opening up new ore reserves and assuming two fully operational longwalls in the expansion lease area constitute the initial planned production. These longwalls will provide the 60 000 mill tons per month when production commences in 1990. Generally speaking however all shaft sinking and development is over budget and behind schedule.

A new reduction plant with an initial capacity of 120 000 mill tons per month is under construction and will incorporate several innovative techniques including fully autogenous grinding, a stacker/ reclaimer and a carbon-in-pulp (CIP) recovery system. It was estimated that the introduction of the latter two concepts would result in a CAPEX saving of R20 - 25 million. However the plant is also over budget but is coming on line as scheduled.

Services for the mine include pumping, electric power, water requirements, ventilation and refrigeration, compressed air and backfill. The construction of these services is either on or ahead of schedule but once again over budget. Because ventilation and refrigeration are required for development they could be classified under development. For the purposes of this project report however, ventilation and refrigeration are considered services.

New housing for all employees is required and consists of a hostel complex and mini-township for skilled labour. Skilled personnel will be housed in several new sub-divisions near established residential areas. Geography favours construction of these homes and services because of available facilities already in place. Again however costs are exceeding original estimates.

The remainder of activity on the mine such as underground equipment, workshops, other buildings and equipment and surface transport is combined into a general category. This category has no schedule as such but nevertheless constitutes a large portion of total pre-production expenditure. Here as with the other five categories capital spending has exceeded original estimates.

Table 2.2 summarises money initially estimated and actually spent in the six major categories established (refer to appendices C and E).

Table 2.2 **Summary of major categories with respective CAPEX**
(R 000)

Category	Original Estimates: 1986 Estimate	Original Estimates: Escalated to 1988 at 21%	Present Situation: 1988 Estimate	Present Situation: Percent of 1988 Total Estimate
Shafts	182 420	220 728	250 453	31.46%
Development	35 750	43 258	98 568	12.37%
Reduction Plant	38 500	46 585	102 928	12.91%
Services	40 645	49 180	103 349	12.96%
Housing	54 670	66 151	78 792	9.88%
General	63 547	76 892	163 085	20.46%
TOTALS	415 532	502 794	797 195	100.00%

The 1986 estimate was reflected in the initial feasibility study completed in 1985. In order to realistically compare the original estimate with current actual figures an escalation factor of 21% was introduced for the two year period. This escalation estimate was lower than the actual escalation for the period and was obtained from spreadsheets used for the initial study and follow-up work. (Refer to the appendices for detailed data used in the compilation of these figures.) The 1988 figures given do not include escalation through 1990 when the mine is scheduled to start producing.

It is important at this point to differentiate between inflation and escalation. Inflation refers to the figures published by the CSS (Central Statistical Service) which represents annual consumer price increases for a given basket of goods. Escalation, in the context of this research project, refers to annual price and cost increases associated with the mining industry in particular.

In each of the six categories more money was spent than originally budgeted resulting in an increase of 58.553% in real terms over what was initially estimated. With two more years to go before the mine starts producing this indeed becomes a serious problem. Furthermore, with two more years of escalation factors added to the 1988 estimate this figure is optimistic. Table 2.3 illustrates the amount each of the six categories exceeded original estimates.

Table 2.3 **Percentage Increase over Initial CAPEX Estimate**

Category	Percentage Increase over Initial CAPEX Estimate
Shafts	13.47%
Development	127.91%
Reduction Plant	120.95%
Services	110.14%
Housing	19.11%
General	112.10%

From these figures it is apparent that development is the category most affected by, or most sensitive to, variations in pre-production CAPEX [illegible]ng. These variations can be brought about by four major factors i.e. geological variations, planning discrepancies, above average inflation or escalation rates and poor exchange rates. Other variations include geographical location, method of finance and taxation. Each of the six categories summarised in Table 2.3 will be analysed, keeping in mind the major variations just mentioned, to determine causes of overspending (or underestimation) of pre-production capital expenditure.

3 SENSITIVITY ANALYSIS

In the following chapters, variations on elements comprising the majority of pre-production capital expenditures are analysed to determine the sensitivity of the project in its early phase. Brief descriptions of the individual component are followed by different cash scenarios resulting from variations imposed on the component. The desired result is an informal guideline pointing out quantitative results and potentially sensitive areas which management can use to control pre-production capital expenditures on new gold mines. Shafts and development are analysed together because of their close relationship. Reduction plant, services, housing and general categories are viewed separately to determine reasons for overspending in each of the major categories.

Resources required to accomplish this analysis include access to CAPEX figures for a new gold mine over a period of years. Also, the time value of money, a concept taught through numerous courses and books, must be introduced into the cash flows to realistically compare monies spent during different periods. These cash flows and CAPEX figures are entered into LOTUS 123 spreadsheets, using a personal computer, where cell formulas automatically calculate effects of changing costs. Word Perfect and Multimate word processors allow for efficient compilation of results. Finally, and most important; the practical experience gained while working on a new gold mine where CAPEX figures are associated with problems at hand.

3.1 Shafts and Development

Shafts and development are combined because of their close relationship. Normally, on a new mine, shaft sinking precedes development but when the new mine is situated adjacent to an operating mine this timing can be changed. Access to ore reserves can be established before shaft sinking operations are finished. This geographical factor implies CAPEX savings, but when estimated pre-production costs are based on these savings often an unrealistic sum total is estimated. Geological variations, planning discrepancies, escalation factors and exchange rates all affect the *amount of money* required to bring the mine into production. As shown in Table 2.2 shafts and development account for almost 44% of the CAPEX pie. Pre-production costs between these two elements alone was underestimated by over R85 million.

3.1.1 Geological Variations

Exploration for new gold deposits implies an understanding of the regional geology where drilling from surface is taking place. One can choose the position and direction of a borehole with calculated risks or educated guesses, but in either case some previous knowledge of geological formations is necessary. Witwatersrand geology is fairly uniform stratigraphically but becomes complicated with faulting. Shaft sinking and development rates can normally be predicted accurately since the type of rock and its properties are well known. Delays may occur due to unexpected encounters with heat, water, methane, or mechanical failures but normally are of little consequence. On the other hand localised faulting and other geological disturbances may pose short term problems which effect the amount and timing of capital money needed to complete a job.

A simplified section of regional structural geology with the proposed shaft systems and development is illustrated in Figure 3.1. This proposal covers only the minimum amount of shaft sinking and development required to bring the mine into production. Where the shafts are being sunk, shales and quartzites dominate the first 1 000 metres, followed by approximately 1 200 metres of dolomites and then about 1 200 metres of lavas. Reef is then encountered in alternating bands of reef and quartzite. All hanging wall development occurs in lava and all footwall development (below reef) occurs in quartzites.

Shaft sinking, development and raise boring rates are proportional to the qualities of the rock. Table 3.1 lists various rock types, strengths and respective raise boring rates applicable to this model. These figures were provided by a raise boring contractor employed by the mine. Subsequent investigation revealed that the uniaxial compressive strengths as shown are within known limits but definitely on the

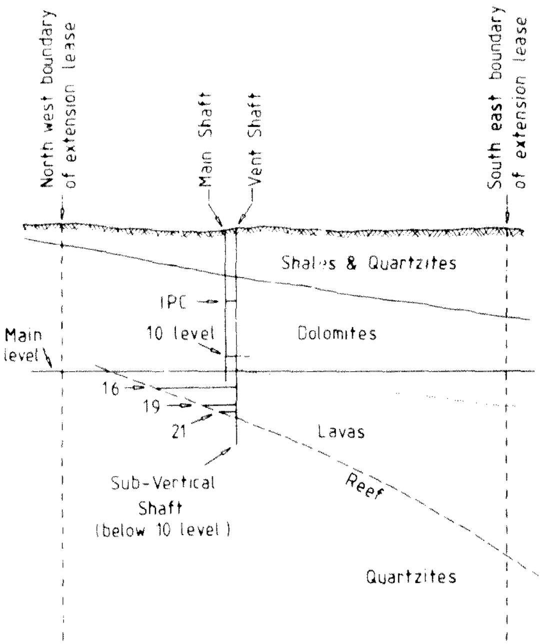

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Figure 3.1 Simplified Geology and Proposed Main Shafts and Development high side.

Table 3.1 Rock types and Strengths

Rock type	Strength	Raise boring rate (2.13m dia)
Shale	155 MPa	21.3m/day
Dolomite	181 - 256 MPa	21.3m/day
Lava	300 MPa	17.4m/day
Quartzite	230 MPa	21.3m/day

These differing strengths result in different development costs. A relatively hard rock, such as quartzite, affords the developer or shaft sinker a reduced advance per blast than say dolomite. Consequently more explosives are required, drill bit life is reduced, machine wear is increased and labour costs per metre go up. More can be said about the increased cost of planning a mine in hard and difficult rock. If the rock type is known however, planning can be projected realistically and capital costs estimated accurately.

While exploration drilling provides accurate and detailed information of major geological structures it cannot supply information about minor but important geological disturbances. Water bearing fissures and unexpected faults are two such disturbances which can slow down or even halt shaft sinking and development.

Cover drilling is extensively used for the detection of water bearing fissures. When water is encountered in this fashion all sinking or developing operations cease until the flow of water has been stopped by successful grouting. This delay results in standing time claimed by the sinking crew or development crew in addition to the cost of sealing off the flow of water. If the ground in which shaft sinking and development takes place remains dry there will be no wet surprises. Schedules are therefore maintained and no additional costs are introduced into the pre-production capital budget. If however water is struck as discussed there will be a corresponding rise in costs associated with such an event. The extreme case here is when water bearing fissures are missed by cover drilling and shaft sinking or development proceeds into the danger of ground. In this case all operations cease and resources must become dedicated to stopping the inflow of water.

Such an occurrence was dramatically illustrated during the flooding of Western Deep Levels No. 1 Shaft in July of 1982. Cover drilling failed to locate a near-vertical fissure at approximately 970 metres below collar. A portion of the sidewall slabbed off, exposing the water-bearing fissure and allowed the inflow of water, measured to be 126 litres per second (*100 000 gallons per hour*).[4] Two hundred thirty five days and 3 587 tonnes of cement later, shaft sinking operations resumed. The extra cost resulting from this mishap was not pre-production CAPEX but serves as an example of what can happen. No cost can however be assigned to loss of life which is an unfortunate probability in these circumstances.

Furthermore, any delay postpones the earning of revenue and therefore reduces the rate of return, and the amount of pre-production capital required increases because the pre-production time period is extended. On the model mine used in this research project almost 200 days have been lost already to either preventive cover drilling and cementation or cementation of water-bearing fissures. Preventive measures may seem expensive but the chance of losing a R100 million shaft complex is too great a risk.

Unexpec . faults may cause minor problems in shaft sinking and development but generally can be overcome. Increased CAPEX results when localised faulting displaces the reef horizon to an extent which requires additional development to establish ore reserves.

Figure 3.2 represents a actual encounter on the model mine and illustrates one such minor occurrence. Early geological information obtained from scatter mining in the existing mine revealed highly faulted ground with a sequence of downthrows, each 30 to 100 metres. The disturbances were projected into the lower levels of the extension lease area but when the developing crosscut reached the projected reef horizon no reef was encountered. Continuation of development resulted in a reef intersection but only after extra capital money, not planned for, was spent. At approximately R250 per cubic metre, with 90 metres of unplanned development required, this resulted in R250 0ι) extra pre-preduction CAPEX spent on a single crosscut. Extra money was also allocated for underground diamond drilling to establish the extent of the faulting before further development of ore reserves on other levels commenced. This particular incident appears minor until applied to the five remaining levels. Suddenly the figure of R250 000 increases to almost R7 million.

To determine the sensitivity of total pre-production capital expe....ture to geology, the major elements subject to geological variations must be analysed. Of the total R415 532 000 estimated for pre-production CAPEX, R182 420)00, or 43%, is allocated for shafts. Development CAPEX amounts to R 35 750 000, or 8.6%. It is impo.'ta' . to note here that the shaft sinking figure includes winders, headgear arrangements, surface construction and shaft equipment. In 1988 Rand terms it costs approximately R 18 000 per linear metre to sink and line a 10.0 metre diameter shaft. (Refer to appendix K). According to the initial feasibility study a total of 4 670 metres of shaft

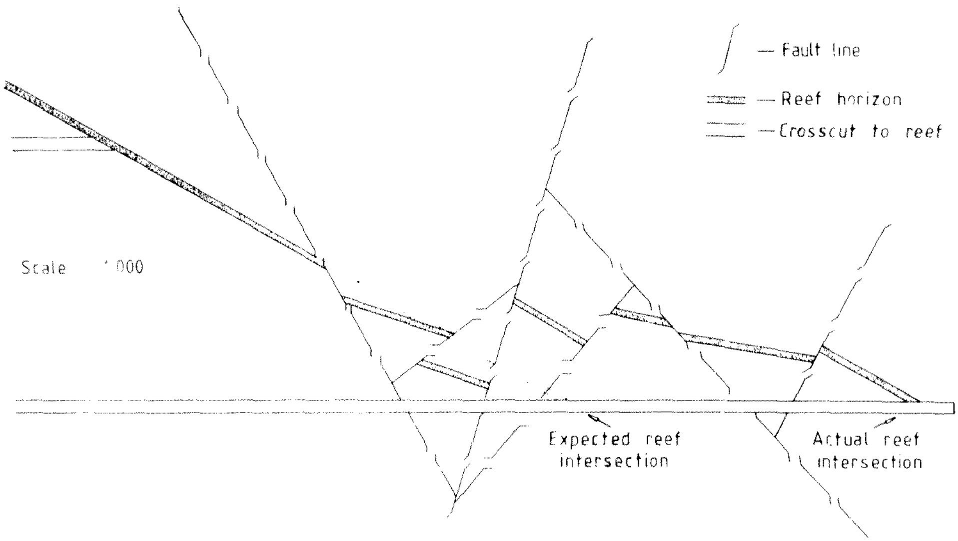

Figure 3.2 Cross Section of Localised Faulting

sinking is scheduled for completion before the mine comes into production. At present rates this amounts to approximately R84 060 000 attributed directly to sinking and lining, or 20.2% of the total pre-production CAPEX. Thus shaft sinking and development, two major elements subject to geological variations, together account for approximately 28.8% of the money estimated to bring the new mine into production.

Table 3.2 summarises the effect of geological variations on pre-production capital expenditure. Major delays in either shaft sinking or development may also result in pushing out the planned start-up date for the mine. The resulting costs are difficult to quantify and are question marks. In any case extra capital expenditures and postponement of revenue combine to make the overall viability of the project less attractive.

Table 3.2 **Effect of Geological Variations on Shaft Sinking and Development CAPEX**

Category	Delay (days)	Extra cost (Rands)
Shaft Sinking		
Cover Drilling & Cementation	118	?
Rope Race Development	48	?
Development		
Cover Drilling & Cementation on 10 level	93	?
4 250 extra metres	131	7 803 000

For development the extra metres cost was calculated at R180 per cubic metre, in December 1985 terms, as assumed in the initial feasibility study. Actual development costs of R250 per cubic metre, in 1988 terms, are covered by effects of escalation and exchange rates. The 131 days required to do the 4 250 extra metres of development assumes six levels, each with three blasting ends averaging 1.8 metres advance per day. Fault negotiation during follow-on development will also introduce delays and extra costs but in this case is not considered a pre-production capital expense.

3.1.2 Planning Discrepancies

Extreme geological variations will effect planning with the introduction of unexpected delays or work not accounted for. Other planning discrepancies result either from the omission or underestimation of critical path elements. Figure 3.3 represents both the initial planned events from early project days and the revised planning schedule from updated evaluations of work.

As can be seen all initial events are behind schedule. Reasons for this include new work introduced into the shaft sinking program coupled with slower than expected sinking and development rates. The ventilation shaft was initiated on 10 January 1985 and completed on 5 June 1987. It has a diameter of 7.3 metres, is 1 712 metres deep and has an upcast ventilation capacity of 750 cubic metres per second. The main shaft has a final depth of 1 937 metres, a finished diameter of 9.15 metres and 610 cubic metres

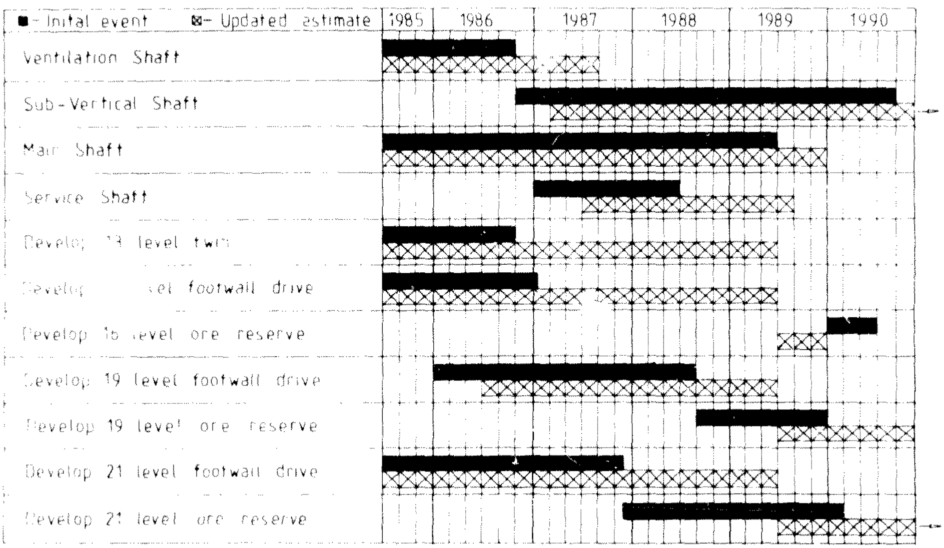

Figure 3.3 Initial Planned Events and Updated Estimates

per second of intake ventilation capacity. The sub-vertical shaft has a final depth of 1 500 metres, a finished diameter of 7.3 metres and 390 cubic metres per second of intake ventilation capacity. These figures can be used in conjunction with the 1988 CAPEX estimates to calculate the cost of sinking a similar shaft system in the Republic of South Africa. Using the 'ratio'[2] method (scaling costs proportionate to shaft dimensions) also allows an approximation of costs for smaller or larger shaft systems.

New work introduced into the shaft sinking program includes the early development of the intermediate pumping chamber (I.P.C.) and extra off-station work. Conventionally, IPC and main pumping arrangements are completed when shaft sinking is finished. Often it takes two years after a shaft system is commissioned before the main pumping system is commissioned. In this case however, production would commence almost immediately upon commissioning of the shaft system. Normally, development work is required to establish ore reserves for a period of years after the shaft system is completed and an IPC is not needed. Water from these development ends can be handled with relatively small and temporary pumping systems. Pumping requirements for production, however, include settling dams and high-lift pumps installed in the intermediate pump chamber. Extra off-station work was given to the shaft sinking crews instead of waiting until the shaft system was commissioned before bringing in standard development crews. Management made this decision to facilitate bringing the mine into production nine months earlier than originally planned. Instead of September 1990 as the targeted production start-up the revised date of January 1990 was chosen. Also, instead of sinking the sub-vertical shaft to an ultimate 39 level it was decided to sink to 46 level. This would allow earlier access to deeper ore reserves required to maintain production levels as planned

Development according to the initial feasibility study totaled 10 620 metres between four major levels required to bring the mine into production in 1990.[3] This figure however did not cater for extra ventilation capacity required, two interlevels, extra material and man travelling drives or necessary development simply overlooked. In one case the reef raise development was accounted for but the access crosscut to reef, amounting to almost 700 metres of development. was forgotten. By 1988 this figure had increased to 25 844 (total) metres. 6 634 of these extra metres resulted from planning discrepancies.

Table 3.3 shows delays from planning discrepancies and associated costs. In the case of shaft sinking, as with geological variations, delays are difficult to cost. There is a direct cost for the development of excavations not planned for but only a question mark for the cost of the delay itself. The same assumptions regarding development were made as with the effect of geological variations. Also, seventeen days were lost during shaft sinking due to breakdowns and accidents. While not necessarily a planning discrepancy perhaps miscellaneous delays should be included when setting up schedules.

Table 3.3 **Effect of Planning Discrepancies on Shaft Sinking and Development CAPEX**

Category	Delay (days)	Extra cost (Rands)
Shaft Sinking		
10 Level *Development*	21	?
Mid-shaft loading installation	106	?
Development		
6 634 extra *metres*	205	12 180 000

3.1.3 **Escalation Factors and Exchange Rates**

For the purpose of this report money spent on shafts includes winders and other essential equipment common to most shaft systems. *In the main shaft two man* winders, each 5.5m X 1.83m wide double drum, and one 5.1m double drum Blair multi-rope rock winder were planned for permanent hoisting. Three winders, each 5.5m X 1.83m wide double drum, are required for permanent hoisting in the sub-vertical shaft. In addition to the overall underestimation of escalation within the Republic of South Africa the Rand exchange rate has not fared well. Winders estimated to cost R9 million ended up costing R14 - 15 million.

Escalation also effects the price of steelwork needed to equip the shaft. Recent wage increases brought about by the advent of Union movements have raised the costs of producing steel in South Africa. A suggestion for all imported machinery i.e. winders is to price the equipment in the currency of the country where they are purchased. It would be a mistake in this case to apply inflation rates of South Africa but the exchange rate and any import duties must be considered. Rather use the estimated yearly inflation rates from the country of origin, then apply a range of exchange rates with any import duties. The portion of excess CAPEX attributable to escalation and exchange rates for major shaft equipment is summarised in Table 3.4. This represents R14 199 000 of the extra CAPEX required to bring the mine into production.

Development on the other hand is not subject to the exchange rate as such but has as escalation factor of its own. In the original feasibility study the cost of breaking and removing a cubic metre of rock from the mine was estimated to be R180 per cubic metre. Recent costing exercises completed by myself show that in 1989 it will cost approximately R250 to blast and hoist the same cubic metre of rock. (Refer to Appendix J). At the time of the feasibility study approximately 10 620 metres of development on four major levels was anticipated. Using R180 per cubic metre with 3.0m X 3.4m ends results in R19 498 320 budgeted (R21 496 898 in 1988 terms assuming 5% escalation for two six month periods) for this development. Actual CAPEX required in 1988 for the same development is however R27 081 000, an increase of R5 584 102. If the figure of 18% per annum is used for escalation the amount budgeted in 1988 terms becomes R27 149 461, much closer to the actual amount of CAPEX required. Taking into account the extra metres introduced via geological variations and planning discrepancies amounts to an extra R7 771 176 attributed to development escalation. This represents the difference between the R180 per cubic metre assumed and the R250 per cubic metre realised.

Table 3.4 Price Increases for Major Shaft CAPEX Equipment

Equipment	1986 Estimated Price (R)	1988 Actual Price (R)
Man Winder	9 400 000	9 743 000
Man Winder	9 400 000	11 484 000
Rock Winder	15 600 000	17 035 000
Permanent Hoisting Equipment	4 300 000	5 270 000
Man Winder	9 400 000	12 857 000
Man Winder	9 400 000	11 430 000
Rock Winder	8 700 000	12 580 000
Totals	66 200 000	80 399 000

In addition to the shaft systems and development discussed there is also a service shaft to consider. This service shaft serves only three levels and was underestimated by almost 50% What started out a R9 million project in 1986 escalated to almost 13 million by 1988. The same reasons i.e. geological variations, planning discrepancies, escalation factors and exchange rates were responsible for the increase in approximately the same proportions as the major shafts.

To summarise the shafts and development category it appears that geological variations and planning discrepancies share equal responsibility for the increase in pre-production CAPEX. Development in particular is the most sensitive element in this category. Escalation factors and exchange rates apply both to shaft equipment and development costs. Another consideration not analysed is the effect of geographical location. Shaft sinking obviously will not be effected but development is. The amount of development stays the same whether done independently or from an existing mine. Timing on the other hand improves, allowing quicker access to ore reserves thus shortening the pre-production CAPEX period.

3.2 Reduction Plant

Ultimate plant capacity is planned for 180 000 tonnes per month but pre-production CAPEX only covers costs of constructing a plant capable of treating 120 000 tonnes per month. Process steps include:

a) Primary crushing.

b) Stockpiling using a stacker/reclaimer system.

c) Run-of-mine milling. The mills are equipped with wraparound variable speed motor drives.

d) Linear screening to remove grit and woodchips.

e) Thickening of pulp.

f) Leaching of gold with cyanide in air-agitated pachucas.

g) Carbon-in-pulp (C.I.P.). Adsorption of gold by carbon in an eight-stage contactor circuit.

h) Elution of gold from carbon using the Anglo American Research Laboratory (AARL) process.

i) Recovery of gold from eluate using electrowinning cells.

j) Regeneration of carbon

k) Treatment of slime tailings to produce backfill.

l) Facility to install a flotation plant to recover gold values from backfill if required.

The actual gold recovery process description will not be covered in this research project. Some of its features are confidential and the summary given above describes the type of equipment necessary for inclusion in pre-production capital expenditure.

The reduction plant, according to Table 2.3, is almost 121%, or R56 million in 1988 real terms, over budget. Since the mine is scheduled to come into production nine months earlier than originally planned some of the CAPEX allocated for the reduction plant had to be brought forward. This could be considered a planning discrepancy but is more a management decision. Other reasons however include the effect of escalation and the exchange rate. Mill ring gears had to be imported from Germany and control equipment had to be purchased overseas. The fact that the recovery process of carbon-in-pulp will be employed for the first time (on a large scale within the group) requires attention. Conventional storage silos and surge bins are being replaced with a stacker/reclaimer system also never before tried within the group.

3.2.1 Geological Variations

Geological variations generally have no direct effect on the pre-production cost of a reduction plant. They may however have an effect if the ore milled during trial milling proves difficult and requires extensive metallurgical testing. This may result in minor delays and extra cost, especially since in this case CIP technology is being tried for the first time, but usually is of little consequence.

3.2.2 Planning Discrepancies

In real terms the pre-production CAPEX for the reduction plant was underestimated by 121%, or approximately R56 million. Because no detailed breakdown was given in the initial 1986 CAPEX forecast it is difficult to determine the cause for such an increase. It appears that the 'ratio' method was used, based on a similar plant of the same capacity. If this is the case then planning discrepancies would account for only a small portion of the increase. Moving the start-up date forward by nine months obviously has some sort of effect. Compared to the overall six year pre-production period however, nine months would not make much of a difference. Escalation factors and exchange rates look to be the most likely factors which effect reduction plant pre-production CAPEX.

3.2.3 Escalation factors and Exchange Rates

Escalation factors and exchange rates account for most if not all of the reduction plant increase. In real 1988 terms a total of almost R47 million was initially forecast in 1986 (refer to Table 2.2). By 1988 this figure exceeded R102 million, the majority of which can be assigned to three headings. Civil work at R17 million, milling section at R30 million, and CIP section at R10 million. The civil work and CIP section estimates are close, but the milling section was grossly underestimated due to the import of two adjustable-speed ring motors from Germany. These motors were ordered three years ago but by 1988, due to mainly to the poor Rand exchange rate, their price was R25 million each. Two fully autogenous grinding mills, manufactured entirely in South Africa, were matched with these motors. Local increases in steel prices, bought about by wage hikes, contributed to a slight escalation in price for these mills.

As in the case of imported equipment required for shafts the equipment necessary for the reduction plant should be costed in the currency of the country of origin. Exchange rates and import duties can then be applied to accurately estimate the portion of pre-production CAPEX needed for the reduction works.

3.3 Services

Services has been chosen as a category for the purpose of this analysis rather than a detailed breakdown of the individual effects of its elements. These elements are pumping, electric power, water, ventilation, refrigeration, compressed air and backfill. Together they resulted in a 110%, or R54 million (real 1988 terms), increase over what was initially allocated. Pumping, for reasons previously discussed, accounts for most of the CAPEX increase and electric power accounts for the least. For that matter electric power came in almost exactly on budget. This says something in itself.

Main pumping requirements are to be met utilizing intermediate pump chambers in the main and sub vertical shafts. Each stage is designed to overcome approximately 760 metres of lift. Surge dams will be excavated at the bottom of the longwalls with boreholes providing drainage between levels. Major assumptions include development tonnes amounting to 16% of reef tonnes mined, water consumption (including backfill and cooling) is 5 tons per tonne mined and the friction loss for the columns chosen is 3 metres for each 100 metres of pipe. Figure 3.4 illustrates the pumping capacity required to bring the mine into its first year of production.

A point well illustrated here is that while initial production is only 60 000 mill tonnes per month, pumping capacity caters for 120 000 mill tonnes per month. It would be much more expensive in the long run to design an initial pumping system to service only 60 000 mill tonnes per month. The idea is to equip the shaft with columns and complete all required development while the construction crews, equipment and material are in place.

Temporary power requirements were planned to be met with a 15 Mva sub-station from a 132 Kv scarfell line providing approximately 15 Mw from a 6 6 Kv supply

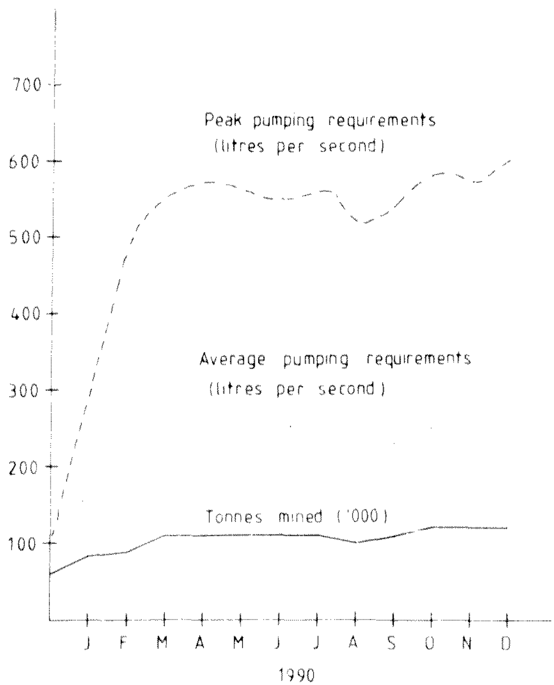

Figure 3.4 Pumping Capacity Required to Bring the Mine into Production

Peak power requirements were estimated to be 12 Mw with an average use of 8 Mw. The permanent power supply of 85 Mw will be completed prior to start-up in 1990.

Water requirements, obtained from the Rand Water Board, were estimated to be 11.2 Ml per day. This assumes 1.5 tons water per tonne milled and 2.6 Ml per day potable water consumption. Two storage tanks were envisioned, one 1 Ml and one 5 Ml tank.

Ventilation planning for the extension assumed excess capacity from the operating mine, which was not consulted. This resulted in under-design of the extended operation from the standpoint of ventilation. Consequentl, extra raise bore holes were added to the new project to ease the shortfall. Heat problems on lower levels of the mine brought development progress to a standstill. Where 90 metres per month was assumed reasonable often an advance of 10 metres per month was achieved. Table 3.5 summarises early development progress for the four major levels. This poor record was attributed mainly to inadequate ventilation.

Table 3.5 **Development Record for Four Major Levels** (metres per month)

Period	13 level	16 level	19 level	21 level
July 1985	33.7	6.0	5.1	22.4
August	0.0	3.7	11.8	38.1
September	22.9	20.1	50.2	53.6
October	0.0	32.4	70.6	28.4
November	0.0	40.5	90.4	38.2
December	19.9	70.8	86.3	11.6
January 1986	39.9	81.2	80.2	56.6
February	37.4	53.5	58.4	51.3
March	18.9	84.5	87.2	54.6
April	30.4	91.5	85.7	53.1
May	71.5	102.0	102.0	101.0
June	174.6	101.3	83.4	40.3
July	160.0	78.8	52.4	45.8
August	160.1	123.8	75.5	54.8

Initially two main intake airways and two exhaust airways were planned. These airways were deemed sufficient ventilation for two longwalls with a quantity of 3.5 cubic metres per second per kilotonne mined and a quality of 28 degrees centigrade wet bulb. An upcast velocity of 18 metres per second and a downcast velocity of 10.5 metres per second were foreseen and 58 Mw of refrigeration was also planned. By 1988 however five intake airways and four return airways were deemed necessary to provide adequate ventilation.

Compressed air requirements were broken into the categories of sinking and permanent. Sinking air was designed for 150 drills fed by 3 X 2.36 cubic metres per second, or about 5 000 c.f.m., compressors. Permanent compressed air requirements were based on a minimum of 1 000 drills used to mine a total of 200 000 tons per month. The initial plant caters for 350 drills and consists of 3 X 50 drill reciprocating units and 1 X 350 drill centrifugal unit for 50 000 tons per month mined. An extra 3 X 350 drill centrifugal units will be added to accommodate compressed air requirements during full production later in the life of the mine.

Backfill services consist of a surface batching plant, storage tanks near the shaft on surface, ranges down the shaft to dams situated above projected longwall positions and ranges from the dams into the longwall stopes. Eventually the entire mine will rely on backfill for regional support. In 1986 the initial estimate for backfill services was R3 million. In 1988 the estimate was still R3 million, an error yet to be realised. A preliminary backfill reticulation design completed by myself (while working on the model mine) resulted in an estimated R9 million in 1988 terms. This estimate covers expenses only between the shaft agitating silos and stope face positions.

Columns required for these and other miscellaneous services are summarised by Table 3.6.

Table 3.6 Service Columns Required

Service	Number	Diameter
Pump columns	3	406mm
Mud columns	2	150mm
Compressed air columns	2	500mm
Chilled water columns	2	300mm
Power/phone cables	25	
Grout/service ranges	3	38mm
Backfill columns	24	80mm

3.3.1 Geological Variations

Geological variations have little to do with the extra pre-production CAPEX required for the services category. Perhaps in the sense of ventilation and refrigeration, in lieu of unexpected extremes of heat encountered, could geological variations be considered an important factor. Also, if larger quantities of water than expected were encountered, pumping capacities and associated CAPEX would have to increase. In this case, larger quantities of water than initially expected will have to be pumped by the extended division than originally planned. This however is not a function of geological variations but one of planning discrepancies.

3.3.2 Planning Discrepancies

Planning discrepancies mainly affected the pumping arrangements. IPC development in the surface main shaft complex was completed several years ahead of schedule and production pumping not accounted for had to be included. When the initial feasibility study was completed in 1985 no contributions from the operating mine were allowed. Assumptions were made regarding pumping capacities, compressed air availability and ventilation. Perhaps the reason electric power was accurately estimated was because from the beginning it was assumed independent from the operating mine.

IPC development has already been discussed but production pumping requirements closer to the longwall positions has not. In the initial feasibility study it was assumed that pumping columns could be placed in the existing service shafts from 21 level to the main level. In fact there was no space available for these extra columns so an entire settling system and pump chamber had to be developed and commissioned. Water from the longwall to be assumed now travels on 21 level to the sub-vertical shaft, then via a series of stages to the IPC in the main shaft for pumping to surface.

One way or another it appears the entire R54 million shortfall experienced in the services category is a result of planning discrepancies. Further investigation reveals pumping and ventilation under-design as responsible for most if not all of this pre-production CAPEX increase.

3.3.3 Escalation Factors and Exchange Rates

Escalation factors in this instance may account for a portion of the extra CAPEX required but is not significant. Pumping equipment, air and water columns, and electrical cables are all acquired locally and as such are not subject to exchange rates or import duties.

To summarise the services category, planning discrepancies account for most if not all of the extra CAPEX required in this category. Bad assumptions were made regarding pumping and ventilation capacities to be provided by the existing mine. The single reason for these bad assumptions was lack of communication between the operating mine and the extended division. Geographical location appears to be an advantage in *the services category* but *may* also be considered an underlying cause for the bad assumptions made. An existing mine able to provide pumping capacity, power, water, ventilation and compressed air will definitely result in costs savings when applied realistically.

3.4 Housing

Housing in this case includes modern hostel complexes and construction of houses in white, coloured and black townships. Increases in CAPEX in this category amount to just over 19%, or almost R13 million in 1988 real terms, above what was initially estimated. Raw material required to build hostels and homes is very expensive and labour for these projects is increasingly more expensive. Services for these buildings include fresh water and sewage reticulation, electric power and telephone lines. The post office however assumes the cost for telephone lines.

It is difficult to estimate the amount of money saved by building new townships adjacent to existing townships. The amount of money, in 1988 terms, to build an average three bedroom mine house with garage and servants quarters is approximately R75 000.

An access road, 5.5 km long, in 1988 terms, costs R2.5 million to build. A good estimate for a typical paved road where cut and fill balance is R500 000 per kilometre. This cost is naturally added to the cost of housing along with pipes and cables required for modern services.

3.4.1 Geological Variations

Geological variations have absolutely nothing to do with increased pre-production CAPEX costs, as far as housing is concerned, on a new mine.

3.4.2 Planning Discrepancies

Planning discrepancies, as with geological variations, have little if any effect on pre-production housing CAPEX. A workforce size is assumed using comparisons from other similar mines and the houses and hostels are built accordingly. For example, historical records for the group show that average productivity rates are approximately 30 tonnes (overall) per unskilled labourer per month. Combine this figure with the monthly tonnage expected from the mine and a workforce profile results. The number of skilled employees can similarly be estimated and the appropriate number and grade of houses are built accordingly.

The one flaw in this logic is the possibility of building houses for senior unskilled employees and their families. Depending on the social position taken by the mining company involved this could quickly add up to millions of extra Rands or nothing at all. For the purposes of this research project however the possible addition of these homes occurs only after the mine comes into production.

3.4.3 Escalation Factors and Exchange Rates

Since houses built in the Republic of South Africa (applying to the mines) are 100% local content, exchange rates do not play a role either. Escalation factors therefore account for the entire pre-production housing CAPEX increase of almost R13 million. This factor can be attributed to underestimation of expected escalation rates. Up to 1985 it was perfectly acceptable to assume annual escalation rates of 10%-12%. Compounding the difference between what was assumed and the actual figures of 16%-19% per annum over three years adds up to approximately 19%. This accounts entirely for the shortfall of capital experienced

Geographical location plays an extremely important role here. The ability to build houses near established residential areas results in savings in road construction, services installation, material transport costs and community facilities. Since estimation of these savings can be done accurately, with only escalation rates to consider, geographical location itself is not a sensitive area.

3.5 General

The general category covers all the items either too small to be considered individually or grouped together under general or pre-production capital expenditure from the start. These combined elements do however represent a 112%, or R86 million in 1988 real terms, increase over original estimates so an attempt will be made to expose the main reasons for this increase. General expenditures, in this case, refers to underground equipment, workshops, other buildings and equipment, surface transport, general and pre-production expenses.

To eliminate any confusion, the overall general category includes the items of general (as defined in the CAPEX estimates used by the model mine) and pre-production expenses.

3.5.1 Geological Variations

Geological variations have little or no effect on the general category. There may be some minor hidden costs included in the general category, pertaining to geological variations, but nothing of consequence.

3.5.2 Planning Discrepancies

Planning discrepancies, as with geological variations, have little or no effect on pre-production general CAPEX with perhaps one exception. Since the development category was adversely effected by planning discrepancies it follows that underground equipment will be similarly effected. Extra development requires extra equipment. In this case extra underground equipment adds an estimated

R6 million to R7 million to pre-production CAPEX. This is a relatively minor figure but nevertheless should be noted. The remaining items in the general category are not affected by planning discrepancies.

3.5.3 Escalation Factors and Exchange Rates

Escalation factors, or costs included in general or pre-production expenses, must therefore account for most of the increase experienced within the general category. Underground equipment, workshops, other buildings and equipment and surface transport are vulnerable to escalation in the same manner as housing and to a lesser extent the reduction plant. Underground equipment is subject to higher escalation rates than the other items and is analysed more extensively. Once again, exchange rates play only a minor role due to almost 100% local manufacture. Isolated components are perhaps imported but are of little consequence.

Underground equipment includes all rolling stock and vehicles required for development plus drills and winches. Table 3.7 gives 1988 prices for typical underground equipment required for primary and ore reserve development. Transport charges and general sales tax are not included.

Table 3.7 **Prices for Typical Underground Equipment** (1988 terms)

Equipment	Price (R)
0.25 cubic metre Loader	35 000
0.40 cubic metre Loader	45 000
Self-propelled Loader	107 900
6 ton Diesel Locomotive	50 000
10 ton Diesel Locomotive	85 000
6 ton Hopper	7 888
Drill Carriage	2 270
Drill Machines	1 360
Air Legs	510
37 Kw Slusher Winch	8 185
Hydraulic Drill Rig (2 or 3 boom)	640 000
5 tonne LHD	250 000
20 tonne Dump Truck	300 000
1 tonne Service Bakkie	20 000
Scissor Truck Utility Vehicle	180 000
Hydraulic Hammer	150 000

After interviewing *several representatives* from various companies it appears prices between competitors are close. The important fact is the escalation experienced with this type of machinery. For example, referring to Table 3.7, in 1986 the same 10 ton diesel locomotive cost approximately R50 000. Since this product is manufactured under licence entirely in South Africa the increase is attributed to local inflation and wage increases. These interviews with representatives exposed union muscle flexing, particularly in the steel industry, which brought about phenomenal wage increases during the past two years. Using the standard future and present value formulae an escalation rate of 30.38% per annum is revealed for typical underground equipment.

To summarise the general category it appears escalation factors account for much of the increase experienced. There is another element however, that of debenture interest payments, covered in the following chapter which actually accounts for 50% of the increase experienced in the general category.

4 RESULTS AND DISCUSSION

In the previous central chapters the categories of shafts, development, reduction plant, services, housing and general are analysed to determine underlying causes for the 59% increase in overall pre-production CAPEX experienced. Geological variations, planning discrepancies, escalation factors and exchange rates are the main reasons for the increase. *In this research project the cost of developing a new mine was analysed with information obtained from 1985 to 1988 CAPEX estimates. No mention was given however to the practice of pushing out capital spending to later periods. Some of this delayed pre-production CAPEX will be spent prior to production and some will be spent after production begins.*

A comparison between the initial feasibility study and actual progress outlines the most sensitive area, that of shafts and development, on a new gold mine in the Republic of South Africa. Rating the six categories for sensitivity provides a visual summary of this project report. Minor considerations not covered in the central chapters adds the finishing touch.

Following this are proposed solutions and methods of isolating and controlling pre-production CAPEX.

4.1 Comparison Between the Initial Feasibility Study and Actual Progress

Before the critical factors responsible for the 59% increase in pre-production capital expenditures can be identified a comparison between the initial feasibility study and actual progress must be completed. Development and shaft sinking are the two main categories focused upon.

The development from the existing mine of 13, 16, 19 and 21 levels to the sub-vertical shaft position for the extended division was crucial in the initial feasibility study. This development was delayed for various reasons:

a) Insufficient ventilation and consequent heat build-up.

b) Geological structure changes resulting in increased development distances.

c) Striking of water.

d) Long tramming distances.

e) Waste hoisting problems on the operating mine.

The completion of the ventilation shaft was also delayed due to:

a) Striking of water.

b) Poor ground conditions in the 11 level horizontal rope races.

c) Stopping sinking operations to install a mid-shaft loading system on 10 level. This became necessary when development by the existing mine on 13 level, the main level, fell behind by approximately nine months. An extra mid-shaft development crew was required to excavate the sub-vertical shaft hoist chambers according to schedule.

d) *Breaking away of the main return airway* on 10 level which was not allowed for in the initial feasibility study.

The sub-vertical shaft originally had a bottom working level of 896 metres below collar. For various reasons it was decided to deepen the shaft to an ultimate depth of 1 500 metres below collar. Even after rescheduling the new shaft design it was subsequently noted that no allowance had been made for cutting and commissioning of pumping and rock handling facilities and for the ore pass system.

Original planning entailed the operating mine pumping the expansion project's water. However in January

1988 conditions showed that this would not be possible. The extended division therefore had to excavate and commission their own pumping arrangements. Development of the major excavations was completed by means of a mid-shaft loading system situated on 10 level of the ventilation shaft. The operating mine was also required to develop settling and pumping excavations to handle longwall water on the lower levels of the mine.

Development delays on [illegible] have necessitated the earlier development of 10 level hanging wall drive (through 10 level mid-shaft loading) and 13 level footwall drive, to provide return airway capacity

The development from the existing mine was crucial to provide access, airways and the opening of ore reserve on a new longwall planned for production in 1990. Insufficient ventilation, increased development distances and tramming problems all contributed to development falling behind schedule.

Insufficient ventilation included the following problems:

a) Initially only 40 cubic metres per second was available for 13 and 21 level.

b) Purchase and installation of two fans on 13 level increased air volumes to 110 cubic metres per second for 13, 16, 19 and 21 levels. However only 80 cubic metres per second could be used for development to the extended division until the completion of a new ventilation shaft on the existing mine.

c) A low mass/volume air flow coupled with a constant heat input, led to significantly higher temperatures than would be normally expected.

d) Additional heat load was input to the system due to hot water intersections. Excessively high face temperatures (35-38 degrees centigrade wet bulb) resulted causing poor labour efficiencies.

21 level was actually stopped by the Inspectorate and specialised cooling equipment had to be installed.

e) When water was switched off over weekends and holidays, the heat build-up resulted in no work being possible on the following Monday and sometimes Tuesday.

f) Additional development not allowed for in the initial feasibility study placed further pressure on an already overextended system.

Increased development distances in both primary development ends and opening of ore reserves were due primarily to changes in the original interpretation of geological structure. Table 4.1 compares original feasibility estimates with actual distances

Table 4.1 **Comparison of Estimated and Actual Development Distances**

Development	Estimate (m)	Actual (m)
13 H/W drive	2200	2955 (+ 755)
13 H/W twin	0	2631 (+2631)
16 F/W drive	3000	4030 (+1030)
19 F/W drive	3200	4427 (+1227)
21 F/W drive	3100	3530 (+ 430)
Service # I.S.S	400	581 (+ 181)
16 level ore reserve development	300	600 (+ 300)
Vent development	0	58 (+ 58)
17 level ore reserve development	640	1390 (+ 750)
18 level ore reserve development	790	1990 (+1200)
19 level service shaft station development	0	322 (+ 322)
19 level ore reserve development	140	970 (+ 830)
20 level ore reserve development	550	1230 (+ 680)
21 level ore reserve development	640	1130 (+ 490)

The total amount of development estimated in the 1985 initial feasibility study was 14 960 metres. For various reasons, by 1988 this figure had increased to 25 844 metres. Extra costs of developing 10 844 extra metres are compounded by an escalation factor of 18% per annum for development costs.

On 13 level a twin had to be developed for ventilation purposes (2 631 metres). This was not allowed for in the initial feasibility study. The original planning had allowed for 13 level hanging wall drive to be a multi-blast smokebox. However due to difficulties encountered by the operating mine during development, it was necessary to reduce the size of the haulages on 16, 19 and 21 levels. 19 and 21 levels are intake airways for the extended division, and a reduction in intake air capacity was incurred. Thus the 13 level hanging wall twin was necessary to compensate for this. Also on 13 level, the main shaft station development was not catered for in the initial feasibility study. Minor problems on 13 level arose from increased tramming distances and the intersection of a water bearing formation.

On 16 level the increased footwall (primary) development was attributed to geological structure changes. Ore reserve development on this level increased due to faulting. This is the top level of the service shaft designed to accommodate the new longwall. Poor ground conditions resulted in the entire headgear development for the service shaft collapsing, causing extensive damage to the initial shaft system and the shaft itself.

19 level primary development was also underestimated due to geological structure changes. Localised faulting, illustrated by Figure 3.2, also increased the amount of ore reserve development required. The service shaft between 16 and 19 level is actually 'upside down' because 19 level is the bank level. No cubic metres excavated from the service shaft or associated station development were accounted for in the initial feasibility study. The feasibility study also did not make any allowance for a cross cut to reef, although the respective reef raise was included.

Geological structure changes also increased the amount of primary footwall development on 21 level and localised faulting increased the amount of ore reserve development metres. Numerous reasons for delays on this level eventually led to the realisation that it would not be completed on time for the projected production start-up. When this level fell so far behind schedule it was decided to change priorities and devote more resources to ore reserve development. Initially 21 level was required as an intake airway. Since it will not be completed on time it was agreed that the existing mine would provide the intake capacity.

Other general development delays, especially the 17, 18 and 20 level interlevels, were attributable of faulting and the need for extra raises and boxholes. On all of the levels mentioned above no consideration was given to boxholes, follow-on stubs, dams, cooling chambers, borehole excavations, etc. Main development between 13 and 21 levels at the new longwall position was delayed because of additional raise boring required for ventilation. Removal of raise bore chips seems to be a condition often overlooked. Finally, during the fire on the existing longwall allocated to the extended division, all development on the four major levels ceased for approximately three months. Water had to be used to flood the longwall and seals prevented any further development.

Tramming problems resulted from excessive tramming distances and numerous breakdowns. Round trip tramming times presently average 2.5 hours and long travelling times to and from the working faces reduced effective face times considerably.

An interesting observation is the high turnover and unplanned absenteeism experienced in the area of the project being developed from the existing mine. It is difficult to quantify the amount of work lost due to poor or no supervision and a continual shortage of labour. There is something to be said for favourable environmental conditions underground.

With regard to timing down to the main level in the sub-vertical shaft; the shaft is one full year behind schedule due to the following reasons:

a)	Cover drilling	118 days
b)	10 level development not planned	21 days
c)	Poor ground in the 11 level rope races	48 days
d)	Installation of mid-shaft loading	106 days
e)	Rope changes and breakdowns	17 days
	Total	310 days

4.1.1 Sensitivity Rating

An attempt to exactly quantify the effects of geological variations, planning discrepancies, escalation factors and exchange rates on each of the six categories would be unreasonable and inaccurate. The results of this research project are only as accurate as the source of information. Information which varies from group to group and mine to mine. Certain isolated items are accurately costed and may be used for reference, but the main goal of this research project is to point out pre-production CAPEX sensitivity.

As shown in Table 2.3 the categories of development, reduction plant, services and general all exceed original CAPEX estimates by over 110%. Housing and shaft estimates were also exceeded, but to a much lesser extent. All six categories and the major factors which influenced them are rated as follows, from least sensitive to most sensitive.

a) Housing escalation factors

b) Shaft escalation factors and exchange rates.

c) Development escalation factors

d) Development geological variations.

e) Development planning discrepancies.

f) Service planning discrepancies.

g) Reduction plant escalation factors and exchange rates.

Pre-production capital expenditures always have been and always will be subject to influences which apply upward pressure on the cost of bringing a mine into production. While not necessarily sensitive in the same order as the above rating, these major categories must be carefully analysed in future feasibility studies to keep pre-production CAPEX under control. This rating does not include normally minor considerations not covered in the central chapters of this research project.

4.1.2 Minor Considerations not Covered in Sensitivity Analysis

Minor considerations for the purposes of this research project include methods of financing a project, tax structures and geographical location.

The issue of geographical location has been briefly discussed in the central chapters. To generalise, geographical proximity to existing mining operations, infrastructure and communities requires less capital to get a new mine into production than say a mine in the middle of the Potchefstroom gap. Apparent advantages however of favourable geography must not be taken for granted. It would be wise in all cases to plan a new mine totally independent from an existing operation. This way a 'most expensive' case can be included in a feasibility study. For the mine used as the model in this report it appears the 'least expensive' case was put forward for approval.

Methods of financing a new mine or expansion project vary considerably but normally have a relatively minor effect on overall pre-production CAPEX. In this case R119 million was financed through the issue of unsecured convertible debentures and the balance funded with revenue from the operating mine. Table 4.2 sums due dates and respective interest due on these debentures.

Table 4.2 Due Dates for Debenture Interest

Call	Date	Interest Due (R)
First	12/85	490 500
Second	06/86	1 716 750
Third	12/86	2 207 250
Fourth	06/87	2 943 000
Fifth	12/87	3 679 000
Sixth	06/88	4 905 000
Seventh	12/88	6 131 000
Eighth	06/89	7 603 000
Ninth	12/89	9 320 000
Tenth	06/90	10 791 000
Eleventh	12/90	10 791 000
Twelfth	06/91	10 791 000

These unsecured convertible debentures were issued at par price of R44.00 each. An initial R4.00 was required by the vendors purchasing the debentures in July 1985. Call dates spaced at six monthly periods outlined the full extent to whic these debentu es were to be utilised. Each vendor is expected to pay an additional R5.00 every six months until the full debenture price of R44.00 is reached. Interest on these debentures amounts to 18% per annum until such time as the extended division reached a sustained mill production rate of 120 000 tonnes per month. The point is that these interest payments were not included in the initial feasibility study. Up to June 1990, within the pre-production period specified, a total of R49 786 500 was omitted. Out of the R99 538 000 increase in the General category, the debenture interest payments represent 50% of the extra money required. Obviously the factors of geology, planning, an escalation and exchange rates have nothing to do with this error. It was simply a very costly oversight.

Taxes for a pre-production mine do not have any direct effect on pre-production capital expenditures. Normally, in the case of a new mine, pre-production CAPEX is accumulated until the mine begins generating revenue. Capital expenditure, plus a capital allowance, are then deducted over a period of time until yearly revenue exceeds remaining CAPEX carried forward. Only then does the mine start paying taxes on profits. In this case however, the majority of pre-production CAPEX originated from a producing mine. Because the extension is not legally independent this allows for a full write-off of CAPEX in the same year occurred against revenue generated by the producing mine. Hence the amount of CAPEX spent is not effected but the cash flows are.

Unfortunately an indirect consequence of this is the willingness to spend money as needed with little thought towards cost management. Perhaps this is the view of an outsider, but the mining industry in South Africa has been blessed with inexpensive high grade gold deposits. Abundant cheap labour has allowed this blessing to be exploited profitably. Times are changing however. Grades are continually decreasing and costs are continually rising, but mining industry mentality stays the same. Herbert Hoover, the preeminent mining engineer of his time, believed the mark of a good mine manager was a history of continually decreasing unit costs. [illegible] mining projects in the Republic of South Africa must concentrate on the reduction of unit costs. The concept of getting "stof" out of the mine at any cost needs to be replaced with efficient extraction methods based on sound engineering principles. Every mine faces the same destiny; the cost of removing a unit of ore exceeds the value contained within the same unit. This destiny can however be postponed by efficient management of available resources applied to both pre-production and production environments.

Recent legislation calling for major taxation reforms may soon change all this. The possibility of capital expenditures being deducted from revenue over a period of years exists, as does a minimum tax on companies declaring dividends but not paying taxes.[(5)] A flat tax rather than a progressive rate has also been proposed.

Instead of being able to write off 100% of the CAPEX incurred during a financial year the Margo Commission recommends a three year 50:30:20 rate.[(6)] Indications are the 10% capital allowance presently enjoyed by deep level mines would also fall away.[6] Present real capital investment in the mining industry is already on the decline.[1] The implementation of this recommendation would further discourage capital investment in the industry which provides South A ca with more than two-thirds of its foreign exchange

The minimum tax on companies (MTC) is a cash flow tax whose effect is only realised when the mine starts operating at a profit.[8] In the extreme case it could alter the pattern of CAPEX spending if pre-production costs for an extension equalled or exceeded revenue generated by the operating mine.

A flat tax rate has the effect of reducing the amount of tax paid by high grade mines. Progressive taxes favour marginal producers but could also encourage CAPEX spending on operating mines for the sake of tax savings. Actual pre-production costs would not be changed, but the net after tax cash flows will be effected.

Depending on who you talk to, CAPEX write-off rates and MTC progressive vs flat tax rates have positive and negative implications for the mining industry. For the purpose of this research project none of these proposed tax reforms are certain yet. While the overall profitability of operating mines would certainly be effected, the effect on pre-production capital expendiutures and present values for new mining ventures is minimal.

At the end of 1988 the report of the Marais committee on mining taxation was published, with somewhat different recommendations. The final position should become clear during 1989.

4.2 Isolation and Control of Sensitive Areas

Once potential problem areas are identified, steps must be taken to achieve accurate estimates of the amount of pre-production CAPEX required. Setting up a sort of 'check-list' covering all possible areas for a new mine is an alternative which requires much time and effort but results in a comprehensive exercise. This check-list can then be matched with current prices applicable to the mining industry. Refer to the appendices of this research project for a guideline to such a check-list and 1988 prices.

With this in mind the factors of geological variations, planning discrepancies, escalation and exchange rates can be evaluated for effect. Remembering the sensitivity rating and the major categories most prone to cost increases will help serve as a guideline for identification of potential problem areas. The concept of applying probability to the extent of these factors, thus estimating their effect in Rands, can be considered but is not covered in this research project.

4.2.1 Estimation Procedures

Two basic methods of estimating pre-production capital expenditures have been considered. The 'ratio' method of applying costs proportionate to historical models of similar capacity is one method. The other method entails detailed estimating of costs, both present and future. Even within the same group, costs in the Republic of South Africa are rising too fast to assume 'ratio' proportions will stay the same. Therefore a more detailed approach is required for future feasibility studies to be valid.

Geological variations cannot be predicted accurately due to the little amount of information available. Surface boreholes are expensive and time consuming, and historical continuity of reef leads to assumed mine valuations. It would be extremely naive however to assume the geological structure outlined by a dozen or so boreholes will remain the same through production.

Planning discrepancies should not account for the 22% of the extra overall CAPEX as experienced on the model mine. With a structured, detailed approach the effect of planning discrepancies can be reduced to a minimum.

Escalation factors and exchange rates are probably the most difficult influences to predict. South African inflation rates calculated for consumer prices averaged 12.6% between 1974 and 1984.[(1)] Furthermore, having peaked at 15.2% in 1981 a steady downward trend was observed through 1984 when yearly inflation was 11.7%. Also in 1984 the exchange rate averaged 0.6954 U.S. Dollars per rand following a continual downward trend from 1980.[1] Planning a new mine in 1985 required use of these statistics plus popular opinion of future economic events. Hence the 10% and 11% per annum escalation factors used in the initial feasibility study for the model mine. No one could foresee the prolonged high inflation rates and poor exchange rates experienced through 1988.

4.2.2 Feasibility Implications for New Mining Projects

Detailed capital estimating will give more accurate feasibility studies. The 'most expensive' case represents a conservative approach but is necessary in these times. Today we speak in billions of Rands required to bring a modern gold mine into production. Serious underestimating of pre-production CAPEX could result in the suspension of a project. Even if sufficient ore reserves are available to justify a new mine, the supply of capital required at time zero must be sufficient to bring the mine into production over an extended period.

4.3 Applying Control in a Mining Environment

It is one thing to talk about CAPEX and operating within budget. It is quite another thing to do it. Underestimation, or overspending, of money on new mines is an old problem. Overspending is often blamed on management whereas the root problem is underestimation before management takes control of the project.

4.3.1 Dedication to Control

Once given a CAPEX guideline management must adhere to it as closely as possible. A 'buck here and a buck there' soon add up and capital spending gets out of hand. Charging items to different accounts may work for a short time but eventually causes a shortage of funds somewhere. Also, the practice of pushing out or delaying capital expenditures fails to actually solve the problem. Instead it creates compounded problems an extended period.

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4.3.2 Management Responsibilities

Top management is responsible for the overall success of a new project. Delegating responsibility through the ranks, down to the person putting together the nuts and bolts, is necessary. People must be held accountable. In this manner overspending can be reduced to a minimum.

5 CONCLUSIONS AND RECOMMENDATIONS

In the case of the model analysed pre-production CAPEX was underestimated by ± 59%. It is not the intention of the report to criticise mine management but to illustrate the shortfalls of conventional thinking when estimating capital expenditures.

Within the mining industry, international recognition of the control over working costs reflects on the ability of the local mining profession. Competition is simply who can produce an ounce of gold the cheapest. I firmly believe that the gold price will not (cannot) fall below the lowest working cost per ounce produced.

While the sensitivity rating shows development is most vulnerable to cost increases, escalation factors and exchange rates applied to the reduction plant proved to be the most expensive area. A suggestion for locally manufactured items is to apply escalation factors calculated within the mining industry. Establish a working cost index from a mine milling a constant amount over a minimum of four quarters.

Working costs associated with the constant mill figures are then monitored for increases. These increases represent a more accurate escalation factor than the inflation figures published by the CSS.

For items manufactured overseas, use escalation rates applicable to the country of origin. Currency fluctuations can then be applied over a range to cater for changing Rand exchange rates.

My strongest recommendation for planning on the mine is the use of qualified mining people with access to modern computers and software. Too often mine planning is done from a centralised office where actual contact with the mine and the people involved is remote. In this case the expansion project was accomplished without consulting the mine involved, resulting in erroneous assumptions as to what the operating mine could realistically accomplish. Shortages of pumping capacity and ventilation capacity on the mine resulted in extra time and money required to complete the jobs.

Ancient methods of hand drawn charts and development designs should be replaced with modern computerised packages. Today the technology exists which allows a common PC to accomplish what once required a mainframe or mini-computer. The ability to design a shaft system and associated development can be done on a CAD system within a matter of days. Once the base case is established alterations can be made to determine the best (or the most profitable) arrangement. Moving the site of a main shaft will not change the cost of sinking but could theoretically result in millions of extra Rand spent or saved in development costs over the life of the mine. A typical PC with 40 Mb of storage capacity and color graphics capabilities accompanied by a printer and plotter will do the job.

Minimum software requirements are the mining CAD (developed in South Africa) coupled with dBASE and LOTUS 123 for data manipulation. Expect to pay about R30 000 for the computer equipment and about R50 000 for the software in 1988 terms. Training the mine planner to operate the system depends on the calibre of mine planners employed.

State of the art computer developments in South Africa are directly applicable to the mining discipline. The same CAD software package discussed allows for the input of a geological data base which allows not only development design but stoping sequences to be imposed. Resulting cash flows can be generated for short term planning or for the life of a mine. All within a matter of minutes. If a fire takes out a longwall for example, management has the tools necessary to evaluate the consequences immediately and plan accordingly.

5.1 Summary and Conclusions

A detailed approach, with nothing overlooked, is required these days to provide an accurate estimation of capital costs. Bringing a mine into production and digging a hole in the ground are entirely different activities. It is possible to accurately estimate the cost of bringing a mine into production and do so under budget. Gold production in South Africa means hard currency necessary to maintain a stable economy. Future plans for new mines must be accomplished with a minimum of pre production CAPEX. Todays operating mines will someday have to be replaced with new mining projects if South Africa is to maintain its lead in free world gold production.

5.2 Recommendations for Future Analysis

The purpose of this research project was to illustrate the sensitivity of pre-production capital expenditures on a new gold mine. Reduction plant expenditures were underestimated more than any other category because of escalation factors and exchange rates. The most sensitive category however was development.

Present conventional mining practice will eventually be replaced with modern techniques but the factors resulting in cost underestimating will be the same. Bad estimates of escalation factors, exchange rates, geological variations and planning details could in many cases contribute towards the demise of a mining project if not carefully considered through each phase of the project. An increased awareness however of the factors discussed will improve the chances for a successful operation.

APPENDIX A

Initial Feasibility Study
Breakdown of Pre-Production CAPEX (R'000)

All financial figures given in December 1985 terms. Financial years ending June 30.

Category	1985	1986	1987
Shafts	3 835	25 355	43 835
Reduction Plant	-----	-----	3 300
Pumping	-----	-----	-----
Ventilation	-----	660	275
Refrigeration	-----	-----	-----
Compressed Air	-----	1 100	550
Underground Equipment	1 287	-----	-----
Electric Power	990	-----	1 870
Workshops	-----	-----	-----
Black Accommodation	-----	3 300	4 950
Other Buildings and Equipment	-----	330	2 310
Surface Transport	363	187	110
Housing	-----	6 160	7 700
General	3 047	165	1 650
Development	2 530	9 900	7 370
Pre-production Expenses	-----	3 300	4 400

Category	1988	1989	1990
Shafts	39 820	45 870	23 705
Reduction Plant	5 500	14 300	15 400
Pumping	-----	1 650	2 750
Ventilation	220	550	3 740
Refrigeration	-----	4 950	7 150
Compressed Air	2 200	3 850	2 750
Underground Equipment	-----	1 100	4 400
Electric Power	1 430	2 420	1 540
Workshops	550	550	550
Black Accommodation	4 730	3 300	3 960
Other Buildings and Equipment	858	660	330
Surface Transport	-----	330	770
Housing	8 470	8 030	4 070
General	715	2 200	1 485
Development	6 160	6 160	3 630
Pre-production Expenses	[illegible] 900	9 900	12 100

APPENDIX B

Forecast of Operations for the Extended Division
Financial years ended June
(R'000 if not stated)

Year end June Years per cycle	1986 1	1987 1	1988 1
Mill rate (TPM)	0	0	0
Yield (grams/ton)	0	0	0
Kilograms gold	0	0	0
Gold Price (R/kg)	0	0	0
Costs per ton milled	0	0	0
Working costs	0	0	[illegible]
Revenue	0	0	[illegible]
Profit	0	0	[illegible]
Sundry Mine Revenue	0	0	0
Expenditures	9 460	11 616	19 433
Working profit	-9 460	-11 616	19 433
Capital Expenditure	40 997	74 536	78 037

Year end June Years per cycle	1989	1990 1	1991 1
Mill rate (TPM)	0	0	60 000
Yield (grams/ton)	0	0	[illegible]
Kilograms gold	0	0	4 680
Gold Price (R/kg)	0	0	32 210
Costs per ton milled	0	0	163.[illegible]
Working costs	0	0	117 641
Revenue	0	0	150 743
Profit	0	0	33 102
Sundry Mine Revenue	0	0	404
Expenditures	21 376	20 615	0
Working profit	-21 376	-20 615	33 506
Capital Expenditure	119 471	108 709	87 781

Year end June Years per cycle	1992 1	1993 1	1994 1
Mill rate (TPM)	80 000	100 000	120 000
Yield (grams/ton)	6.5	6.5	6.5
Kilograms gold	6 240	7 800	9 360
Gold Price (R/kg)	35 431	38 974	42 871
Costs per ton milled	160.07	163.11	169.89
Working costs	153 667	195 732	244 642
Revenue	221 089	303 997	401 272
Profit	67 422	108 265	156 630
Sundry Mine Revenue	593	815	1 076
Expenditures	0	0	0
Working profit	68 015	109 080	157 706
Capital Expenditure	77 306	50 803	69 795

Year end June Years per cycle	1995 1	1996 1	1997 1
Mill rate (TPM)	120 000	120 000	120 000
Yield (grams/ton)	6.5	6.5	6.5
Kilograms gold	9 360	9 360	9 360
Gold Price (R/kg)	47 158	51 874	57 061
Costs per ton milled	187.88	205.57	226.13
Working costs	269 107	296 021	325 627
Revenue	441 399	485 541	534 091
Profit	172 292	189 520	208 464
Sundry Mine Revenue	1 184	1 302	1 432
Expenditures	0	0	0
Working profit	173 476	190 822	209 896
Capital Expenditure	83 026	100 144	162 257

Year end June Years per cycle	2003 6	2009 6	2029 20
Mill rate (TPM)	123 333	176 666	180 000
Yield (grams/ton)	6.5	6.5	6.5
Kilograms gold	9 620	13 780	14 040
Gold Price (R/kg)	80 714	142 992	179 083
Costs per ton milled	317.19	515.51	643.49
Working costs	472 139	1097118	1389936
Revenue	791 769	1978689	2514324
Profit	309 629	881 571	1124388
Sundry Mine Revenue	2 095	5 305	6 741
Expenditures	0	0	0
Working profit	311 725	886 876	1131128
Capital Expenditure	195 638	257 187	232 897

Year end June Years per cycle	2031 2	2033 2	2036 3
Mill rate (TPM)	175 000	152 500	0
Yield (grams/ton)	6.5	6.5	0
Kilograms gold	13 650	11 895	0
Gold Price (R/kg)	179 083	179 083	179 083
Costs per ton milled	643.49	643.49	0
Working costs	1351328	1177586	0
Revenue	2444482	2130191	0
Profit	1093154	2130191	0
Sundry Mine Revenue	6 741	6 741	0
Expenditures	0	0	0
Working profit	1099895	959 346	0
Capital Expenditure	196 995	196 995	0

APPENDIX C

Summary of Initial CAPEX Forecast for the Proposed Mine Extension
(Estimated 14 February 1986)

Heading	Total of Forecast (R'000)	Spent to 30/06/85 (R)
Ventilation Shaft	22 463	3 364 502
Main Shaft	94 168	0
Sub-Vertical Shaft	68 050	0
Service Shaft	8 800	0
Reduction Plant	39 180	0
Pumping	4 900	0
Ventilation & Refrigeration	19 800	0
Compressed Air	10 045	0
Underground Equipment	12 069	1 190 810
Electric Power Supply	20 200	1 140 041
Workshops	3 536	0
Black's Accommodation	21 765	0
Other Buildings & Equipment	6 217	0
Surface Transport	3 590	411 542
Housing	30 130	0
General	13 574	726 321
Development	35 101	2 708 633
Waybill & General Expenses	36 000	0
Sundry Persons	1 000	0
Grand Total Mine Excluding Inflation	450 587	9 541 849
Inflation Factor		0.0
Inflation Provision on Grand Total	96 151	0
Grand Total Including Inflation	546 738	9 541 849

Forecast in six monthly periods (R'000)

Heading	1985 1	1986 2	1986 3
Ventilation Shaft	4 419	5 101	4 690
Main Shaft	13 005	12 138	12 853
Sub-Vertical Shaft	0	0	2 000
Service Shaft	0	0	0
Reduction Plant	20	60	1 000
Pumping	0	0	0
Ventilation & Refrigeration	0	1 000	100
Compressed Air	817	800	428
Underground Equipment	645	233	0
Electric Power Supply	508	452	0
Workshops	244	642	300
Black's Accommodation	0	2 025	3 870
Other Buildings & Equipment	241	1 870	1 522
Surface Transport	431	237	220
Housing	1 850	2 000	2 000
General	245	3 803	1 280
Development	3 551	4 900	4 710
Waybill & General Expenses	1 830	2 000	2 000
Sundry Persons	0	0	100
Grand Total Mine Excluding Inflation	27 806	37 261	37 073
Inflation Factor	0.0	[illegible]	5.00
Inflation Provision on Grand Total	0	[illegible]	1 854
Grand Total Including Inflation	27 806	37 261	38 926

Forecast in six-monthly periods (R'000)

Heading	1987 4	1987 5	1988 6
Ventilation Shaft	3 966	922	0
Main Shaft	11 936	10 300	9 900
Sub-Vertical Shaft	5 000	8 900	12 300
Service Shaft	1 100	1 500	1 800
Reduction Plant	2 300	2 200	3 300
Pumping	0	500	0
Ventilation & Refrigeration	200	250	0
Compressed Air	0	500	1 500
Underground Equipment	500	0	0
Electric Power Supply	0	3 000	600
Workshops	500	500	300
Black's Accommodation	3 470	3 100	2 000
Other Buildings & Equipment	422	160	0
Surface Transport	220	800	250
Housing	2 500	2 000	6 135
General	900	300	800
Development	4 044	3 100	3 100
Waybill & General Expenses	2 000	4 500	4 500
Sundry Persons	400	500	0
Grand Total Mine Excluding Inflation	39 458	43 032	46 485
Inflation Factor	10.00	15.00	21.00
Inflation Provision on Grand Total	3 946	6 455	9 762
Grand Total Including Inflation	43 403	49 486	56 246

Forecast in six-monthly periods (R'000)

Heading	1988 7	1989 8	1989 9	1990 10
Ventilation Shaft	0	0	0	0
Main Shaft	9 700	9 400	3 806	1 130
Sub-Vertical Shaft	12 700	11 960	10 090	5 100
Service Shaft	1 800	1 500	1 100	0
Reduction Plant	6 500	8 000	7 900	7 900
Pumping	500	1 100	1 200	1 600
Ventilation & Refrigeration	1 400	4 950	6 700	5 200
Compressed Air	2 000	1 500	1 500	1 000
Underground Equipment	0	1 000	4 000	4 500
Electric Power Supply	7 000	800	4 500	2 200
Workshops	300	300	450	0
Black's Accommodation	1 000	2 000	2 300	2 000
Other Buildings & Equipment	120	290	981	611
Surface Transport	220	220	300	280
Housing	5 505	4 140	2 300	1 700
General	3 000	1 350	1 070	100
Development	3 100	3 100	1 987	800
Waybill & General Expenses	4 500	4 500	5 000	5 170
Sundry Persons	0	0	0	0
Grand Total Mine Excluding Inflation	59 345	56 110	55 184	39 291
Inflation Factor	27.00	33.00	39.00	46.00
Inflation Provision on Grand Total	16 023	18 516	21 522	18 074
Grand Total Including Inflation	75 368	74 626	76 705	57 364

APPENDIX D

Initial CAPEX Forecast for the Proposed Mine Extension (Estimated 14 February 1986)

Heading	Total of Forecast (R'000)	Spent to 30/06/85 (R)
Ventilation Shaft		
Site Levelling	88	88 173
Site Establishment	2 302	2 301 857
Shaft Collar	238	238 257
Miscellaneous Costs	1 634	45 713
Sink and Line Shaft	18 201	690 502
Main Shaft		
Construction of Main Terrace	2 466	0
Headgear and Shaft Collar	3 487	0
Man Winder House	1 380	0
Platform Winder	2 615	0
Services Duct	1 500	0
Concrete Batching Plant	350	0
No. 1 Man Winder (5.5m diameter)	9 400	0
No. 2 Man Winder (5.5m diameter)	9 400	0
Rock Winder	15 600	0
Personnel Duct	190	0
Sink Line and Equip Shaft	33 100	0
Station Development	1 600	0
Sinking Hoisting Equipment	3 600	0
Permanent Hoisting Equipment	4 300	0
Winder Spares	480	0
Permanent Signalling	250	0
Rope Reeling Arrangements	390	0
Main Loading and Transfer Arrangements	2 200	0
Shaft Bottom Arrangements and Spillage	500	0
Bank Layout and Site	500	0
Site Investigation and Drilling	150	0
Emergency Diesel Alternator	110	0
Waste Handling on Surface	400	0
Surface Protection of Bank Terraces	[illegible]	0

Heading	Total of Forecast (R'000)	Spent to 30/06/85 (R)
Sub-Vertical Shaft		
Initial Shaft System (ISS) Including Headframe Barrel, Winder Chambers and Development	14 100	0
Sink Line and Equip Shaft to 25 Level	11 300	0
Station Development to First Ore Pass Positions on Five Major Levels	4 500	0
No. 1 Man Winder	9 400	0
No. 2 Man Winder	9 400	0
Rock Winder	8 700	0
Winder Spares	500	0
Sinking Hoisting Equipment	4 300	0
Permanent Signalling System	200	0
Mid-Shaft Loading System on 25 Level	550	0
Brow Box on 21 Level	450	0
Reef & Waste Passes to 26 Level	3 300	0
Deepen Shaft to 29 Level	900	0
Air Filtration and Cooling System for Hoists	450	0
Service Shaft (16-19 Level)	8 800	0
Reduction Plant	39 180	0
Pumping	4 900	0
Waybill and General Expense Account	36 000	0
Sundry Persons	1 000	0

Heading	Total of Forecast (R 000)	Spent to 30/06/85 (R)
Ventilation & Refrigeration		
Return Airway Booster Fans	40	0
Main Shaft Sinking Ventilation	700	0
Sub-Vertical Shaft Sinking Ventilation	450	0
Ventilation Shaft Permanent Fans	3 350	0
Sub-Vertical Underground Coursing Fans	100	0
21 Level Intake Airway	900	0
13 to 14 Level Return Airway and Borehole	1 600	0
Refrigeration Including Bulk Coolers and Chilled Water Reticulation	12 300	0
Compressed Air System	10 045	0
Underground Equipment		
13, 15 & 21 Level Equipment	1 501	1 190 810
19 Level Development	568	0
Three LH Units	500	0
Additional u/g Equipment	5 500	0
Raise Boring Machines	4 000	0
Electric Power Supply		
Temporary Power Supply	1 800	1 140 041
Initial Electric Power	300	0
Surface Electric Power	5 800	0
Main Shaft Electric Power	7 800	0
Sub-Vertical Shaft Power	4 500	0
Development		
Main Level at 120m/month	6 600	1 622 330
Development on Three Levels	27 200	1 086 303
Sub-Vertical Shaft Development	1 300	0

Heading	Total of Forecast (R'000)	Spent to 30/06/85 (R)
Workshops		
Workshops	886	0
Drill, Loco and Carpenter Shops	1 300	0
Winch, Truck and Transport Shops with Change Houses	750	0
Workshop Equipment	600	0
Black's Accommodation		
Services for Hostel Blocks (864 men)	800	0
Hostel Blocks for 864 Men	3 020	0
Temporary Kitchen Facilities for 1200 Men	250	0
Hostel Administration Including Pay Hall, X-Ray and Dressing Station	600	0
Parking Facilities	100	0
Sports Fields	45	0
First Aid Room	50	0
Hostel Complex for 9 336 Men	12 400	0
Married Quarters	700	0
Permanent Kitchen and Dining Facilities for 6 500 Men	3 800	0
Surface Transport		
Construction of Access Road	883	411 542
Surface Transport	487	0
Roads	2 220	0
Housing		
Purchase of 135 Erven in White Township	1 850	0
104 Houses in Township	8 500	0
40 Single Quarters & Flats	2 490	0
Services for 370 Stands	6 290	0
Additional Housing	11 000	0

Heading	Total of Forecast (R'000)	Spent to 30/06/85 (R)
Other Buildings & Equipment		
Heavy Machinery Store	424	0
Main Shaft Engineering Buildings	350	0
Temporary Administration	181	0
Initial Magazine & Fuse Store	300	0
Office Furniture & Survey Equipment	150	0
Car Shelters	70	0
Security Complex	200	0
Mine Store	660	0
Shaft Offices & Change House	1 330	0
Crush and Cap Lamp House	800	0
Main Shaft Covered Walkway	100	0
Proto & Fire Fighting Building	80	0
Heat Tolerance Training Centre	462	0
Shift Boss Store	110	0
Office & Canteen for Workshops	50	0
Micro Computers & Equipment	300	0
General		
Geotechnical Survey	122	71 678
Telephone Service	1 100	2 415
Rand Water Board Supply	1 832	652 228
Purchase of Freehold		0
Reticulation of Bank, Plant, Offices, Hostel & Stores	1 000	0
Sewage Disposal and Treatment Plant	1 650	0
Stormwater Drains	550	0
Surface Equipment	120	0
Badge Reader Arrangements	400	0
Back Filling Plant and Reticulation	3 000	0

APPENDIX E

Summary of Updated CAPEX Forecast for the **Proposed Mine Extension**
(Estimated 21 June 1988)

Heading	Total of Forecast (R'000)	Spent to 30/06/88 (R)
Ventilation Shaft	25 160	25 160 244
Main Shaft	120 757	90 409 713
Sub-Vertical Shaft	90 876	45 397 000
Service Shaft	13 660	6 660 000
Reduction Plant	102 928	27 718 753
Pumping	22 420	3 500 000
Ventilation & Refrigeration	47 838	7 619 169
Compressed Air	12 734	5 082 309
Underground Equipment	19 070	7 970 012
Electric Power Supply	20 357	6 921 661
Workshops	5 975	3 979 526
Black's Accommodation	32 722	17 279 000
Other Buildings & Equipment	15 171	8 410 894
Surface Transport	7 931	6 600 395
Housing	46 070	18 736 238
General	20 984	5 654 633
Development	98 588	47 348 000
Pre-Production Expenditures	91 772	36 570 000
Sundry Persons	2 182	1 173 000
Grand Total Mine Excluding Inflation	797 195	372 190 547
Inflation Factor	0.0	0.0
Inflation Provision on Grand Total	16 018	0
Grand Total Including Inflation	813 213	372 190 547

Forecast in six-monthly periods (R'000)

Heading	1988 7	1989 8	1989 9	1990 10
Ventilation Shaft	0	0	0	0
Main Shaft	9 067	11 547	7 793	1 940
Sub-Vertical Shaft	11 730	11 150	12 218	10 381
Service Shaft	2 000	1 610	1 450	1 940
Reduction Plant	27 505	24 083	15 671	7 950
Pumping	4 240	5 700	4 430	4 550
Ventilation & Refrigeration	7 114	7 895	12 760	12 450
Compressed Air	3 350	3 350	712	240
Underground Equipment	500	1 525	3 550	5 525
Electric Power Supply	1 495	3 790	4 490	3 660
Workshops	0	0	135	1 860
Black's Accommodation	2 268	2 360	4 205	6 610
Other Buildings & Equipment	1 060	455	2 105	3 140
Surface Transport	431	50	500	350
Housing	4 830	6 724	6 600	9 180
General	3 364	1 344	6 371	4 250
Development	12 660	10 120	12 700	15 760
Pre-Production Expenditures	11 600	13 600	15 500	14 502
Sundry Persons	709	0	0	300
Grand Total Mine Excluding Inflation	103 923	105303	111 190	104 588
Inflation Factor	0.0	0.0	5.0	10.00
Inflation Provision on Grand Total	0	0	5 [illegible]60	10 459
Grand Total Including Inflation	103 923	105303	116 749	115 046

APPENDIX F

Updated CAPEX Forecast for the Proposed Mine Extension
(Estimated 21 June 1988)

Heading	Total of Forecast (R'000)	Spent to 30/06/88 (R)
Ventilation Shaft		
Closed Estimates	1 552	1 551 919
Miscellaneous Costs	3 992	3 991 800
Sink and Line Shaft	19 617	19 616 525
Main Shaft		
Closed Estimates	8 583	8 582 872
Sink Line Equipment	45 991	38 041 000
Sinking Hoisting Equipment	3 640	3 640 000
Headgear and Shaft Collar	4 419	4 418 841
Man Winder House	1 785	1 785 000
L.H. Man Winder (5.5m dia)	9 743	8 300 000
R.H. Man Winder (5.5m dia)	11 484	10 430 000
Personnel Duct	369	216 000
Rope reeling Arrangements	605	605 000
Bank Area and Road	328	328 000
Rock Winder	17 035	12 763 000
Rock Winder House	1 355	100 000
Station Development	3 860	1 000 000
Permanent Hoisting Equipment	5 270	0
Winder Spares	720	0
Permanent Signalling	390	0
Main Loading and Transfer Arrangements	3 190	100 000
Shaft Bottom Arrangements and Spillage	740	100 000
Bank Layout and Surface Change-Over	200	0
Track Layout to Timber Yard	1 050	0

Heading	Total of Forecast (R'000)	Spent to 30/06/88 (R)
Sub-Vertical Shaft		
Initial Shaft System Including Headframe, Barrel Winder Chambers and Development	16 232	4 372 000
No. 1 Man Winder (5.5m X 1.5m)	12 857	9 769 000
No. 2 Man Winder (5.5m X 1.5m)	11 430	8 035 000
Rock Winder (5.5m X 1.5m)	12 580	9 994 000
Sink Line & Equip to 35 level	26 536	12 036 000
Station Development	5 531	1 031 000
Reef & Waste Passes to 33 level	2 490	0
Hoist Air Filtration & Cooling System	470	160 000
Miscellaneous Costs	2 750	0
Surface Shaft Temporary Services	700	0
Service Shaft (16-19 level)		
Sinking Hoisting Equipment	940	410 000
Sinking Winders	400	400 000
Initial Shaft System	2 630	2 630 000
Concrete Mix and Batch Plant	40	0
Raise Bore, Line and Equip	3 180	2 920 000
Station Development	300	0
Man and Material Winder	2 200	0
Permanent Hoisting Equipment	500	0
Shaft Bottom Arrangements	110	0
Permanent Signalling	80	0
Reef and Waste Passes	1 200	300 000
Off Station Development	1 200	0
Hoist Air Filtration and Cooling System	180	0

Heading	Total of Forecast (R'000)	Spent to 30/06/88 (R)
Reduction Plant		
Closed Estimates	250	249 753
Temporary Services	165	165 000
Eng. & Metallurgical Store	660	366 000
Geotechrical Survey	80	80 000
Terrace Construction	830	830 000
Roads, Drainage & Toile	950	850 000
Reduction Plant Civil Wo	17 000	6 072 000
Plant Offices & Change House	550	0
Reef & Waste Conveyor System	5 473	1 843 000
Stockpile Arrangements	9 000	3 589 000
Milling Section	30 000	8 939 000
Thickners & Woodchip Removal	6 600	1 100 000
Pipe Bridges, Towers, Trestles	1 800	300 000
Leach Section	6 400	600 000
C.I.P. Adsorption & Elution	10 000	1 329 000
Gold Recovery Section	4 000	500 000
Slimes Dam	3 000	0
Cyanide, Lime and Flocculant Section	500	0
Permanent Reticulation	400	100 000
Backfill, Residue and Slimes Disposal	3 000	500 000
Laboratory Services	200	107 000
Misc. Metallurgical Costs	200	100 000
Commissioning Costs	700	0
Plant Control Building	500	100 000
Plant Control Instruments	400	0
Fencing and Gate	270	0
Pumping		
Initial Intermediate Pump Chamber	1 400	1 400 000
Completion of I.P.C.	5 340	2 100 000
Longwall Pumping System	580	0
Service Shaft Pumping System	7 600	0
9, 10, and 20 Level Pumping	7 500	0

Heading	Total of Forecast (R'000)	Spent to 30/06/88 (R)
Ventilation & Refrigeration		
Closed Estimates	93	93 169
Sub-Vertical Shaft Sinking Ventilation System	600	346 000
Vent Shaft 10 Level Development	2 162	862 000
Main Level Return Airway	6 011	1 211 000
Access Cross-Cuts for two Interlevels	2 725	400 000
Service Shaft Multiblast Raise Bore Hole	877	477 000
204m Raise Bore Vent Hole	410	410 000
Upcast Raise Bore Holes for Six Levels (two holes 408m long & 3.63m dia.)	3 150	800 000
S.V. Shaft Multiblast Raise Bore Hole	1 710	300 000
Refrigeration Plant	9 420	2 722 000
Permanent Ventilation Fans	5 100	0
Exhaust Fans for two Levels	960	0
Intake Airway on 21 Level	2 400	0
Bulk Air Coolers and Associated Development	2 400	0
Chilled Water Reticulation	1 550	0
Inter-Shaft Airway	2 090	0
Fire Detection System	460	0
Fans Store and Testing Equipment	380	0
Underground Development Fans	240	0
Methanometers	40	0
Dust Extraction for Main Rock Transfer System	240	0
2 Chilled Water Dams (5Ml)	890	0
Main Level Energy Recovery Turbine	280	0
Self Rescuers	[illegible]	0
Return Airway Development	2 160	0
Refuge Bays	840	0
Ventilation System Above the Main Level	210	0

Heading	Total of Forecast (R 000)	Spent to 30/06/88 (R)
Ventilation & Refrigeration		
Closed Estimates	93	93 169
Sub-Vertical Shaft Sinking Ventilation System	600	346 000
Vent Shaft 10 Level Development	2 162	862 000
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Exhaust Fans for two Levels	960	0
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Bulk Air Coolers and Associated Development	2 400	0
Chilled Water Reticulation	1 550	0
Inter-Shaft Airway	2 090	0
Fire Detection System	460	0
Fans Store and Testing Equipment	380	0
Underground Development Fans	240	0
Methanometers	40	0
Dust Extraction for Main Rock Transfer System	240	0
2 Chilled Water Dams (5Ml)	890	0
Main Level Energy Recovery Turbine	280	0
Self Rescuers	400	0
Return Airway Development	2 160	0
Refuge Bays	840	0
Ventilation System Above the Main Level	210	0

Heading	Total of Forecast (R'000)	Spent to 30/06/88 (R)
Compressed Air		
Closed Estimate	2 794	2 794 309
Additional Compressed Air	8 210	2 288 000
Longwall Compressed Air Supply	950	0
Shaft Compressed Air Columns	780	0
Underground Equipment		
Environmental Testing Equipment	100	0
Closed Estimate	3 970	3 970 012
Additional Development Equipment for 4 Levels	10 500	4 000 000
Underground Stope Props	4 500	0
Electric Power Supply		
Temporary Power Supply	2 155	2 155 000
Surface Electric Power	5 300	2 055 000
Closed Estimates	722	721 661
Compressor Station Power Supply	570	460 000
Refrigeration Power Supply	570	570 000
Reduction Plant Power Supply	920	460 000
Initial Power for I.P.C.	330	0
Main Shaft Power	7 800	0
Power Control	120	0
Workshops		
Closed Estimates	1 231	1 230 526
Drill, Transport and Carpenter Shops	1 633	1 633 000
Workshop Equipment	1 401	1 116 000
Winch, Truck, & Loco Shops	780	0
Hostel Maintenance Shop	930	0

Heading	Total of Forecast (R'000)	Spent to 30/06/88 (R)
Black's Accommodations		
Services for Initial Accommodations	2 487	2 487 000
Initial Accommodations	4 990	4 990 000
Hostel Administration Including X-Ray, Pay Hall and Dressing Station	2 660	1 803 000
Bus and Parking Facilities	135	0
Sport Fields and Complex	349	49 000
First Aid Room Equipment	50	18 000
Kitchen and Dining Facility	3 566	3 016 000
Hostel Complexes (6 000 men)	15 680	4 116 000
Married Quarters	375	0
10 Rondavels for Visiting Wives	370	0
Additional Hostel Services	2 120	800 000
Other Buildings & Equipment		
Closed Estimates	3 984	3 983 894
Miscellaneous Shaft Engineering Buildings	457	257 000
Security Complex	1 952	1 952 000
Initial Magazine and Fuse Store	815	600 000
Computers and Equipment	562	147 000
Monitoring Control Centre	696	576 000
Survey Equipment	450	200 000
Micro Filming for Drawings	175	175 000
Workshop Office Building	220	220 000
Walkway from Crush to Hostel	300	300 000
Additional Change House Facilities	685	0
Training Centre	630	0
Crush and Cap Lamp House	840	0
Proto Building and Equipment	645	0
Heat Tolerance Training Centre	880	0
Mine Overseers and Foreman Store	360	0
Main Office Building and Services	1 520	0

Heading	Total of Forecast (R'000)	Spent to 30/06/88 (R)
Surface Transport		
Closed Estimates	1 030	1 030 395
Additional Surface Transport	3 747	3 247 000
Completion of Roads	3 154	2 323 000
Housing		
Closed Estimates	1 906	1 906 238
Services for 370 Stands	5 075	5 075 000
503 Houses in White Township	38 789	11 755 000
Stormwater Service	200	0
General		
Closed Estimates	2 453	2 452 633
Permanent Sewage Plant	1 756	846 000
Purchase of Freehold	3 590	1 690 000
Water Supply	2 900	0
Reticulation of Bank, Plant, Offices, Hostels & Stores	644	384 000
Telephone Services	950	0
Exploration Diamond Drilling	789	282 000
Card Reader Arrangements	300	0
Security Fencing and Alarm System	350	0
Backfill Underground Reticulation System	2 400	0
Assaying Facilities	844	0
Contributions to Group Training Centre & Hospital	3 848	0
Surface Equipment	160	0

Heading	Total of Forecast (R'000)	Spent to 30/06/88 (R)
Development		
Main Level Development at 120 metres per month	16 921	16 921 000
16, 19 and 21 Level Development	43 147	28 117 000
13/17 Footwall Drive South	3 370	300 000
Main Level Station Completion	12 000	1 100 000
Main Shaft Reef and Waste System for 204 metres	1 120	110 000
Development to Second Shaft System on 13 Level	5 200	600 000
Ore Handling Facilities	200	200 000
15 level Development	4 610	0
Longwall Re-Establishment	3 040	0
10 Level Footwall Drive Development	7 680	0
Sub-Vertical Shaft Development	1 300	0
General Expenses	41 487	20 084 711
Debenture Interest Payable	50 285	16 485 289
Sundry Persons	2 182	1 173 000

APPENDIX G

Costing Exercise for Surface and Underground Track Layouts

This exercise estimates the cost per metre for the installation of trackwork on surface and underground.

Costs

For 610mm and 22kg rails:

22kg rails	R	218.419	each
4.3m switch	R	1694.005	each
Concrete Sleepers	R	13.778	each
Fish Plates	R	8.864	(pair)
Bolts	R	3.292	per kg
Pandrol Clips	R	4.000	per kg (estimated)

Installation labour — R60 per metre for ideal surface conditions.

R90 per metre for typical underground conditions.

The figures for installation labour were calculated using wages of the construction crew required. A period of time spent on a development contract allowed me to calculate the unit cost for labour concerning trackwork.

Assumptions

9 sleepers per 4.3m switch
18 sleepers per 9.1m rail (0.5 spacing)
8 bolts per joint
4 clips per sleeper

Results

Expect to pay approximately R150 per metre for surface trackwork (not including concrete work) and around R200 per metre for underground track laying.

APPENDIX H

Summary of Planning meeting minutes relevant to this research project between 14 October 1987 and 21 April 1988.

28/10/87	Re-raising of the destroyed longwall was discussed with three possible options. 1. Re-establish the existing stope faces. 2. Develop and re-raise from the existing follow-on footwall drives. 3. Develop and re-raise from the existing deep footwall drive. At this point in time option three is the most favoured. This is relevant to the research project because more capital is needed sooner than expected for equipment.
04/11/87	Re-raising the destroyed longwall from deep footwall position would require an additional R5 500 000 during 1989 and early 1990.
02/12/87	It was pointed out that the extended division has completely lost a fully producing longwall due to a fire, subsequent flooding and seismic events. Regardless it was felt that the operating mine should hand over a fully producing longwall to the extended division as specified in the initial feasibility study. More capital than originally planned will therefore be required to produce the same results.
06/01/88	Development progress on 16 level has slowed due to an unexpected intersection with the cobble reefs. This means the end must turn to go deeper (80 - 100 metres) in the footwall to avoid unfavourable rock mechanics. This development will project what can be expected on 11 level in the future. The existing A service shaft cannot handle the tonnage assumed therefore it must either be upgraded or assisted with the development of an access raise system. The existing B service shaft has never actually been commissioned due to excessive heat

problems. No provision was made in the initial feasibility study for work required to get these service shafts operating at design capacity. It was assumed they would be given to the extended division fully operational.

13/01/88 Until such time as the sub vertical shaft is completed it is assumed the operating mine will pump the extended division's water on the lowest level. Water will be generated from numerous development ends and three producing longwalls. Surge dams must be excavated and built at the bottom of each longwall.

20/01/88 The operating mine informed the extended division it could not possibly assist with pumping as previously assumed. There are no pumping excavations available. This means the extended division needs extra capital to excavate and equip its own settling dams and pump chambers. Now the development of the IPC becomes high priority. If the IPC is not finished soon, the mine may have to delay the start of the production.

27/01/88 Money allocated for the development of 13 level footwall drive has been moved forward with the present allocation going to the hostels.

There may not be enough money for the development of the planned reef and waste pass system.

The R4 700 000 allocated for pumping is inadequate.

The 36 square metre intake airway off the main shaft has been underestimated in terms of CAPEX as have other intake airways. The figure of R180 per cubic metre assumed in the initial feasibility study is no longer valid. A more realistic figure is R250 per cubic metre. This figure applies to most development ends whether small standard ends or large winder excavations. Upon subsequent investigation it was discovered that this figure is actually R280 per cubic metre.

Present CAPEX estimates for compressed air cover the compressors and main shaft columns but not the purchase and installation of a 20 inch column required on the main level to the A service shaft, a distance of 3.5 kilometres.

It was decided to contract out raise boring machines rather than purchase them.

21/04/88 Development rates on the main level could reach 200m/month under ideal conditions. This is a twin haulage. If single end development were the case a maximum of 90m/month could be expected. An average of 160m/month would be adequate to bring the mine into production on schedule.

Development rates on 16 and 19 levels are also estimated at 90m/month for a single end with a possible 110m/month for multiple ends. To finish these ends on time however requires an average of 195m/month. Apparently these developments will not be finished before the projected start-up date.

Development rates on 21 level are very bad (45m/month maximum) due to excessive heat. Two coolers need to be repaired at a cost of R52 000 and will six weeks. It appears this development will not be finished in time for the projected production start-up.

Development off station from the service shaft is running short of ventilating capacity. This may result in the stopping of another development project in order to provide both fresh air and exhaust capacity. Completion of this service shaft and associated ore reserve development is necessary to bring the 76 longwall into production as planned. In the initial feasibility study the expected tonnage profile was to come from two fully producing longwalls ceded to the extended division. Due to a fire in the largest of the two longwalls and unexpected geological losses the introduction of an extra two longwalls and some scatter mining was deemed necessary. This naturally requires more pre-production CAPEX than originally estimated.

Development on 15 level in necessary to provide access to the scatter mining areas. This was not accounted for in the initial feasibility study.

Development of 10 level footwall drive has commenced to provide future exhaust capacity. This was not accounted for in the initial feasibility study.

APPENDIX I

Summary of Raise Boring Capital Costs for Mining (in 1988 Terms)

Raiseboring times and costs for a 2.13m diameter vertical hole in Dolomite (181 - 256 MPa), Cobble Reef (50 MPa), Quartzites (230 MPa) and Shales (155 MPa).

Activity	Days	Cost (R)
Connect Machine & Collar	1.0	2 469
Pilot Drill	21.3m/day	357/m
Break out bit stub	0.5	1 235
Attach reaming head	0.5	1 235
Ream	9.1m/day	1 027/m
Break out reamer	0.5	1 235
Pull rods;dismantle machine	1.0	2 469
Move machines on site	1.0	2 469

Therefore cost per hole = R11 109 + (R1 383 * length of hole)

Note: This does not include development costs of excavating a raisebore cubby, providing services, standing time, pouring concrete and removal of raiseboring chips.

Raiseboring times and costs for a 2.13m diameter vertical hole in Lava (300 MPa)

Activity	Days	Cost (R)
Connect Machine & Collar	1.0	2 469
Pilot Drill	17.4m/day	421/m
Break out bit stub	0.5	1 235
Attach reaming head	0.5	1 235
Ream	7.4m/day	1 188/m
Break out reamer	0.5	1 235
Pull rods,dismantle machine	1.0	2 469
Move machines on site	1.0	2 469

Therefore cost per hole = R11 109 + (R1 609 * length of hole.

Note: This does not include development costs of excavating a raisebore cubby, providing services, standing time, pouring concrete cr removal of raiseboring chips.

APPENDIX J

Summary of Development Costs in 1988 compared with Development Costs in 1986

Average development costs (Rands per tonne) for May 1988

Mine	1	2	3	4	5	6	7
R/t	94.72	83.47	96.50	87.77	85.19	77.77	111.47

Mean cost for all seven mines = R 90.84/tonne.
Assuming 2.75 tonnes per cubic metre = R249.81/cubic metre.

Average development costs (Rand per tonne) for May 1986.

Mine	1	2	3	4	5	6	7
R/t	64.75	67.01	66.45	66.80	66.76	55.01	70.70

Mean cost for all seven mines = R 65.35/tonne
Assuming 2.75 tonnes per cubic metre = R179.72/cubic metre.

To determine the development escalation rate the future value formula of $Fv = Pv * (1 + i)^n$ is used.

Fv = future value of R 249.81 per cubic metre.

Pv = present value of R 179.72 per cubic metre.

n = 2 (number of periods to compound)

i = resulting yearly interest (escalation) rate.

In this case i, or the escalation rate, equals 17.9% per year

APPENDIX K

Summary of Shaft Sinking Costs in 1988

Shaft sinking and lining costs for a 10 metre diameter shaft were calculated to a depth of 1 810.5 metres. Total sinking costs were R26 137 587.88 and total lining costs were R5 370 669.79. This works out to a cost per metre for sinking and lining of R17 403.07. While this cost was calculated in August 1988 it does not represent 1988 costs for sinking and lining. Money spent over the period reaching a depth of 1 810.5 metres would have to be inflated, in monthly increments, to August 1988 terms.

Approximate costs for sinking and commissioning a surface shaft, 9 metre diameter, to a depth of 1 950 metres in 1988 terms:

Dimensions for various development ends:

Development end	Dimension (metres)
Cross-cut to reef	3.0 * 3.4
Follow on footwall drive	3.0 * 3.0
Boxhole to stope	2.4 * 1.8
Shaft ore pass	2.13 diameter
Internal ore pass	1.8 * 2.4
Reef raise	1.8 * 2.0
Access raise	3.4 * 2.4
Shallow footwall drive	3.0 * 2.7
Footwall drive boxhole	1.8 * 1.8

Item	Cost (R million)
Initial Temporary Services	2.0
Shaft Offices	1.0
Crush and Caplamp	1.0
Bank Layout	1.1
Power	1.9
Tar Road	0.5
Surface Waste Handling	2.5
Shaft Telephone Services	0.5
Initial Track Layout	0.9
Man Winder	10.9
Rock Winder	12.3
Sink, Line & Equipment	46.7
Rope Reeling Arrangements	0.5
Permanent Hoisting Equipment	2.4
Main Level Station Development	3.8
Main Loading Arrangements	2.8
Shaft Bottom Arrangements	1.2
Miscellaneous	2.0
Total	94.6

Ventilation network -
Intake levels are 19, 21, 21, 13, 13.
Exhaust levels are 10, 13, 16, 16.

Need an extra raise bore hole between 16 and 18 levels to provide exhaust capacity for the 82 longwall.

Notes on Reduction Plant from interview with chief metallurgist:

Major cost items are the adjustable speed ring motors for the mills. While the mills were manufactured in South Africa the ring motors were imported from Germany at a cost of R25 million each.

It was felt that the stacker/reclaimer replacing conventional storage bins and the carbon-in-pulp section replacing the conventional filter section would result in a capital savings of R20 million to R25 million.

Miscellaneous costs in 1988 terms calculated from personal experience as planning and projects mining engineer on a new gold mine under construction.

Conventional wire meshing (cables and chain link) is approximately R19.55 per square metre. This figure was obtained from 627 square metres of a winder chamber meshed for a 1988 cost of R12 257.85.

Shotcreting is approximately R46.78 per square metre. This figure was obtained from 2 225 square metres of winder chamber shotcreted at a 1988 cost of R104 085.50.

Cost to excavate underground winder chamber.

Development	Cubic metres
Crosscut to winder chamber	625
Drainhole cubby	27
Filter chamber	170
Winder chamber	10 725
Total	11 547

Estimated cost of excavation R1 593 486
Actual cost of excavation in 1988 R2 868 274

These development costs in 1988 terms work out to approximately R248.40 per cubic metre. The figure of R250 per cubic metre appears in most development calculations whether related or independent. In this case the figures were supplied by a contractor separate from the mining company involved.

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