A PRE – FEASIBILITY STUDY OF THE KLOOF EASTERN BOUNDARY AREA PROJECT, KLOOF GOLD MINE

Konstandinos Ghoussias

A Research Report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering.

Johannesburg, 2003

DECLARATION

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

Konstandinos Ghoussias

1ST day of AUGUST 2003

ABSTRACT

The ore reserves of the Kloof Sub Vertical Shaft operations are coming to an end and as such, the Eastern Boundary Area mining operations, which will extract the Ventersdorp Contact Reef ("VCR"), must be commissioned to replace the diminishing reserves. Although feasibility studies have been carried out on the eastern portion of the Kloof Gold Mine lease area, none have been undertaken to investigate the potential benefits of including the new mineral rights recently acquired from JCI. This project report is a pre-feasibility study into the potential value to Kloof of accessing and extracting the resources of the Eastern Boundary Area.

This project report shows, using DCF analysis, that the Eastern Boundary Area has potential to economically generate the additional reserves that will be required to supplement Kloof's diminishing Three Shaft reserves. An NPV and IRR are calculated for the project, the results of which support the commissioning of further investigative work in order to obtain a better understanding of the orebody and to generate results that are more accurate.

Despite its popularity, traditional DCF analysis has fundamental shortcomings, as do the commonly associated measures of NPV and IRR. This project report identifies and reviews these shortfalls and comments on methods to overcome these as far as practically possible.

ACKNOWLEDGEMENTS

The support of all those who, in various ways, assisted me with the preparation of this project report is gratefully acknowledged.

I would like to thank my supervisor, Professor R. C. A. Minnitt for his guidance during the preparation of this project report.

I would also like to thank the management of Kloof Gold Mining Company Limited for the permission to publish and for the disclosure of sensitive data relevant to this project report.

Particularly, I would like to thank my wife for her tireless motivation and encouragement during the preparation of this project report.

TABLE OF CONTENTS

PART II

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The Kloof Gold Mining Company Limited ("Kloof"), a subsidiary of Gold Fields Limited ("Gold Fields"), owns minerals rights to, and is currently exploiting a number of gold deposits in the West Witwatersrand Goldfields. The Kloof operations comprise the Kloof Gold Mine ("Kloof GM"), the Leeudoorn Gold Mine ("Leeudoorn GM") and the Libanon Gold Mine ("Libanon GM"). Until recently, these mines operated as divisions of Kloof but have now been incorporated into the Kloof GM structure. Leeudoorn GM is now known as Kloof 7 Shaft and Libanon GM as Kloof 8 Shaft.

Mining operations on the Kloof GM are planned to extend down to the 43 level, a depth of approximately 3340 meters below datum (a reference point 1828,797 meters above mean sea level). A large area of ground exists below the 43 level, extending to the eastern boundary of the Kloof GM's Managerial District that has not yet been mined. Johannesburg Consolidated Investments ("JCI") owned the mineral rights to the area beyond the eastern boundary of the Kloof Managerial District, however practical mining constraints prevented JCI from mining this orebody economically.

Consequently, given that Kloof could mine this portion of ground economically, it purchased the mineral rights from JCI. The area combining the JCI Managerial District and the unmined portion east of the Kloof Managerial District is known as the Eastern Boundary Area.

1.2 DEFINITION OF THE PROBLEM

The ore reserves of the Kloof Number 3 Sub-Vertical Shaft operations are coming to an end and as such, the Eastern Boundary Area mining operations must be commissioned to replace the diminishing reserves, thereby maintaining an acceptable utilisation of the shaft hoisting facilities. The production build up from the Eastern Boundary Area must coincide as far as practically possible with the decline in production from the Kloof Three Sub-Vertical Shaft.

Although feasibility studies have been carried out on the eastern portion of the old Kloof Gold Mine lease area, none have been undertaken to investigate the potential benefits of including the new mineral rights that have been acquired from JCI. This project report is a pre-feasibility study into the potential value to Kloof of accessing and extracting the resources in the northern component of the Eastern Boundary Area via a Tertiary Shaft located in the Kloof Three Shaft Complex.

1.3 OBJECTIVE OF THE RESEARCH REPORT

The primary objective of this project report is the financial valuation of accessing and extracting the ore resources of the Eastern Boundary Area of the Kloof GM via a tertiary shaft located in the Kloof Three Shaft Complex.

The Discounted Cash Flow ("DCF") method of financial valuation was applied to assess the economic feasibility of the Eastern Boundary Area project. Various mining and macro-economic parameters fundamental to the cash flows of the operations were modelled using a financial modelling spreadsheet. The sensitivity of the project cash flows to fluctuations in these factors was tested through the use of Monte Carlo simulations.

Furthermore, an analysis of the DCF method of valuation was carried out in order to assessing the applicability of such a method to mineral projects.

1.4 SCOPE AND LIMITS OF THE RESEARCH REPORT

The nature of the project, specifically with regards to depth of operation, meant that strict guidelines, based on proven techniques, had to be followed for the design of mining parameters for the Eastern Boundary Area project. The design of the mine was thus done based on existing, proven mining techniques currently in place at Kloof GM's existing operations.

Although the Eastern Boundary Area project had been made public in the Gold Fields Annual Financial Statements, the detailed information pertaining to the project remains confidential. A condition to the granting of permission by Gold Fields to use this information to compile this report was that the actual information relating to the project not be disclosed. As such, all information cited in this report has been distorted using various distortion factors.

Although the original data was distorted for the purpose of this report, and the results of the financial valuation differed from that of the original valuation, the conclusions that could be drawn remained consistent. As such, the objective of the report was not adversely affected in any way.

PART I

CHAPTER 2

GEOLOGY AND ORE RESERVES

2.1 INTRODUCTION

The quantity, quality and distribution of the potentially viable components of a deposit are fundamental elements, without which a decision to exploit cannot be soundly based (Annels, 1990). This chapter details the geology of the Eastern Boundary Area with respect to the structure, sedimentology and estimated ore resource of the VCR, the main reef to be exploited. Potential difficulties associated with the geology of the area are identified and their impact on the project highlighted.

2.2 DEFINITION OF PROJECT AREA

The project area under consideration is defined as follows:

- The western boundary at the 39 level Ventersdorp Contact Reef (VCR) elevation on Kloof GM and Leeudoorn GM
- The northern boundary at the Kloof GM/Libanon GM divisional boundary
- The eastern boundary at the Witpoortjie Fault
- The southern boundary at the southern limit of zone 13

The area is illustrated in Figure 2.1.

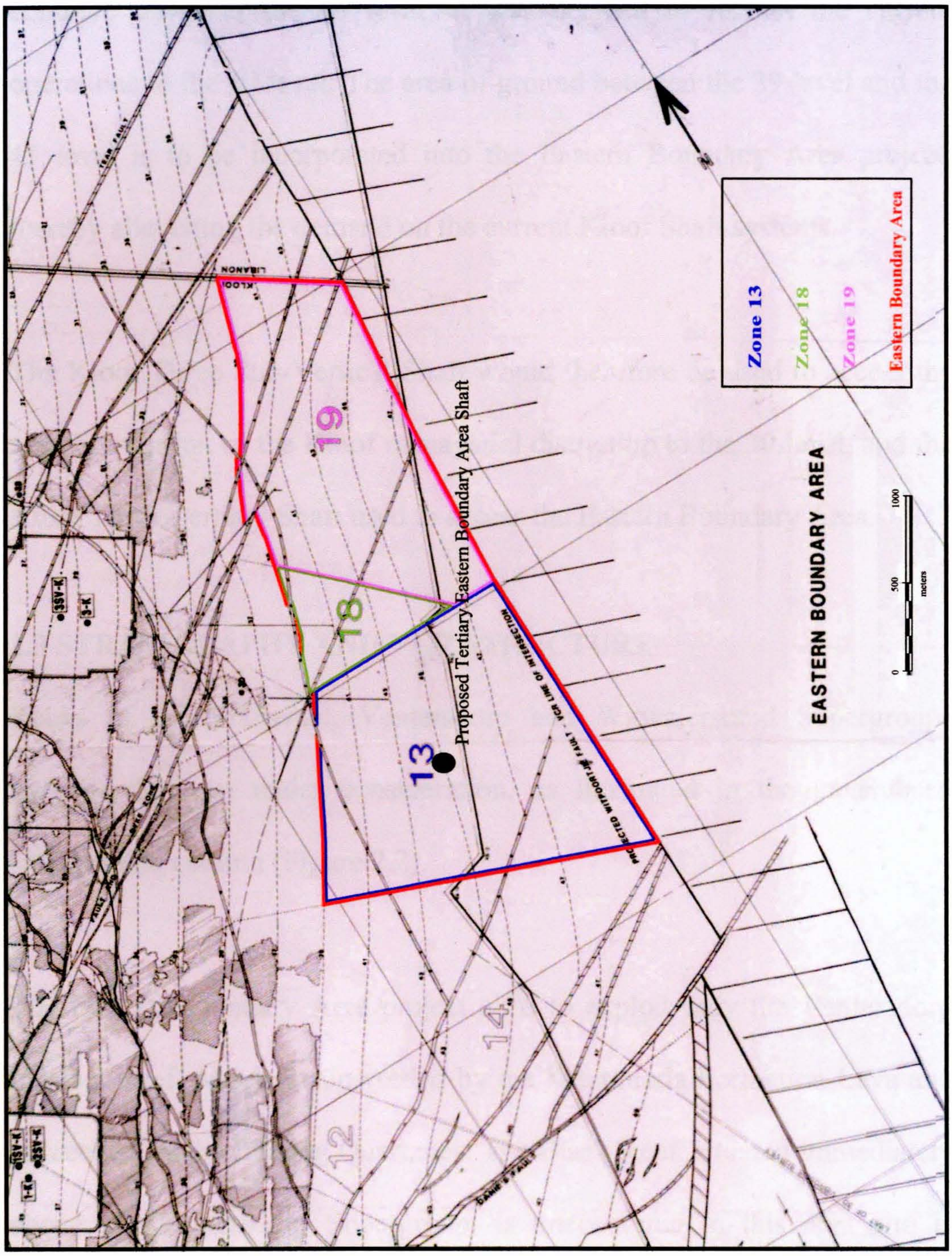

Figure 2.1 Project Area of the Kloof Eastern Boundary Area showing the distribution of the homogenous value zones and reef contours.

Although mining operations at the Kloof GM were originally designed to continue down to the 43 level, it was decided to restrict the current operations to the 39 level. The area of ground between the 39 level and the 43 level is to be incorporated into the Eastern Boundary Area project, thereby alleviating the demand on the current Kloof Shaft systems.

The Kloof Three Sub-Vertical Shaft would therefore be used to access the northern portion of the Kloof managerial district up to the 39 level, and the Kloof Three Tertiary Shaft used to access the Eastern Boundary Area.

2.3 STRATIGRAPHY AND VCR STRUCTURE

Rocks of the Transvaal, Ventersdorp and Witwatersrand Supergroups underlie the area under consideration, as illustrated in the generalised stratigraphic column (Figure 2.2).

The Eastern Boundary Area project aims to exploit only the Ventersdorp Contact Reef, which is superseded by the Westonaria Formation Lava and succeeded by the Elsburg Quartzites. The Black Reef, situated immediately above the Ventersdorp Supergroup, is uneconomic in this area and is excluded in the valuation. The Westonaria Formation Lava is typically very friable (van Coller, 1997) and rock mechanics layouts will be significantly influenced by its presence (See Chapter 3.2 - Rock Mechanics).

Thickness	Lithology	Formation	Sub Group	Group	Super Group
200-500m	Andesitic Lava and Tuff	HEKPOORT ANDESITE		PRETORIA	TRANSVAAL SEQUENCE
50-200m	Quartzite	TIMBALL HILL			
	Shale				
	Quartzite	ROOIHOOGTE			
	Chert Breccia				
300m	Chert rich Dolomite	ECCELS	Malmani	CHUNIEPOORT	
150m	Dark Chert-free Dolomite	LYYTLETON			
500m	Light Dolomite with Chert	MONTE CHRISTO			
100m	Dark Dolomite	OAK TREE			
10-20m	Carb. Shale with Quartzite	BLACK REEF			
400-500m	Amigdaloidal Andesitic	LORRAINE		KLIPRIVIERBURG	VENTERSDORP
100m	Lava	ORKNEY			
250m	Aphantic Lava	ALBERTON			
0-40m	Porphorytic Lava	WESTONARIA			
	Ventersdorp Contact Reef	VENTERSPOST			
	Coarse Green Quartzite	ELSBURG QUATRZITE	Turffontein	CENTRAL RAND	WITWATERSRAND
6m	Kloof Reef				
0-3m	Libanon Reef	KIMBERLY			
0-80m	Shale and siltstone	BOOYSENS SHALE			
10-15m	Quartzite	KRUGERSDORP	Johannesburg		
	Cobble Reef	BIRD CONGLOMERATE			
3m	No5 Upper Reef				
90m	Quartzite	LUIPAARDSVLEI			
40m	No. 4 Uppers	LIVINGSTONE			
	Quartzite	RANDFONTEIN			
10m	No. 3 Upper Reef				
30m	Quartzite				
10-15m	No. 2 Upper Reef	JOHNSTONE			
90m	Quartzite	LANGLAAGTE			
	No. 1 Upper Reef				
60m	Middlevlei Reef				
	Green Bar				
15m	Carbon Leader				
	Quartzite	MARAISBURG			
	Jeppestown Shale	ROODEPOORT			

Figure 2.2 General Stratigraphy of the Kloof Eastern Boundary Area.

The Booysens Shale, situated immediately below the Kloof and Libanon Reefs, is also typically highly friable (van Coller, 1997). Any development tunnels that intersect the Booysens Shale will thus require a significant amount of additional support from a Rock Mechanics consideration and would thus negatively impact on the support costs for those tunnels. The mine layout was designed bearing this in mind, and although it was necessary in some areas, development in the Booysens Shale was generally avoided. The negative impact on the overall support cost was therefore minimised.

A structural map for the VCR in the area south and southwest of the South Deep Mine was obtained from JCI. This plan was derived from a seismic survey and a limited number of surface boreholes. A Goldfields Limited VCR structural map was compiled in 1994 and derived primarily from a 3D vibroseismic survey conducted over the deep southeastern part of Kloof GM and Leeudoorn GM. To facilitate the purchase of the mineral rights, a single VCR structural plan was required. Goldfields and JCI thus combined the two datasets and generated a VCR structure plan that was accepted by both parties (Figure 2.3).

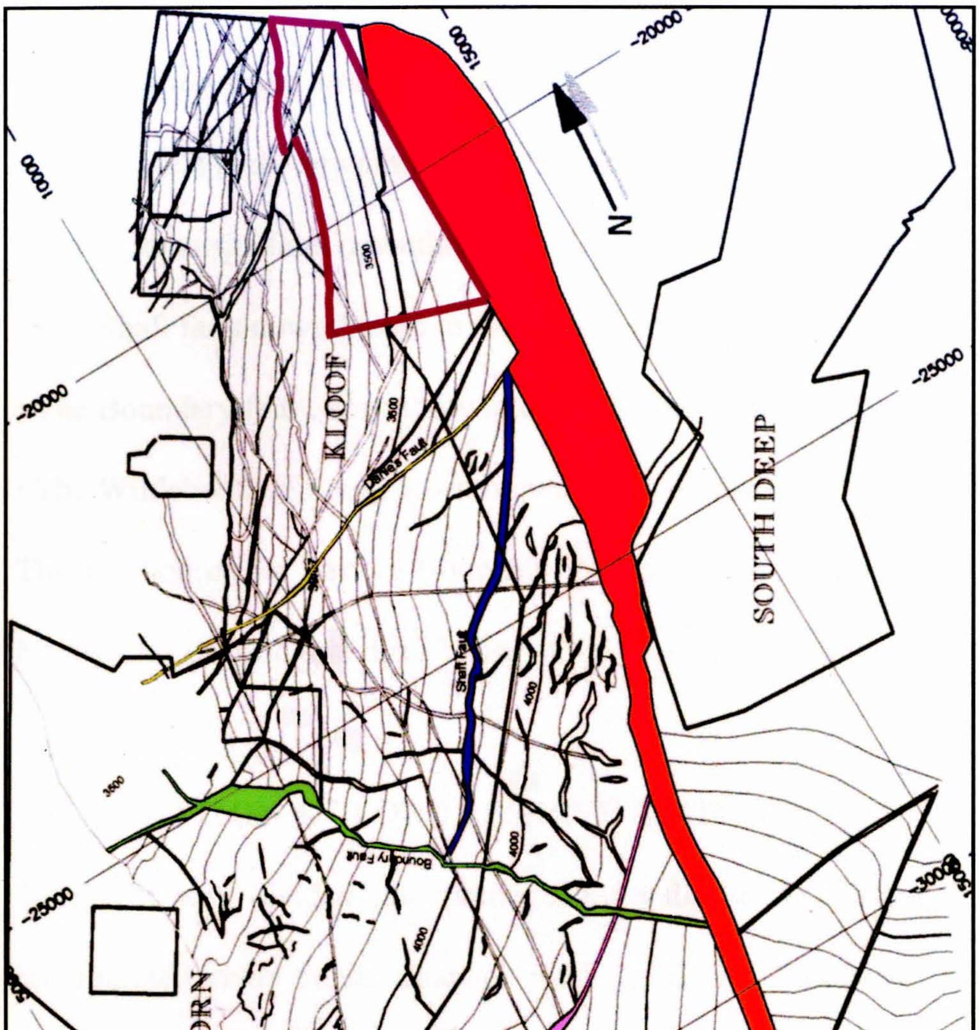

Figure 2.3 Combined VCR Structure with Geological Discontinuities.

The following major structures, shown in Figure 2.3, were identified:

- The Danie's fault, downthrown to the south 30m - 70 m
- The Witpoortjie fault downthrown to the west 500m - 1100m
- The Shaft fault downthrown to the northwest 150m -200m
- The Boundary fault, downthrown to the southeast 100m -200m
- The Wildebeeskuil Fault, downthrown to the northwest 100m – 200m

The position of the Eastern Boundary Project is also shown in Figure 2.3. No significant structural disturbance of the project area is anticipated.

2.4 VALUATION AND ORE RESERVE ESTIMATE

The VCR was divided into homogenous value zones (Figure 2.1) that incorporated value trends, channel width trends and lithofacies. Fault and dyke losses were excluded, and various reef dips were applied to structural blocks to calculate a project area of the homogenous value zones of 5.2 million square meters (Table 2.1). Based on the zone characteristics, an estimated in-situ ore resource of 6.7 million ounces of gold was calculated for the Eastern Boundary Area, subdivided into zones 13, 18 and 19.

Table 2.1 Estimated In-Situ Ore Resource of the Eastern Boundary Area.

Zone	m^2	cmg/t	Kg Gold	Ounces of Gold
13	2,653,787	1,820	130,439	4,193,773
18	437,379	677	7,992	256,955
19	2,129,767	1,208	69,502	2,234,537
Total	**5,220,933**	**1,475**	**207,977**	**6,685,265**

CHAPTER 3

MINE DESIGN PARAMETERS

3.1 INTRODUCTION

Along with the geology of an ore body, the mine design parameters form the key technical aspects for consideration in the valuation of a mineral project. Issues covering Rock Mechanics, Ventilation, Shaft Design, Mining Method and Extraction Profile all form fundamental technical constituents when projecting the production profile and revenue streams of an operation. Furthermore, these aspects have a material effect on the estimation of both the capital and operating costs required for the commissioning of a mine. A careless design of these aspects can result in a gross misrepresentation of the financial viability of a project.

The Eastern Boundary Area was planned to replace the diminishing production from the Kloof Three Sub-Vertical Shaft. As such, the Eastern Boundary Area was designed to have a peak production rate of 150,000 tons per month. This chapter details aspects of the mine design parameters of the Eastern Boundary Area and addresses the effect of these parameters on the financial valuation of the project. Potential risk areas are identified for further consideration in the sensitivity analysis of the project.

3.2 ROCK MECHANICS

Rock mechanics simulations conducted on the Kloof Three Sub-Vertical Shaft area identified the following parameters that must be adhered to for the design of the mining operations in the Eastern Boundary Area:

- *No major excavations (shafts or stations) must be sited within a distance of 650 meters from the Witpoortjie fault.*

- *A pillar of 60 meters width must be left along the entire length of the Witpoortjie fault to act as a "clamping pillar".* This clamping pillar has been taken into account for calculating the ore reserves of the Eastern Boundary Area. Although the pillar will be recovered at the end of the mining operations as part of a pillar scavenging exercise, it was considered prudent to exclude this ground from the production profile given that any seismic activity along the fault could render the pillar unmineable and thus sterilise these reserves.

- *Bracket pillars of at least 15 meters wide will be required for the faults and dykes that are present in the area.* These have been incorporated into the reserves calculation and have been represented as "fault losses".

- *A minimum of 80 meters (perpendicular to the plane of the reef) must be maintained between any footwall drives and the reef.* This restriction has a negative impact on the viability of the project in that additional waste development will be required to develop the cross cuts to the plane of the reef. This additional waste development has been included in the production profile as part of the production build up, as well as in the on-going development.

- *Additional support will be required for any development that will traverse the Westonaria Formation Lavas and the Booysens Shales.* The design of the mining layout was such that traversing of the Westonaria Lavas and Booysens Shales is minimal. The effect on the total support cost for the mine is therefore negligible.

3.3 VENTILATION

3.3.1 Ventilation Requirements

The quantity of air required for tabular orebodies, scattered stoping and longwalling is 3,5 m^3/s per kiloton per month (McPherson, 1989). This results in an air quantity requirement of 273 m^3/s per month for the Eastern Boundary Area. Allowing 10% for leakages, this requirement increases to 300m^3/s per month.

Given the higher monthly tonnage profile, the peak ventilation requirements of the current Kloof Three Sub-Vertical Shaft operations exceed those of the Eastern Boundary Area. Furthermore, production from the Eastern Boundary Area is designed as replacement tonnage, rather than additional tonnage. Thus, the *total* Kloof production profile will in fact reduce slightly as the production from the Kloof Three Sub-Vertical Shaft diminishes and the production from the Eastern Boundary Area increases.

Current Kloof Three Sub-Vertical Shaft ventilation capacity is therefore sufficient to meet the Eastern Boundary Area ventilation requirements and as such, actual ventilation costs currently incurred for the Kloof Three Sub Vertical Shaft were used to forecast the ventilation costs of the Eastern Boundary Area.

3.3.2 Refrigeration Requirements

The expected Virgin Rock Temperature ("VRT") was calculated based on the Geothermal Gradient Equation for Carletonville mines (McPherson, 1989):

$$\begin{aligned} T &= 16 + (10{,}5 \times d) \\ &= 16 + (10{,}5 \times 3.6) \\ &\approx 54\ ^{\circ}\mathrm{C} \end{aligned}$$

The distance below surface in kilometers (d) was taken as 3600 meters, the mean depth of mining operations for the Eastern Boundary Area. The cooling effect of air at a depth of 3600m is negative (McPherson, 1989), i.e. the air releases heat into the system.

Refrigeration would thus be required to cool working areas in the Eastern Boundary Area to prescribed levels. Using Whillier's graph (McPherson, 1989) the cooling requirements for the area were calculated as 300kW per kiloton per month. When applied to the Eastern Boundary Area tonnage profile, this results in a peak cooling requirement of 23.4MW per month.

Eastern Boundary Area refrigeration requirements will increase slightly over the current Kloof Three Sub-Vertical Shaft requirements, given the increase in mean mining depth, however the excess refrigeration capacity that will develop following the slight reduction in total production from Kloof should more than offset the additional refrigeration requirements.

The current Kloof Three Sub-Vertical Shaft refrigeration capacity would therefore be sufficient to meet the refrigeration requirements of the Eastern Boundary Area. Thus, as with the ventilation costs, the current Kloof Three Sub-Vertical Shaft refrigeration costs were used to forecast the Eastern Boundary Area refrigeration costs.

3.4 SHAFT DESIGN

In order to access the Eastern Boundary Area as cost effectively as possible, the shaft should ideally be sunk as close as possible to the middle of the project area as possible. To comply with rock mechanics requirements however, the shaft was sited at co-ordinates X = 20700; Y = -12930, intersecting the 45 level VCR contour (Figure 2.1). Although this position is not precisely in the middle of the project area, it is ideal in that the Booysens Shale Zone is avoided and the shaft falls beyond the minimum 650m distance from the Witpoortjie fault, as per Rock Mechanics requirements.

The shaft will be sunk from 42 level down to shaft bottom and will comprise of the 42 level (headgear arrangements), 43 level (tramming level), 44-49 levels (working levels), 49½ level (water handling facilities) and 50 level (belt level). The total length of vertical hoist of the shaft will be 568m.

Ore and waste will be hoisted via the Eastern Boundary Area Shaft to 43 level where it will be trammed to the Kloof Three Sub-Vertical Shaft and hoisted to 23 level. It will then be trammed to the Kloof One Shaft where it will be hoisted to surface. The tramming costs have been incorporated into the operating costs.

To ensure proper utilisation of the shaft system, the Tertiary Shaft was designed according to the parameters of Kloof Three Sub-Vertical Shaft. This design would ensure that any equipment that could be passed through the Sub-Vertical shaft would also be able to pass comfortably through the Tertiary Shaft and vice versa. The Tertiary Shaft was therefore designed to comprise of 2 skips, 1 cage and 1 counterweight. The shaft will be able to hoist 150,000 tons of ore per month, and 60,000 tons of waste per month, easily meeting the requirements of the required tonnage profile.

All the immediate station development i.e. station cross-cuts, will be carried out concurrently with the shaft sinking process, the cost of which will be incorporated into the capital expenditure for that year. The remaining station development i.e. Fitter and Boiler Shops, refuge chamber, sub-station, shaft ore-passes and travelling ways, will be incorporated into the capital expenditure profile for the year in which it is incurred. All other development i.e. footwall haulages will be considered main development and will be incorporated into the operating costs during the years in which it is incurred.

3.5 MINING METHOD

The Eastern Boundary Area project will adopt the down-dip mining method. The mining layout will be such that the centre-to-centre distances between raises will be 100 meters. The raises will be 10m wide and dip pillars of 30m thicknesses will be left between panels. The resulting stope faces will be 44m in length and will be established at an angle that will facilitate the cleaning of the faces using gravity as shown in Figure 3.1.

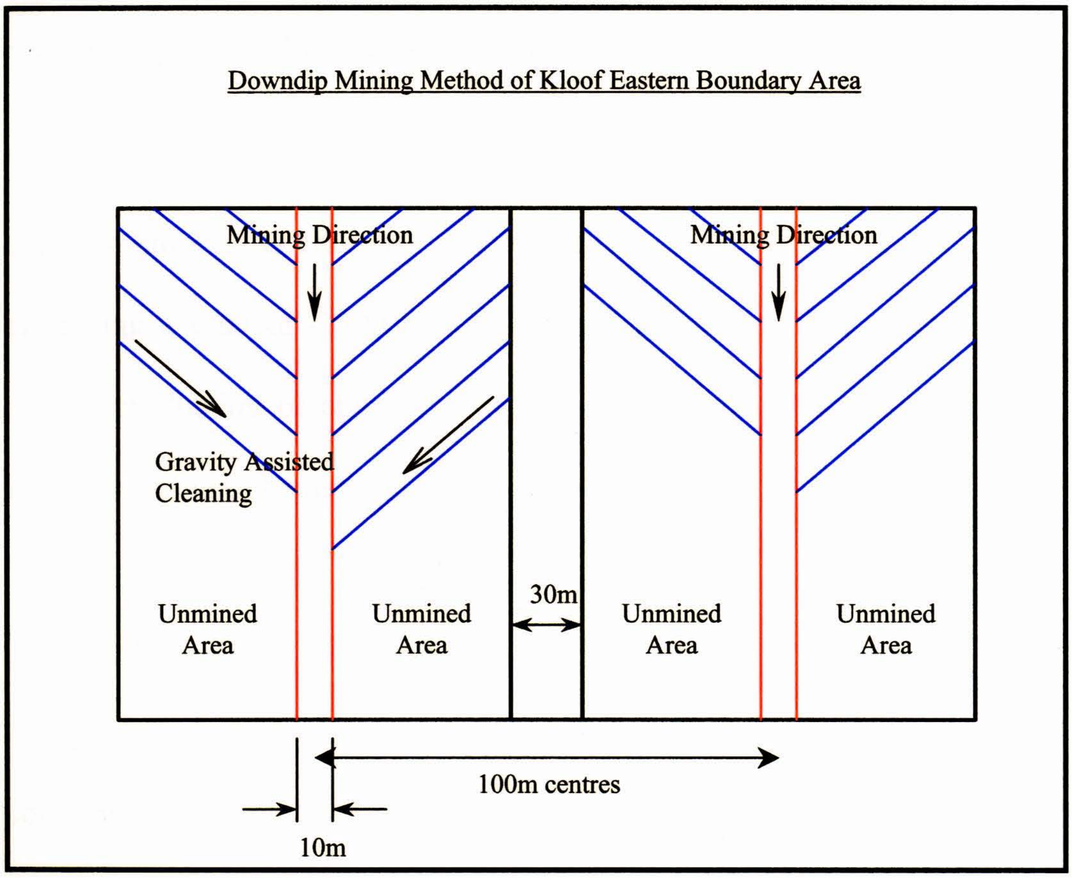

Figure 3.1 Eastern Boundary Area Mining Method

In order to calculate the monthly tonnage profile for the Kloof Three Shaft Eastern Boundary Area, certain assumptions for a downdip stoping method were made. These were based on the production efficiencies of the existing Kloof Three Sub-Vertical Shaft operations and are shown in Table 3.1.

Table 3.1 Assumptions made for Downdip Mining Method

Development Rates		Stoping Rates	
Wide raise width	6m	Face length	44m
Wide raise height	2.5m	Stoping width	1.55m
Face advance	12m/month	Face advance	12m/month
Specific Gravity	2.75	Specific Gravity	2.75
Tonnage/raise:	495tpm	Tonnage/panel	2251tpm

It was calculated that once a raise has been developed, 2 crews would conduct stoping operations, one on either side of the raise, thereby producing a total of 4,500 tons per month per stope. This resulted in an annual production of approximately 54,000 tons per stope, and has been incorporated into the monthly tonnage profile.

3.6 EXTRACTION SCHEDULE

Short-term production forecasts have a high degree of reliability and corresponding high levels of confidence when compared to long-term or life-of-mine forecasts. All forecasts however, whether short term or long term, exhibit some degree of uncertainty. The dynamic nature of markets means that this uncertainty increases as the length of the forecast increases.

Thus, to ensure a realistic and up-to-date forecast, as market conditions change, so too should the forecast. Despite their inherent uncertainties however, forecasts are an essential aspect of mine valuation, providing potential investors with a guide on which to base investment decisions.

In general, a long-term extraction profile is an estimation of the total amount of ore that can be economically extracted from the mine and should therefore be used as an indication of the *total earning potential* of the operation over its life, rather than a forecast of annual earnings (Rahn, 1973). When calculating the Eastern Boundary Area extraction profile, various assumptions had to be made with regards to certain mining factors. These are based on actual historical efficiencies achieved by the Three Sub-Vertical operations, and are shown in Table 3.2.

Table 3.2. Extraction Profile Assumptions

Variable	Factor
Block Factor	90%
Fault Loss	3%
Mine Call Factor	76%
Processing Recovery Factor	97%
Dilution Factor / Other Sources	22%

The extraction profile of the Eastern Boundary Area was calculated based on the above assumptions and is shown in Table 3.3. Figure 3.2 is a graphical representation of this extraction profile.

Table 3.3 Extraction Profile of the Kloof Eastern Boundary Area

	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Zone Name																	
Area-Excluding Losses (m^2)																	
3T / Zone 19		0	0	59,047	109,659	202,448	236,189	269,931	303,672	303,672	236,189	168,707	134,965	81,991	0	0	2,106,471
3T / Zone 13		11,528	57,641	115,283	184,453	184,453	184,453	184,453	207,509	207,509	253,622	299,735	276,679	207,509	138,339	110,672	2,623,838
3T / Zone 18		0	13,217	72,694	105,737	105,737	79,303	52,869	0	0	0	0	0	0	0	0	429,557
Total		11,528	70,859	247,024	399,849	492,638	499,945	507,252	511,181	511,181	489,812	468,442	411,644	289,501	138,339	110,672	5,159,866
Area-Including Losses (m^2)																	
3T / Zone 19		0	0	52,116	96,787	178,683	208,464	238,244	268,025	268,025	208,464	148,903	119,122	72,367	0	0	1,859,198
3T / Zone 13		10,175	50,875	101,750	162,800	162,800	162,800	162,800	183,150	183,150	223,850	264,550	244,200	183,150	122,100	97,680	2,315,832
3T / Zone 18		0	11,666	64,161	93,325	93,325	69,994	46,662	0	0	0	0	0	0	0	0	379,133
Total		10,175	62,541	218,027	352,912	434,808	441,257	447,707	451,175	451,175	432,314	413,453	363,322	255,517	122,100	97,680	4,554,163
Production (kilotons)																	
3T / Zone 19		0	0	175	325	600	700	800	900	900	700	500	400	243	0	0	6,243
3T / Zone 13		50	250	500	800	800	800	800	900	900	1,100	1,300	1,200	900	600	480	11,380
3T / Zone 18		0	50	275	400	400	300	200	0	0	0	0	0	0	0	0	1,625
Total		50	300	950	1,525	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,600	1,143	600	480	19,248

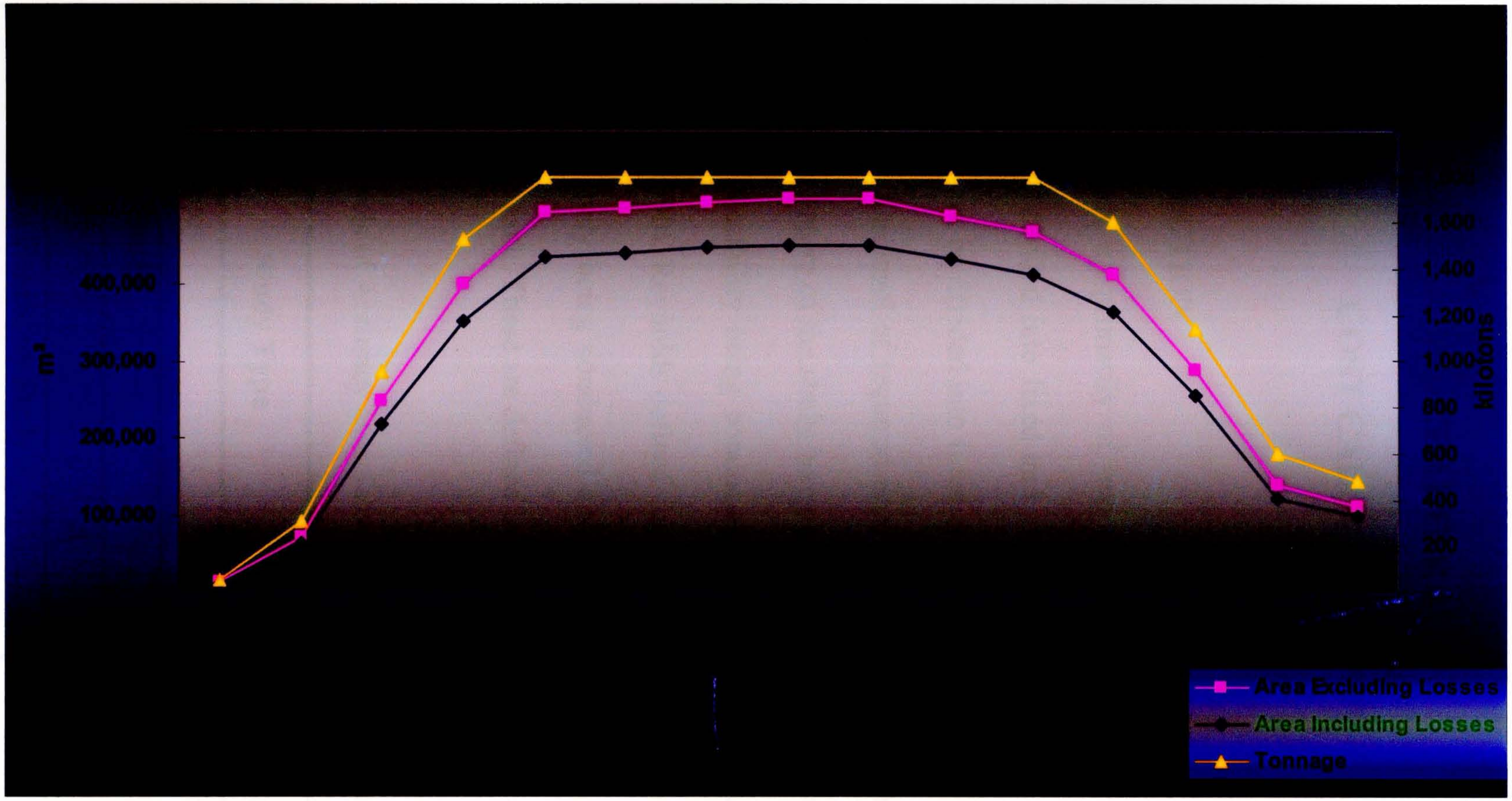

Figure 3.2 Graphical Representation of the Extraction Profile of the Kloof Eastern Boundary Area

PART II

CHAPTER 4

COST CALCULATIONS

4.1 INTRODUCTION

Costs are made up primarily of two components, namely capital costs, which can be divided into fixed and variable capital costs, and operating costs, which can be divided into fixed and variable operating costs (Noakes et al, 1993). The level of required accuracy for cost estimation is directly related to the nature of the study being conducted and generally, the higher the level of feasibility being conducted the higher the required accuracy (Reynolds, 1990). Reynolds defined four levels or classifications to define the type of study being conducted and the associated levels of accuracy expected with each. These are defined in Table 4.1 below.

Table 4.1 Levels of Accuracy associated with Feasibility Studies.

Study Type	% Margin of Error
Conceptual Study	±50
Pre-Feasibility Study	25 – 30
Feasibility Study	10 - 15
Final / Bankable Feasibility Study	±5

4.2 CAPITAL COSTS

4.2.1 Fixed Capital Costs

In order to estimate the fixed capital costs of the Eastern Boundary Area project, the six-tenths rule described by Mular (1982) was adopted. The rule states that the fixed capital costs of an operation can be estimated by relating the operation to a similar operation, equal in nature and of approximately equal capacity. This rule is shown below:

$$\textbf{Cost1} \div \textbf{Cost 2} = (\textbf{Capacity 1} \div \textbf{Capacity 2})^{0.6}$$

The fixed capital cost and capacity of the existing operation, as well as the estimated capacity of the proposed operation are applied to the formula to calculate a fixed capital cost estimate for the new operation.

In the case of the Eastern Boundary Area, the project to which comparison was made was the Leeudoorn Tertiary Shaft, which also has a capacity of 150,000 tons per month, but with a total length of vertical hoist of 672m, thus comparing favourably with the Eastern Boundary Area. Furthermore, the Leeudoorn Tertiary Shaft lies immediately adjacent to the Eastern Boundary Area project and employs the same mining method, providing for a greater degree of confidence in the results generated by the six-tenths rule.

The estimated fixed capital costs were inflated to current terms at the South African Consumer Price Index ("SA CPI") rate. The estimate excluded capital items that, for the reasons defined in Section 3.3, would not be required for the Eastern Boundary Area given the existing infrastructure e.g. refrigeration and ventilation, but that had been included in the Leeudoorn capital expenditure.

Table 4.2 shows the total fixed capital requirements of the Eastern Boundary Area and includes:

- Winders, Cages, Skips and Counterweights
- Ropes and Attachments
- Bins (Shaft Top and Bottom) and Spillage Arrangements
- Crushers, Feeders, Conveyors and Weigh Flasks
- Ventilation Requirements (Pipes and Fans)
- Communication and Power Infrastructure
- Development (Shafts, Ore-Passes, Declines and Horizontal Development)
- Pumping

The costs quoted in Table 4.2 also take into consideration the cost of installation of each item.

Table 4.2 Estimated Fixed Capital Costs for the Eastern Boundary Area.

Category		Cost (R)
Shaft		
	Sink, Line and Equip	89,191,010
	Ore-passes	26,573,415
Engineering Costs		
	Winders	80,384,580
	Rope Reeling	2,143,589
	Permanent Signalling	1,286,153
	Winder Spares	6,430,766
	Permanent Hoisting Equipment	12,861,533
	Main Loading Arrangement	25,723,066
	Shaft Bottom & Spillage Arrangements	6,430,766
Pumping		
	Pump Chambers, Dams and Engineering	68,594,842
Ventilation		
	Compressed Air Piping	321,538.00
Electric Power		
	Cables, Substations and Switchgear	13,926,241
Sub Total		333,867,500
Contingency (10%)		33,386,750
TOTAL		**367,254,250**

4.2.2 Variable Capital Costs

Variable capital costs, or working capital, form an often-underestimated component of total capital costs. Mining ventures are at risk of failure if inadequate provision is made for working capital, especially in early phases of operations, when revenue returns do not meet expectations (Noakes et al, 1993). The six-tenths rule provides a simple yet accurate method to estimate the fixed capital costs of a new operation however, no readily available formula is known for generalising variable capital costs.

Some texts suggest using a percentage of the fixed capital costs, usually 10%, as an estimate of working capital costs. The Eastern Boundary Area working capital requirements were estimated based on the methodology developed by Noakes et al (1993), who stated that, by determining the time period (T) for the expected first revenue return, ranging from 1 – 12 months, the annual working capital cost can be estimated as the sum of:

- Monthly fixed operating cost x T
- Monthly variable operating cost x T
- Monthly financing and Head Office administration cost x T
- Stores Inventory for 1 – 3 months at cost
- Material-in-Process Inventory for 1 – 3 months at cost
- Spares Inventory for 1 – 3 months at cost

The working capital requirements are calculated based on the above methodology and the results included in the financial model calculations shown in Table 5.2. Although this method of calculating the working capital yields a conservative estimate, in mineral project valuation it is generally more favourable to err towards a conservative figure than to underestimate. The working capital costs can easily be modified once actual operating data has been generated.

4.3 OPERATING COSTS

There are very few rules-of-thumb that can be used to estimate operating costs. In the case of the Eastern Boundary Area project, reference was again made to a known operation with similar characteristics to estimate the total operating costs. Taute's Cost per Unit Volume relationship was used, which states that the total expenses incurred in operating a mine, portray general relationships to the volume of business done during a given time period (Taute, 1952). These relationships are described as follows:

- Most of the total expenses of production tend to vary directly with the volume of production. These are termed variable or direct costs and consist primarily of wages, materials and power / tools.

- During the operation of a business there are certain expenses such as executive salaries, salaries of office employees, travelling expenses and other general expenses. These expenses are in a sense fixed, but may be regulated from time to time and are thus termed regulated expenses. They can be divided into fixed and variable portions.

- There are certain expenses such as power costs, which, by the nature of their relation to operations, also have a fixed and variable portion to them. These types of expenses are referred to as mixed expenses.

Taute (1952) also noted that if a company did not operate at all and all employees were retrenched, there would still be some expenses that would have to be met. These expenses, which are independent of the volume of production are termed fixed operating expenses or overheads and consist of insurance, rent, taxes, interest, depreciation and maintenance expenses.

Total expenses would therefore fall into two categories as follows:

- The *constant* operating expenses consisting of
    1. Fixed expenses
    2. The fixed portion of regulated expenses
    3. The fixed portion of mixed expenses

- The *variable* operating expenses consisting of:
    1. Wages and materials
    2. The variable portion of regulated expenses
    3. The variable portion of mixed expenses

Thus, the relationship between total costs and production can be written as:

$$y = a + bx$$

where:
y = total expenses
a = constant expenses
b = variable expenses
x = volume produced

Based on the above formula, actual operating costs for the Three Sub-Vertical Shaft were used to estimate operating costs of the Eastern Boundary Area. It was decided to correlate the two operations since the Eastern Boundary Area was merely an extension of the Three Sub-Vertical Shaft and mining parameters that could significantly influence operating costs did not vary greatly between the two operations.

The fixed portion of the Eastern Boundary Area operating cost was kept constant, while the variable cost was increased in line with the build up in production. The SA CPI was once again applied as an inflation factor to bring the estimate to current value terms, as shown in Table 4.3.

Table 4.3 Breakdown of the operating costs for the Eastern Boundary Area

	Category	Cost (R/Ton)
Mining		
	Stoping	161.0
	Development	59.5
	Ancillary Mining	18.2
	Other	42.7
Transport		
	U/G Transport	38.3
	Hoisting	32.9
	Surface Transport	1.0
Metallurgical		
		25.6
Mine Services		
	Pumping	15.3
	Ventilation	2.6
	Refrigeration	7.4
	U/G Engineering Services	36.5
	Other	6.1
TOTAL		**447.1**

The same approach was adopted when estimating the operating costs for the pre-feasibility study conducted on the extension of mining operations in the Kloof Four Shaft Area. Following commencement of the operations, the original estimated operating costs where compared to the actual operating costs and were found to yield levels of accuracy exceeding those required for a pre-feasibility study.

CHAPTER 5

DISCOUNTED CASH FLOW VALUATION

5.1 INTRODUCTION

Mining companies exploit exhaustible resources in the form of orebodies and in order for a mining company to survive and grow, these resources must be replenished at a rate equal to, or greater than the rate of depletion. Mining companies are constantly looking for opportunities to expand their resources, either through the purchase of existing operations or through exploration and, as such, usually have a pipeline of potential projects that are being evaluated. Investment decisions relating to potential projects thus form a crucial part of any mining company's day-to-day operations.

In order for a mining company to be able to make sound investment decisions, evaluation of the potential projects is necessary. These evaluations not only allow the company to make decisions on the projects, but also allow the company to rank potential projects. Different appraisal and valuation techniques are available to potential investors, each with its own strengths and flaws, but the most popular and widely used is the Discounted Cash Flow valuation.

5.2 DISCOUNTED CASH FLOW ANALYSIS

"It can be argued that the worth of a project is the value of the project's future cash flows less the required investment. However, the time in which the investments and returns are received is also an important factor" (Torries, 1998). Time distorts the value of cash flows relative to one another i.e. R100 received in a year's time will not have the same value as R100 received today. This concept is termed the time value of money, and forms a crucial aspect of project appraisal, especially so in the case of projects with a long estimated life.

Discounted cash flow, as the term describes, is the cash flow of a project at some point in time in the future, discounted at a particular rate, to account for the time value of money, to its present value (Torries, 1998). This can be written as:

$$PV_t = \frac{FV_t}{(1+i)^t}$$

where:

PV_t is the Present Value of a cash flow

FV_t is the Future Value of a cash flow

i is the Discount Rate

t is the time period in the future at which the cash flow is received

This expression can be re-written to show the relationship of the future yearly cash flows (CF_t) to the discounted value of the yearly cash flows (DCF_t) as follows:

$$DCF_t = \frac{CF_t}{(1+i)^t}$$

"The sum of the discounted yearly cash flows gives the present value of the entire income stream at the beginning of the time period. The further into the future the cash flow is to be received, the higher the discount factor and the lower the cash flow's present value" (Torries, 1998). Discounted Cash Flow can be thought of as a means of relating the amount of expected future profits to the amount of the initial investment of a project.

5.3 INPUTS INTO DISCOUNTED CASH FLOW ANALYSIS

Lattanzi identified the following principal input factors to a discounted cash flow analysis:

- The tonnage and grade of the reserves.
- The production of ore and saleable mineral.
- The revenue to be received from the sale of the mineral.
- The cost of production.
- The payment for royalties and taxes.
- The capital expenditure.
- The discount rate.

5.3.1 Mineable Reserves

The principal asset that forms the value in any mining project is the mineral reserve, and an accurate determination of the reserve is critical to an accurate discounted cash flow valuation. Estimates of mineral reserves have two components, namely tonnage and grade. The size (tonnage) and grade of any reserve is estimated using geostatistics, the underlying data being obtained from boreholes and exploratory drilling. Geostatistics cannot yield a definitive result and as such, by its inherent nature, introduces a certain degree of uncertainty into the estimate.

Once an estimation of the size and grade of the reserve has been determined, further discrepancy is introduced into the reserve in that during mining, dilution of the reserve takes place as a result of waste being mined. This waste mining has the same effect as reducing the grade of the reserves, the result being that the grade of ore mine is marginally less than that of ore in-situ.

Dilution by waste rock increases the tonnage of material mined and therefore increases the costs. Dilution also reduces the grade, thereby reducing the total recovered metal and consequently reducing revenue. Allowance must therefore be made for dilution in the inputs into the Discounted Cash Flow valuation.

Most frequently, when mining projects fail, they do so because the mineable reserve has not been properly identified (Gentry et al, 1984). The most common relating to mineral reserves is an inaccurate estimation of the size and grade of the deposit. This results in a over-estimation in mined grade and subsequently an over-estimation of revenue, especially in the early part of the project when production is still being ramped up and cash flows are tight. Accurate reserve estimation, the fundamental constituent of any discounted cash flow analysis in mining, is therefore critical.

5.3.2 Production

For the purposes of Discounted Cash Flow valuations, rate of production is a key determinant in the calculation of revenue. Generally, for existing operations, production can be forecast quite accurately based on historical operating results. For a new project however, the production forecast is purely theoretical based on the mine design.

In such cases, it is imperative that production be ramped up to full capacity over time. Failing to allow for a build up in production over the initial period of the project results in an over-estimation of the production and consequently an over-estimation of revenue to be received.

Just as dilution from waste mining reduces the grade of ore when estimating mineable reserves, inefficiencies in metallurgical recoveries reduce the grade of the ore when estimating production of saleable mineral. Plant losses result in a marginal portion of the grade being lost to tailings resulting in a shortfall in the amount of saleable mineral produced and consequently a reduction in the revenue to be received. An appropriate plant recovery factor is thus as important as an appropriate dilution factor.

In the case of a new plant, metallurgical recovery is estimated on the basis of test work carried out on bulk samples. An element of risk exists, relating to how representative of the entire orebody the bulk sample is. In the case of an existing plant however, the recovery can be accurately estimated based on historical operating information. There will still be an element of uncertainty, even with an existing plant, due to the different chemical composition of the new ore compared to the existing ore being processed.

5.3.3 Revenue

Revenue is determined by production, grade, dilution factor, metallurgical recovery factor, commodity price and the rate of exchange between the currency in which costs are incurred and the currency in which the mineral price is quoted.

The exchange rate forecast is calculated on the differentials between the Consumer Price Index of the local currency and the Consumer Price Index forecast of the currency in which the mineral price is quoted.

The price of the mineral commodity is normally beyond the control of the mine operator, although an element of mineral price uncertainty can be mitigated through the use of hedging instruments, in which a portion of the mine's production is sold at a fixed price at a certain point in time in the future. It is unlikely though that any mining operation would commit 100% of its production for the entire portion of its mining life, therefore an element of price uncertainty will always exist.

Mineral commodity price not only forms the most important determinant of revenue, but also the most important determinant of overall value (Lattanzi). Some texts argue that mineral prices are impossible to forecast into the future with any real certainty and that Discounted Cash Flow valuations should be done based on flat commodity prices going forward. This not only results in a gross misrepresentation of the mine's value, but could also result in a project being rejected or accepted unfoundedly.

In the author's opinion historical trends, supply/demand fundamentals and cyclicality of the mineral commodity price are issues that should be addressed in compiling an educated and calculated forecast. It must be borne in mind however, that there will always be a great deal of uncertainty and risk inherent in any such forecast.

5.3.4 Operating Costs

In general, operating costs are estimated under the functional headings of mining, processing, and general and administration, each of these being subdivided into estimates of the cost of labour, materials and supplies, and services such as electrical power and insurance (Lattanzi). The estimation of operating costs is usually based on a derived rate per unit of production cost. This unit cost will vary depending on the rate of production, the equipment required to meet that rate of production, the mining method, and the infrastructure required. The multiple of the unit cost and the rate of production results in an estimate of the nominal operating cost.

Although variations in the unit cost estimates can be quite small, when applied to the total production estimate over the life of the project, they can be significant. It is therefore imperative that sensitivity analyses be carried out on operating cost estimates.

5.3.5 Royalties and Taxation.

Taxation, and often royalties, account for a liability common to every Mining project DCF valuation. Taxes and royalties are usually paid to parties who require compensation for the exploitation by the company of the mineral reserves in question, and are payable to the government, the local community, or a private party. Taxes and royalties are usually revenue or production based and must be incorporated into the Discounted Cash Flow valuation, as they represent an added cost to the operation.

Different types of taxation are payable in different countries, and can include Income Tax, Secondary Tax on Companies and Value Added Tax. Furthermore, different commodities may incur different taxes within the same country, as in the case of the South African gold mining companies, whose tax liabilities vary from mine to mine according to a formula.

In most cases, when determining the income to be taxed, deductions such as various expenditure items are allowed, with the result that the tax liabilities can often become a significant factor in determining the profit after tax of a company. Tax and royalty calculations, and the associated deductions allowable under the various jurisdictions, must be calculated accurately to avoid under-estimation or over-estimation of the tax liability and thus the total project value.

5.3.6 Capital Expenditure

Capital expenditure estimates are calculated as pre-production capital required to commission the mine, and as on-going capital, or working capital, required to replace worn out equipment throughout the productive life of the mine (Lattanzi).

Pre-production capital expenditures for mining projects are usually massive, given the nature of the equipment and facilities being commissioned and can be in the hundreds of million Rands. Pre-production capital is expended early in the project, usually during the construction period in the first few years, although can be incurred at a later stage in the project as well in the case of a planned expansion. The estimates of pre-production capital expenditure are usually prepared based on quotes from a number of suppliers and are mostly relatively accurate however, given the magnitude of the amounts associated with pre-production capital expenditures, variations in these can have a significant influence on the project value.

Working capital expenditure is much less than pre-production capital, but given that it is incurred on an ongoing basis, can be quite large in the total scope of the project, especially in the case of a project with a long life, and can thus form a substantial part of the capital estimate. Working capital can be estimated as a percentage of operating costs (Noakes et al, 1993).

A major factor for consideration when estimating capital expenditure of a mining project is ensuring that the time period allowed for construction and commissioning of those items is realistic. Over-optimistic schedules can result in capital overruns and, in the case of the pre-production capital, can have serious time value of money implications for the value of the project.

Also, capital expenditure estimates prepared at earlier stages of study will be subject to wider limits of inaccuracy as compared to those compiled closer to commencement date. As is the case with operating costs, it is again imperative that sensitivity analyses be performed to investigate the influence on value of wide variations in pre-production capital expenditure.

Another aspect relating to capital expenditure is that of environmental reclamation, rehabilitation and closure. With environmental legislation becoming progressively more stringent, the cost of final reclamation of the mining site must be estimated with relative accuracy. Environmental legislation now requires that a formal closure plan be prepared and costed prior to the commencement of production, and that financial provision be put in place throughout the life of the operation in order to ensure that funds are available to pay for final reclamation.

Generally, the impact of the environmental rehabilitation provision on the discounted cash flow valuation of a mine depends on the life of the mine. In mine with long operating lives, annual environmental rehabilitation provision is unimportant, but in mines where the anticipated life is only a few years environmental rehabilitation provision can be significant.

5.3.7 Discount Rate

Along with grade and mineral commodity prices, the discount rate impacts a discounted cash flow the most significantly. Depending on the life of the project, relatively small variations in the discount rate can result in variations in the project's NPV of up to 50% (Smith, 1995). Figure 5.1 is a graphic representation of the impact of variable discount rates on NPV.

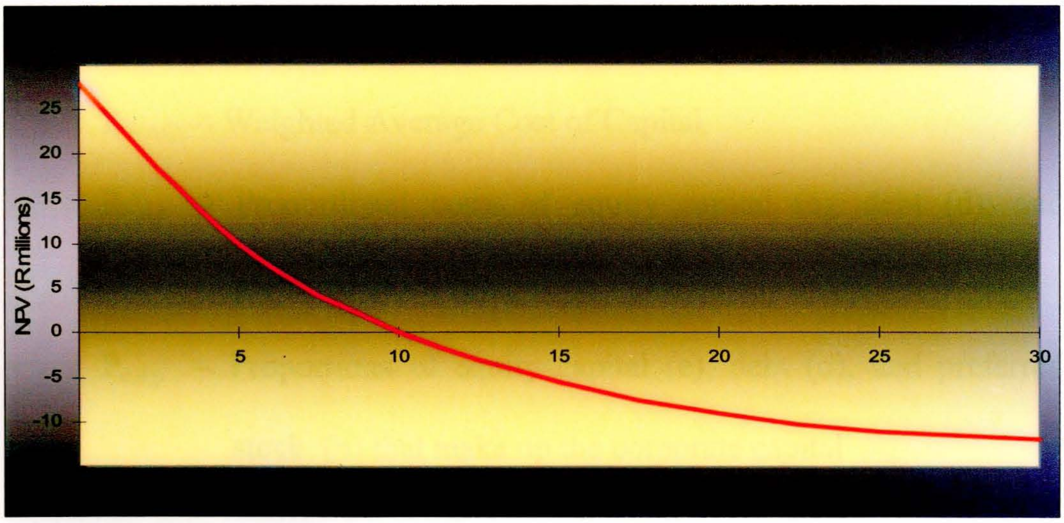

Figure 5.1 The Impact of Discount Rates on Net Present Value

Various experts adopt various methods when determining the discount rate to be used for the valuation of mineral projects. One school of thought, which is commonplace in industry, is to apply a standard discount rate of 10% to mineral projects. This can be dangerous, as no two projects are unique and should thus be treated as such and evaluated on their own unique characteristics.

Another philosophy, proposes the use of the corporate cost of capital as a discount rate. "This value is the weighted average cost of the funds available to a company, including equity (common stock), debt (after tax rate), and preferred shares" (Smith, 1995). Referred to as the Weighted Average Cost of Capital ("WACC"), it can be expressed as follows:

$$R_{WACC} = R_e P_e + R_d P_d + R_p P_p$$

where:

R_{WACC}= Weighted Average Cost of Capital

$R_{e,d,p}$ = Proportional costs of equity capital (e), debt (d), and preferred stock (p)

$P_{e,d,p}$ = Proportions of equity capital (e), debt (d), and preferred stock (p) that make up the corporate capital

Note that the sum of P_e, P_d and P_p must be equal to one.

This discount rate can be seen as the hurdle rate at which an NPV must be positive before a company can break even on a particular project. The value of the NPV, calculated at the WACC discount rate is then the profit or loss, depending on whether the NPV is positive or negative, that a company will make from investing in that project.

In cases where the company has sufficient funds to finance a particular project internally, and no debt or preferred stock is required, only the cost of equity capital needs to be considered. The Capital Asset Pricing Model ("CAPM") is a widely used method of assessing the cost of equity capital and applying it as the discount rate for that particular project. The basis of this method is that the return on a listed share can be related to the stock market as a whole by the relationship:

$$R_e = f + R\beta$$

where:

R_e = expected return on the common share

f = risk-free rate of return (based on government bond rates)

R = risk premium of market returns above risk free rate

β = Beta factor for the common stock.

The beta factor measures the volatility in a listed stock, relative to the movements in the stock market as a whole e.g. if a share were to appreciate by 10% while the stock market as a whole appreciated by 20%, the beta would equate to 0.5.

There are a number of inherent problems associated with using a market-based beta to evaluate an individual mineral project, the most important of which is the dynamic nature of beta (Smith, 1995). The stock market as a whole as well as a company's share price are constantly changing and will thus result in a constantly changing beta value. This results in a constantly changing discount rate, which in turn means that the project will have a constantly changing NPV, making it difficult to decide on whether or not to invest in that project. This holds especially true when a project is marginal and moves from a profit to a loss-making situation as beta changes.

Furthermore, beta measures the variability of the share price of an entire company, and is thus inappropriate for an individual project. Another shortfall of the CAPM is that it cannot be used in the case of an unlisted company. For an unlisted company financing a project from internal sources, neither the WACC nor the CAPM can be used. In this case the principal components making up the discount rate should be evaluated and the Risk Adjusted Discount Rate calculated (Smith, 1995), as shown below.

Discount Rate =

Long-term, risk-free interest rate (Based on the government bond rate)

\+ Mining Project Risk (0% - 16%)

\+ Country Risk

Where:

- Long-term, risk-free interest rate is the minimum rate that the project should achieve to justify any form of risk.

- Mineral Project Risk incorporates the risks associated with reserves, mining, processing, construction, environmental compliance, new technology and market conditions.

- Country Risk refers to risks that are related to country-specific social, economic, and political factors, but is usually priced into the market rate of government bonds.

The decision on which values to use to calculate the discount rate is based on the valuator's perception of risk and the valuators experience, and is thus a decision based largely on intuition. In calculating the discount rate to be used, cognisance should be taken of the stage of development of the project. A project at the pre-feasibility stage is generally discounted at a rate higher than that of a project at the bankable feasibility stage.

5.4 NET PRESENT VALUE AND INTERNAL RATE OF RETURN

Net Present Value ("NPV") and Internal Rate of Return ("IRR") are the two basic measures of project feasibility used in DCF analysis. NPV is a measure of the present value of a project's future cash flows, while IRR is a measure of the rate of accumulation of wealth from that project. DCF evaluation is typically based on either NPV or IRR (Torries, 1998).

5.4.1 Net Present Value

Net Present Value is the sum of the present values of a project's annual cash flows over its life, less the initial investment. In short, NPV is an indication of the worth of a project, given a certain cash flow and discount rate.

NPV can be written as:

$$NPV = \left[\sum_{t=1}^{n} \frac{CF_t}{(1+i)^t} \right] - I_o$$

where:

CF_t = Cash flow in year t

I_o = Initial Investment

i = Discount Rate

n = Total number of years for project

As an evaluation tool, NPV has the advantage that it takes into account the time value of money and provides a single value to a project under certain conditions. The larger the NPV, the greater the value of the project and hence the greater the return that the investor will receive from investing in that project.

NPV is widely used for valuating mineral projects and has proved to be popular for valuating existing projects, new projects and, in some cases, even greenfields projects. NPV also provides a useful means of ranking projects in order of value. It is crucial to bear in mind that when using NPV to rank potential projects, the assumptions made in the initial inputs of the project must be kept consistent.

5.4.2 Internal Rate of Return

As the discount rate of a project increases, the NPV of the project decreases. The discount rate at which the NPV of a project becomes zero is termed the Internal Rate of Return of the project, written as follows:

$$\mathrm{NPV} = 0 = \left[\sum_{t=1}^{n} \frac{\mathrm{CF}_t}{(1+\mathrm{IRR})^t} \right] - \mathrm{I}_o$$

Where:

CF_t = Cash flow in year t

I_o = Initial Investment = CF_o

IRR = Discount Rate that makes the NPV zero

n = Total number of years for project

Alternatively, IRR can be thought of as that discount rate which equates the present value of the initial investment, with the sum of the present values of the future returns (Torries, 1998). The higher the IRR, the higher the rate that is required to equate the NPV of the project to zero, thus the higher the profitability of the project.

Caution should be taken not to confuse the discount rate with the IRR. Although the two are linked, the discount rate is the rate that the investor chooses to discount the future cash flows to present values and reflects the potential risk of a project, whereas the IRR is determined by the characteristics of the project's cash flows. Expressed differently, IRR is determined internally (hence the term *Internal* Rate of Return) while the discount rate is determined externally (Torries, 1998).

Where the risk is perceived to be high, the investor may choose to discount the project at a higher rate, e.g. a project that is exposed to potentially high political risk may be discounted at a rate higher than that of a project with low political risk. Similar adjustments in the discount rate can be made for perceived, geographic, social and economic risk. This is termed the Risk Adjusted Discount Rate ("RADR") and is used as a means to address the issue of risk in the DCF valuation.

Whereas NPV provides a useful measure of the potential wealth that can be derived from a project, it does not indicate the rate at which the wealth will be generated. IRR provides the potential investor with a measure of the return on his/her invested unit of cash from the project and, as such, has proven to be extremely popular for assessing and ranking potential investments.

5.5 DCF VALUATION OF THE EASTERN BOUNDARY AREA

The Eastern Boundary Area DCF valuation is based on the ore reserve and mine design parameters described in Chapters 2 and 3 respectively. Cost estimates are incorporated into the DCF valuation to derive the project's annual operating profit before tax. Taxation is then applied to the DCF valuation to calculate the company's Net Profit After tax. The annual cash flows are then discounted, and the NPV and IRR of the project calculated.

The following inputs apply to the Eastern Boundary Area DCF valuation:

- Operating and capital costs are inflated according to the South African CPI forward curve calculated as at January 2002.

- The discount factor is calculated at 15.5% as follows:
  - 12.5%, based on the rate of the 13-year government bond (R157),
  - 3% project risk, on the basis that the project has adopted a tried-and-tested mining method and that mining operations are to be carried out by a mining company with extensive gold mining experience.

- The Rand - Dollar exchange rate is calculated on the current exchange rate of R11.00/US$, and escalated annually at the South African CPI and the United States CPI forward curve differentials.

- Based on current contributions at existing Kloof shafts, an amount of R0.80/ton of ore mined has been allocated to the environmental trust fund.

- Kloof's current tax rate of 46% was applied to the Eastern Boundary Area on the basis that the project is not an independent legal entity and as such will pay tax at a rate equal to that of Kloof Gold Mining Company.

- Gold price forecast is based on the 10-year historical data shown in Figure 5.2. The cyclicality portrayed is extrapolated and the gold price forecasted at points along these cycles.

Figure 5.2 Trend Analysis of 10-Year Historical Gold Price

Taking into account all the issues highlighted in this chapter with regards to Discounted Cash Flow Valuation, the inputs for the DCF valuation of the Eastern Boundary Area project were calculated. The valuation is calculated and presented in Excel spreadsheet format. The input parameters, the production summary and the cash flow summary are illustrated in Tables 5.1, 5.2 and 5.3 respectively. The results of the DCF analysis are discussed in Chapter 7 below.

Table 5.1 Eastern Boundary Area DCF Valuation - Input Parameters

Eastern Boundary Area

Input Parameters

Blue Cells Require Manual Inputting of Values

	Units	Year Ended	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
		Period	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Macro-economic Parameters																		
SA CPI	(%)		6.1%	6.1%	7.8%	6.9%	6.1%	5.7%	5.7%	5.1%	5.2%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%	4.7%
US CPI	(%)		1.8%	1.8%	1.8%	2.1%	2.1%	2.1%	2.1%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%
CPI Differential	(%)		4.3%	4.3%	6.0%	4.8%	4.0%	3.6%	3.6%	2.8%	2.9%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
Discounting Rate	(%)	16%																
Spot Gold Price	(USD/oz)		282.50	312.50	342.50	377.50	392.50	372.50	337.50	292.50	272.50	247.50	267.50	307.50	347.50	377.50	357.50	332.50
ZAR/USD Exchange rate	(ZAR/USD)		11.00	11.47	12.16	12.75	13.25	13.73	14.23	14.62	15.05	15.41	15.78	16.16	16.55	16.94	17.35	17.77
Spot Gold Price	(ZAR/kg)		99,908	115,270	133,917	154,686	167,266	164,458	154,370	137,533	131,845	122,623	135,713	159,750	184,864	205,643	199,422	189,928

Mining Parameters

Block Factor	(%)	92%
Fault Losses	(%)	3%
Mine Call Factor	(%)	74%
Metallurgical Recovery Factor	(%)	96%
Stoping Width:		
-Zone 13	(cm)	180
-Zone 18	(cm)	157
-Zone 19	(cm)	123
Yield:		
-Zone 13	(g/t)	10.1
-Zone 18	(g/t)	4.3
-Zone 19	(g/t)	9.8

Cost Parameters

Mining:		
Stoping	(R/ton)	161.0
Development	(R/ton)	59.5
Ancillary	(R/ton)	18.2
Other	(R/ton)	42.7
Transport:		
U/G Transport	(R/ton)	38.3
Hoisting	(R/ton)	32.9
Surface Transport	(R/ton)	1.0
Metallurgy:		
Processing	(R/ton)	25.6
Services:		
Ventilation	(R/ton)	15.3
Refrigeration	(R/ton)	2.6
Pumping	(R/ton)	7.4
Engineering	(R/ton)	36.5
Other	(R/ton)	6.1

Table 5.2 Eastern Boundary Area DCF Valuation - Production Summary

Eastern Boundary Area

Production Summary

Blue Cells Require Manual Inputting of Values

	Units	Year Ended	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	TOTAL
		Period	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Production																			
Zone 13	(m^2)		0	13524.9	59638	117279.5	186449.2	186449.2	186449.2	186449.2	210705.8	210705.8	256818.9	302932	277475.5	208305.8	139136	111468.1	2,653,787
Zone 18	(m^2)		0	0	14520.8	73997.93	107040.8	107040.8	80606.5	54172.21	0	0	0	0	0	0	0	0	437,379
Zone 19	(m^2)		0	0	0	61165.14	111777.1	204565.8	238307.1	272048.4	305789.8	305789.8	238307.1	170824.4	137083.1	84109.24	0	0	2,129,767
Total Area Mined	(m^2)			13,525	74,159	252,443	405,267	498,056	505,363	512,670	516,496	516,496	495,126	473,756	414,559	292,415	139,136	111,468	5,220,933
Zone 13	('000 tons)		0	59	262	516	820	820	820	820	926	926	1,129	1,332	1,220	916	612	490	11,667
Zone 18	('000 tons)		0	0	56	284	410	410	309	208	0	0	0	0	0	0	0	0	1,677
Zone 19	('000 tons)		0	0	0	184	336	615	716	817	919	919	716	513	412	253	0	0	6,398
Total ROM Tonnage	('000 tons)		0	59	318	983	1,566	1,845	1,845	1,845	1,845	1,845	1,845	1,845	1,632	1,168	612	490	19,742
Yield																			
Zone 13	(g/t)		10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1
Zone 18	(g/t)		4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Zone 19	(g/t)		9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8
Average Grade	(g/t)		0.0	10.1	9.1	8.4	8.5	8.7	9.0	9.3	10.0	10.0	10.0	10.0	10.0	10.0	10.1	10.1	9.5
Gold Produced																			
Zone 13	(kg)		0	601	2,648	5,207	8,279	8,279	8,279	8,279	9,356	9,356	11,403	13,451	12,320	9,249	6,178	4,949	117,833
Zone 18	(kg)		0	0	239	1,220	1,765	1,765	1,329	893	0	0	0	0	0	0	0	0	7,212
Zone 19	(kg)		0	0	0	1,801	3,291	6,022	7,016	8,009	9,002	9,002	7,016	5,029	4,036	2,476	0	0	62,701
Total Gold Mined	(kg)		0	601	2,887	8,228	13,334	16,066	16,624	17,181	18,358	18,358	18,419	18,480	16,356	11,725	6,178	4,949	187,746
Mine Call Factor	(%)		74%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%	74%
Total Gold Produced	(kg)		0	446	2,144	6,110	9,901	11,930	12,344	12,758	13,632	13,632	13,677	13,722	12,145	8,707	4,587	3,675	139,411
Proccesing																			
Plant Feed Tonnage	('000 tons)		0	59	318	983	1,566	1,845	1,845	1,845	1,845	1,845	1,845	1,845	1,632	1,168	612	490	19,742
Plant Feed Grade	(g/t)		0.0	10.1	9.1	8.4	8.5	8.7	9.0	9.3	10.0	10.0	10.0	10.0	10.0	10.0	10.1	10.1	9.5
Plant Recovery Factor	(%)		96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%
Recovered Gold	(kg)		0	427	2,051	5,845	9,472	11,413	11,809	12,205	13,041	13,041	13,084	13,128	11,619	8,329	4,389	3,516	133,370
Total Saleable Gold	(kg)		0	427	2,051	5,845	9,472	11,413	11,809	12,205	13,041	13,041	13,084	13,128	11,619	8,329	4,389	3,516	133,370

T able 5.3 Eastern Boundary Area DCF Valuation - Cash Flow Summary

Eastern Boundary Area

Cash Flow Summary

Blue Cells Require Manual Inputting of Values

	Units	Year Ended	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	TOTAL
		Period	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Revenue																			
Total Saleable Gold	(kg)		0	427	2,051	5,845	9,472	11,413	11,809	12,205	13,041	13,041	13,084	13,128	11,619	8,329	4,389	3,516	133,370
Spot Gold Price	(USD/oz)		282.50	312.50	342.50	377.50	392.50	372.50	337.50	292.50	272.50	247.50	267.50	307.50	347.50	377.50	357.50	332.50	326.25
ZAR/USD Exchange rate	(ZAR/USD)		11.00	11.47	12.16	12.75	13.25	13.73	14.23	14.62	15.05	15.41	15.78	16.16	16.55	16.94	17.35	17.77	14.64
Spot Gold Price	(ZAR/kg)		99,908	115,270	133,917	154,686	167,266	164,458	154,370	137,533	131,845	122,623	135,713	159,750	184,864	205,643	199,422	189,928	153,575
Total Gold Sales	(R'm)		0.00	49.17	274.69	904.16	1,584.41	1,876.94	1,822.94	1,678.59	1,719.42	1,599.15	1,775.72	2,097.14	2,147.93	1,712.88	875.19	667.77	20,786.11
Total Revenue	(R'm)		0.00	49.17	274.69	904.16	1,584.41	1,876.94	1,822.94	1,678.59	1,719.42	1,599.15	1,775.72	2,097.14	2,147.93	1,712.88	875.19	667.77	20,786.11
Operating Costs																			
Mining:																			
Stoping	(R'm)		0.00	10.16	59.47	193.35	319.49	391.85	414.18	420.69	445.59	449.08	470.19	492.29	455.84	341.77	187.33	157.13	4,808.40
Development	(R'm)		0.00	3.75	21.98	71.46	118.07	144.81	153.07	155.47	164.67	165.97	173.77	181.93	168.46	126.31	69.23	58.07	1,777.02
Ancillary	(R'm)		0.00	1.15	6.72	21.86	36.12	44.30	46.82	47.56	50.37	50.77	53.15	55.65	51.53	38.64	21.18	17.76	543.56
Other	(R'm)		0.00	2.69	15.77	51.28	84.73	103.92	109.85	111.57	118.18	119.10	124.70	130.56	120.90	90.64	49.68	41.67	1,275.27
Transport:																			
U/G Transport	(R'm)		0.00	2.42	14.15	46.00	76.00	93.22	98.53	100.08	106.00	106.83	111.85	117.11	108.44	81.30	44.56	37.38	1,143.86
Hoisting	(R'm)		0.00	2.08	12.15	39.51	65.29	80.07	84.64	85.97	91.05	91.77	96.08	100.60	93.15	69.84	38.28	32.11	982.59
Surface Transport	(R'm)		0.00	0.06	0.37	1.20	1.98	2.43	2.57	2.61	2.77	2.79	2.92	3.06	2.83	2.12	1.16	0.98	29.87
Metallurgy:																			
Processing	(R'm)		0.00	1.61	9.46	30.74	50.80	62.31	65.86	66.89	70.85	71.41	74.76	78.28	72.48	54.34	29.79	24.98	764.57
Services:																			
Ventilation	(R'm)		0.00	0.97	5.65	18.37	30.36	37.24	39.36	39.98	42.34	42.68	44.68	46.78	43.32	32.48	17.80	14.93	456.95
Refrigeration	(R'm)		0.00	0.16	0.96	3.12	5.16	6.33	6.69	6.79	7.20	7.25	7.59	7.95	7.36	5.52	3.03	2.54	77.65
Pumping	(R'm)		0.00	0.47	2.73	8.89	14.68	18.01	19.04	19.34	20.48	20.64	21.61	22.63	20.95	15.71	8.61	7.22	221.01
Engineering	(R'm)		0.00	2.30	13.48	43.83	72.43	88.83	93.90	95.37	101.02	101.81	106.60	111.61	103.34	77.48	42.47	35.62	1,090.10
Other	(R'm)		0.00	0.38	2.25	7.33	12.10	14.85	15.69	15.94	16.88	17.01	17.81	18.65	17.27	12.95	7.10	5.95	182.18
Total Operating Costs	(R'm)		0.00	28.21	165.15	536.94	887.22	1,088.17	1,150.19	1,168.26	1,237.40	1,247.11	1,305.73	1,367.09	1,265.88	949.11	520.21	436.35	13,353.02
Operating Profit Before Tax	**(R'm)**		**0.00**	**20.97**	**109.54**	**367.22**	**697.19**	**788.78**	**672.75**	**510.33**	**482.01**	**352.04**	**469.99**	**730.05**	**882.05**	**763.77**	**354.98**	**231.42**	**7,433.09**
Tax																			
Tax Rate Payable	(%)		46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%	46%
Losses Brought Forward	(R'm)		0.00	367.25	355.69	291.80	48.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Losses Incurred for the Year	(R'm)		367.25	9.40	45.65	123.93	116.76	66.98	20.68	6.02	23.05	3.24	19.54	20.46	-33.74	-105.59	-142.97	-173.40	367.25
Tax Shield	(R'm)		367.25	355.69	291.80	48.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Taxable Income	(R'm)		0.00	0.00	0.00	-48.51	531.92	721.80	652.08	504.31	458.97	348.80	450.46	709.59	915.79	869.36	497.94	404.82	7,017.33
Tax Payable	(R'm)		0.00	0.00	0.00	-22.31	244.68	332.03	299.96	231.98	211.12	160.45	207.21	326.41	421.26	399.91	229.05	186.22	3,227.97
Operating Profit After Tax	**(R'm)**		**0.00**	**20.97**	**109.54**	**389.54**	**452.50**	**456.75**	**372.80**	**278.35**	**270.89**	**191.59**	**262.78**	**403.63**	**460.79**	**363.86**	**125.92**	**45.20**	**4,205.12**
Capital																			
Capital Expenditure	(R'm)		367.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	367.25
Working Capital Requirements	(R'm)		0.00	9.40	55.05	178.98	295.74	362.72	383.40	389.42	412.47	415.70	435.24	455.70	421.96	316.37	173.40	145.45	
Changes in Working Capital	(R'm)		0.00	9.40	45.65	123.93	116.76	66.98	20.68	6.02	23.05	3.24	19.54	20.46	-33.74	-105.59	-142.97	-173.40	
Environmental Contribution	(R'm)		0.00	0.05	0.25	0.79	1.25	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.31	0.93	0.49	0.39	15.79
Total Capital Cost	(R'm)		367.25	9.45	45.90	124.72	118.01	68.46	22.15	7.50	24.52	4.71	21.01	21.93	-32.43	-104.66	-142.48	-173.01	383.05
Net Operating Profit	**(R'm)**		**(367.25)**	**11.52**	**63.63**	**264.82**	**334.49**	**388.30**	**350.65**	**270.85**	**246.37**	**186.88**	**241.77**	**381.70**	**493.22**	**468.52**	**268.40**	**218.21**	**3,822.07**
Discounted Net Operating Profit	**(R'm)**		**(367.25)**	**9.91**	**47.05**	**168.37**	**182.87**	**182.54**	**141.74**	**94.15**	**73.64**	**48.03**	**53.43**	**72.54**	**80.59**	**65.83**	**32.43**	**22.67**	**908.53**
NPV	**(R'm)**	**908.53**																	
IRR	**(%)**	**44.60%**																	

CHAPTER 6

SENSITIVITY ANALYSIS

6.1 INTRODUCTION

Sensitivity analysis is a crucial component of Discounted Cash Flow valuation. Although NPV and IRR provide a useful measure of the project's worth and investment merit, they are both merely snapshots of a single scenario that is defined by the input variables. A sensitivity analysis allows the potential investor to asses the worth and investment merit of a project under different scenarios, representing the *variability* and *uncertainty* of the input variables.

Variability is the result of the dynamic nature of factors that influence a discounted cash flow valuation and in the case of mineral project valuation include commodity prices, exchange rates, inflation etc. Uncertainty is the result of inherent imprecision that arises when estimating input values and in the case of a mineral project includes grade variability, cost variability, underestimation of capital etc (Whitney and Whitney, 1979).

In the case of the Eastern Boundary Area project, a computer software package was used to perform the sensitivity analysis. The package, known as @RISK, utilizes Monte Carlo simulation, a stochastic technique used to conduct sensitivity analysis whereby random numbers are generated for the input variables as per a defined distribution. An analysis of the theory of Monte Carlo simulation is beyond the scope of this report and is therefore excluded.

Output variables are identified and changes thereto, in relation to changes in the input variables, recorded, thereby allowing the potential investor to rank the impact of the input variables to the project's output variables. The output variables defined for the Eastern Boundary Area are the NPV, the IRR and the individual cash flows, year-on-year, throughout the life of the project.

6.2 DISTRIBUTIONS OF INPUT VARIABLES OF THE EASTERN BOUNDARY AREA PROJECT

All input variables of the Eastern Boundary Area project were identified as having an element of variability and uncertainty about them, and were included in the sensitivity analysis. The input variables include:

- The Consumer Price Indices of South Africa and the United States.
- The discount rate
- The gold price
- The ZAR/USD exchange rate
- The mining and cost parameters as shown in Table 5.1.
- The volume of production as shown in the production profile in Table 5.2.
- The initial capital expenditure.

Wherever possible, historical data was used to define the distributions of the input variables.

6.2.1 Consumer Price Index

The forecasts for both the South African and the United States Consumer Price Indices as used in the sensitivity analysis, are based on the forward curves for the two indices as calculated by the Standard Bank Treasury Division. Given that the variations on these forward curves are relatively minor (in the order of 0.5%), a normal distribution was used to define the volatility about these indices. Figure 6.1 shows the distribution for the South African Consumer Price Index with a current mean of 6.1%

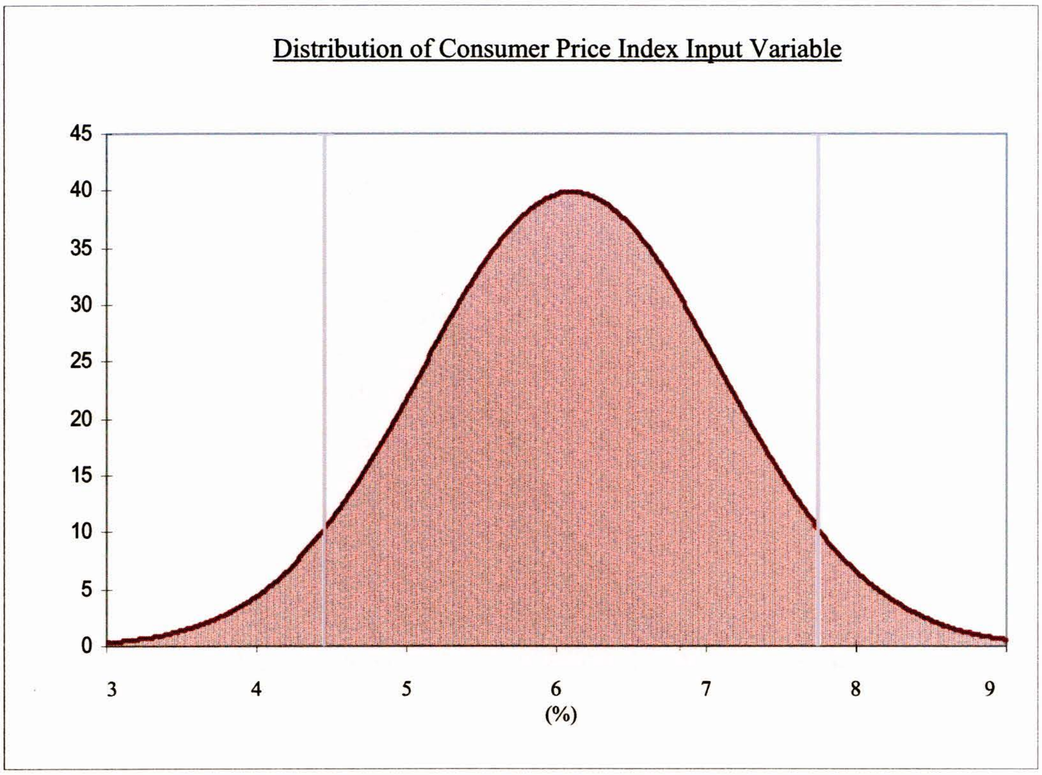

Figure 6.1 Distribution of Consumer Price Index Input Variable

6.2.2 Discount Rate

Selection of a discount rate can vary drastically, depending on a valuator's perception of risk. Tradable Government bonds are an accurate interpretation by the market of a country's perceived political and socio-economic risk and can therefore be taken to represent the Risk-Free rate of return of a country. The only uncertainty relating to the discounted rate therefore, is in the mining project risk, which varies from 0% - 16% as defined by Smith (1995). Combining the country risk with the mining risk results in a 12.5% to 28.5% spread for the discount rate. The associated distribution for the discount rate is illustrated in Figure 6.2.

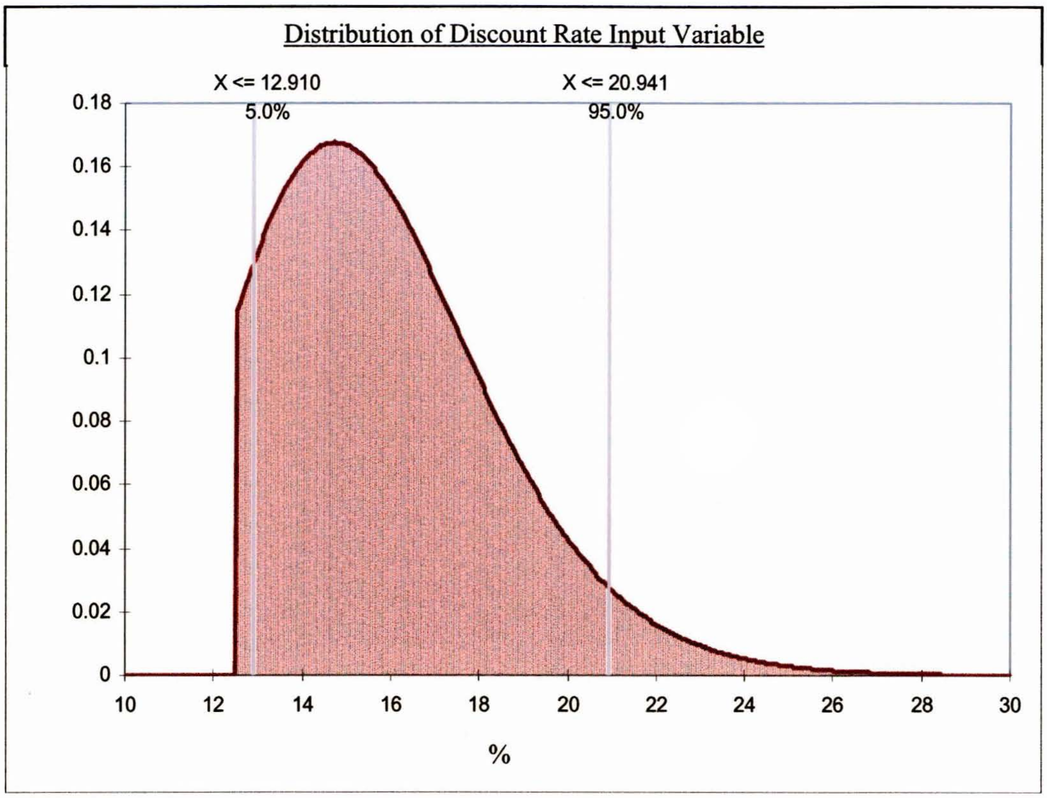

Figure 6.2 Distribution of Discount Rate Input Variable

6.2.3 Gold Price

The distribution of the gold price was analysed for periods of one year, going back five years. The data was found to display a lognormal distribution with the mean following the cyclical trend shown in Figure 5.2. Figure 6.3 shows the distribution of values based on a spot gold price of USD285/oz. Deviations were approximately $10-15/oz on the lower side of the mean and approximately $20-30/oz on the upper side of the mean. This distribution was applied to the gold price input variables for each year of the project life.

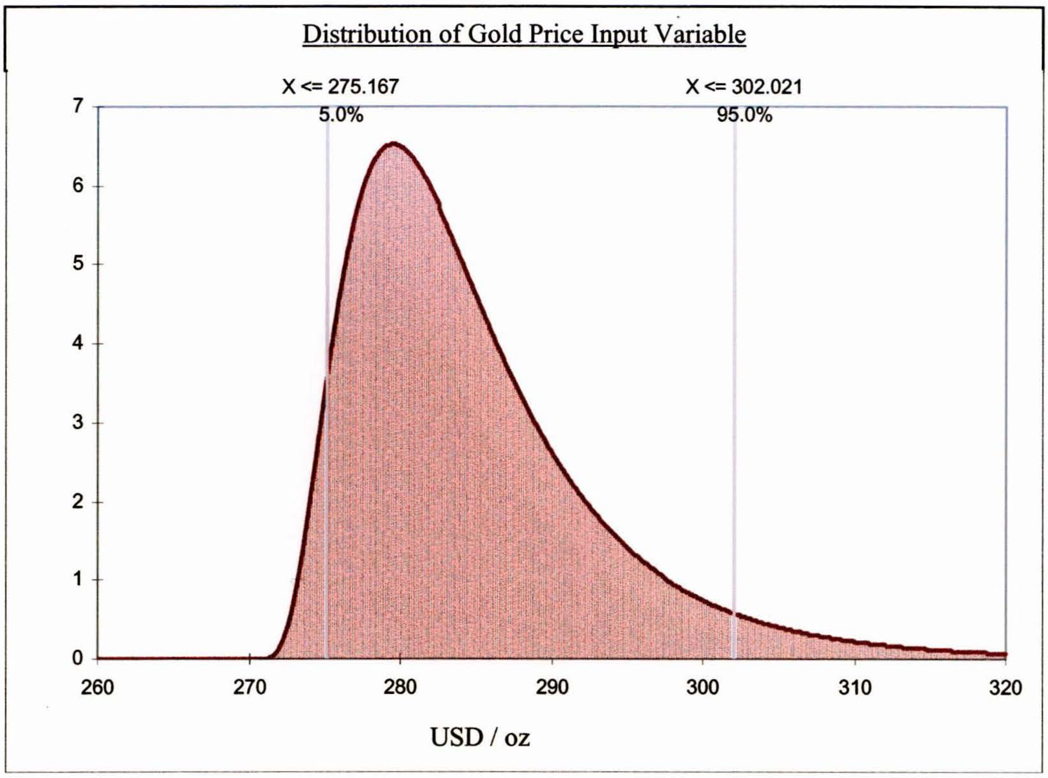

Figure 6.3 Distribution of Gold Price Input Variable

6.2.4 ZAR/USD Exchange Rate

Ideally, the exchange rate should vary according to the differential between the Consumer Price Indices of the two currencies. This is very rarely the case and in reality changes in the exchange rate are of greater magnitude than changes in the CPI differential, especially so in the case of the SA Rand's rate of exchange against the US Dollar. Actual historical data was examined and compared to CPI differential forecasts for the same period and it was found that the difference between the actual exchange rate and the exchange rate as calculated by the CPI differential displayed a lognormal distribution as shown in Figure 6.4. The median of the distribution is based on the ruling Rand / Dollar exchange rate.

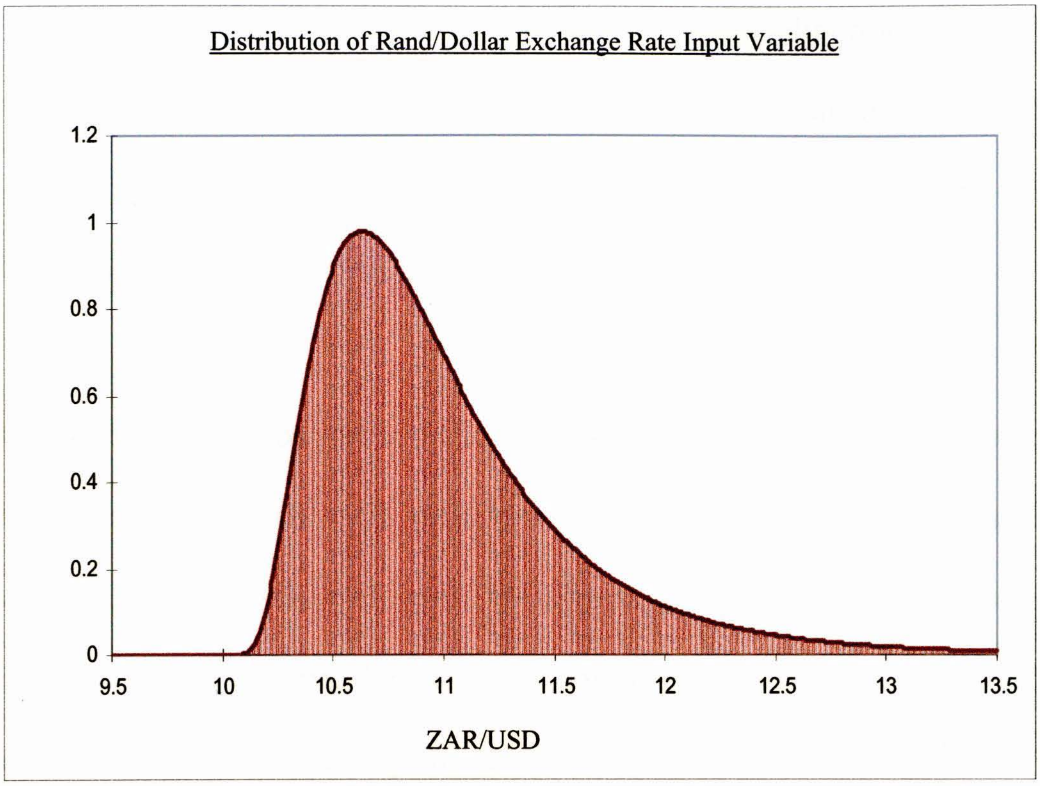

Figure 6.4 Distribution of Rand/Dollar Exchange Rate Input Variable

6.2.5 Mining and Cost Parameters

Mining and cost parameters change as a result of uncertainty, rather than variability. Very seldom, is it possible to correctly estimate the mining and cost parameters of a mining project, due to the number of influential factors that define these parameters. These factors have varying degrees of impact on mining and cost parameters and will be unique for individual projects. Costs, for example, can be made up of a foreign currency component such as diesel, which is priced in US$. As the exchange rate deteriorates, so the price of diesel in the local currency increases, thereby resulting in an increase in the overall costs.

The same can be said about mining parameters. Commodity price is a major determinant in a mining operations cut-off grade, and an increase in the price of the commodity will result in drop in the mine's cut-off grade. This in turn will result in an overall drop in the mining operation's grade.

Generally, mining parameters and costs variables are stressed 10% either side of the mean. Although variations in costs tend generally to be in the order of 10%, variations of up to 20% are not uncommon. In the case of the Eastern Boundary Area, the cost input variables were stressed 10% on the downside and 20% on the upside about the normal distribution, as shown in Figure 6.5.

The upside was stressed 10% more than the downside, as it is *higher* costs that will have a negative impact the overall project and it is the sensitivity of the project to *negative* changes that are of interest to the valuator. Mining parameters were stressed 10% either side of the mean of the distribution shown in Figure 6.6.

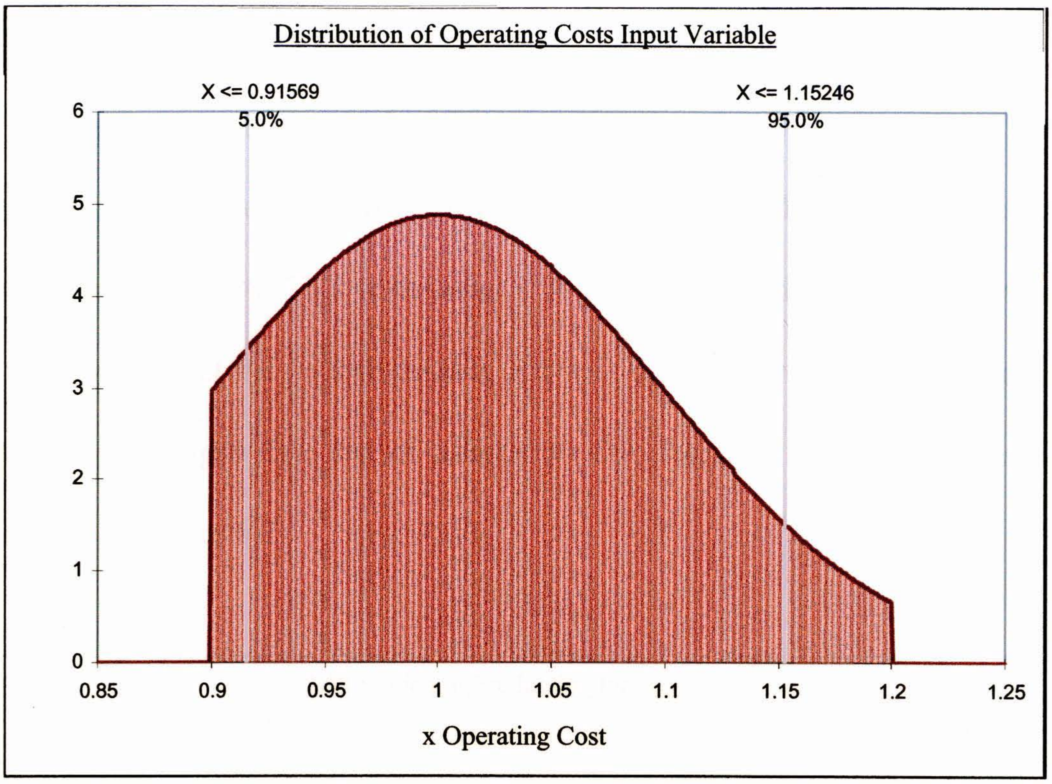

Figure 6.5 Distribution of Operating Costs Input Variable

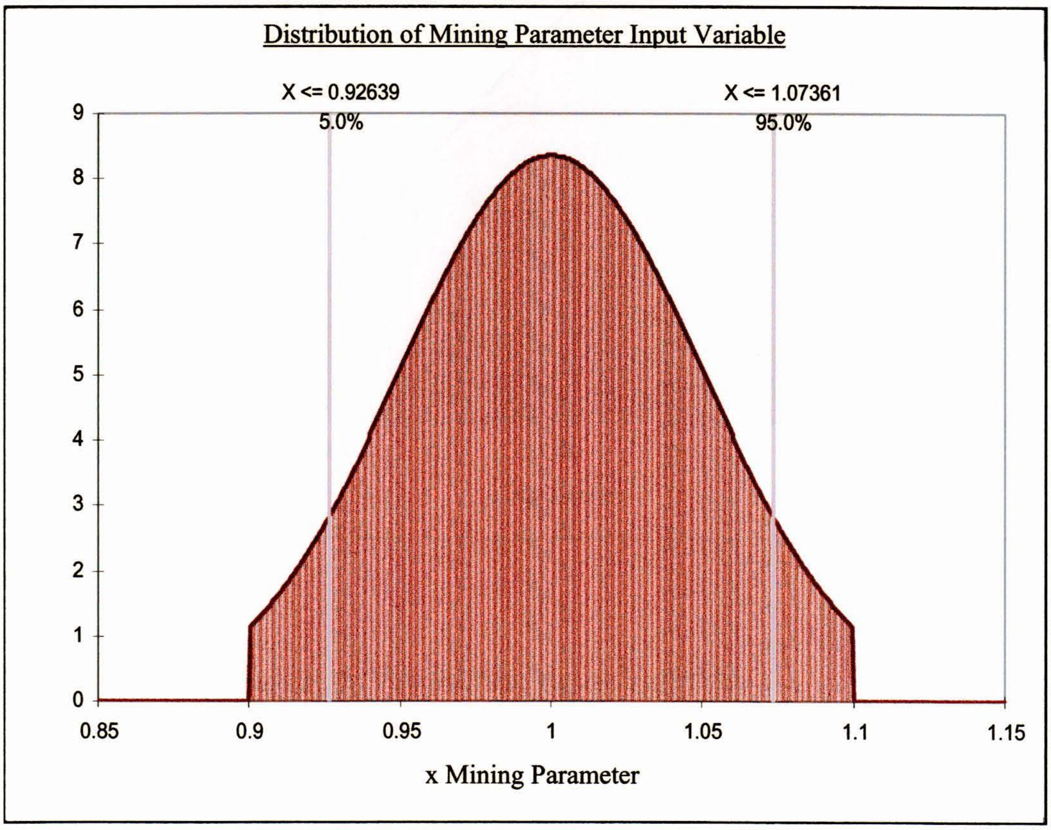

Figure 6.6 Distribution of Mining Parameters Input Variable

6.2.6 Production

The production input variable follows a similar distribution to that of the operating costs, however the downside is stressed to 20% while the upside is stressed to 10%. This is because it is *lower* production that will have a negative impact the overall project and it is the sensitivity of the project to *negative* changes that are of interest to the valuator. The distribution in shown in Figure 6.7.

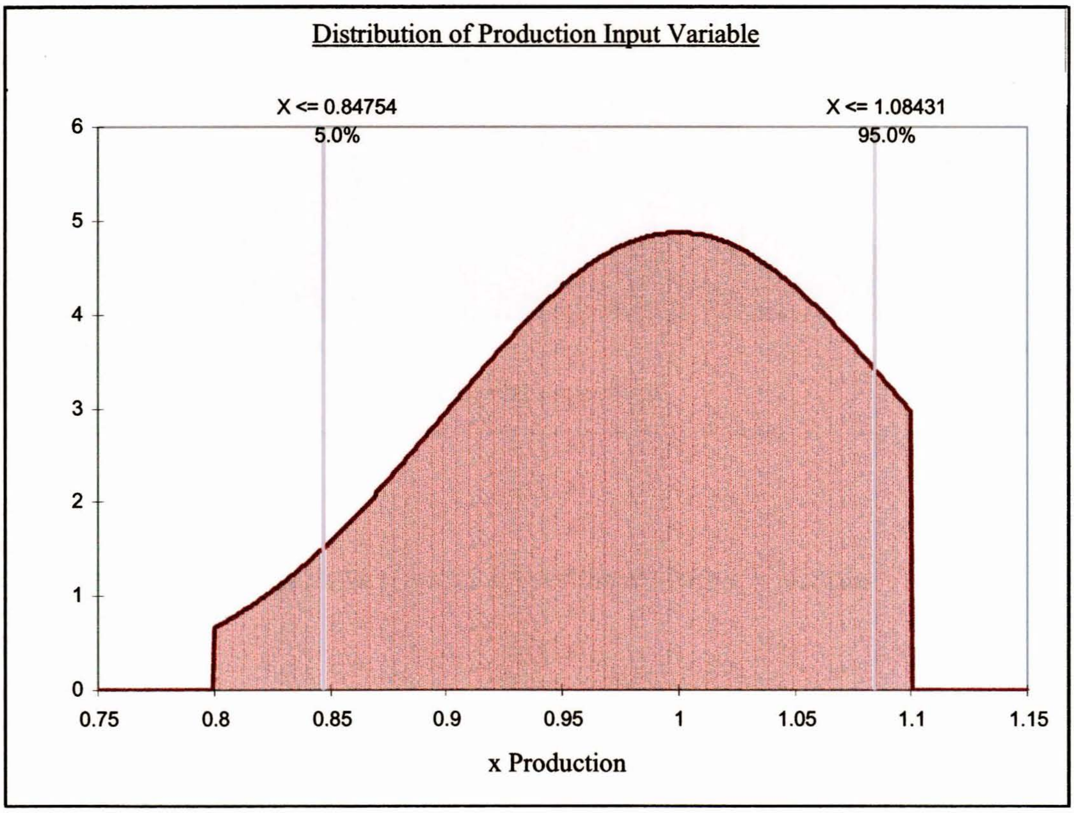

Figure 6.7 Distribution of Production Input Variable

6.2.7 Capital Expenditure

The capital expenditure input variable follows the same distribution as that of the operating costs and is shown in Figure 6.8.

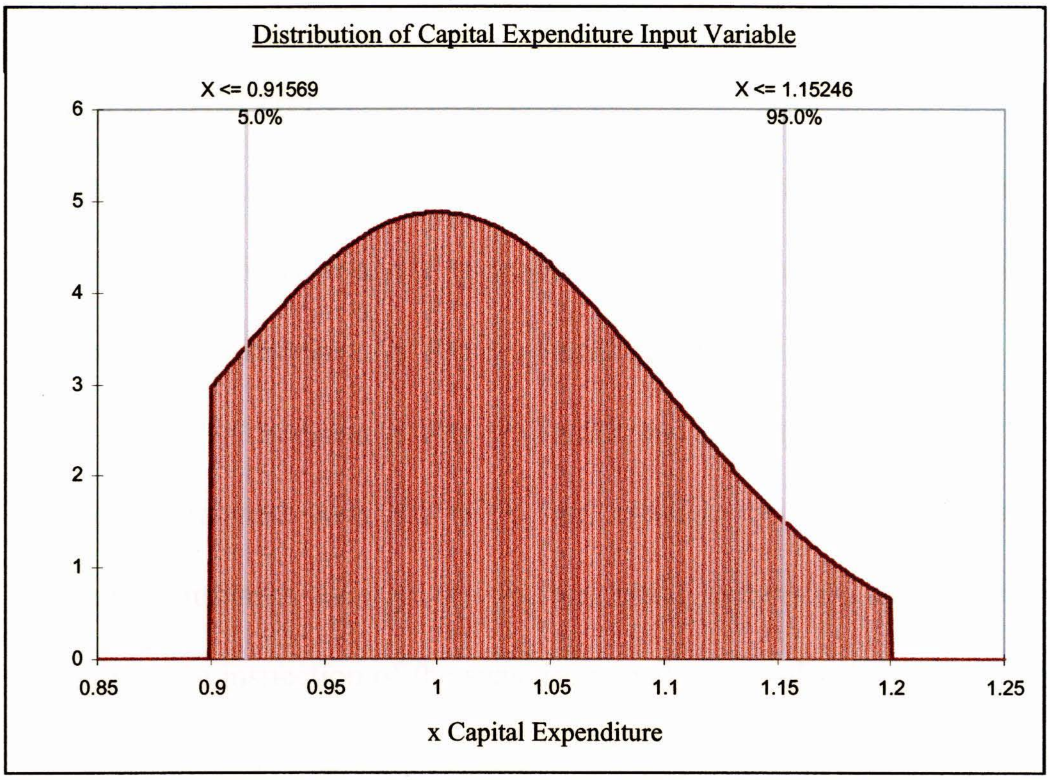

Figure 6.8 Distribution of Capital Expenditure Input Variable

PART III

CHAPTER 7

RESULTS

7.1 INTRODUCTION

Depending on the purpose of a valuation, focus will often be concentrated on certain sensitivity analysis variables more than others. For example, a project being undertaken for social reasons rather than financial ones, will not be concerned with the results of the IRR and the rate of payback. It will only be concerned with the NPV and whether or not the project is profitable. Similarly, the type of valuation being undertaken can also result in a subjective inspection of the sensitivity analysis results. Often therefore, before the valuator begins to develop the financial model, certain variables will have been identified in his/her mind as key in the valuation.

In the case of both pre-feasibility and feasibility studies, the NPV and IRR of the project and the range of values that these variables display in the sensitivity analysis, tend to be the most influential in the decision of whether or not the project warrants further investigation. It is these variables therefore that will be the main focus of the valuator's attention during his/her assessment of the project.

Once the feasibility study confirms a project's viability, it will proceed to the bankable feasibility stage, where the focus of the valuator changes from one of identifying whether or not the project is financially feasible, to one of identifying the variables that most significantly impact the bottom line of the project. This information is crucial in that it enables the valuator to identify various instruments that can be used to mitigate fluctuations in these variables as far as possible, e.g. Commodity Hedging, Interest Rate Swaps, Forward Exchange Agreements, Production Make-up Agreements etc.

7.2 RESULTS

The results of the sensitivity analysis conducted on the Eastern Boundary Area project are shown below. An assessment of changes in the NPV and IRR as well as changes to the annual cash flows, relative to changes in the input variables, is performed. The values that the output variables assume under the varying inputs are presented graphically. The impact of the input variables on the defined output variables is then quantified and ranked.

7.2.1 Discounted Annual Cash Flows

Figure 7.1 depicts the annual net profits (discounted) anticipated year-on-year for the life of the project. Year 1 (2002) shows the negative cash flow associated with the initial capital outlay required for the project. The project cash flows are generally robust, with a positive mean net profit anticipated each year throughout the entire life of the project.

An examination of the results of the sensitivity analysis however, yields less encouraging results. In 2009 the lower 5th percentile of the cash flows become negative. This scenario worsens in the following year, when the lower standard deviation of the cash flows also becomes negative. This remains the case through to 2014.

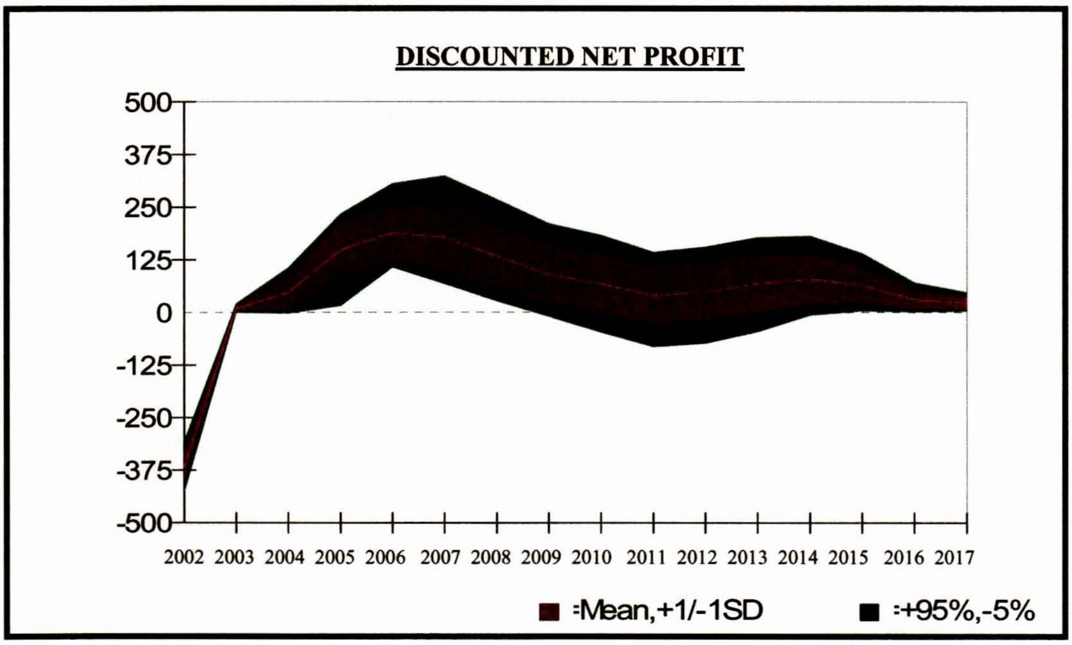

Figure 7.1 Discounted Annual Net Profit

Further analysis of the annual cash flows (Table 7.1.) reveals that years 2003 and 2004 in fact also have the lower 5^{th} percentile as net losses. This is expected however, as the cash flows gradually strengthen while the project builds up to full production.

Closer inspection of the percentile distributions for years 2009 to 2013 reveals that the cash flows are not as weak as may initially have been thought. Year 2011, which is the most negatively impacted of the annual cash flows, is –2.43 and 7.43 at the lower 20% and 25% confidence intervals. This means that somewhere between 20% and 25% the cash flow becomes 0. Interpolation reveals this number to be 21.43%. Translated, this means that for any one year throughout the life of the project, there is, at worst, a 21% chance of the cash flows actually being negative.

For the most part, the project's annual cash flows are robust, with only the latter half of the project being a cause for concern, and this slight, given that, at worst, there exists only an approximately 20% chance of the cash flows being negative in any one year throughout the life of the project. Notwithstanding the relatively small probability, these years are analysed further in section 7.2.3. to ascertain which of the input variables impact most negatively on the cash flows.

Table 7.1 Annual Net Profit Sensitivity Analysis Statistics

	(R'm)	(R'm)	(R'm)	(R'm)	(R'm)	(R'm)	(R'm)	(R'm)	(R'm)	(R'm)	(R'm)	(R'm)	(R'm)	(R'm)	(R'm)	(R'm)
Year	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Minimum	-499.77	-8.77	-46.44	-122.29	-121.67	-99.35	-179.83	-216.08	-266.02	-434.75	-299.18	-371.24	-206.85	-167.16	-99.36	-67.56
Maximum	-229.39	47.51	246.66	393.24	578.46	686.57	615.91	537.72	432.57	306.76	332.55	447.07	337.46	281.63	153.60	115.81
Mean	-367.41	9.37	46.52	147.51	189.34	177.69	133.53	89.84	67.32	40.13	47.96	68.48	78.95	64.21	30.84	22.63
5%	-426.60	-0.18	-2.17	15.48	107.23	68.05	27.02	-9.97	-47.27	-81.81	-73.30	-46.19	-7.00	3.73	1.25	3.41
10%	-414.24	1.78	6.89	39.85	126.12	84.68	47.31	10.47	-7.97	-46.26	-35.22	-6.01	14.10	15.93	6.53	6.64
15%	-406.11	3.02	13.11	56.21	135.30	98.08	60.25	24.61	6.88	-20.08	-9.52	10.15	25.97	23.43	10.24	9.10
20%	-398.30	3.97	17.86	91.40	143.16	108.92	71.24	35.35	17.86	-2.43	3.90	21.49	34.01	29.67	13.69	11.05
25%	-392.46	4.92	21.87	127.53	150.36	119.18	81.28	44.63	27.39	7.34	13.84	30.44	41.65	35.18	16.06	12.73
30%	-387.25	5.79	26.31	137.59	156.95	128.93	90.18	53.62	35.45	14.88	22.09	38.39	48.98	40.86	18.73	14.33
35%	-381.83	6.59	30.50	144.15	162.56	138.80	98.19	60.45	42.61	22.42	30.05	45.61	55.59	45.62	21.02	15.88
40%	-376.91	7.38	34.06	150.08	167.86	147.12	107.68	67.64	49.49	29.48	36.98	53.22	61.87	50.60	23.48	17.54
45%	-372.24	8.16	37.73	156.19	173.91	157.08	116.81	75.88	58.14	36.27	43.64	60.13	68.17	55.67	25.88	19.40
50%	-367.83	8.96	41.72	161.44	180.06	166.96	127.28	85.96	65.08	42.94	50.22	67.22	74.93	60.67	28.27	21.00
55%	-363.00	9.73	45.70	166.76	187.05	177.70	136.27	94.02	72.63	50.23	56.71	75.22	81.26	65.65	30.92	22.59
60%	-358.39	10.54	49.54	172.56	194.15	188.40	145.62	102.15	80.65	56.70	63.97	82.92	88.20	70.46	33.69	24.40
65%	-353.45	11.32	53.50	178.26	201.94	199.91	154.93	110.84	89.13	63.96	70.71	91.36	95.99	76.61	36.71	26.47
70%	-348.80	12.13	58.31	183.92	210.71	211.12	166.20	121.17	97.55	72.58	78.82	99.81	105.07	82.52	40.09	28.61
75%	-343.19	13.07	63.18	190.42	220.88	224.80	178.25	132.52	107.51	80.98	88.58	109.82	114.22	89.28	43.82	31.18
80%	-336.52	14.27	68.93	196.40	232.96	241.60	191.71	144.37	120.10	91.30	99.25	120.96	125.51	96.99	47.89	33.96
85%	-328.58	15.61	76.04	206.21	247.92	258.82	209.96	157.40	134.29	103.46	112.19	133.68	137.10	107.04	52.94	37.03
90%	-320.12	17.58	86.35	216.77	270.27	285.42	231.67	179.75	153.85	119.43	128.74	152.27	154.08	120.68	59.46	41.28
95%	-306.76	20.66	105.84	233.49	305.80	324.24	267.75	210.97	183.39	143.15	154.96	178.15	181.34	140.28	70.88	48.03

7.2.2 NPV and IRR

As mentioned previously, the NPV and IRR of the project can serve as the fundamental basis from which the evaluator will base his/her decision as to whether or not a project warrants further investigation. Furthermore, the NPV and IRR serve as a measure by which other projects of similar nature can be compared. Table 7.2 illustrates the robustness of the Eastern Boundary Area project, yielding a mean NPV of R847m and a mean IRR of 42%.

Table 7.2 NPV and IRR Sensitivity Analysis Statistics

	NPV	IRR
	(R'm)	(%)
Minimum	-1314.58	-8.49%
Maximum	4330.85	88.31%
Mean	846.91	41.69%
5%	-26.98	17.62%
10%	129.16	24.00%
15%	241.02	28.09%
20%	337.68	31.29%
25%	422.44	33.76%
30%	493.54	35.95%
35%	563.62	37.56%
40%	638.50	39.34%
45%	712.40	40.82%
50%	786.78	42.44%
55%	856.31	43.85%
60%	934.49	45.28%
65%	1014.12	46.80%
70%	1101.77	48.46%
75%	1196.82	50.41%
80%	1318.43	52.20%
85%	1455.14	54.72%
90%	1644.09	57.71%
95%	1942.59	63.21%

As in the case of certain Net Annual Profits, the NPV, under stressed conditions, will yield a negative number. Interpolating from Table 7.2, there exists a 5.8% probability that the project will return a Net Present Loss.

In the case of the project IRR, it is not the percentage probability of the IRR being 0% that will be of concern to the evaluator, but rather the probability of the IRR achieving the hurdle rate set for that particular project. This hurdle rate can be dependant on a number of factors such as the nature of the project, the resident country of the project, the level of investigation taking place etc. Generally speaking though, it will be set at a level that is indicative of the risk that a particular project poses, as perceived by an investor/company. At worst, for break-even, the IRR should exceed the current Corporate Cost of Capital and ideally should exceed the current Corporate *Return* on Capital.

As with the calculation of the appropriate discount rate, the Risk-Free rate of return for the country and the perceived mining risk for the project were added to achieve a hurdle rate of 28.5%. By interpolating from Table 7.2, it is calculated that there exists a 15.6% probability that the project will exceed the expected hurdle rate.

The distribution of NPV and IRR values for different input values are shown in Figures 7.2 and 7.3, illustrating the mean relative to the total distribution. The skewness of the distributions is evident, especially in the NPV distribution, where the majority of the values occur below the R1bn level. In the case of the IRR the distribution is skewed to a lesser degree.

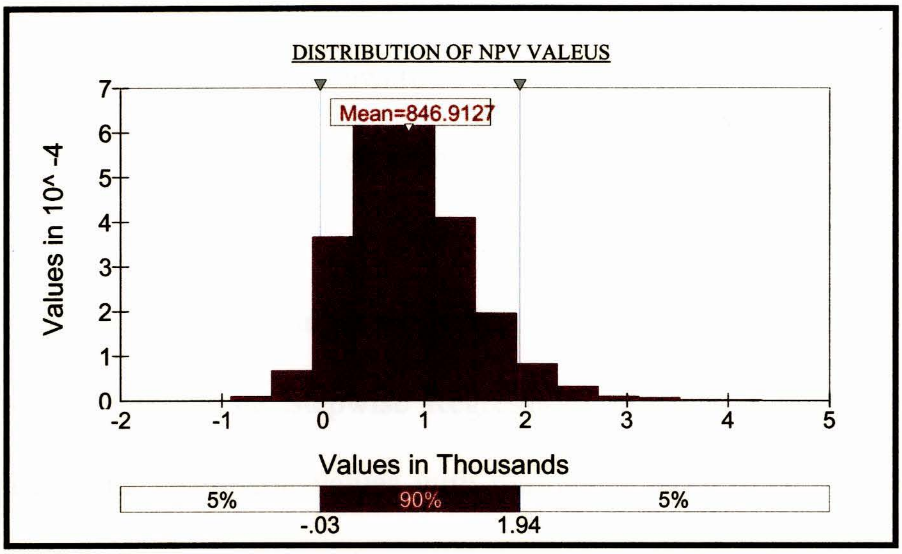

Figure 7.2 Distribution of NPV Values

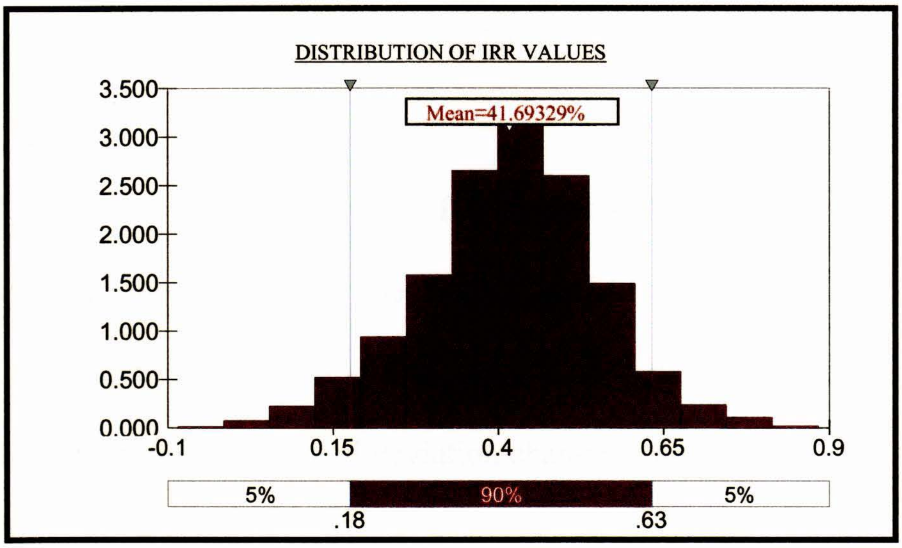

Figure 7.3 Distribution of IRR Values

7.2.3 Ranking of Input Variables

In chapter 7.2.1, the NPV and certain of the annual cash flows were identified as being negative under certain input scenarios. The ability to identify, and quantify those input variables that most negatively impact on the output variables, affords the valuator the ability of identifying which variables to monitor most closely during the life of the project. It also allows the valuator to be aware of those variables up front and thus identify methods to mitigate the risk of those variables in advance.

In order to relate the input variables to the output variable, @RISK makes use of Multivariate Stepwise Regression, which is a technique used for calculating regression values with multiple input values. The coefficients listed in the tornado graphs are normalized regression coefficients termed Standard Beta Coefficients, and are the numbers that quantify the relationship between each input variable and the output variable.

A Standard Beta Coefficient of 0 indicates that there is no relationship between the input and the output variables, while a Standard Beta Coefficient value of 1 or -1 indicates a 1 or -1 standard deviation change in the output, for a 1 standard deviation change in the input.

The tornado graphs of Figures 7.4 – 7.8 rank the input variables that most negatively impact the cash flows for years 2009 to 2013 respectively, the years identified in Chapter 7.2.1 as potential net losses. Since these are the weaker years during the project's life, it is of benefit to the valuator to know which variables most significantly impact the cash flows in those years.

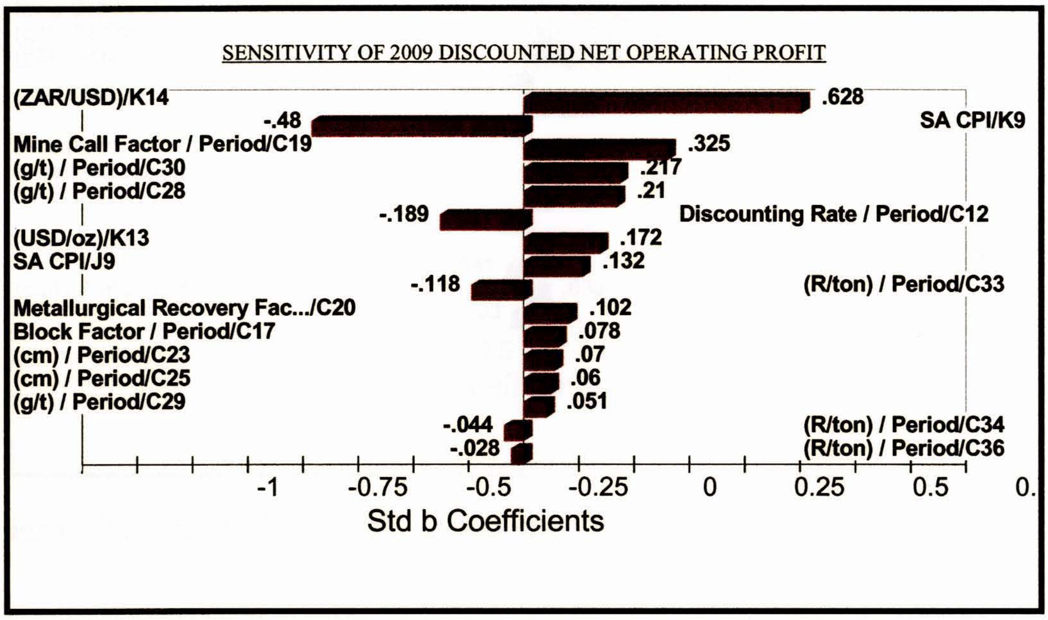

Figure 7.4 Sensitivity of 2009 Discounted Net Operating Profit.

As can be seen from Figure 7.4, the Rand / Dollar exchange rate for 2009 has the greatest impact on the Discounted Net Profit for that year, with a Standard Beta Coefficient of 0.628. This means that a decrease in the exchange rate of ZAR2.06/USD will result in a drop of R44m in the Discounted Net Operating Profit.

Another factor of significant impact is the SA CPI for 2003, with a Standard Beta Coefficient of –0.48. This means that an *increase* in the SA CPI of 1.7% will result in a drop in the Discounted Net Operating Profit of R34m.

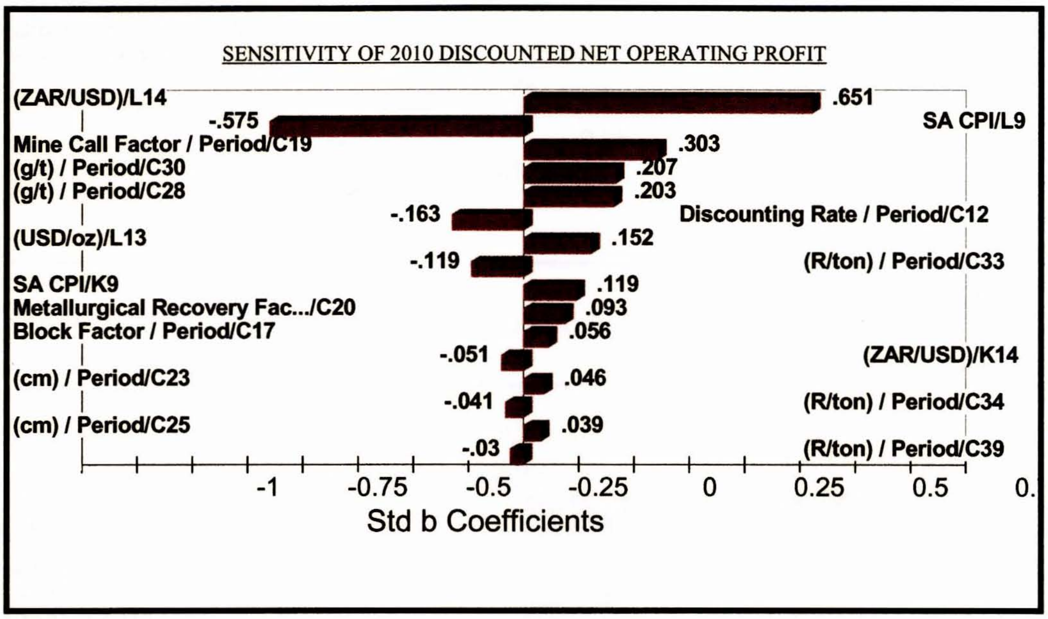

Figure 7.5 Sensitivity of 2010 Discounted Net Operating Profit.

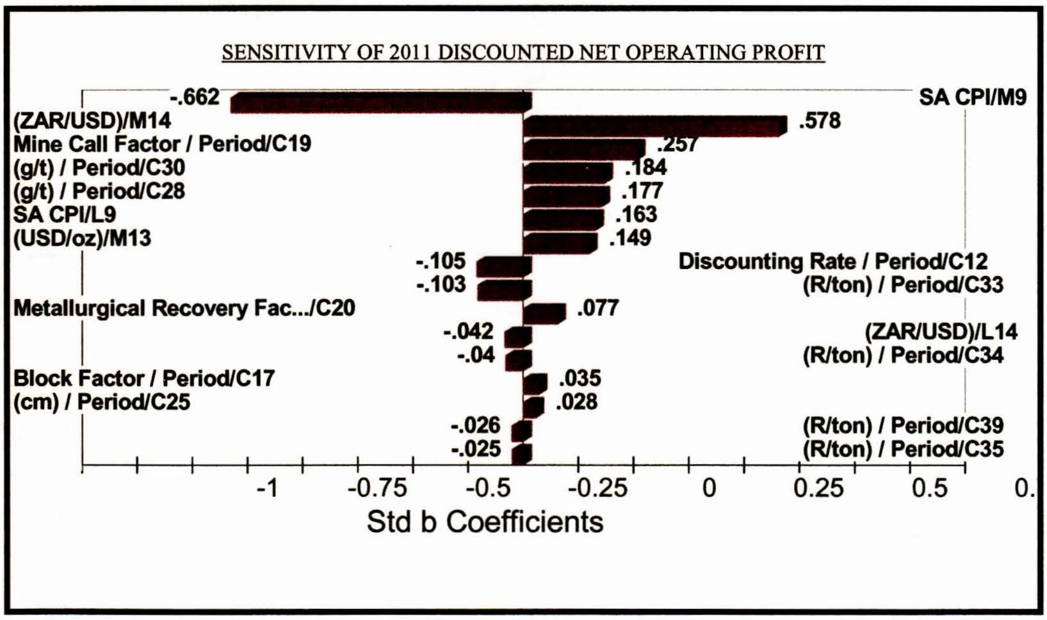

Figure 7.6 Sensitivity of 2011 Discounted Net Operating Profit.

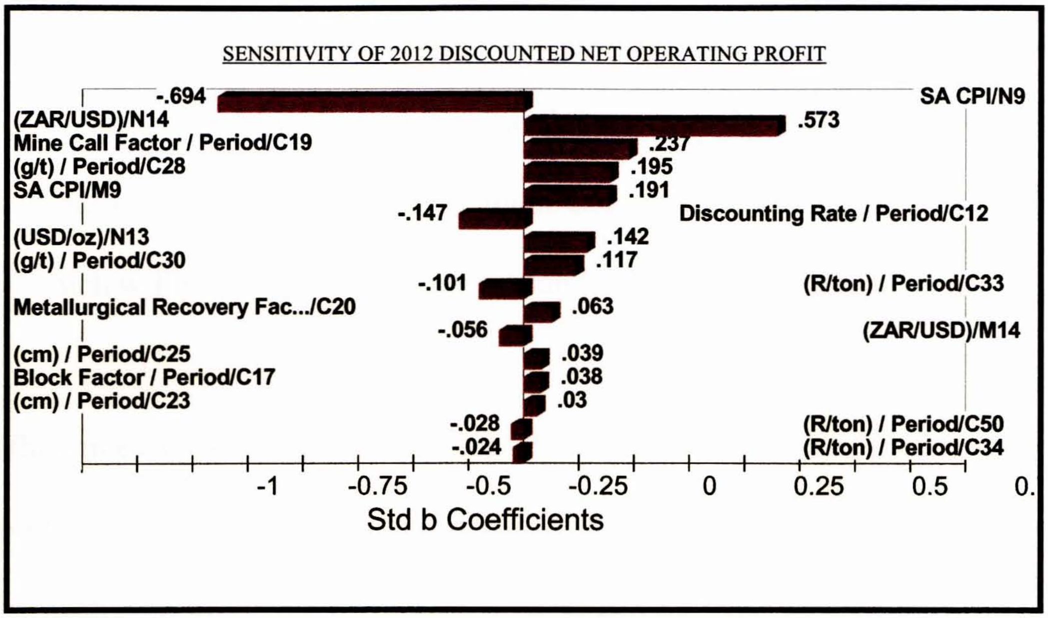

Figure 7.7 Sensitivity of 2012 Discounted Net Operating Profit.

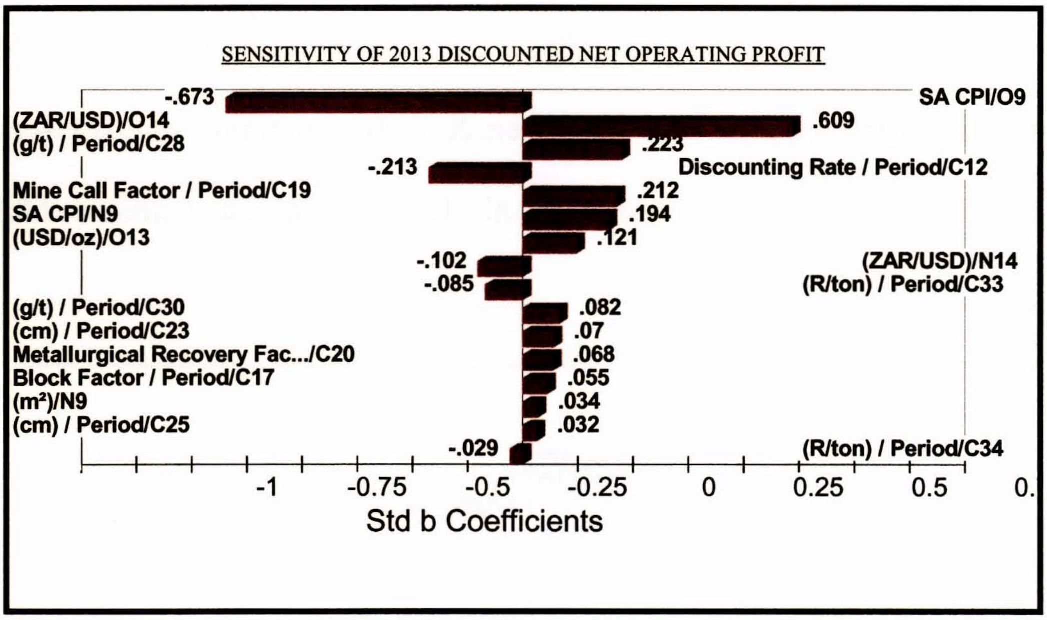

Figure 7.8 Sensitivity of 2013 Discounted Net Operating Profit.

Figures 7.4 to 7.8 show that, for each of the years 2009 to 2013, the two factors that carry the greatest impact on the profits are the SA CPI, which, through the ZAR/USD exchange rate, *indirectly* affects the revenue, and the ZAR/USD exchange rate, which *directly* affects the revenue.

As such, it can be concluded that a large portion of the project risk for years 2009 – 2013 can be mitigated through the use of hedging instruments such as Rand Gold Forward Sales or Foreign Currency Forward Contracts, both of which will protect the exchange rate and thus secure the revenues.

When one examines the risk ranking of the NPV (Figure 7.9), it is contrary to what was reflected in the risk rankings for years 2009 – 2013. Although the exchange rate does impact NPV, it is insignificant when compared to the impact of the Mine Call Factor on NPV. By example, a 5.5% decrease in the Mine Call Factor results in a R248m drop in NPV. The other major impact comes from the grade in Zone 13, the zone with the greatest in-situ gold content. A drop of 1g/t results in a R200m reduction in NPV.

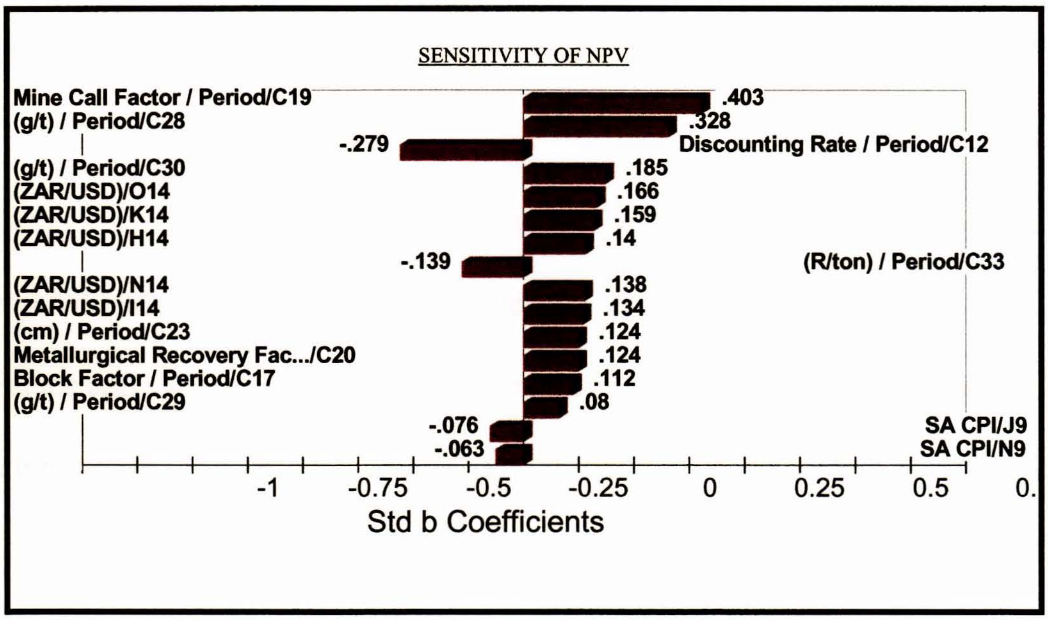

Figure 7.9 Sensitivity of NPV.

As in the case of the NPV, the Mine Call Factor, and the grade of Zone 13 are the two factors that impact most significantly on the IRR of the project. A 5.5% drop in the mine call factor will reduce the project's rate of return by 6%, while a 1g/t reduction in Zone 13 grade will reduce the rate of return by 4.75%.

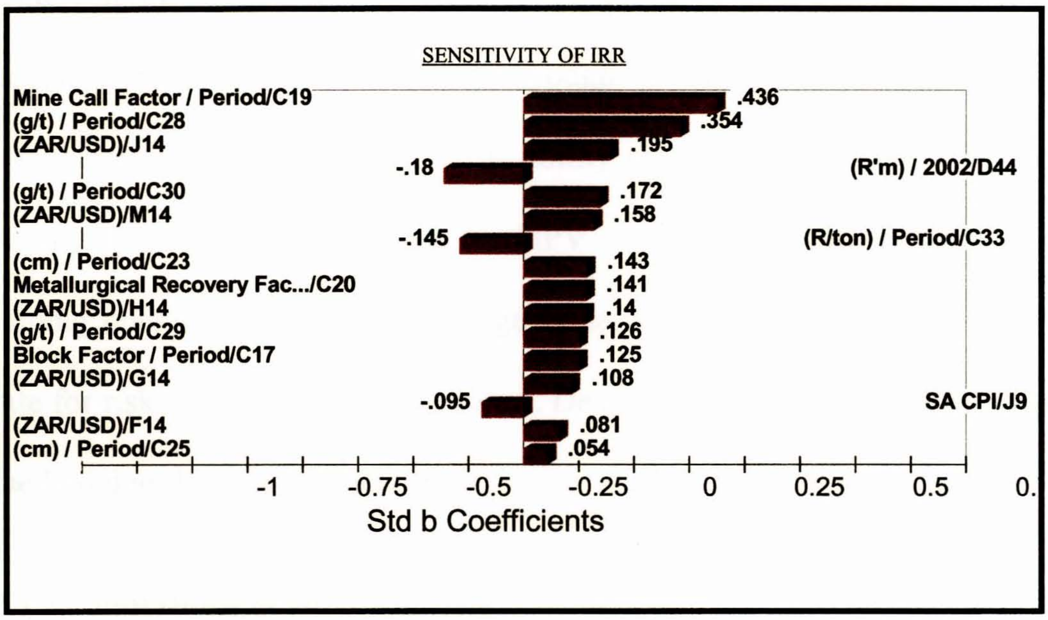

Figure 7.10 Sensitivity of IRR.

In the assessment of both the NPV and the IRR, it was found that the same two variables most negatively impact the project, namely the Mine Call Factor and the grade of Zone 13. These are both production associated and are potential risks that can be mitigated through implementation of stringent control measures once the mining operations commence.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 DCF METHODOLOGY

The Discounted Cash Flow method of valuation is probably the most widely accepted method for valuating mineral projects at any stage in their development, from pre-feasibility through to ongoing operations. The popularity of this method lies in its ability to cater for the time value of money. It involves determining the NPV of the future cash flows that a mining operation is anticipated to generate, discounted by an appropriate rate for risk over the life of the project. Despite its popularity however, this method does have its shortcomings.

8.1.1 Limitations of DCF Analysis

DCF analysis is inherently a forecast of cash flows into the future, a task that, by its nature, is fraught with problems. One of the immediate problems is the act of forecasting itself, be it operating costs, commodity prices, capital costs or the likelihood and possibility of unpredictable events, which in itself introduces uncertainty and variability. If the forecasts are unrealistic, the DCF valuation will yield results that, although may seem correct, are completely wrong. The well-established rule of "Garbage in, Garbage out" doesn't hold truer than for DCF analysis.

Inflation, although not a flaw of DCF, does pose a potential problem to the valuator in that care must always be taken to ensure that forecasts are expressed consistently, i.e. either all nominal or all real. It is incorrect to mix real and nominal forecasts.

As mentioned previously, the discount rate applied to a project's cash flows can significantly impact the net worth of a project. As such, the selection of the discount rate is a greatly debated topic when perceived shortcomings of DCF valuation are considered. One school of thought states that the discount rate reduces the present value to a greater degree the farther out the cash flows are being forecasted and as such, compensates for the increase in uncertainty associated with longer forecasts. The counter-argument states that this effect could result in underestimation of important long-term liabilities such as environmental rehabilitation.

A problem associated with selecting the discount rate is that DCF usually makes use of a single discount rate. A single discount rate suggests a constant risk profile throughout the life of the project, although this is rarely the case. The initial phase of a mining project, which exhibits a high degree of completion risk, cannot exhibit the same degree of uncertainty as the latter phase, which exhibits a high degree of operational risk. It is therefore incorrect to discount all the cash flows at a single discount rate.

In selecting the discount rate, a number of possibilities are available to the valuator (Torries, 1998). These are summarized in Table 8.1. Of the discount rates available, the opportunity cost of capital will theoretically always be correct since an investor will never have unlimited cash resource. As such, an investor cannot be wrong by comparing the value of a potential investment with the next best investment alternative.

Table 8.1 Summary of Discount Rates (Source: Torries, TF, "*Evaluating Mineral Projects: Applications and Misconceptions*")

Type of Rate	Description
Opportunity cost of Capital	Foregone benefits that would have been received from the next best investment.
Risk-Free Rate of Return	Return from a "Risk-Free" instrument e.g. Government Bond.
Cost of Debt	The cost of borrowed funds.
Weighted Average Cost of Capital (WACC)	The risk adjusted rate that weighs the cost of debt and the cost of equity.
Historical Rate of Return	A rate based on constant performance of past investments.
Risk-Adjusted Rate of Return	Any rate adjusted for project risk. The Capital Asset Pricing Method (CAPM) is often used to determine this rate.
Hurdle Rate	A specified minimum rate of return, regardless of how it is derived.
Social Rate of Return	A rate to determine the social value of projects.
Varying Discount Rate over Time	A rate to reflect the changes of risk over time.
Varying Discount Rate by Cash Flow Line Item	A rate that reflects the varying risk among various cash flow components.

The valuator must also bear in mind that the rate itself can be either nominal or real, and whichever is chosen, must remain consistent with the cash flows of the project.

DCF is a measure of a project's worth at a point in time under a certain set of conditions and parameters i.e. DCF is a snapshot in time. It cannot cater for the possibility of changing operations to react to changing factors e.g. a new technological development that could render a previously uneconomic portion of the orebody economic or the decrease in commodity prices that could force an operation to mothball.

In reality, operations change according to changes in the environment, especially so in the case of economic changes. This limitation in DCF valuation can undervalue projects. A new methodology rapidly gaining in popularity that caters for dynamic conditions is the Real Option Pricing method, the theory of which is beyond the scope of this research report.

8.1.2 Limitations of NPV and IRR

Net Present Value and Internal Rate of Return are the two most common measures used in DCF analysis. NPV is a measure of the value of a project, while IRR is a measure of the rate at which that value is realised. Both NPV and IRR are used to measure project viability and, as individual tools, both take account of the time value of money. Both take into account the projects forecasted cash flows and based on those cash flows provide a single number on which an investment decision can be. Both measures however have their flaws.

It is very seldom that a valuator will use NPV or IRR exclusively when valuating a project. Traditional DCF analysis suggests that both measures be examined together when making investment decisions (Torries, 1998). Although for the most part NPV and IRR will yield similar results, there are cases where the two yield conflicting results and will end up complicating the decision-making process, rather than facilitating it (Smith, 1995).

An advantage of NPV is its simplicity. It provides a single number reflecting a project's wealth under a certain set of assumptions. As such, projects can be compared using a single measure; the higher the NPV, the better the project. This holds true provided the assumptions are the same for both projects. Some practitioners view this as a shortfall of NPV when compared to IRR, given that NPV cannot provide the investor a measure of the efficiency of use of his/her invested capital (Torries, 1998).

Since NPV is based on DCF analysis, the two generally share common flaws; the inherent risk associated with forecasting prices into the future and, probably most importantly, the difficulty is selecting the appropriate discount rate. Small adjustments in the cash flows in the early years can have a dramatic effect on the project's NPV.

IRR has its strength in that it provides the investor with a measure of the return on capital. The higher the IRR, the more rapid is the rate at which the wealth is generated. There are cases however, where IRR falls short and may end up returning the incorrect investment decision.

The first of these shortfalls is when comparing exclusive projects i.e. where numerous projects are available to the investor, but where only one project can be invested in. In practice, this is most often the case as there is a limit to the amount of capital available for investment. In such cases, IRR may not always give the value-maximizing decision (Torries, 1998).

Torries shows that this scenario usually occurs when there are differences in the value and timing of the investments of the various projects being compared and in order to obtain a realistic IRR for decision-making purposes, the projects must should ideally have the same investment amounts, and these investments should take place at same times in the projects' lives. Once again, in practice this is very rarely the case, and as such, adjustments must be made in order to allow for a realistic comparison of the various projects. Torries suggests that the IRR of a four-year project can be compared to that of a five-year project correctly, as long as, in the calculation, the returns from the four-year project are re-invested during the fifth year at the opportunity cost of capital.

A further downside of IRR is that calculating IRR is the equivalent of solving for the root of an equation. When the cash flows of a project change sign more than once, i.e. there is a large capital investment later in the project that results in negative cash flows for that year, the equation becomes of the higher order and there will be more than one solution to the equation, thus yielding multiple IRR's (Torries, 1998). The more often the sign changes, the more IRR solutions will exist. This is termed the Multiple-Root Problem of IRR and does not allow for the correct IRR to be identified. In such cases, most texts recommend basing the investment decision based exclusively on NPV.

The use of NPV and IRR as fundamental tools to measure a project‘s feasibility is well accepted. No one measure is correct as each one presents a different perspective of the projects worth depending on the investor and the risk profile. Although a large number of texts recommend NPV over IRR for reasons stated previously, in general it is considered more prudent for the investor to use both NPV and IRR to allow for better-informed decision-making (Smith, 1995). Incorporating Monte Carlo simulation into a valuation is critical in order to minimise the uncertainty associated with forecasting values into the future. It allows the valuator to test the project's value under as many scenarios as may be required.

8.2 ANALYSIS OF THE EASTERN BOUNDARY AREA PROJECT

The initial valuation of the Eastern Boundary Area has yielded promising results, albeit at the pre-feasibility level. The mean NPV and IRR of R847m and 41.7% respectively, reflect the viability of the project, which generally speaking has robust cash flows that are positive throughout its economic life. There is less than 10% chance of the project making a loss.

The sensitivity analysis of the project identified two major factors that most significantly impact the project's bottom line, namely the Mine Call Factor and the grade of Zone 13. Both of these parameters are production related issues that must be monitored throughout the life of the operations to ensure that they remain in line with the forecasted numbers. The sensitivity analysis also revealed weaker cash flows from the project from 2009 to 2013, with a 20% probability that the cash flows could become negative during these years. The factors that impact the greatest on the cash flows for these years are the ZAR/USD exchange rate and the SA CPI, both of which, directly or indirectly, affect the project's revenues. These risks can be mitigated however, through the use of derivative instruments that will lock in the revenues and thus protect the cash flows from any volatility.

On the whole, initial valuation of the Eastern Boundary Area has yielded positive results that support further investigation by Gold Fields Limited.

8.3 RECOMMENDATIONS

The valuation of the Eastern Boundary Area involved a basic DCF analysis in conjunction with a Monte Carlo simulation. Although the project has yielded promising initial results, it must be borne in mind that the valuation was conducted at the pre-feasibility level. As such, in order for the project to advance to the next stage of analysis, further work is required on the part of Gold Fields Limited.

- In order to increase the level of accuracy that would be required for a feasibility study, Gold Fields will need to undertake further in-fill drilling so to better delineate the orebody and further increase the confidence in the data set being used. As per Table 4.1 a level of accuracy of 15% would be required for a feasibility study.

- Given that the project was conducted independent of the greater Kloof Gold Mining Company structure, the tax calculation of the pre-feasibility DCF analysis was done in a rudimentary fashion to allow for ease of calculation. For the purposes of a feasibility study however, the cash flows will need to be incorporated into the Kloof structure to allow for a more accurate tax calculation, and thus a more accurate valuation. Similarly, the capital expenditure will have to be incorporated into the

Kloof structure to allow for a tax shield of unredeemed capital expenditure, as well as to allow for a holistic depreciation of the assets.

- The pre-feasibility study made no allowance for employment of equity capital or debt capital. As such, no repayment was incorporated into the DCF analysis. Depending on the source of funds and the ratio of debt:equity, the cash flow model will have to be expanded further to incorporate the cash flow after debt repayment. Furthermore, the sensitivity analysis will also have to be expanded to include the interest rate as a variable input parameter.

- It is recommended that an independent technical expert review the feasibility study once it is complete, especially so should the company wish to finance the project through debt.

In General, based on the pre-feasibility study carried out, all signs indicate that the project be advanced to the feasibility level. Initial indications are that the project is profitable and, pending further investigation, could replenish the dwindling reserves of the Kloof Three Sub-Vertical Shaft.

REFERENCES

Annels, A.E. (1990). "Mineral Deposit Valuation – A Practical Approach"

Gentry, D.W., O'Neil, T.J. (1984) "Mine Investment Analysis", Society of Mining Engineers of the AIME Inc., New York City, New York.

Lattanzi, C.R., "Discounted Cash Flow Analysis Input Parameters and Sensitivity", Micon International Limited.

Mandron, A. (2000). "Project Valuation: Problem Areas, Theory And Practice", *The Current State Of Business Disciplines,* Vol. 3 pp. 997-1017.

McPherson, M.J. (1989). "Environmental Engineering on South African Mines"

Mular, A.L. (1982). "The Estimation of Preliminary Capital Costs", *Mineral Processing Plant Design,* Society of Mining Engineers of the AIME Inc., New York City, New York.

Noakes, M., Lanz, T. (1993). "Cost Estimation Handbook for the Australian Mining Industry", *MineCost 90,* The Australian Institute of Mining and Metallurgy.

Rahn, F.J. (1973). "The Valuation of a Gold Share", *Johannesburg Institute of Mine Surveyors, South Africa.*

Reynolds, E. (1990). "What Does it Mean?", *Mining Industry Capital and Operating Cost Estimation Conference- MineCost 90,* The Australian Institute of Mining and Metallurgy.

Smith, LD (1995). "Discounted Cash Flow Analysis – Methods and Discount Rate", Rio Algom Limited.

Taute, A.H. (1952). "Some Notes on the Economics of Mechanization in Relation to the Cost of Native Labour", *South African Mine Managers Association.*

Torries, T.F. (1998). "Evaluating Mineral Projects: Applications and Misconceptions", Society for Mining, Metallurgy and Exploration Inc., USA.

Van Coller, W (1997). “The Geology of the Eastern Boundary Area”, Kloof Gold Mining Company Limited.

Whitney, J.W., Whitney, R.E. (1979), “Investment and Risk Analysis in the Minerals Industry”, Whitney & Whitney Inc., Reno, Nevada, USA.

BIBLIOGRAPHY

Accounting Practices Committee of the Chamber of Mines (1995), "Accounting and Reporting Practices in the Mining Industry", The South African Institute of Chartered Accountants, Johannesburg, South Africa.

Annels, A.E. (1990), "Mineral Deposit Valuation – A Practical Approach"

Gentry, D.W., O'Neil, T.J. (1984) "Mine Investment Analysis", Society of Mining Engineers of the AIME Inc., New York City, New York.

Gold Fields Limited (2001), *Annual Report 2001*, Johannesburg, South Africa.

Harvey, C.R., Graham, J.R. (2001), "The Theory and Practice of Corporate Finance: Evidence from the Field", Journal of Financial Economics, Vol. 60, pp 187-243

Kingshott, A.L. (1967), "Investment Appraisal – A Practical Guide to the Application of Discounted Cash Flow Techniques", Ford Motor Company Limited, Essex, Great Britain.

Lattanzi, C.R., "Discounted Cash Flow Analysis Input Parameters and Sensitivity", Micon International Limited.

Lawrence, M.J., Dewar, G.J.A. (1999), "Mineral Property Valuation", PACRIM '99 Conference, Australia.

Mandron, A. (2000) "Project Valuation: Problem Areas, Theory And Practice", *The Current State Of Business Disciplines,* Vol. 3 pp. 997-1017.

Mobil Oil South Africa (Pty) Ltd. "DCF Investment Analysis", Printpak (Cape) Ltd., Dacres Avenue, Epping, Cape.

Noakes, M., Lanz, T. (1993) "Cost Estimation Handbook for the Australian Mining Industry", *MineCost 90*, The Australian Institute of Mining and Metallurgy.

Peterson, P., "Advantages and Disadvantages of Capital Budgeting Techniques", Florida State University, Florida, United States.

Phelan, S.E. (1997) "Exposing the Illusion of Confidence in Financial Analysis, School of Commerce, La Trobe University, Melbourne, Australia.

PricewaterhouseCoopers (1999), “Financial Reporting in the Mining Industry for the 21st Century”, PricewaterhouseCoopers, Johannesburg, South Africa.

Prince, L.J. (1962), “Methods of Evaluating Certain Mining Economics Problems with special reference to the use of Present Values”, University of the Witwatersrand, Johannesburg, South Africa.

Roberts, C., “The Valuation Of Advanced Mining Projects & Operating Mines: Market Comparable Approaches”

Roscoe, W.E., “Valuation of Mineral Exploration Properties Using the Cost Approach”, Roscoe Postle Associates Inc., Toronto, Canada.

Samis, M.R., (1994) “Project Evaluation Using Contingent Claims Analysis – An Overview”, University of the Witwatersrand, Johannesburg, South Africa.

Smal, C. (1991), “The Time Value of Money – A Practical Approach”, Butterworths, Durban, South Africa.

Smith, LD (1995). "Discounted Cash Flow Analysis – Methods and Discount Rate", Rio Algom Limited.

South African Mineral Resource Committee (2000) "South African Code for Reporting of Mineral Resources and Mineral Reserves", The South African Institute of Mining and Metallurgy, Johannesburg, South Africa.

Spence, K (2000), "An Overview of Valuation Practices and the Development of a Canadian Code for the Valuation of Mineral Properties", Canadian Institute of Mining, Metallurgy and Petroleum.

Storrar, C.D. (1977), "South African Mine Valuation", Chamber of Mines of South Africa, Johannesburg, South Africa.

Van Coller, W (1997). "The Geology of the Eastern Boundary Area", Kloof Gold Mining Company Limited, 1997.

VanLandingham, S. (1983), "Economic Evaluation of Mineral Property", Hutchinson Ross Publishing Company, Pennsylvania, USA.

Whitney, J.W., Whitney, R.E. (1979), "Investment and Risk Analysis in the Minerals Industry", Whitney & Whitney Inc., Reno, Nevada, USA.

Wright, M.G. (1973), "Discounted Cash Flow", second edition, McGraw-Hill Book Company, Berkshire, England.