OPTIMISATION OF MINING CUT AT ZIMBABWE PLATINUM MINES THROUGH ECONOMIC EVALUATION

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

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DECLARATION

I declare that this research report is my own, unaided work, submitted in accordance with the Degree of Master of Science at the University of Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University. I have read the University Policy on Plagiarism and hereby confirm that no plagiarism exists in this report. I also confirm that there is no copying, nor is there any copyright infringement. I willingly submit to any investigation in this regard by the School of Mining Engineering, and I undertake to abide by the decision of any such investigation. The author hereby confirms that this article content has no conflict of interest.

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ABSTRACT

Zimbabwe Platinum Mines (Zimplats) extracts Platinum Group Metals (platinum, palladium, rhodium, gold, iridium, ruthenium and osmium), and base metals (nickel, copper and cobalt) from the Great Dyke of Zimbabwe. Historically, the price of platinum has been higher than that of palladium until, 2017 when the palladium price overtook the platinum price. Recent trends from 2017 to 2020 have revealed that the annual revenue for Zimplats from palladium now exceeds revenue from platinum due to a higher palladium price, which is likely to persist in the short to medium term. The current 2.5 m mining cut at Zimplats was determined with an aim of maximising platinum production because platinum has been the biggest revenue contributor for Zimplats based on the volumes produced and a high platinum price. However, the change in platinum and palladium prices motivated the need to optimise the mining cut at Zimplats mine to maximise palladium extraction.

This research evaluated several possible mining cut scenarios within the mineralised orebody profile to maximise palladium extraction, revenue and subsequently, the Net Present Value. The study was done on Ngwarati Mine one of Zimplats' operations. The current mining cut was used as the base case, and four other possible mining cut scenarios namely 2.25 m, 2.75 m, 3.00 m and 3.25 m were evaluated in the research. This was achieved by simulating various positions of the mining cut across the reef profile and carrying out an economic evaluation to get the Net Present Value. The study found that by varying the mining cut according to the prevailing and projected prices, Zimplats could increase revenue.

The research found that a 2.75 m mining cut is the optimal cut size for Ngwarati Mine, based on the current economic assumptions. The optimal mining cut had the highest NPV of $271.4 million, giving a $20.2 million positive differential cash flow against the base case option. The research findings can be applied on Zimplats' other mines. The success and implementation of the research findings will assist in value creation and thus improve shareholder value. A sensitivity analysis done found that the NPV is most sensitivity to changes in 6E grade, followed by palladium price and lastly operating cost. Therefore, it is recommended that the company should manage these factors to ensure sustainable value creation.

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- My wife Nomsa and family for their love, encouragement and support. The research took me away from them for several days, but they were always patient and tolerant during those absent moments. I cherish your understanding during those tough trips from Zimbabwe to South Africa.

While the permission to use some of the material contained in this research report is gratefully acknowledged, opinions and suggestions expressed are those of the author. They may not necessarily represent the policies of Zimplats. While recognising the valued contributions of the people mentioned above, the author takes full responsibility for any errors, omissions and ambiguities in the research report.

DEDICATION

To my two daughters Yanano and Mwaita, I dedicate this work to you with the aim to leave a lasting legacy for you. You are the ones who kept me going and I will celebrate with you in all my successes. You are dearly loved.

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ABBREVIATIONS

Au	Gold
Ag	Silver
Capex	Capital expenditure
CBA	Cost Benefit Analysis
CEA	Cost Effective Analysis
Cr	Chromium
Cu	Copper
CUA	Cost Utility Analysis
CMA	Cost Minimisation Analysis
DBS	Depth Below Surface
DCF	Discounted Cash Flow
Fe	Iron
FOG	Fall of Ground
FoS	Factor of Safety
GCD	Ground Control Districts
IRR	Internal Rate of Return
LHD	Load Haul Dump (vehicle)
LOM	Life of Mine
MOz	Million ounces
MSZ	Main Sulphide Zone
Mtpa	Million tonnes per annum
Ni	Nickel
NPV	Net Present Value
Opex	Operating Cost
OR	Operations Research
Pd	Palladium
PGM	Platinum Group Metal
Pt	Platinum
ROM	Run of Mine
t	Tonne (Metric)
TMM	Trackless Mobile Machinery
WACC	Weighted Average Cost of Capital

SYSTEM OF UNITS

The international metric system of units (SI) are used throughout the design in all documentation, specifications, drawings, reports and all other documents associated.

CHAPTER 1: INTRODUCTION

1.1 Chapter overview

This chapter provides the research background, an overview of the research area and the motivation behind the research. Fluctuations of commodity prices on the global market are discussed and how mining companies can tap into potential benefits arising from the fluctuations. The chapter looked at how the Zimbabwe Platinum Mines (Zimplats) could potentially alter mining cut to increase mining revenue and improve the Net Present Value (NPV) of its current mining projects.

1.2 Background information

Zimplats extracts Platinum Group Metals (PGMs) from the Great Dyke of Zimbabwe and currently operates four underground mines namely Ngwarati, Rukodzi, Mupfuti, Bimha and Mupani with a total production output of 6.2 Million tonnes per annum (Mtpa). This research was only focussed on Ngwarati Mine. The location of the mines is shown in Figure 1.1.

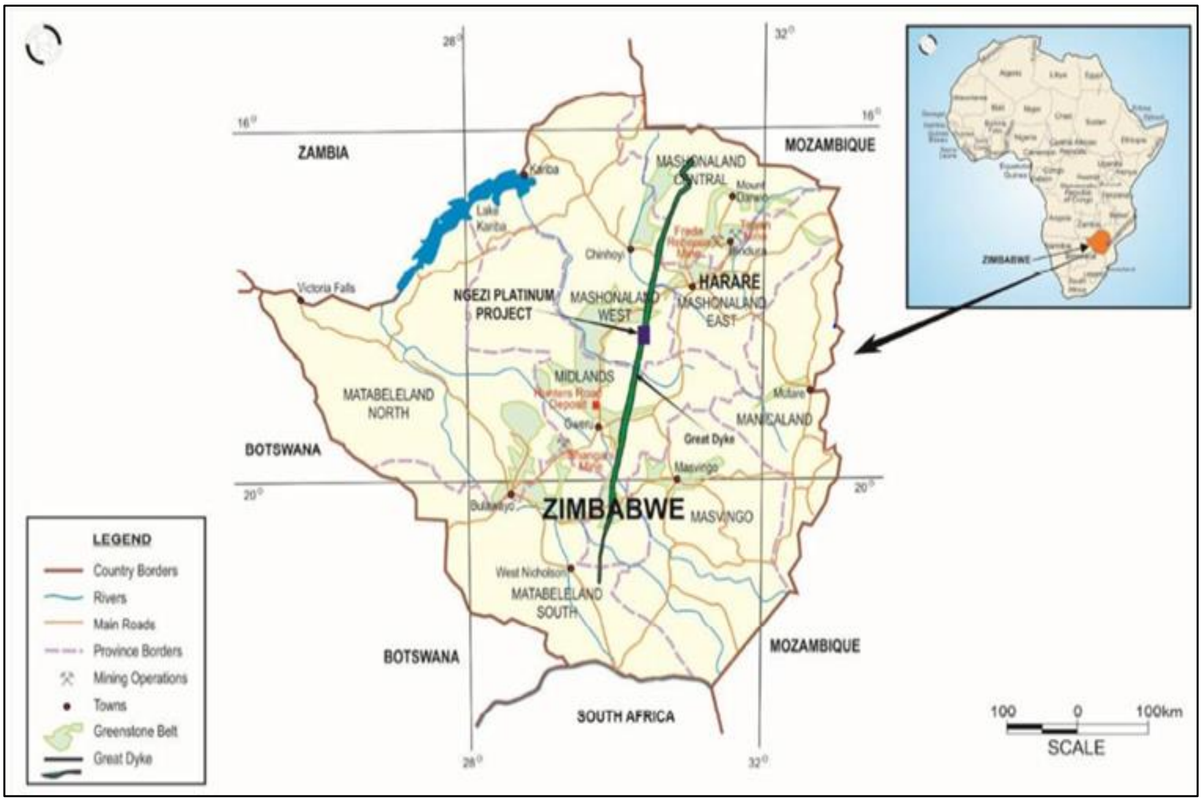

Figure 1.1: Location of Ngezi Mine (SRK, 2016)

In terms of mining rights, the company holds two leases, mining lease 36 and 37. Lease 36 is located in Selous, whilst Lease 37 is in Ngezi, where current mining activity is taking place. Selous houses a metallurgical process plant and refinery. Selous and Ngezi are 77km apart. Ngezi Mine is situated on the southern edge of the Hartley Geological Complex, which forms part of the Great Dyke reef. The Great Dyke is a layered mafic-ultramafic body intruded into Archaean granites and greenstone belts. The dyke is a highly elongated, slightly sinuous, 550 km long intrusion which is north-east trending with a maximum width of 12 km (Schoenberg, et al., 2003). According to Oberthur (2011), it has vast ore deposits containing gold (Au), silver (Ag), chromium (Cr), PGMs, nickel (Ni) and copper (Cu). The concentration of PGMs of economic interest is restricted to sulphide disseminations which are close to the contact between the mafic and ultramafic rock formations (Musa & Matahwa, 2018). Figure 1.2 shows a cross-section of rock formations on the Great Dyke.

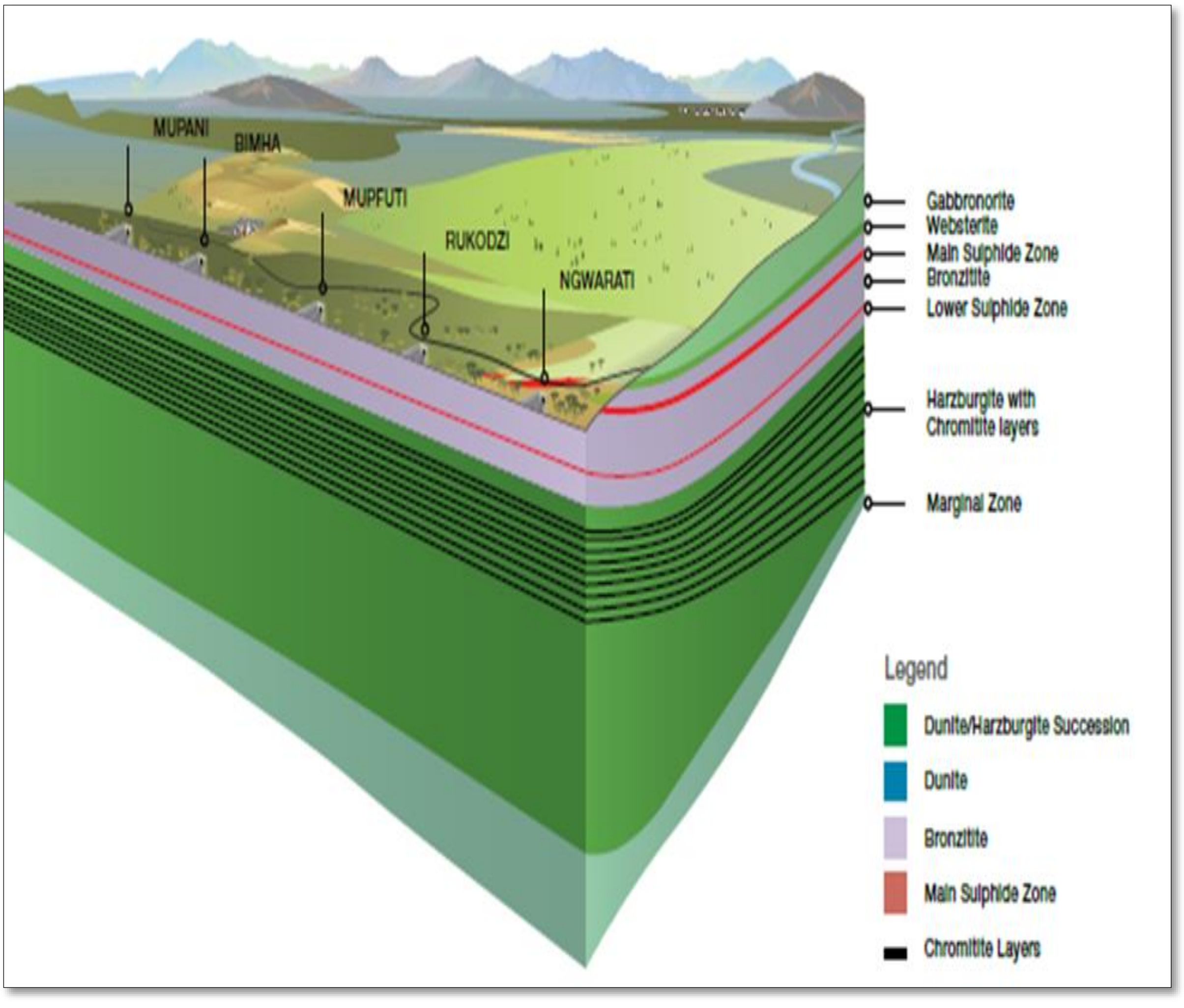

Figure 1.2: Cross section of rock formations on the Great Dyke *(Zimplats, 2018a)*

The Main Sulphide Zone (MSZ), as labelled in Figure 1.2 is a lithological continuous layer between 2 m and 10 m thick. The zone can be identified visually on the face underground. The sulphides have a shiny metal look which can be seen by the eye and can be used for visual correlation of the Pt during grade control underground. The base of the MSZ has a gradational basal contact with a 1 m to 5 m thick zone of high PGM values. The contact showing an abrupt change in sulphide mineral content in the rock is used as a marker for Mineral Resource evaluation, as well as mining grade control and is commonly referred to as the Base of the Main Sulphide Zone (BMSZ) (Oberthur, 2011). The sulphide peak, which is visually identified in exposures and drill-hole cores, is the marker around which a mining cut is defined. The PGM content and distribution within the mineralised zone is consistent from drill-hole to drill-hole over large areas. MSZ mineralisation is vertically gradational and distributed around a high-grade central zone. This gradation means that the selected mining cut on which Mineral Resources are based is dependent on what is likely to be economically mineable rather than on a sharp geological boundary. Having a transitional boundary reduces the effect of dilution, particularly in the footwall where the gradation is more pronounced, resulting in the diluting material still containing some metals (Zimplats, 2018a).

At Zimplats, the mineralised orebody channel is defined in layered seams by the geology and exploration departments. The orebody channel evaluated for mining extraction contains 17 seams in total, with each seam being 0.25 m in thickness. Figure 1.3 shows the arrangement of the seams and PGMs distribution across the reef channel.

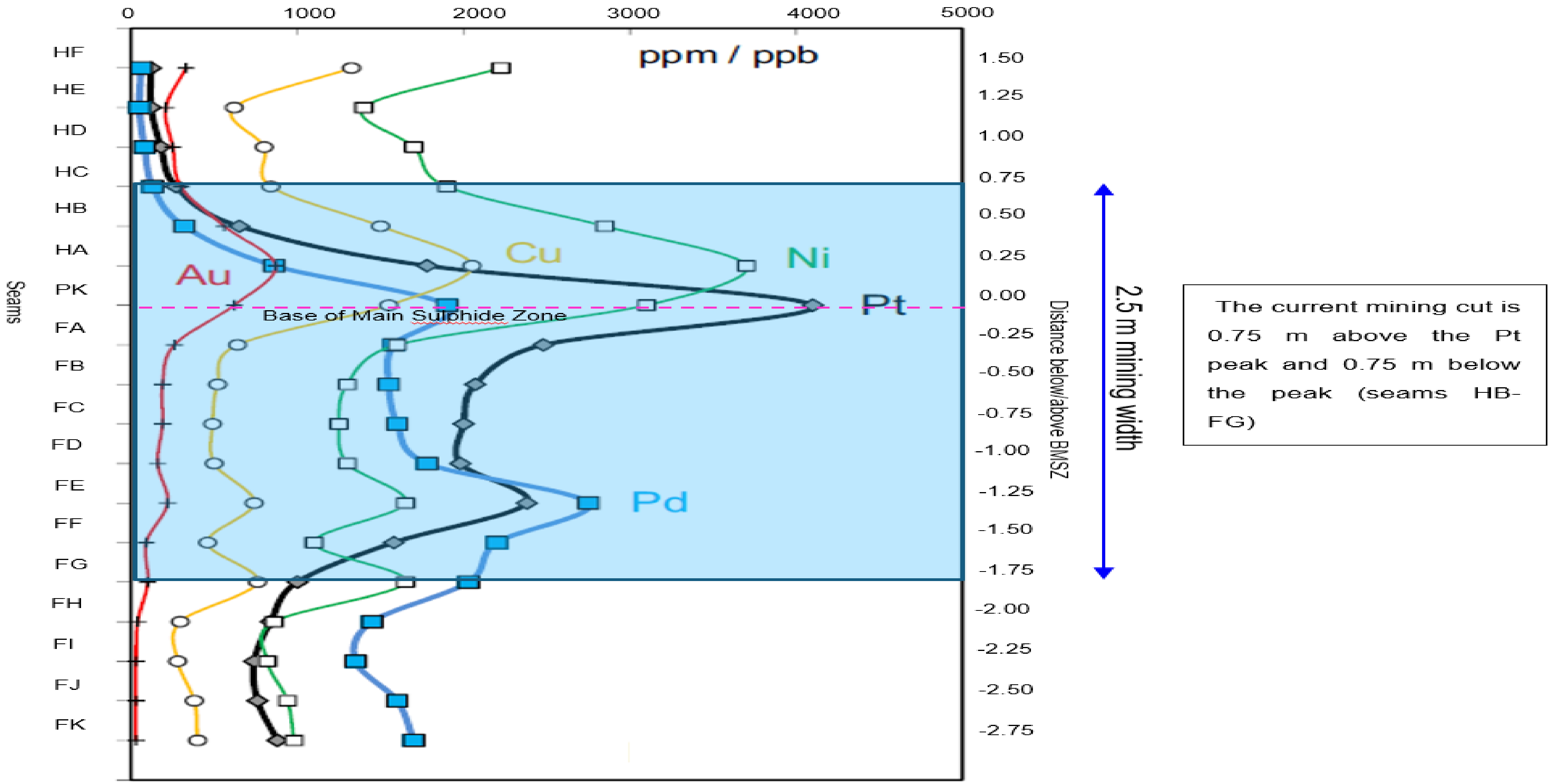

Figure 1.3: Geochemical profile showing metal distribution of selected elements in the Main Sulphide Zone for Ngezi mines (Zimplats, 2012)

The seams have a naming sequence relative to their positions on the profile. Seam with the prefix "PK" defines the position of a peak platinum (Pt) value where the highest concentration of Pt is found. Seams with the prefix "H" are located in the hanging wall, whilst seams with the prefix "F" are located in the footwall on the orebody channel. The naming of each seam in illustrated in Table 1.1.

Table 1.1: Mining seams arrangement on the Ngezi Mines orebody

Name of seam	**Description**
HF	Hangingwall seam F positioned 1.75 m above peak
HE	Hangingwall seam E positioned 1.50 m above peak
HD	Hangingwall seam D positioned 1.25 m above peak
HC	Hangingwall seam C positioned 1.00 m above peak
HB	Hangingwall seam B positioned 0.75 m above peak
HA	Hangingwall seam A positioned 0.50 m above peak
PK	The peak platinum value seam
FA	Footwall seam A positioned 0.50 m below peak
FB	Footwall seam B positioned 0.50 m below peak
FC	Footwall seam C positioned 0.50 m below peak
FD	Footwall seam D positioned 0.50 m below peak
FE	Footwall seam E positioned 0.50 m below peak
FF	Footwall seam F positioned 0.50 m below peak
FG	Footwall seam G positioned 0.50 m below peak
FH	Footwall seam H positioned 0.50 m below peak
FI	Footwall seam I positioned 0.50 m below peak
FJ	Footwall seam J positioned 0.50 m below peak
FK	Footwall seam K positioned 0.50 m below peak

The seams assist in determining mill grade during Mineral Reserves estimation and grade assaying during mining. The grades of various metals on the reef profile mined at Zimplats mines varies across the vertical reef profile. The variation in grade informs the optimal mining cut determination. The current optimum mining cut is 2.50 m which constitutes ten economic seams situated on a horizon, as shown in Figure 1.3. The current mining cut is defined by seams 'HB to FG' though, during mining, an additional 0.07 m tolerance of over break is allowed in both hanging wall and footwall.

As shown in Figure 1.3, the 2.50 m mining cut is aligned to a width on the reef that maximises the extraction of Pt, as shown by the line graph plots of individual elements. Base metals, Ni and Cu, have a higher concentration towards the hanging wall on the current mining cut. On the contrary, the palladium (Pd) enrichment increases towards the footwall. This extraction pattern has been the norm since the inception of Zimplats operations in 2005 based on economics prevailing at the time. This research presents an opportunity to adjust the position of the mining cut considering the prevailing economic situation in the minerals market.

1.3 Problem statement

The current mining cut of 2.50 m used at Zimplats' Ngezi mines was determined to maximise Pt production because Pt has been the biggest revenue contributor for Zimplats based on the volumes produced and a high Pt price. Figure 1.4 shows the revenue contribution of the various metals on Zimplats' metal sales for financial years 2017 to 2020.

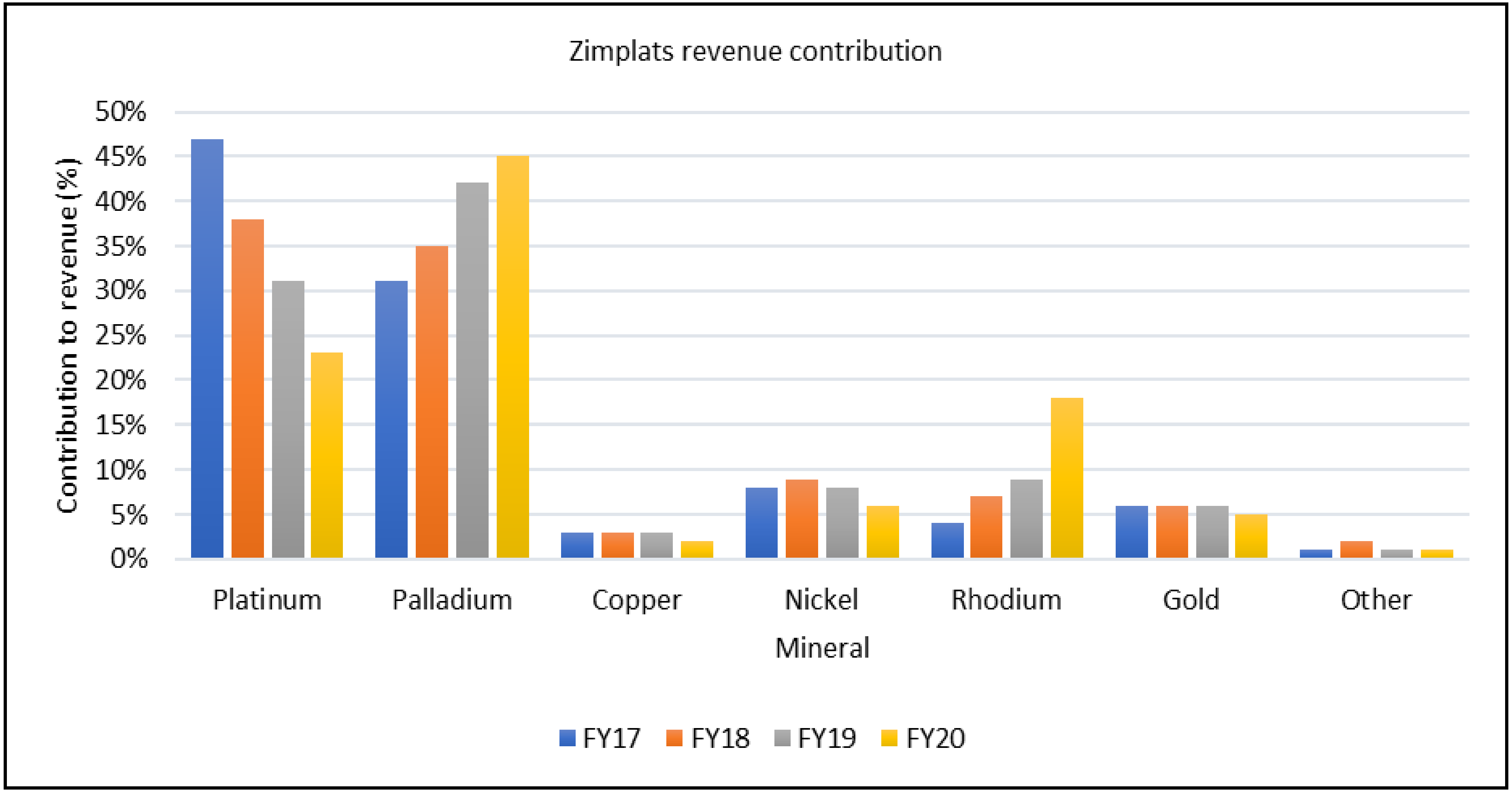

Figure 1.4: Contribution to revenue for various selected metals (Zimplats, 2020)

On the reef profile, which Zimplats extracts, six elements (6-E) make up the highest proportion of the total metal recovery basket. The 6-E are Pt, Pd, Au, ruthenium (Ru), rhodium (Rh), iridium (Ir) with a proportional split by volume of 49%, 33%, 10%, 5%, 3% and 2%, respectively. Ag, cobalt (Co), Ni and Cu constitute the rest of the basket, *albeit* in smaller proportions (Zimplats, 2020). Figure 1.4 shows that the revenue contribution for Pt has been declining while that of Pd has been increasing over the four-year period. The historic record contribution of Pt reached a high of 49% of total metal sales revenue in 2015 (Zimplats, 2015). However, in the financial year 2020, this contribution has significantly reduced to 23%, while the contribution of Pd rose to 45% of total sales revenue from 30%, as depicted in Figure 1.4. The shift in the contribution is due to changes in international market demand factors. For the years 2018 to 2020, the price of Pd has sustainably overtaken the price of Pt due to a higher demand for Pd than Pt (Caveney, 2019). The price trend over the period is illustrated in Figure 1.5.

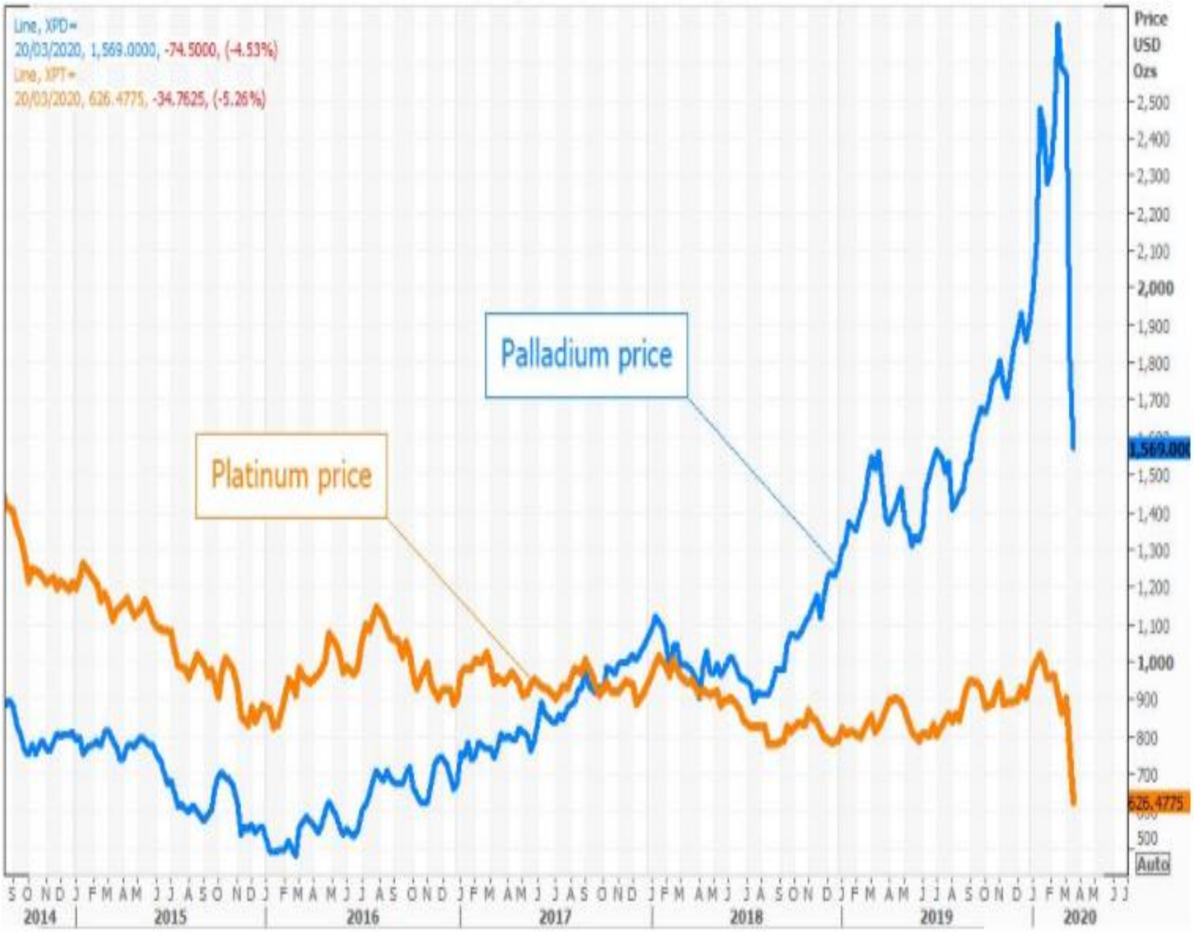

Figure 1.5: Historical price trend for Pt versus Pd (Hobson, 2020)

Figure 1.5 shows two trends, with the price of Pt decreasing and the price of Pd increasing, over time. These trends have resulted in Pd contributing more to Zimplats' revenue than Pt, as illustrated in Figure 1.4. According to Van der Walt & Pakiam (2019), this trend is likely to be prolonged into the medium term. Thus, the plan is to shift the mining cut to a position that maximises Pd extraction and hence improve the company's revenue and, ultimately, the NPV. The variation of head grades across the orebody profile, as shown in Figure 1.3, provides an opportunity to vary the mining cut slice upwards or downwards across the reef face to maximise Pd metal extraction and economic value. This raises the question, *"What is the optimum mining cut position in relation to the Pd face grade peak at Zimplats Ngezi mines?''*

1.4 Research aim and objectives

The aim of the research was to optimise the mining cut at Ngezi mines to maximise the company's revenue and, ultimately, the NPV. This was achieved by varying the mining cut to a position that maximises the extraction of Pd by increasing bias towards the Pd based peak head grade. The research study was done using Ngwarati Mine's orebody. The objectives of the research were to:

- Review the geological block model of Zimplats' Ngwarati Mine ore body;
- Review the metal distribution in the Main Sulphide Zone for Ngwarati Mine;
- Review literature on underground mine optimisation in general and mining cut optimisation in particular; and
- Determine the optimum mining cut position in relation to the Pd peak for Ngwarati Mine and the preferred cut inferred on the other mines in Ngezi operations.

1.5 Research scope

As mentioned in Section 1.2, Zimplats currently operates four steady-state underground mines, namely: Ngwarati, Rukodzi, Bimha, Mupfuti. A fifth mine, Mupani Mine, is still under development and will come in to replace Rukodzi and Ngwarati after complete depletion. However, the research study was based on the Ngwarati Mine data, with the assumption that the study results will be inferred to all the other mines. This is because there is not much variability in the mineralisation across the mines, with boundaries being defined more by the economics of trucking the ore out rather than variation in mineral characteristics. The study assumed that the current suite of machinery operating at the mine will not be changed. The project area is shown in Figure 1.6.

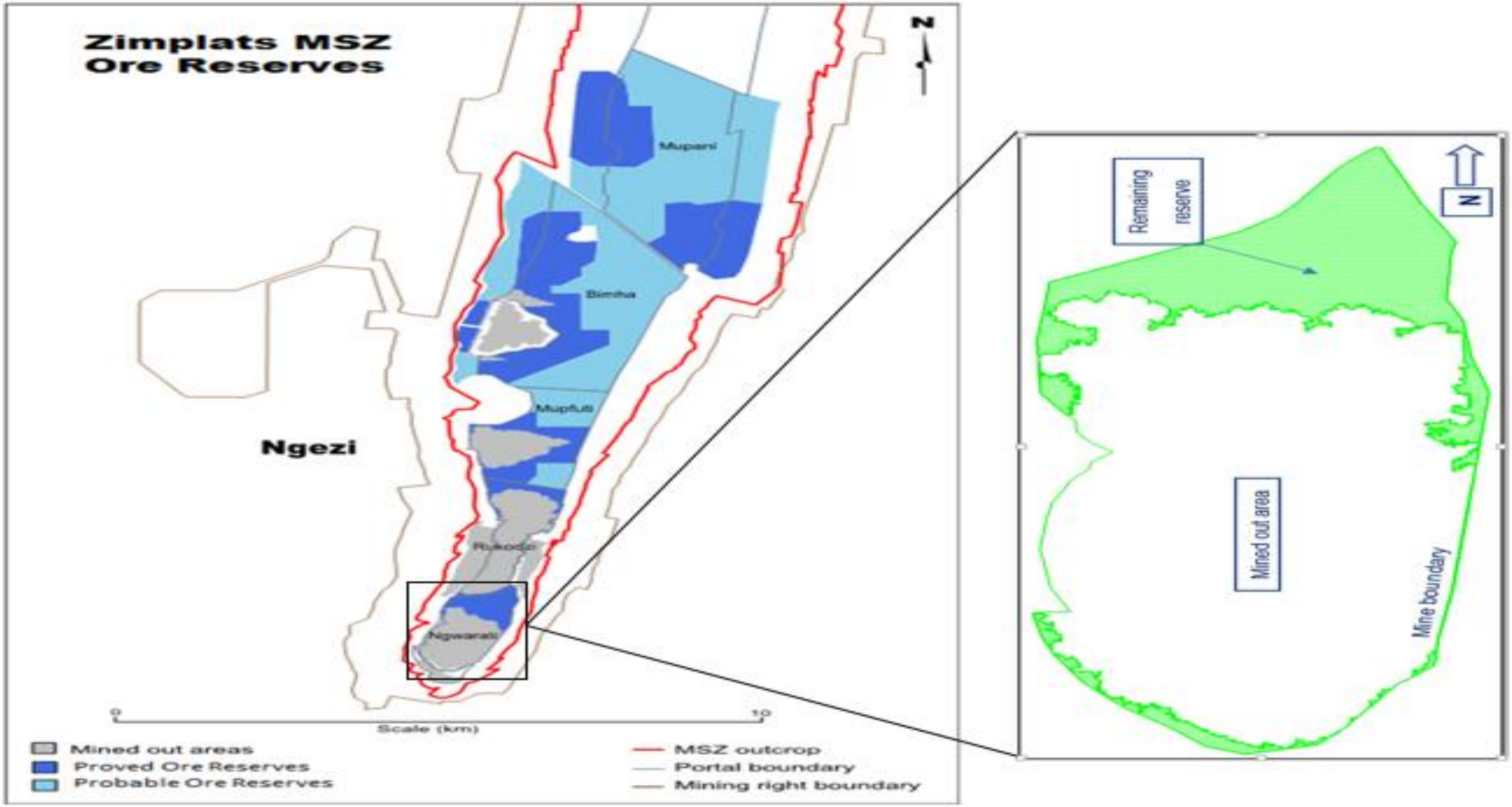

Figure 1.6: Plan showing Zimplats Mineral Reserves for Annual Reporting 2020 and project area which is Ngwarati Mine *(Zimplats, 2020)*

1.6 Research significance

Since the Pt price has continued to trail that of Pd for over three years now, Zimplats will benefit from optimising the mining cut by increasing Pd contribution. There is not much impetus to maintain a Pt based peak head grade when the Pt price has remained subdued since 2018 to date. A mining cut that maximizes Pd extraction will improve the overall company's revenue base. This will be key to increasing shareholder value and thus ensure the sustainability of the company.

1.7 Research report outline

This chapter provided background information, outlined the problem statement, research scope, significance and justification for the research study. Chapter 2 explains the importance of optimisation to the mining industry and how optimisation assists in creating value. Mineral commodity prices are volatile due to supply and demand factors, and thus, optimisation becomes important for mining companies to remain profitable. Chapter 2 also explains why optimisation in mining has generally been focussed on open-pit mining and lagging in underground mining. The optimisation is further discussed under stope boundary optimisation with particular focus on mining cut. Factors that affect mining cut are discussed. Since the optimal mining cut for the research was determined by economic evaluation, several methods of economic evaluation are discussed in the chapter. Chapter 3 describes the research methodology. It describes the process of data collection and how it was analysed. Primary data was collected from monthly production reports from the mining, mineral processing and finance departments. Chapter 4 analyses the mining cut options through an economic evaluation. The data collected was ran through a financial model, which is based on a Discounted Cash Flow (DCF) model. Conclusions and recommendations are made in Chapter 5.

CHAPTER 2: LITERATURE REVIEW

2.1 Chapter overview

This chapter discusses value creation in the mining industry and the various metrics used to measure it. It further reviews the literature on value creation in mining through optimisation by briefly explaining the lag in the development of underground mining optimisation techniques compared to open-pit mining. Traditionally, underground mine design and planning optimisation had limited attention due to the complexity and variability of mining methods in underground mines relative to open-pit operations. However, there have been several optimisation techniques and studies available, and some of them have been implemented effectively to optimise underground mines. Some of the techniques are briefly discussed in this chapter. The chapter also discusses the economic evaluation of underground stope optimisation, focusing on mining cut and the factors that affect the determination of mining cut. Economic evaluation is then discussed to close off the chapter. Several methods of economic evaluation and metrics of measuring value of a project are discussed.

2.2. Value creation in the mining industry

Companies invest in businesses to create value, and it is the aim of every mining business to create optimum value for its various stakeholders (Tholana, 2012). To demonstrate how value is created in the mining industry, Camus & Garcia (2011) outlined the key activities that define a mining value chain shown in Figure 2.1.

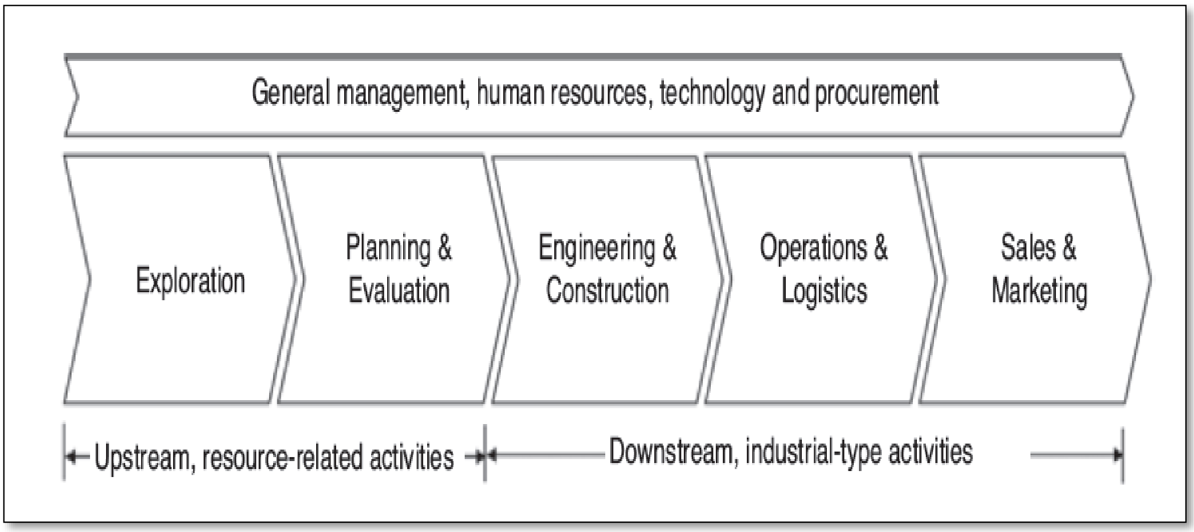

Figure 2.1: Schematic presentation of a mining value chain (Camus & Garcia, 2011)

On the value chain, primary activities are complemented by support activities that serve to provide transversal services to the mining business process. The activities on the value chain are classified as upstream and downstream activities. The upstream activities represent the technical aspect of the business, which is the Mineral Resources management function. The aim of this function is to establish the amount of Mineral Resources available and convert them into Mineral Reserves. The output of this process is the generation of a mine business plan premised on designs and extraction assumptions. On the other hand, the downstream activities work primarily to implement the mine business plan. Sub-activities include project management, engineering design and production (Camus & Garcia, 2011). The value chain ends with marketing-related functions that are accountable for costing and revenue realisation.

Traditionally, the notion has always been that value creation in the mining business is driven by downstream activities with a focus on cost rationalisation. Research by Camus & Garcia (2011) provided new insights that show that mining value directly results from managing Mineral Resources related to upstream activities of a value chain. This is because when a mining company is valued, investors are more interested not so much in the earnings per period but in the factors associated with available Mineral Resources. These factors have a significant influence on investment decision-making. It is, therefore, important that companies declare in the public domain Minerals Resource information so that value is proportionately determined. The optimal value is then created through the optimisation of processes on a mining value chain from exploration to marketing of a commodity.

2.3 Optimisation in mining

Optimisation is a process of making a design, system, or process as perfect, functional, or effective as possible (Musingwini, 2016). The purpose of optimisation is to achieve the 'best' result against a set of prioritised criteria and constraints (Nhleko, *et al*., 2018). The results include maximising the desired outputs such as NPV, productivity, reliability, efficiency and utilisation or minimising undesired outputs such as waste and cost. Mine planning and optimisation play an essential role in the mine value chain as operations are measured against planned targets to evaluate operational performance (Musingwini, 2016). An optimised mine plan is expected to be sufficiently robust to ensure that actual outcomes are close or equal to planned targets. Globally, the bulk of mining activities currently happen either on the surface and underground operations, with a limited number of operations occurring in marine operations. All these sub-groups are amenable to optimisation.

Optimisation can be done in both underground and surface mines. Over the years, several methods have been formulated to optimise open-pit mines dating to the early 1960s. On the contrary, the optimisation of underground mines has been lagging (Ataei, *et al*., 2017). Figure 2.2 shows the optimisation methods that have been used to optimise mining limits for both surface and underground mines.

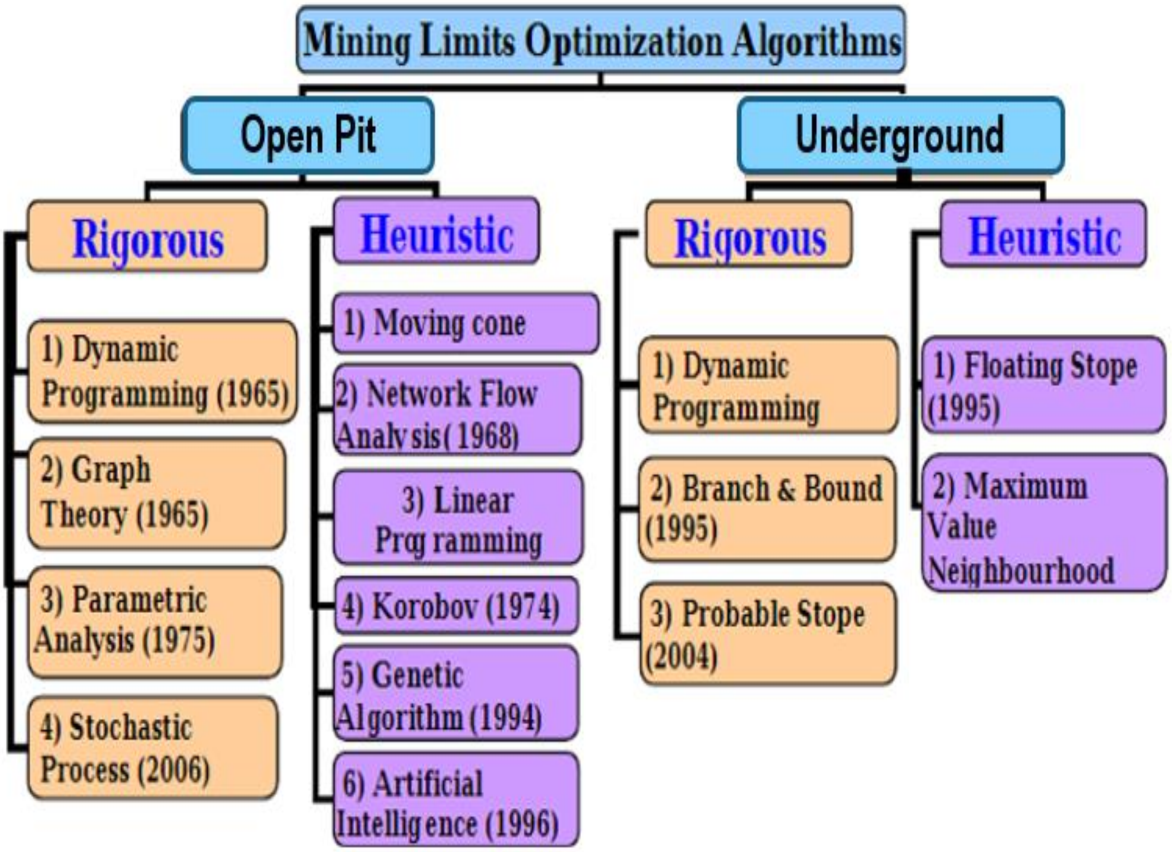

Figure 2.2: Mining limits optimization algorithms based on the economic value of block models (Shahriar, *et al.*, 2007)

Less research has been done in the area of underground mine optimisation; hence fewer techniques are available to optimise underground mines. This is due to many constraints associated with underground mines compared to open-pit mines, which makes optimising underground mines more computationally complex (Ataei, *et al.*, 2017). Furthermore, there are numerous underground mining methods in use, and developing a generic optimisation solution for different underground mining methods has proved to be difficult. However, there has been notable traction in recent years towards optimising underground mines as companies invest in Operations Research (OR) due to factors such as declining Mineral Resource grades and orebodies getting deeper (Chavan, 2018). The focus of this research was on underground mines because, as stated in Chapter 1, Zimplats operates entirely on underground mining operations.

2.4 Underground mining optimisation

Faced with a volatile and constantly dynamic market environment, mining companies are being swayed towards predictive and responsive approaches to improve operational efficiency, safety systems within the workplace and cultivate new business models (Oxford Business Group, 2021). For example, a sizeable number of mining operations globally are shifting towards lower-grade ore deposits as the higher-grade and close-to-surface deposits are fast depleting. Failure to adapt to the operating environment will define whether a mining company sinks or survives. Several mining companies have established research and development departments or OR in an effort to optimise their processes. Of keynote in the history of OR in mining has been the use of mathematical models commonly known as algorithms to solve mine planning problems in the mining value chain. The application of OR techniques in mining dates back to 1965 when Lerchs and Grossman developed an algorithm to optimise and design open-pit mines (Milani, 2016). There have been subsequent improvements and development of new algorithms though most of them are still based on Lerchs and Grossman's algorithm. The algorithm has been successfully and widely used in open-pit mining and integrated into several other widely used software (Ataee-pour, 2005).

There are several other areas along the underground mine value chain that are amenable to optimisation. The broad areas include mining method selection, development layout, production scheduling, and stope boundary optimisation (Topal & Sens, 2010). This research focused on stope boundary optimisation in general and mining cut optimisation in particular. The focus on mining cut is because the economic boundary of a stope is one of the key levers that mine planners can control to create optimal value.

2.5 Stope boundary optimisation

Nhleko *et al,* (2018) defined a stope as an excavation or void created in an underground mine to remove ore from surrounding rock. An optimum stope boundary is a limit for material that can be mined economically through underground mining methods (Nhleko, *et al.*, 2018). Stope boundary optimisation is a significant step of underground mining optimisation due to its direct impact on the economics of an underground mine. It maximises value by selecting the best possible layout; by considering operational, geotechnical and physical constraints.

Nhleko *et al*, (2018) also demonstrates that the selection of a mining method takes into account the size and orientation of the orebody, ground conditions that will have a bearing on the size of stopes and the percentage of waste material accepted as ore dilution. The method selected for drilling and blasting the ore will also influence the acceptable stope dimensions. For example, in narrow reef ore bodies, a single stope will mine the full width of the reef. Conversely, with wider orebodies, multiple stopes may be required to mine the full width of the orebody. Waste pillars are left between open stopes as primary support before backfilling is done to act as primary support. In stope optimisation, these factors can be reduced to dimensional constraints on the minimum and maximum stope size, acceptable stope shapes and pillar widths. In determining these parameters, the guiding principle is that the quantity of metal recovered in the stope must be enough to cover the cost of mining, processing and marketing (Nhleko, *et al*., 2018).

For a narrow and steeply dipping orebody, the primary decision on stope geometry comes from the selected width of the reef to be mined. This assists in reducing the stope optimisation challenge from a three-dimensional problem to a one-dimensional one. Rendu (2014) demonstrates that for a mining outline to be determined, there is a need to identify optimal positions of the hangingwall and footwall of ore zones intersected by drill holes. The limiting constraints considered are minimum mining width, internal waste width, the influence of geological structures, and the maximum mining width (Rendu, 2014). The minimum and maximum mining widths are ordinarily stated in the vertical, horizontal or normal orientation to the direction of mineralisation (Rendu, 2014). Therefore, the first step is calculating the limiting lengths in the direction of the drill hole. Continuity of ore and waste in-between the drill holes is left to visual and manual extrapolation to achieve the desired stope boundary.

A stope boundary has many elements, including orebody lateral extend, depth below the surface (DBS), extraction and mining cut. As explained in Section 2.4, this research focussed on mining cut. Mining cut is defined as the vertical distance between the hangingwall and footwall of an underground stope (Sandanayake, *et al.*, 2015). Determining the optimum cut is a major concern in most underground mines as it depends on various factors, which include: the size of equipment to be operated in the stopes, mining dilution, geological characteristics of the orebody, the safety of personnel and the production parameters (such as hole diameter and head grade) (Soltanmohammadi, *et al.*, 2010). In the case of the Great Dyke reef profile, the smaller the mining cut, the higher the Run of Mine (ROM) head grade though it reduces blasted tonnage per face if other dimensions are kept constant. The inverse holds true. Therefore, optimisation of the mining cut plays a pivotal role in the overall economics of a mine (Nieto & Bascetin, 2006). Factors that affect mining cut determination are discussed in the next section.

2.6 Key factors in optimising mining cut

2.6.1 Mining dilution

As a mining project develops from conceptual to production phases, there exists a variety of uncertainties that affect the operation's designs and economic value (McCarthy, 2001). An important design parameter considered is mining dilution. Mining dilution is defined as a portion of waste material included in the ore stream during its extraction and transportation to a processing plant (Peroni & Camara, 2016). Unplanned dilution has the effect of reducing previously estimated mill grades of ore. Figure 2.3 shows the two forms of dilution in an underground stope.

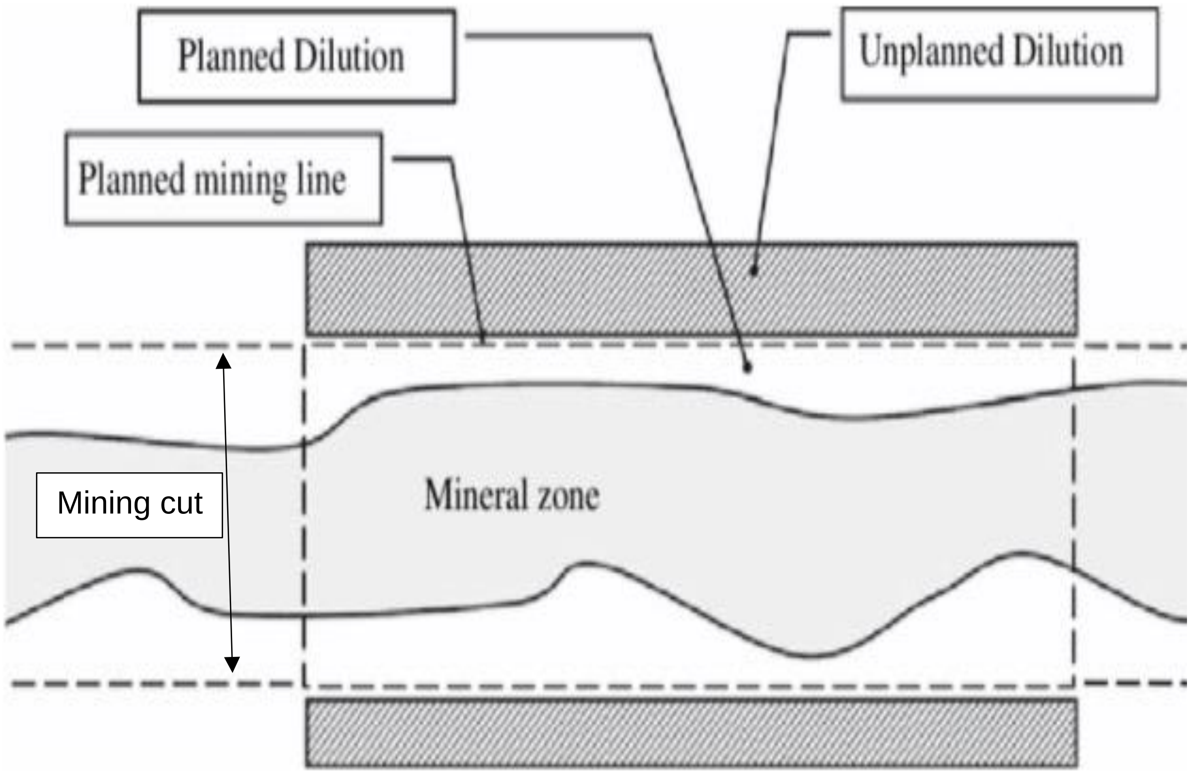

Figure 2.3: Schematic illustration of planned and unplanned dilution (Henning & Hani, 2008)

Mining dilution can be a major contributor to low head grade performance on a mine. Mining dilution can be divided into two classes, namely: external or unplanned dilution and internal or planned dilution. External dilution is related to the designed stope width (mining cut), contact dilution and over-break of hangingwall or footwall relative to planned mining boundaries. According to Rossi & Duetsch (2014), dilution during mining operations is usually designed by the mining engineer during the development of a mine plan. As shown in Figure 2.3, unplanned dilutions generally result from geometric characteristics of the orebody, the mining operation, characteristics of geological contacts between reef and waste, and limitations of the mining equipment to extract ore to the planned boundaries (Rossi & Deutsch, 2014). Unplanned ore dilution directly influences the operating cost of a stope and, ultimately, the profitability of a mining operation. Poor management of unplanned dilution can mean tens of thousands of dollars in lost revenue depending on the mining operation. The following initiatives can be used to minimize external dilution (Rossi & Deutsch, 2014):

- Defining the contact surfaces of ore and waste;
- Selection of the proper equipment to attain the desired selectivity;

- Mining along the contact surfaces and
- Modelling the effects of unavoidable dilution.

Internal dilution can be related to volumes of waste or barren rock within a mineralised zone. Geologists account for this type of dilution during Mineral Resource modelling. Degrees of internal dilution vary within various types of ore deposits; specifically, lithological and grade distributions within the ore significantly influence the degree of dilution (Ebrahimi, 2013). Furthermore, mineralogy of the ore, grade estimation method and application of cut-off grade are the other factors that govern internal dilution. Relative to the mining cut, dilution accounted for during mine planning means that the stope boundaries are designed to reduce dilution even in instances where it is unavoidable. If stope boundaries are increased, the grade gets lower and can fall under cut-off grade. This leads to a situation where badly planned stopes may seem feasible but result in operating loss as the ore gets diluted. Reducing the stope size can lead to ore losses, which is also undesirable (Tommila, 2014). The final decision about the mining cut to be used should be based on financial analysis of the chosen methods in the preliminary phase of stope design.

2.6.2 Mining recovery

Mining recovery and dilution are usually interrelated. With certain underground mining methods, a high recovery involves getting extra tonnes of the ore from the sidewalls or hangingwall as planned dilution. Conversely, often good ore can be obtained by leaving behind some ore in the mine but at low recovery. The second scenario has little ore contamination and usually results in high ore grades. In underground open stope methods, a significant amount of the orebody is left as pillars to support the hangingwall. The sizes of pillars left vary depending on the strength of the orebody, thickness of the orebody, which is a function of the mining cut, depth of the mining area below the surface, and permanent support requirements to prevent ground instability as a result of overlying burden. Where subsidence is allowed, most of the pillars are recovered on retreat using 'pillar robbing' methods, the amount recoverable depending to a considerable extent on roof characteristics (David, 2014). According to David (2014), the rate of output possible with any stoping method depends to a large extent upon the size of the ore body, especially the mining width and the width of the stopes; a high rate of output is difficult in narrow stopes (David, 2014).

2.6.3 Size of mining equipment

The choice of machinery to use underground is sometimes dictated by the size of excavation being mined. Correct matching between machine and stopes size is vital for optimal safety and productivity. This is because, in underground operations, equipment size and capacities are often constrained by workspace limitations (Fiscor, 2014). When it comes to the primary considerations for sizing underground machinery, the main concerns are the width and height of the stopes. The equipment is chosen to fit into the planned excavation size. The main purpose of equipment selection is to select the optimum and cost-effective equipment that must comply with the mining conditions or limitations and meet the basic requirements as well as the preferences of the mine (Aykul, *et al.*, 2007). Figure 2.4 shows a typical underground stope and typical heights in which the machinery can fit depending on the mining cut.

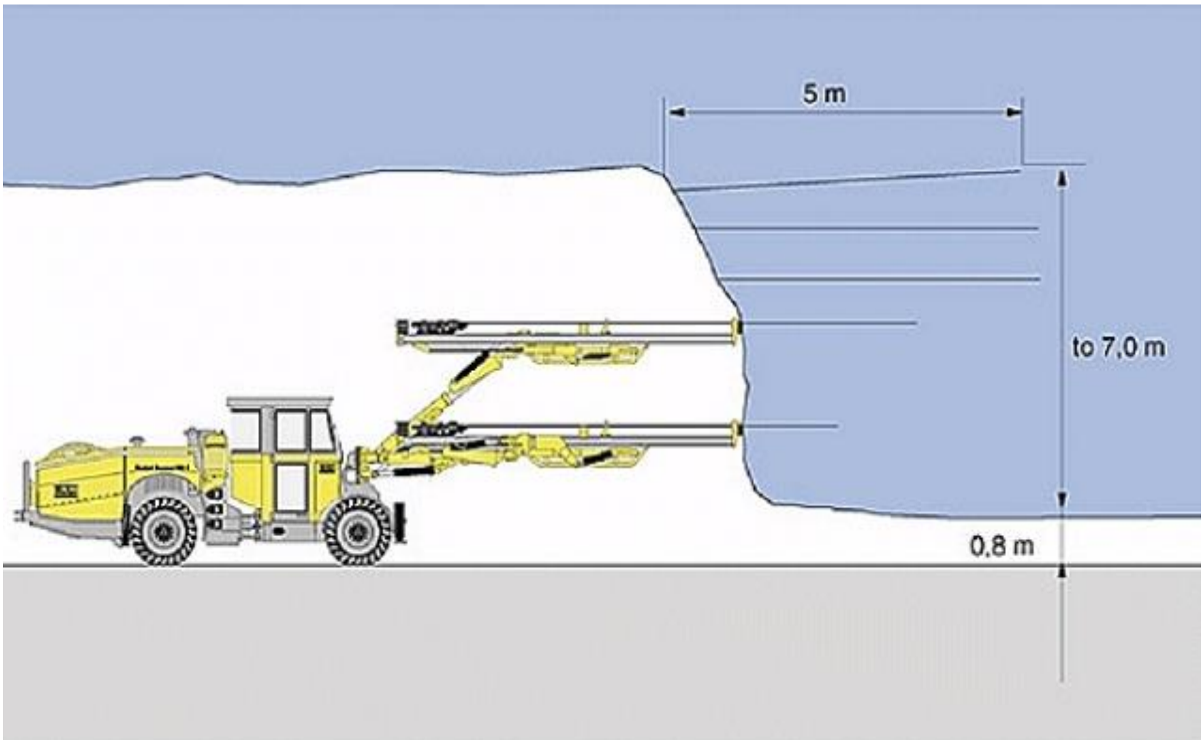

Figure 2.4: Typical cross-section of a machine in an underground stope (Hamrin, 2010)

A mine that does selective mining opts for low profile machinery. In larger stopes, the machinery chosen is designed to move large volumes, so a mine prefers bigger machinery. Therefore, machinery is ordered to fit into a planned excavation as preferred by the mine. During the optimisation of the stope dimensions, the engineer considers not just the dimensions of the machine's usual workspace but all spaces in which the machine may have to pass through during operation. The mining cut must accommodate infrastructure like electrical cables for powering drilling rigs to avoid interference with the machinery during operations.

2.6.4 Safety of underground personnel

Mining cut also affects the safety of people working underground. It influences the employees' mobility, posture, and vision when working underground (Fotta & Mallett, 1997). One of the biggest causes of injuries underground is the fall of ground (FOG). FOG is defined as the unplanned or unintentional falling of rocks in a mine in an area where people could be working (Kousick & Zipf, 2000). The unplanned falls have the potential to cause injury to personnel or damage to equipment. The rock falls could come from the hangingwall or sidewall of an underground stope. Folla & Mallett (1997) stated that the nature of the injury and the relative frequency of injuries is determined by the size of the excavation, mining method, and rock properties being mined (Fotta & Mallett, 1997). This research focussed on the relationship relative to the excavation size, which includes the mining cut.

Fotta & Mallett's (1997) research carried out at the coal mining industry in the United States of America revealed that regardless of employment size, as mining cut increases, underground personnel are increasingly at higher risk of injury from FOG. The higher the height, the bigger the rock's fall-out height, which increases the severity of an injury (Fotta & Mallett, 1997). Though new ground control and management techniques are helping to reduce FOG, globally, it remains a source of work-related fatalities in underground mines (Kousick & Zipf, 2000). To improve in managing the factors analysed above, mining companies are making use of available optimisation strategies such as smooth-wall blasting to reduce falls of grounds incidences and use of gel based explosives to reduce stress fracturing of rock. The less the fracturing helps in reducing unintended rock falls which are a major cause of underground mining accidents.

2.7 Mining cut optimisation methods

Several techniques can be used to optimise the mining cut, including mathematical models and economic valuation. Mathematical models and algorithms that have been developed for the overall stope boundary optimisation include Dynamic programming, Optimum Limit Integrated Probable Stope (OLIPS) model, Branch and Bound, The Floating stope method and the Maximum Value Neighbourhood (MVN) (Nhleko, *et al.,* 2018). However, this research used economic evaluation because the mentioned mathematical models focus on the overall economic limit of a resource over Life of Mine (LOM). In contrast, this research aimed to optimise the vertical extent of the orebody to maximise the economic profit by selecting the best possible mining cut under operational, technical and physical constraints. Economic evaluation helps understand the cost factors related to an intervention. Economic evaluation can be conducted prospectively or retrospectively. For example, economic evaluation can be used before recommending broad implementation of an effective program or strategy and thus it was suitable in this research.

2.8 Economic evaluation

An economic evaluation is a comparative analysis of two or more interventions in terms of their cost and benefits based on inputs given versus outcomes generated (Adhikari, 2017). Fundamentally, economic evaluation entails that both the costs and benefits of all the available options are considered. There are four main methods of economic evaluation, which include Cost Minimisation Analysis (CMA), Cost-Effective Analysis (CEA), Cost-Utility Analysis (CUA) and Cost-Benefit Analysis (CBA) (Adhikari, 2017).

These evaluation methods are defined by the methodology used to measure the outcomes or effects of an intervention. The chosen technique should reflect the decision that the economic evaluation is designed to inform. For example, if an evaluation aims to inform the choice between two alternative blasting solutions for the same rock type, a CEA may be the appropriate method. In CEA, costs are in dollars, but benefits are left in some natural unit, like the number of years derived from the benefit. When a decision involves alternatives that have tangible and non-tangible effects, such as an environmental control regulation, a CUA becomes the appropriate choice. When it is possible to assign a monetary value to all the interventions in the evaluation, a CBA may be deemed the most appropriate method of economic evaluation (Adhikari, 2017). The above-stated evaluation techniques are discussed in the next sections.

2.8.1 Cost minimisation analysis

In CMA, the costs of two or more interventions with an expected identical outcome are measured. The intervention with the lowest cost is selected. Achieving' value for money' resonates with either a desire to achieve a predetermined objective at the lowest cost or to get the most out of the benefit from a limited amount of resources. CMA is a tool normally applied in the medical sector to measure and compare the costs of different medical interventions (Gellman, 2013). However, it can also be applied to mining problems. Rascati (2007) used CMA to evaluate the effect of different chemicals against an expected outcome to aid in the recovery of minerals in a processing plant (Rascati, 2007). The disadvantage of this method is that it has limited comparisons for key performance indicators that provide the same benefits (Gellman, 2013). There is a decline in CMA use in economic evaluations because the method introduces a bias in measures of uncertainty that results in overestimation or underestimation of the value of information (Seshamani, 2013). It was, therefore, not used for this research.

2.8.2 Cost-utility analysis

CUA is an adaptation of CEA, which measures an intervention's effect on both the quantitative and qualitative aspects of a project (Poetz & Jeffrey, 2006). CUA is a useful method for analysing and comparing programs that aim to achieve a similar goal in physical or non-monetary terms. The method develops an overall measure of utility or value based on the preferences of individuals. CUA can be used in mining to measure the LOM of a mining operation when used on a process such as dump harvesting, which is carried after decommissioning the primary production areas. The CUA method was not used for this research as the expected results of CUA are in non-monetary terms.

2.8.3 Cost-effective analysis

In CEA, the cost of production is measured against the effectiveness of an intervention. CEA evaluates costs in monetary units and the effectiveness of an option in relation to physical units. Since the two are incommensurable, they cannot be added or subtracted to obtain a single criterion measure. They can only be computed as a ratio of costs to effectiveness using Equations 2.1 and 2.2 (Nease, 2003). Equation 2.1 measures the cost per unit of effectiveness. Projects can be ranked by CE ratios from the lowest to highest, with the most cost-effective project having the lowest CE ratio. Equation 2.2 measures the effectiveness per unit of cost. Effectively, projects should be ranked from highest to lowest EC ratios.

$$\boldsymbol{CE\ ratio} = \frac{\boldsymbol{C_1}}{\boldsymbol{E_1}} \qquad \textbf{(2.1)}$$

$$\boldsymbol{EC\ ratio} = \frac{\boldsymbol{E_1}}{\boldsymbol{C_1}} \qquad \textbf{(2.2)}$$

where C_1 is the cost of option 1 (in monetary units); and E_1 is the effectiveness of option 1 (in physical units). Since costs and benefits are measured in non-comparable units, their ratio provides a measure with which to assess relative efficiency (Nease, 2003). The CEA method evaluates relative costs from the outcomes of two or more courses of action. It can be used as an alternative to CBA which is discussed in the next sub-section. Several analysts use CEA when there are constraints in using CBA. One of the more common constraints is the inability to monetise perceived benefits. CEA is commonly used in healthcare, to assist in evaluating those outcomes on which a monetary value cannot be assigned, for example number of lives saved after administration of a vaccine (Gellman, 2013). Therefore, CEA was not chosen for this study because the desired outcome is in monetary terms.

2.8.4 Cost-benefit analysis

A CBA is a systematic evaluation of the economic advantages (benefits) and disadvantages (costs) of a set of investment alternatives (Salehi & Moghaddam, 2008). CBA measures costs and benefits in commensurate metrics, usually monetary. This allows the computation of the net cost or benefit associated with an intervention (Edeger, *et al.*, 2014). CBA has two functions which include: (i) determining if an alternative option is sound as well as ascertaining if and how much its benefits outweigh its costs (ii) providing a basis for evaluating alternatives by comparing the total expected cost of each alternative with its total expected benefits (Sraders, 2019). CBA has been used for a long time. The method dates back to 1848, when Jules Dupit, a French engineer, highlighted the CBA for economic evaluation (Landau, 2020).

CBA is often used at the beginning of project evaluation when several or different options are considered, appraised and compared, to choose the best option. Subsequently, it can be extended to the evaluation of the overall impact of a project in quantifiable and monetised terms. The technique assumes that a monetary value can be assigned to every cost and benefit of a project, including both tangible and intangible items. As such, one major advantage of a CBA is its ability to clearly and systematically consider various factors that should influence the strategic decision (Boardman, *et al*., 2006).

Decisions that are made through CBA are done by comparing value measures such as the NPV of a project's costs versus the NPV of its potential benefits (Landau, 2020). Decisions are made based on the quantum of net benefit. Due to the time value of money principle, the net benefit anticipated in a CBA is assigned a 'discount' factor which effectively reduces the value of projected future costs or benefits, putting them on par with costs and benefits incurred today. This factor called a 'discount rate' in financial terms varies depending on the project being evaluated. The sum of the discounted benefits of an option minus the sum of the discounted costs, all discounted to the same base date, gives the NPV of the option (Zyl, 2015).

One of the disadvantages of CBA in mining projects is that it is mainly best suited for projects with shorter LOMs, and it allows stakeholders involved with a project to make proper decisions. However, longer projects can be problematic in terms of CBA because external factors such as inflation and interest rates may impact the accuracy of the analysis. Nevertheless, the use of CBA is a crucial step in determining if any project is worth pursuing (Landau, 2020). The project area, Ngwarati Mine, is left with an estimated four years, which by industry standards is a short LOM, and therefore CBA was ideal to use for the research evaluation. This research carried a CBA of mining cut variation in PGMs extraction aiming to maximise Pd extraction using the Discounted Cash Flow (DCF) valuation technique.

2.8.5 Discounted cash flow

A DCF is a valuation method that values a project by forecasting its future cash flows and then discounts the cash flows to calculate the NPV of the project (University of Norwich, 2017). The DCF method assumes that the present range of values of the company at a particular valuation date is equal to the present value of future cash flows to the company's shareholders. The cash flows are projected using some reasonable assumptions on the expected future performance of the project. In other words, the NPV is the value of the projected annual cash flows in today's equivalent amounts (Janiszewski, 2011).

The DCF method is the preferred choice of economic valuation because it best attempts to measure the value created by a business precisely and directly with the ability to be used in most evaluation scenarios. The method demonstrates that the value of a project is derived from the inherent value of future cash flows, which is an essential metric to any stakeholder involved in the project. The DCF method is advantageous because it includes all major assumptions about the business with several scenarios built-in, making it amenable for sensitivity analysis (Alden, 2019). Financial projections for the company shall be based on assumed values of key independent factors that impact the company's financial performance. The thorough analyses of the variables affecting financial performance and the right selection of the key drivers are the necessary elements of the DCF approach. Examples of key financial performance drivers include (Janiszewski, 2011):

- production volume;
- commodity price;
- profitability margins;
- revenues;
- capital and operating expenditures and
- taxes and royalties.

However, the method also has disadvantages. The DCF has sensitivity when many assumptions are incorporated in the evaluation, and that creates variability. For example, if a certain key assumption is significantly at variance to best practice or a benchmark value with a project of similar scope, this may lead to a wrong outcome (Alden, 2019). This is driven by the fact that generally, forecasting is prone to uncertainties in political, technical, commercial, or natural factors. Additionally, the DCF method does not consider any market-related valuation information, such as the valuations of comparable companies as a 'reasonability check' or in the case of a questionable assumption that may lead to an outcome that is substantially different from what market forces are indicating. In this instance, however, sensitivity analysis were carried out to level out some of the variances that may be brought about by factors highlighted above (Corporate Finance Institute, 2015).

When carrying out a DCF analysis, the following pointers with the acronym C.V.S. are a useful guide:

- Confirm - historical financials for accuracy
- Validate - key assumptions for projections
- Sensitize - variables driving projections to build a valuation range.

The NPV of future cash flows is calculated using Equation 2.3 (Corporate Finance Institute, 2015):

$$\mathbf{DCF} = \frac{\mathbf{CF}}{(\mathbf{1}+\boldsymbol{r})^{\mathbf{1}}} + \frac{\mathbf{CF}}{(\mathbf{1}+\boldsymbol{r})^{\mathbf{2}}} + \frac{\mathbf{CF}}{(\mathbf{1}+\boldsymbol{r})^{\mathbf{3}}} \ldots . \frac{\mathbf{CF}}{(\mathbf{1}+\boldsymbol{r})^{\boldsymbol{n}}} \qquad \textbf{(2.3)}$$

where CF is cash flow in the period, r is the discount rate and n is the number of periods. NPV and IRR are the two basic measures of feasibility used by the DCF analysis method. NPV is a measure of value, whereas IRR is a measure of the efficiency of capital. Both NPV and IRR are used to indicate and assess project feasibility.

2.8.6 Discount rate

A discount rate, also known as a hurdle rate, is the rate of return that shareholders require from investment to cover the cost of capital and compensate for the risk that comes as a result of investing in a particular project. The hurdle rate used for the financial valuation in this research is a summation of three components, namely: the weighted average cost of capital (WACC), technical risk premium and country risk premium. WACC is the cost to the company of its total debt and equity funding. The WACC is quoted in real terms and applied to post-tax net cash flows. Additionally, a technical risk should be incorporated to account for project-specific technical risks. A country risk premium is a factor associated with doing a project within a specific country (Torries, 1998).

2.8.7 Net Present Value

NPV is the sum of the present values of all future cash flows, less the initial capital investment. It reflects the perceived value of a project, given the specific assumptions with reference to the discount rate and a set of future cash flow projections. NPV is a measure of an investment's worth and is used for decision-making concerning investment potential (Torries, 1998). NPV has several advantages. Firstly, it accounts for the time value of money, and it gives a single project value for a given discount rate and set of cash flow assumptions that investors or shareholders use for decision-making purposes. Secondly, it is generally accepted that the higher the NPV, the better and more attractive it is for shareholders to embark on the project. Torries (1998) mentioned that the NPVs of individual projects can be evaluated to determine comparative worth, provided each NPV is generated consistently to enable fair and objective comparisons and trade-offs.

2.8.8 Internal rate of return

As the discount rate increases for a specific cash flow, the NPV of the cash flow decreases. IRR is thus, defined as the discount rate at which the NPV equals zero. Alternatively, IRR may be defined as that rate that equates the initial investment with the future value of the resulting cash flows. The higher the IRR, the more profitable a project is in terms of return on capital invested. The difference between the hurdle rate and IRR is that the shareholder or investor selects the discount rate, whereas the cash flow arrangement determines the IRR (Torries, 1998).

While NPV and the maximisation of wealth are hypothetically the correct investment-ranking criteria, NPV is not a good indicator to show the return per invested unit of capital. IRR, on the other hand, gives indications of the return per invested unit of capital. This makes IRR one of the mining industry's most used investment assessment criteria. Regarding mining project valuations, DCF is a widely understood and preferred evaluation method. Hence a DCF analysis with related NPV and IRR analysis was used to evaluate the different mining cut scenarios in this study.

2.9 Chapter summary

The optimisation of stope boundaries is an essential component of underground mine design and planning. In this research chapter, methods of stope boundary optimisation were discussed, and it shows there is still an opportunity for further development of other improved algorithms that guarantee optimal solutions in underground mining. Economic evaluation is equally important and assists decision-makers on the viability of options for mining projects. Several economic evaluation methods were discussed in this chapter. CBA in general and the DCF method, in particular, were selected as the evaluation methods for this research. The DCF valuation technique was chosen because it captures the underlying fundamental drivers of a business, such as the cost of equity, WACC, discount rate and revenues. Consequently, this results in a better estimate of the intrinsic value of the business. However, in instances where a project is based on long-term assumptions, there could be variations in the business profile, and therefore, it will require constant revalidation. The next chapter describes the research methodology.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Chapter overview

This research is based on the quantitative approach. A quantitative approach is defined as a process of collecting and analysing numerical data to find trends, averages, come up with predictions, check causal relationships and generalise results to wider populations (Earl, 2010). This chapter describes the methodology that was used to collect data. Most of the data were collected from Zimplats' technical and financial reports. The chapter also describes how the data was analysed to answer the research question.

3.2 Input data and sources

As explained in Chapter 2, the DCF method was used for this study. The method requires geological, production, technical and economic data as inputs. These are discussed in the next sections.

3.2.1 Geological data

As mentioned in Section 1.5, data for Ngwarati Mine only was used in this research study. Figure 3.1 shows the remaining Mineral Reserve for Ngwarati Mine with remaining mineable area of 618 701 m^2 over which the evaluation was done. The production outline is as of the end of December 2020 production month.

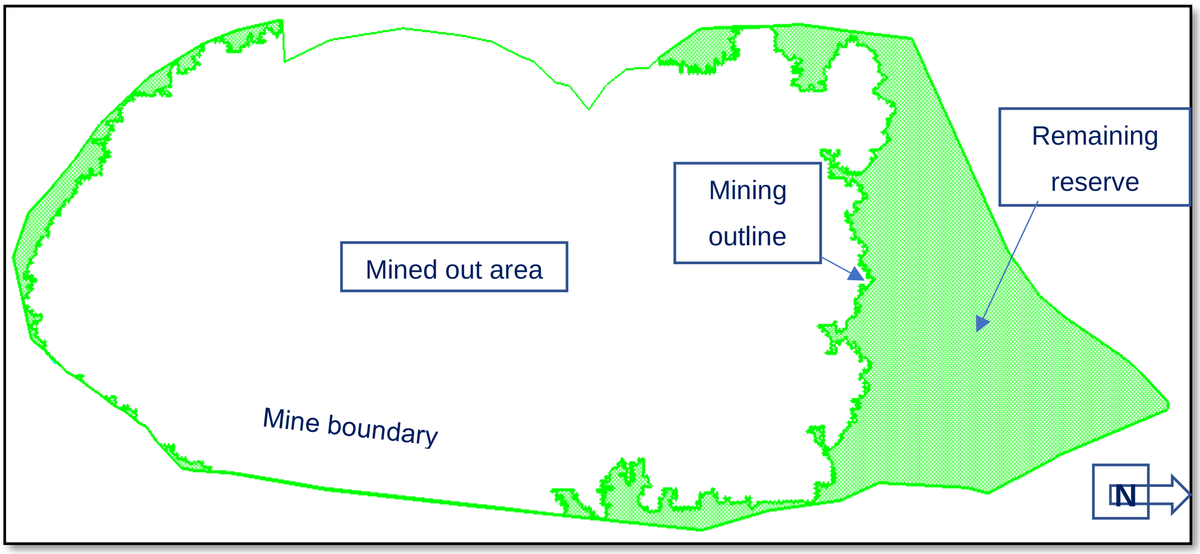

Figure 3.1: Ngwarati Mine plan showing remaining Mineral Reserves

The remaining footprint, as shown in Figure 3.1, was evaluated against Ngwarati Mine’s geological block model. The block model was constrained to show only the metal-bearing portion and is coloured by attribute, as shown in Figure 3.2 and Figure 3.3.

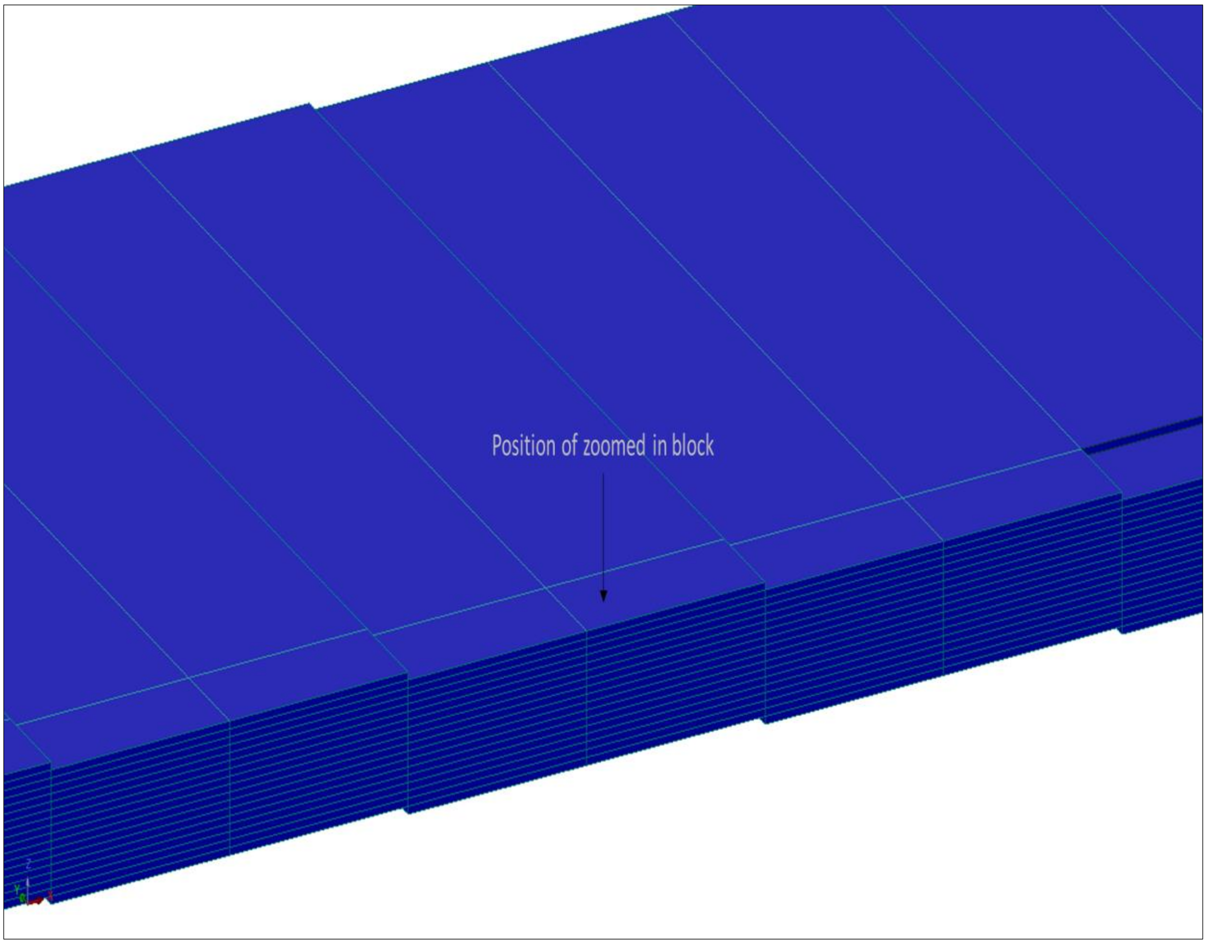

Figure 3.2: Constrained block model

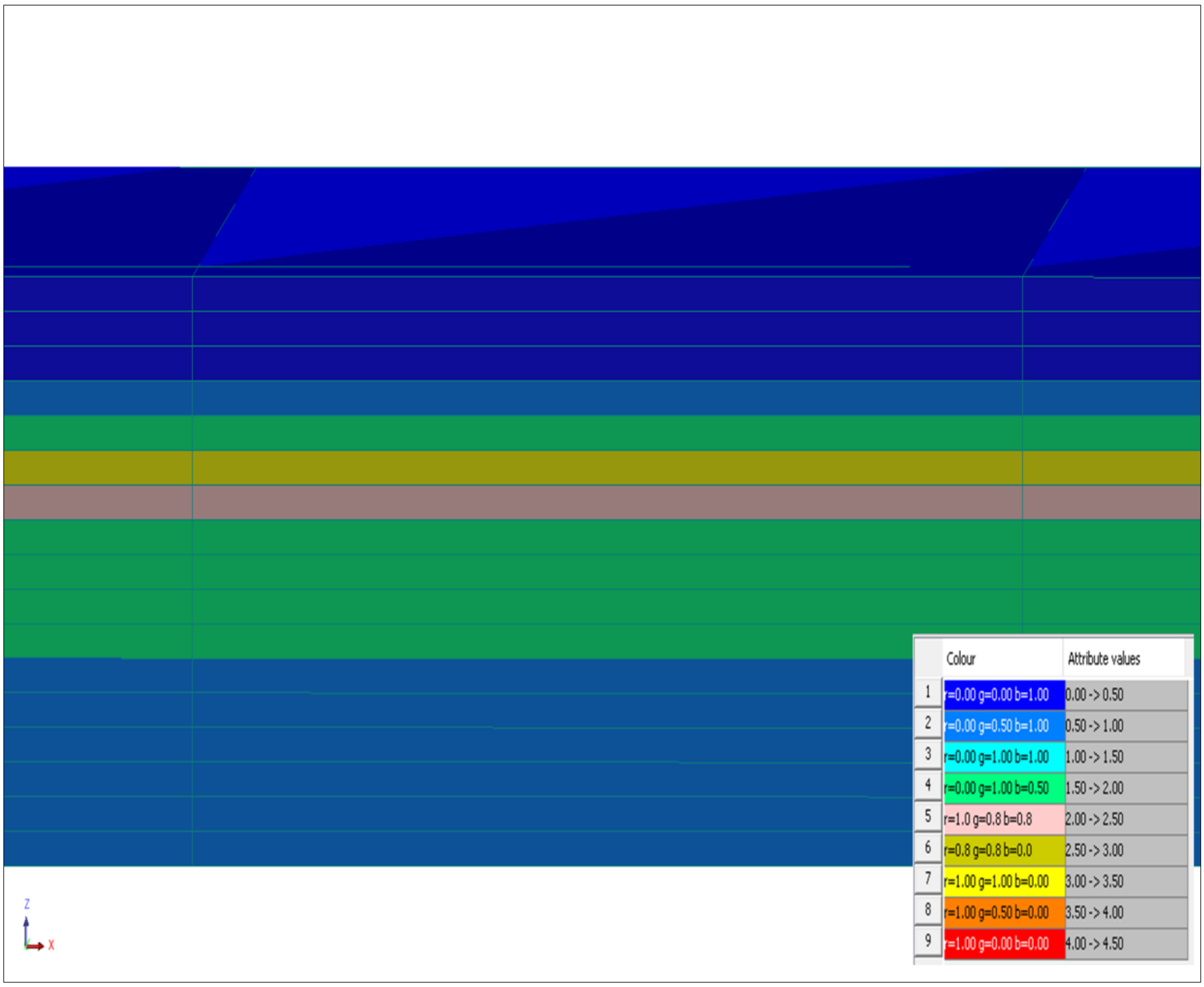

Figure 3.3: Pt distribution across the reef channel

Figure 3.2 shows a constrained zone of the block model and illustrates that the mining cut evaluation is to be carried out in the mineralised zone of the reef using platinum as the control element. The zone explained above is evaluated to measure occurrence of Pt and assigned colour attributes as shown in Figure 3.3. The position of the peak Pt value was established and confirms that the zone on which the evaluation was carried out is mineralised. This is important so that face grades are assigned and assists in the financial evaluations. Thus, the block model obtained from Ngwarati Mine was assumed to be valid and reliable.

3.2.2 Production data

Monthly production statistics for both mining and processing departments were collated from the Zimplats production database. As explained in Section 1.5, the production data used for trending the research is from the production year 2018 to

2020 when Pd price has maintained a higher price than the Pt price. The data includes actual ore mined, ore milled, mining cut and head grade. Zimplats' production year spans from 1st July to 30th June from year to year. The production data is tabulated in Appendix 7.1. This production performance and plan were based on the current mining cut of 2.50 m. The research seeks to demonstrate the potential increase in revenue from the production year 2021 on the remaining Mineral Reserves for Ngwarati Mine.

3.2.3 Economic data

Economic data collected included operating costs, current and forecast mineral prices of PGMs and base metals, royalty rates per each mineral, tax rates, capital costs and discount rate. The economic data was collected from Zimplats financial database. The metal pricing forecasts in the research were based on Zimplats' 2021 financial assumptions. The commodity price forecast shown in Appendix 7.2 is for a ten-year period up to the financial year of 2030, with subsequent years after that assumed constant as last reported in 2030.

Tax and royalty rates are as per the schedule published by the Zimbabwe Revenue Authority. The tax thresholds used are presented in Appendix 7.3. A discount rate of 20% was used for the financial evaluation in the research, which was informed by the cost of debt and country risk ranking. This is a combination of 8% project risk, 2% technical risk and 10% country risk. WACC is the cost to the company of its total debt and equity funding. The WACC was quoted in real terms and applied to post-tax net cash flows. The recommended WACC as the basis for setting project hurdle rates is 8% provided by the Zimplats Treasury department. In addition, a technical risk premium was incorporated to account for project-specific technical risk. Currently, Zimplats uses a premium of 3% for green-fields and 2% for brown-fields projects. The technical risk premium applied for this research evaluation was aligned with the brown-fields' 2% premium. The country risk premium, a risk rate associated with operating within a specific country, was at 10% (Nyarota, *et al*., 2015), which is applicable to Zimbabwe. Although several arguments can be proffered to either increase or decrease the hurdle rate, it is imperative that the rate used for evaluation be consistent in application to establish accurate comparisons.

Since the scope of the research did not propose to change the current suite of underground mining equipment, the same capital costs were assumed for all mining cut scenario evaluations. Appendix 7.4 shows the revenue contribution for the 6Es from the production year 2018 to 2020. This data was used to correlate the actual trend and the outcomes from the evaluations done in Chapter 4.

3.2.4 Geotechnical data

The mine design criteria to determine the different extraction ratios at different pillar sizes were collected internally from the Rock Engineering department. This data was used to determine the in-situ pillars left in relation to a specific mining cut using numerical modelling. This was used to derive the extraction ratio per mining cut. Mining extraction is defined as the ratio between the actual Mineral Reserve extracted versus the in-situ proven Mineral Reserve (Zimplats, 2018b, p.8). The ratio is expressed in centares or as a percentage. Comparing the two revealed the mining quality in terms of dilution and pillar integrity. This data was obtained from Zimplats' mining, geological, rock engineering Code of Practice. As mentioned in Section 1.4, the aim of this study was to determine the optimal mining cut for Zimplats' mines. A change in the mining cut from the current 2.5 m will result in pillar sizes and mining recovery changes. A reduction in the mine cut will reduce pillar sizes and thus, increases the mining recovery. The inverse also holds true. Appendix 7.5 shows the pillar sizes at different depths below surface "DBS" (on dip and strike) as extracted from the rock engineering Code of Practice which was used to calculate mining extraction per each mining cut to evaluate the LOM on each mining cut.

3.2.5 Ground control districts

A ground control district (GCD) is defined in the Implats Code of Practice as "a portion of a mine where similar geological conditions exist which give rise to a unique set of identifiable rock-related hazards for which a common set of strategies can be employed to minimise the risk resulting from mining" (Zimplats, 2018b, p.8). GCDs are subdivisions of orebodies on a mine, based on geotechnical conditions that occur, into areas in which the same standard strata control methods, mining directions, and support strategies can be implemented. Based on the rock mass response to mining, the Zimplats orebody mining horizon has been classified into different GCDs. These are based on the most prominent rock-related hazard within each particular area. At Ngezi operations, the ground is divided into four, though only two classes (e.g. ground class C and ground class D) are found. The rock mass classification system used at Zimplats is based on Barton's Q system. The Q system is a classification system that combined six parameters, namely (Barton, 1988):

- Rock quality designation (RQD)
- Number of joint sets (J_n)
- Roughness of the most unfavourable joint or discontinuity (J_r)
- Degree of alteration or filling along the weakest joint (J_a)
- Water inflow (J_w)
- Stress condition given as the stress reduction factor (SRF); composed of:
    - Loosening load in the case of shear zones and clay bearing rock
    - Rock stress in competent rock
    - Squeezing and swelling loads in plastic, incompetent rock.

The six parameters are grouped into three quotients giving the overall rock mass quality given by Equation 3.1:

$$\mathbf{Q} = \frac{\mathbf{RQD}}{\mathbf{J_n}} * \frac{\mathbf{J_r}}{\mathbf{J_a}} * \frac{\mathbf{J_w}}{\mathbf{SRF}} \qquad \textbf{(3.1)}$$

After calculating the Q value, the ground is categorised accordingly and marked on the ground class map by a geologist. Table 3.1 shows the ground class ratings and support recommendations per class.

Table 3.1: Ground class rating table (RME, 2018)

Ground Class	Description	Q-Rating	Roof bolts	Roof bolt spacing	Cable anchors	Minimum Pillar Size
A	Good	Q≥10	Non-groutable	1m x 1.2 m	–	4 m x 4 m
B	Fair	4≤Q<10	Non-groutable	1m x 1.2 m	–	4 m x 4 m
C	Poor	2≤Q<4	Non-groutable	1m x 1.0 m	Non-groutable	4 m x 4 m
D	Very Poor	Q<2	Special recommendation issued	Special recommendation issued	Special recommendation issued	Special recommendation issued

3.3 Analysis of mining cut options

In the evaluation of mining cut options, a mining cut of 2.50 m was set as the base case as it is the current cut used at the mines. The mining cut was then iterated at 0.25 m intervals to conform to Zimplats' sampling standard intervals and seam layers defined in the reef model shown in Figure 1.3. The evaluated mining cuts have a lower and upper bound from the base case position. The lower bound was set at 2.25 m whilst the upper bound was set at 3.25 m which are the minimum and maximum thresholds, respectively, in which the current production equipment can optimally operate. The study assumed that the current suite of machinery operating at the mine was used for all the mining cuts. Overall, five possible mining cuts were evaluated, which are 2.25 m, 2.50 m, 2.75 m, 3.00 m and 3.25 m. This resulted in the following the placement scenarios per mining cut shown in Table 3.2.

Table 0.2: Possible mining cut iterations per each mining cut

Mining cut size (m)	Possible mining cut scenarios on seams HE - FK
2.25	9
2.50	8
2.75	7
3.00	6
3.25	5
Total	35

From these scenarios, the optimal mining cut was selected and evaluated based on six elements (Pt, Pd, Au, Rh, Ir, Ru) to give a composite 6E head grade plus base metals Ni and Cu. The different possible mining cut placement scenarios are graphically shown in Figure 3.4 to Figure 3.8 with the correlation to the base case (shaded portion) shown on the left axis. The base case is the current mining cut being used at Zimplats Mines. The footwall and hangingwall positions are fixed on all mining cut scenarios; therefore, as a cut increase, the possible options decrease. As the mining cut decreases, the possible options increase. Within the 17 mining layers HE-FK, a selected mining cut is iterated to fit the possible number of seams to give the mining cut options per mining cut.

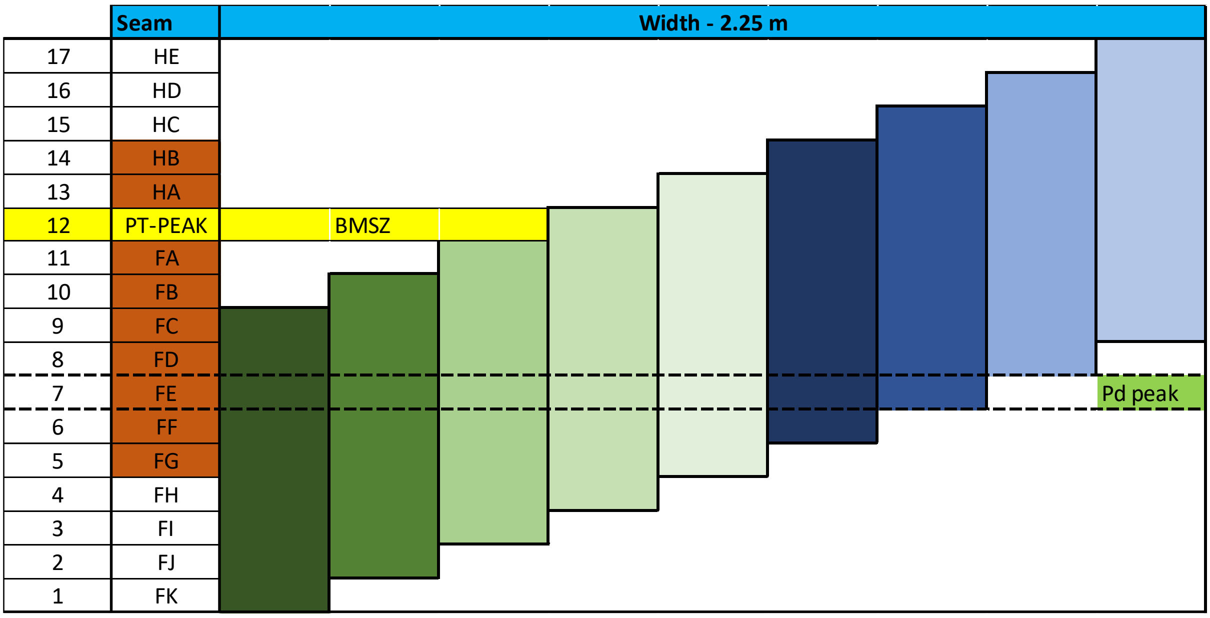

Figure 3.4: Possible mining cut placement scenarios for the 2.25 m mining cut

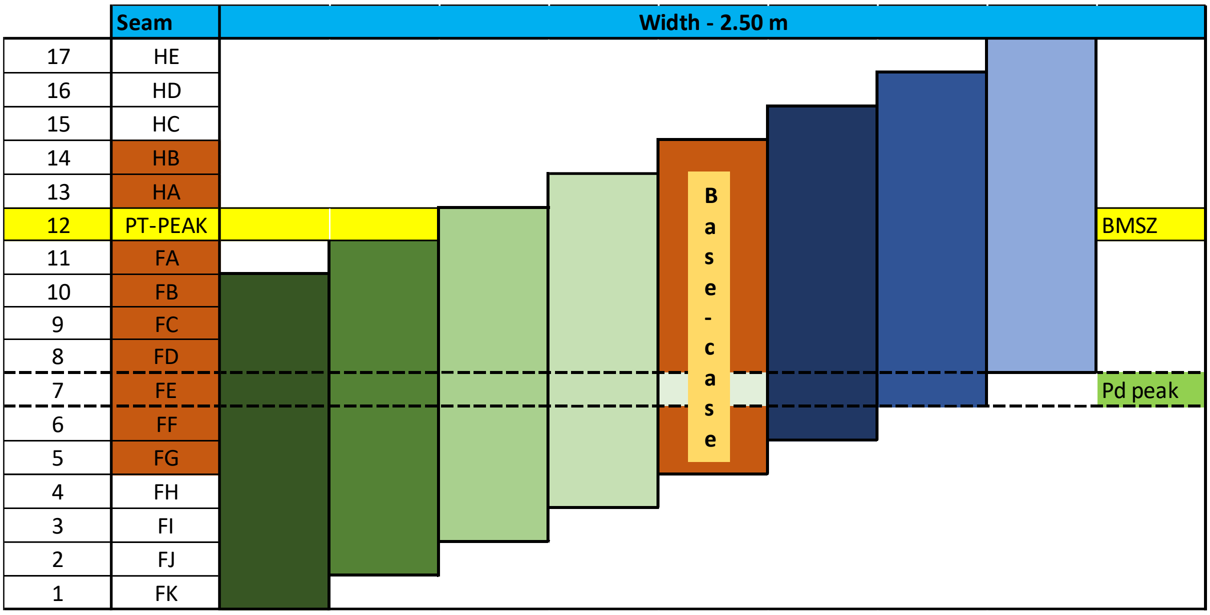

Figure 3.5: Possible mining cut placement scenarios for the 2.50 m mining cut

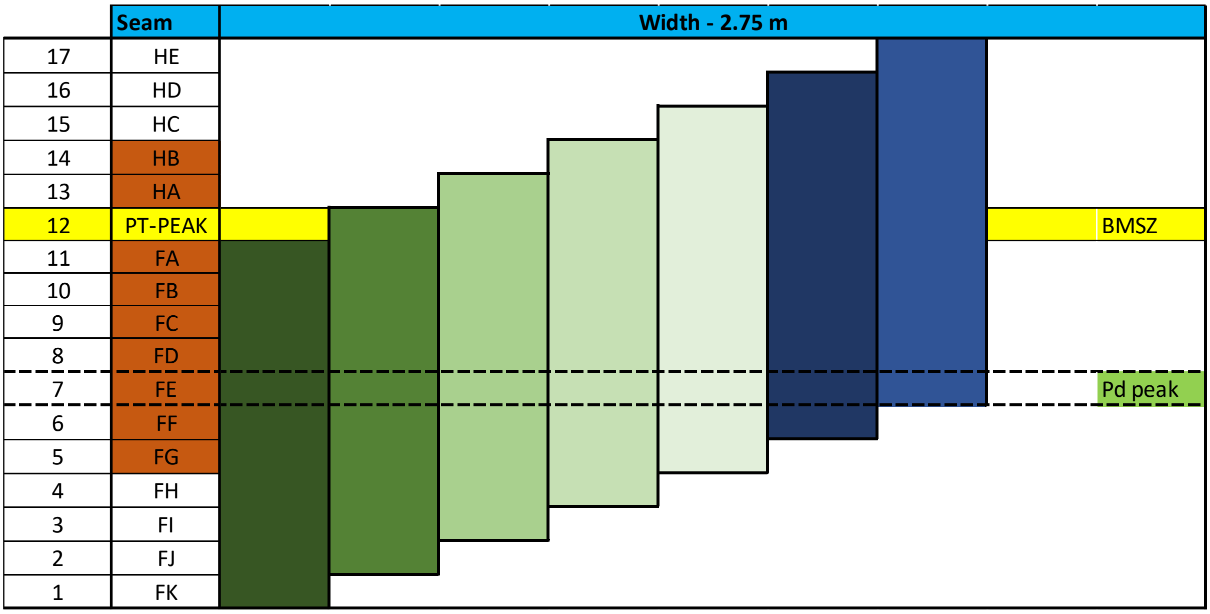

Figure 3.6: Possible mining cut placement scenarios for the 2.75 m mining cut

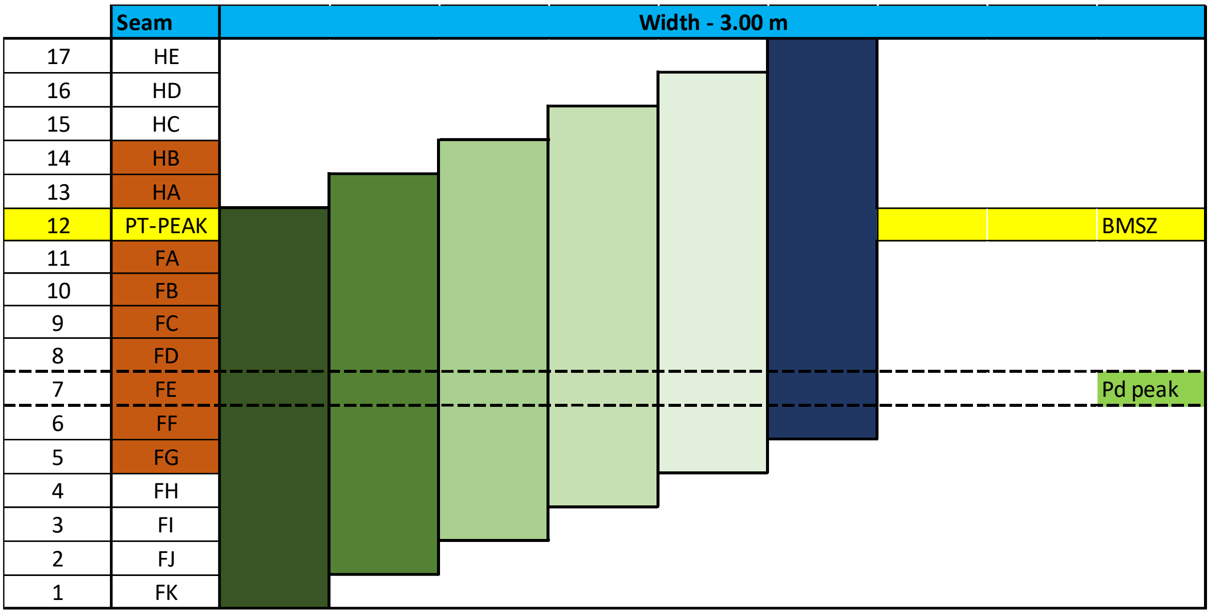

Figure 3.7: Possible mining cut placement scenarios for the 3.00 m mining cut

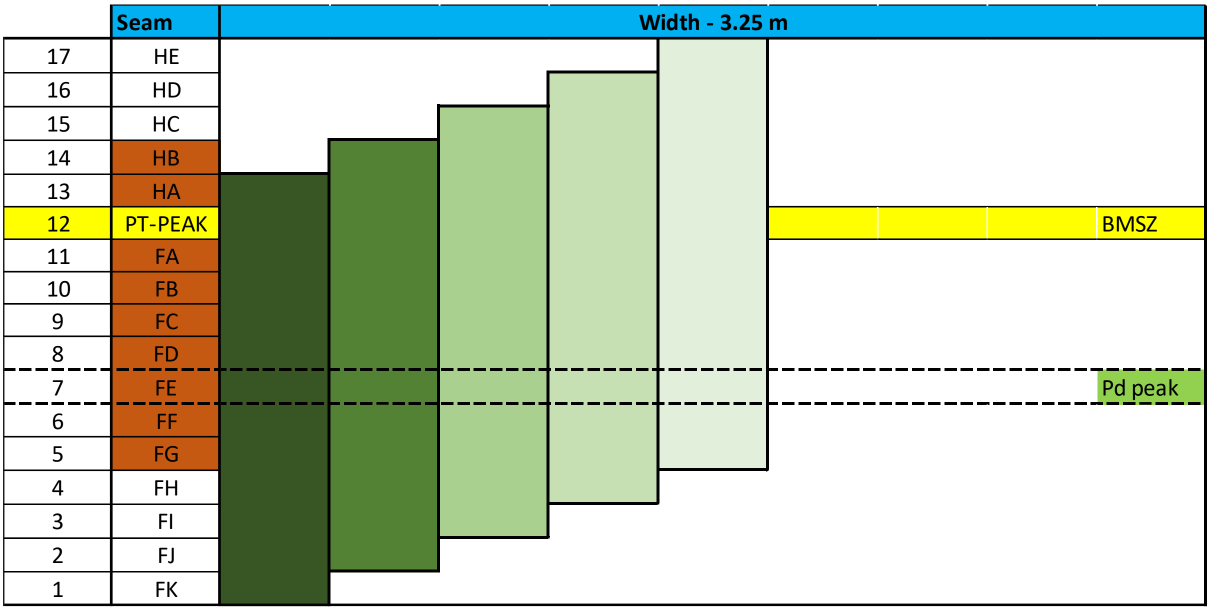

Figure 3.8: Possible mining cut placement scenarios for the 3.25 m mining cut

Each mining cut was iterated within the metal distribution profile (seam layers HF to FK in Figure 1.3). At each mining cut iteration, the 6E grade, tonnage, operating costs, life of mine and the resulting NPV were evaluated and compared to determine the optimal mining cut selected based on maximum NPV. The 6E head grade and tonnage were taken from the block model. Ngezi Mines plant's average concentrator processing recovery rate of 81% and a smelter recovery of 98% were used. These input factors were used to calculate the total amount of metal produced. Spectrometric analysis done in the laboratory comes up with a metal split for concentrate matte to ascertain how much of each mineral is available. This analysis is not part of this research though the split was input in the Zimplats financial model for economic evaluation. The revenue was then calculated as a product of the price per mineral and the total amount. Operating costs were included in the evaluation and these differ with each mining cut size. This is driven by the fact that the larger cuts come with higher mining volumes. Each mining cut scenario was given corresponding statutory payments such as royalties and tax and the outcomes were the undiscounted operating cashflow. A discount factor was applied to the evaluation to give a discounted cashflow and subsequently the NPV.

3.4 Ethical considerations

A formal permission letter was obtained from Zimplats to use the Company’s data solely for the purpose of this research. The objective of the research is clearly outlined in the letter. The letter is attached in Appendix 7.6. The research did not involve human participants so an ethical clearance waiver from the University of the Witwatersrand was obtained (Appendix 7.45).

3.5 Chapter summary

The chapter described how data for the research study was collected from the different departments at Zimplats. It highlighted how quantitative information was also collated at each stage along the production value chain. The block model was validated in Datamine mining software and was found to conform to the expected mineralisation profiles. This is essential as this is the basis of the mining footprint to be evaluated. Historical production data was also collected, and it correlated to the values evaluated from the block model. Economic data was collected as well as all the relevant financial assumptions required in a DCF. The different possible mining cut placement scenarios were also discussed in the chapter. Each iteration is financially evaluated for profitability, with the option having the highest NPV selected. Head grade, tonnage, processing recovery and metals prices are the key components in determining revenue. The results are presented and analysed in Chapter 4.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Chapter overview

Head grade, tonnage, processing recovery and metals prices are the key components in determining revenue. These are the factors used in the mining cut evaluation analysed in this chapter. The data used for the evaluation as outlined in Chapter 3 was for Ngwarati Mine, and the results were deemed applicable to all the other Zimplats mines since the mineralisation characteristics are similar across the Great Dyke. The evaluation was done over 618 701 m^2, which is the remaining mineable area. The mining seams defining a selected mining cut were evaluated against the Ngwarati Mine geological block model to give a head grade and corresponding tonnage. The head grade and tonnage were computed against a processing plant recovery to give the ounces per element. The Zimplats financial model was then used to determine revenue per mining cut, factoring in the capital expenditure, operating costs and applicable statutory financial obligations to calculate the NPV for each possible mining cut scenario. A differential cash flow is presented at the end of the chapter, comparing each mining option with the base case.

4.2 Mining cut evaluation and analysis

The inputs for mining cut evaluation consist of the Mineral Reserve, mining, ore processing and pricing factors. The different mining cut scenarios stated in Chapter 3 were evaluated against the Ngwarati Mine block model to come up with a head grade and tonnage per cut, which are summarised in Figure 4.1 to 4.5. Each mining cut option was iterated relative to the corresponding seams to get a 6E head grade and corresponding tonnage. The full Mineral Reserves evaluation calculations are shown in Appendix 7.7 to 7.11.

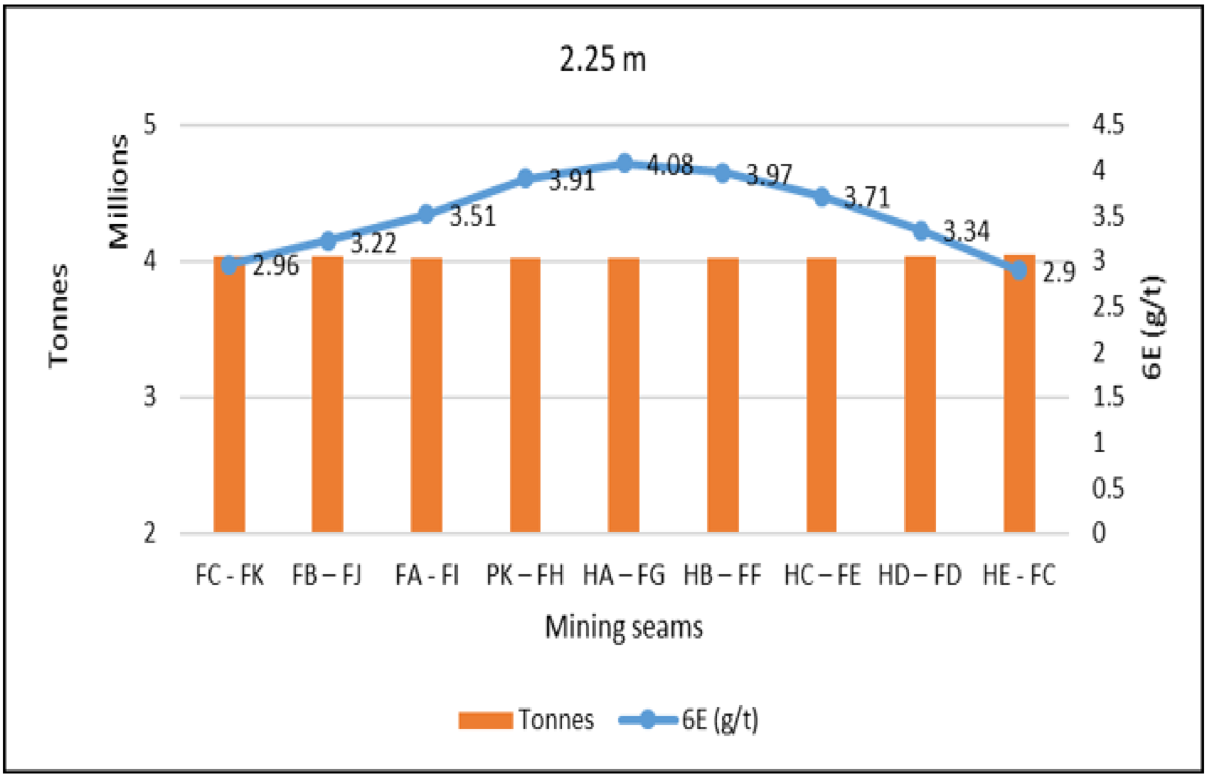

Figure 4.1: Grade and tonnage for the 2.25 m mining cut scenarios

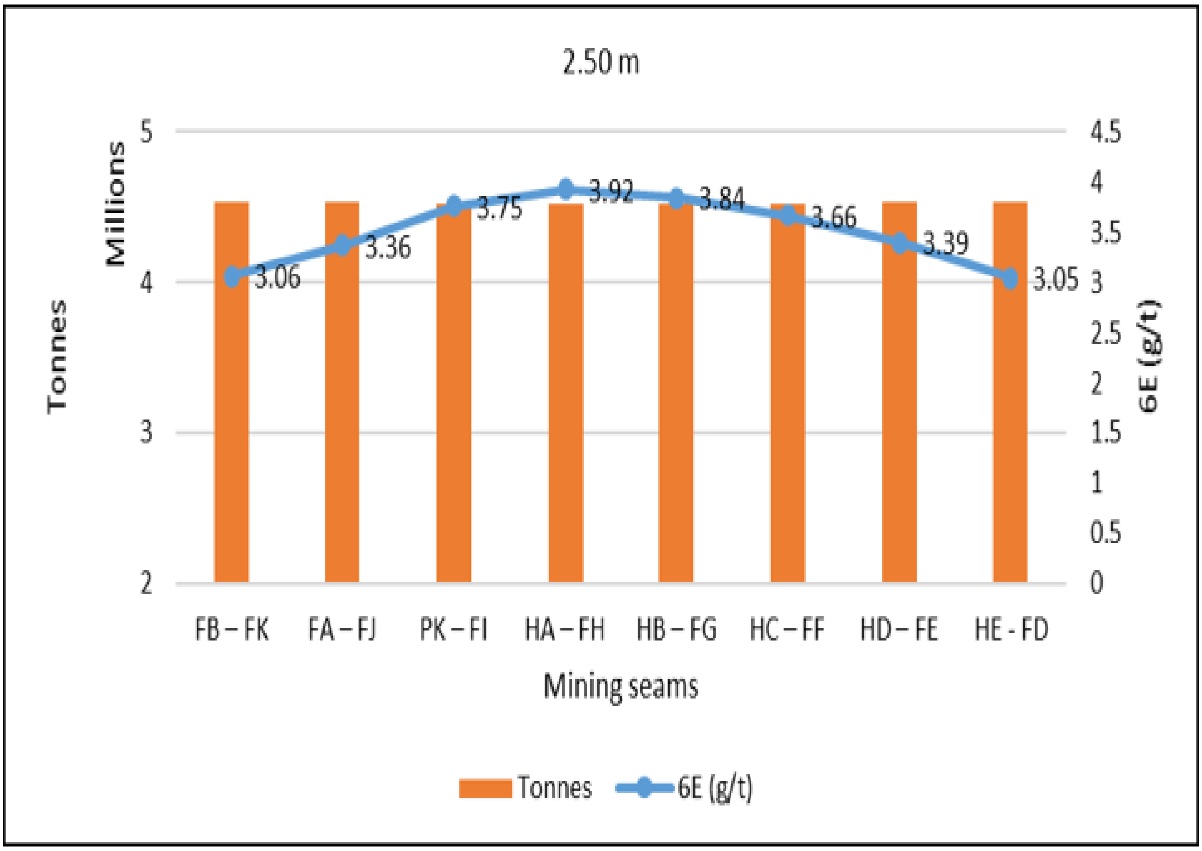

Figure 4.2: Grade and tonnage for the 2.50 m mining cut scenarios

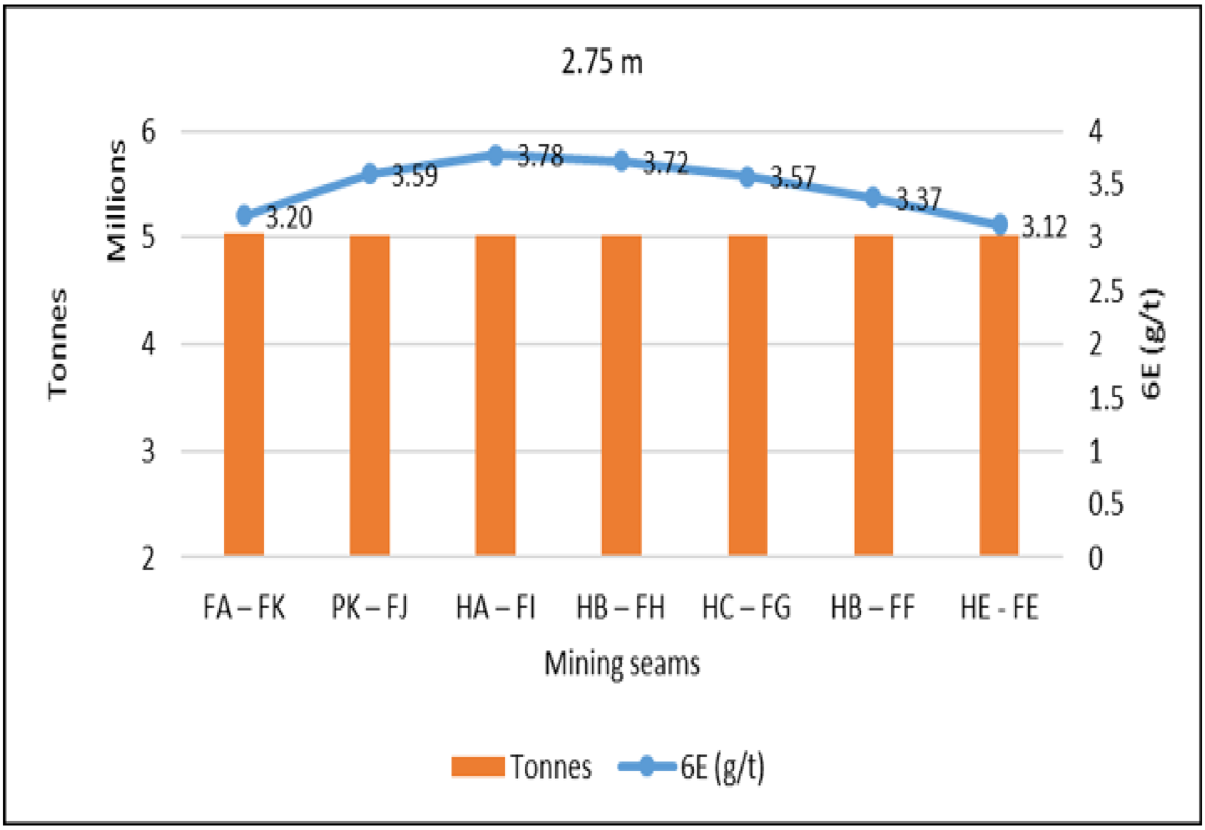

Figure 4.3: Grade and tonnage for the 2.75 m mining cut scenarios

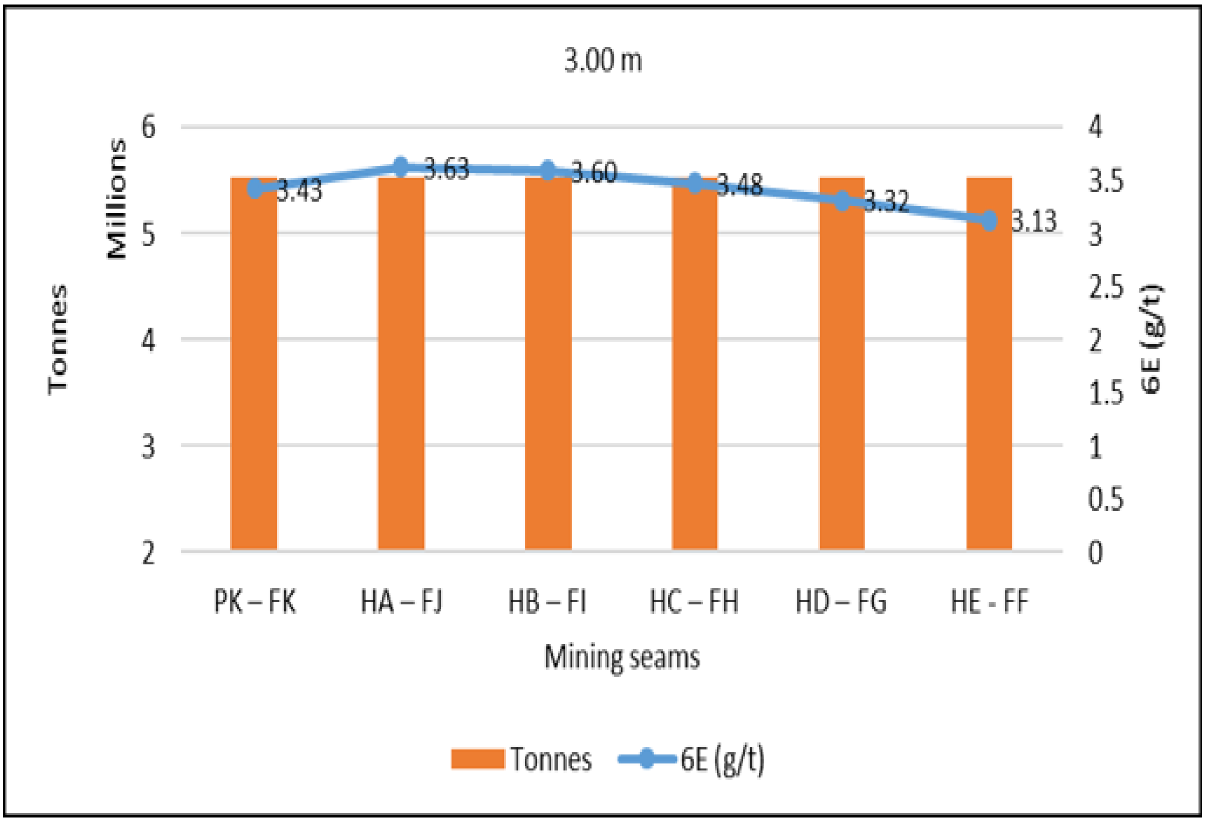

Figure 4.4: Grade and tonnage for the 3.00 m mining cut scenarios

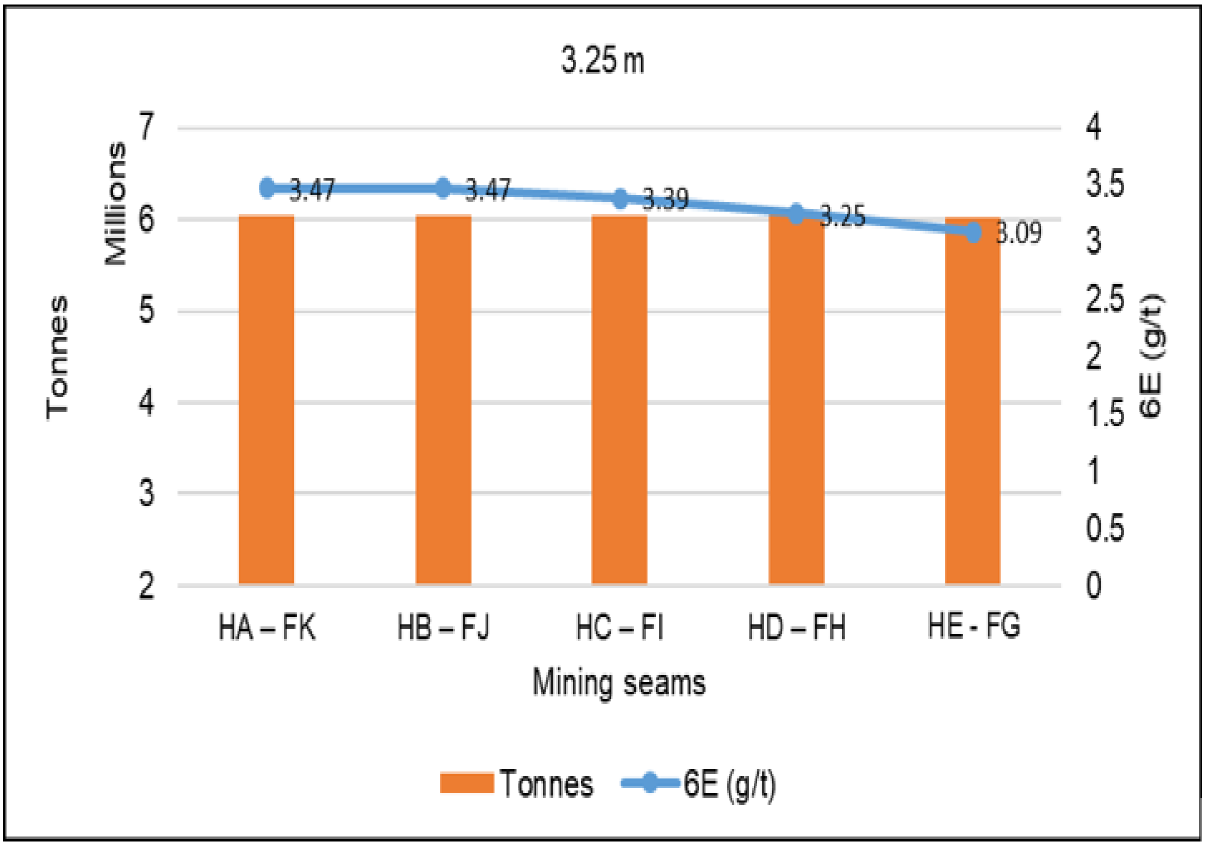

Figure 4.5: Grade and tonnage for the 3.25 m mining cut scenarios

From the above graphs, it was deduced that though a smaller mining cut has lower tonnage compared to a bigger mining cut, it relatively achieved higher peak grades. What was concluded is that there is generally a trade-off between grade and tonnage where bigger mining cuts produced more tonnage at a lower grade. The resultant head grades for each mining cut scenario and the corresponding tonnage as derived from the block model were entered into the Zimplats financial evaluation model, which is in Appendix 7.12. From the model, the head grade was multiplied by the corresponding tonnage for a mining cut. The tonnage per cut was split over a 4-year mining period which is the estimated remaining life for the Ngwarati Mine. This was determined by design rate of production for the mine set during the bankable feasibility study at 1.2 mtpa at a 2.5 m mining cut. The result from the above calculation was multiplied by the processing plant recovery per element and the proportional split to achieve the concentrate ounces produced per element. The concentrate ounces were then multiplied by a smelter recovery of 90% to give the matte ounces. This is the last stage of processing on the Zimplats mineral beneficiation value chain. The matte ounces were multiplied by the price for the corresponding element to get gross revenue per mining cut. As expected, the bigger mining cuts had higher gross revenue than the smaller mining cuts due to the increased tonnage. From the relationship explained earlier, the higher grades on the smaller mining cuts do not directly influence an increase in revenue. However, the influence of handling the increased volumes came with increasing operating costs which are discussed in the next section of the evaluation. The mining operating costs used for the DCF for each mining cut are attached in Appendix 7.13. The calculated gross revenues for each mining cut scenario are tabulated together with DCFs from Appendix 7.14 to 7.58.

4.3 Mining cut scenarios DCFs

Gross revenue was just the first step in determining the potential profitability of each mining cut option. The next step was to input the calculated revenue for each mining cut scenario into the DCF to calculate the NPV per mining cut. A total of 35 DCFs were generated, which correspond to the possible mining cut scenarios evaluated in the research. The NPV per each mining cut scenario was established and compared versus the base case to get a differential cash flow from the current performance as a percentage. The summary of absolute NPVs and differential NPV per mining cut compared to the NPV of the base case mining cut are shown in Figure 4.6 to Figure 4.15. The differential NPV is the difference between the NPV of a selected mining cut scenario subtracted from the base case scenario expressed as a percentage. A negative differential meant the base case scenario remains the better mining cut than the option evaluated and vice versa.

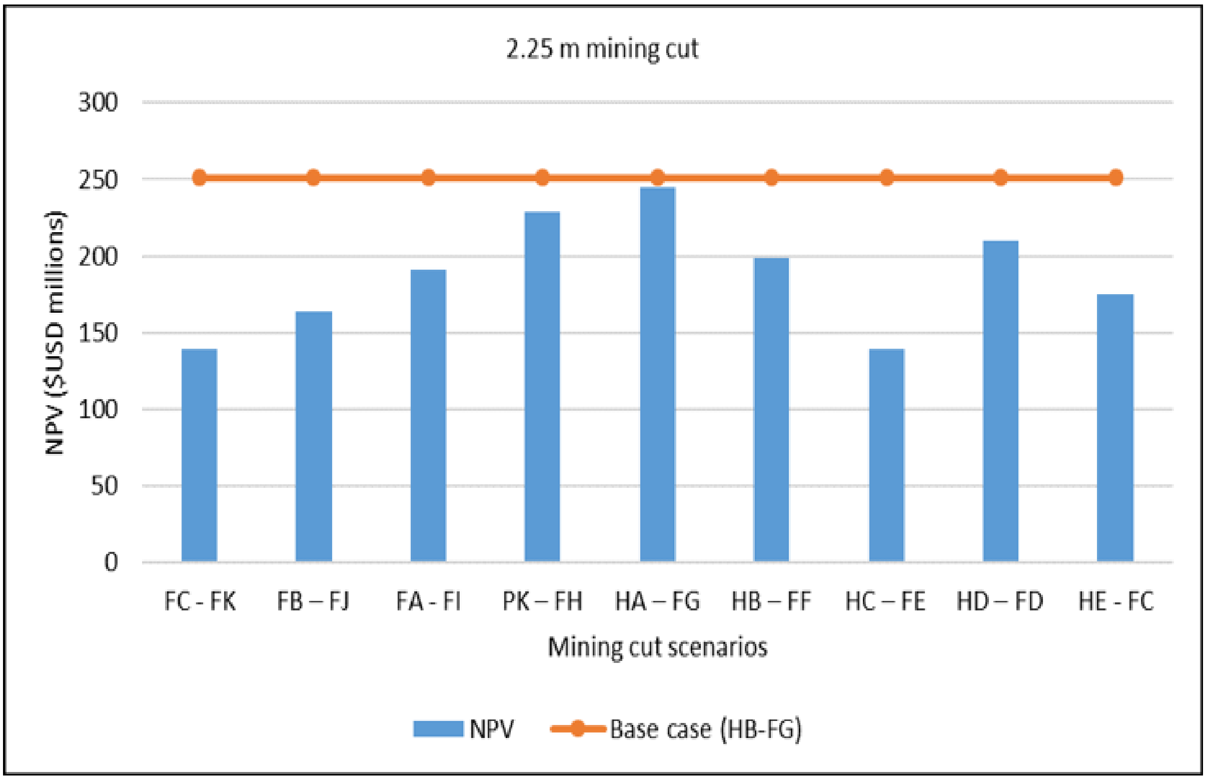

Figure 4.6: NPVs for 2.25 m mining cut plotted versus base case (current 2.50 m)

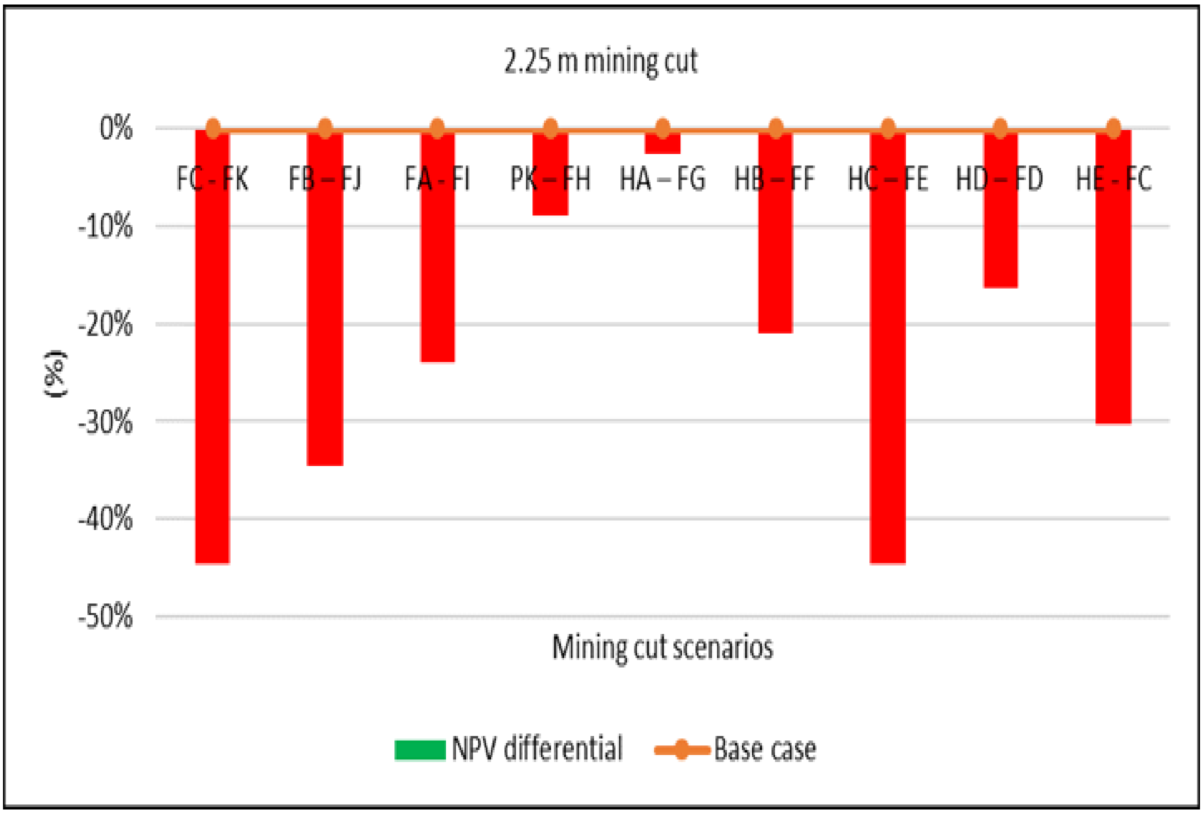

Figure 4.7: NPVs differential for 2.25 m mining cut

As shown in Figure 4.6, all the mining cut scenarios on the 2.25 m option achieved a positive NPV though they performed lower than the base case option. The NPV differentials for all the scenarios shown in Figure 4.7 had negative percentages, which means the mining cut as in current practice remains preferable to any of the options on the 2.25 m options. This is explained by the fact that though some options on the 2.25 m variations had higher grades and a lower operating cost per tonne compared to the base case, those factors did not outweigh the impact due to a drop in tonnage per mining cut. Therefore, the base case maintained a higher NPV. Figures 4.8 and 4.9 are showing the 2.50 m cut options.

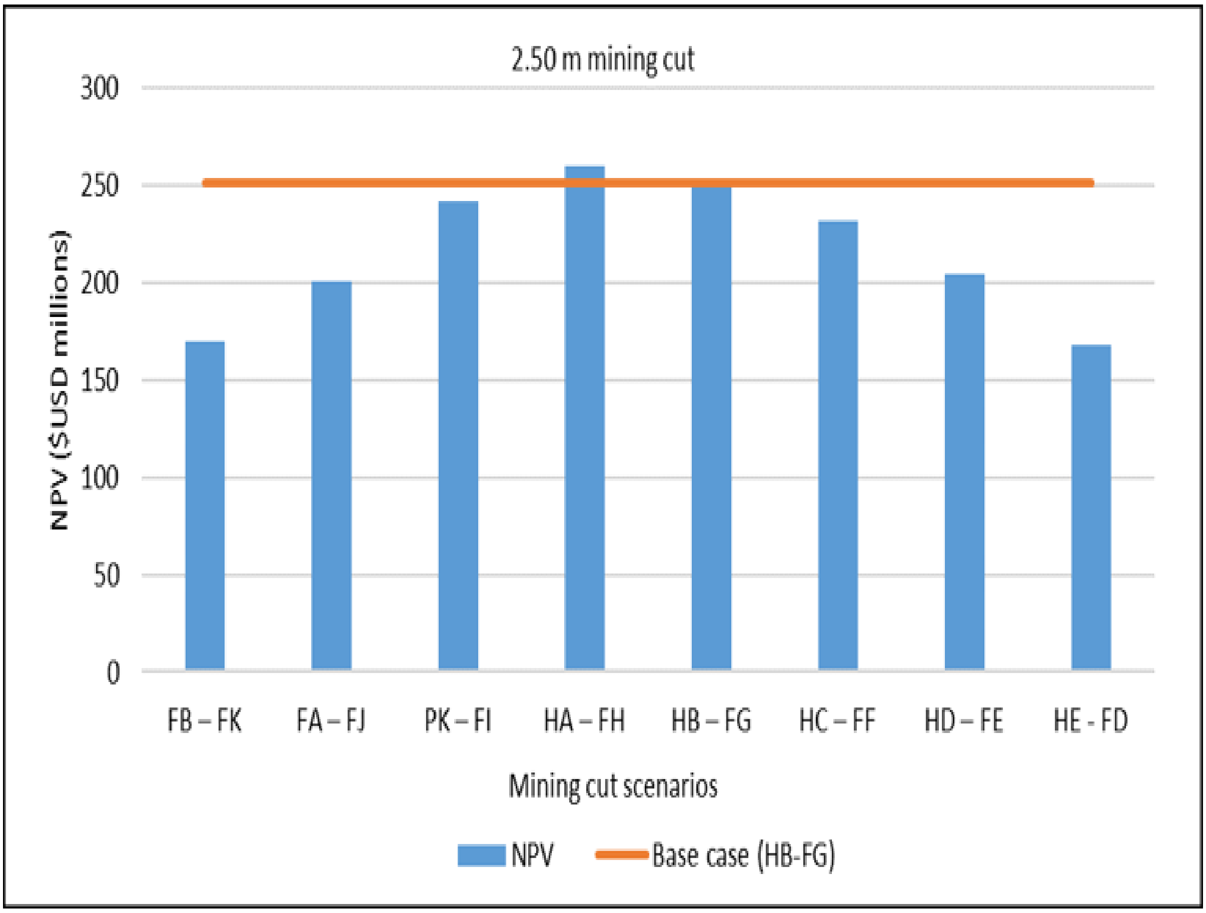

Figure 4.8: NPVs for 2.50 m mining cut plotted versus base case (current 2.50 m)

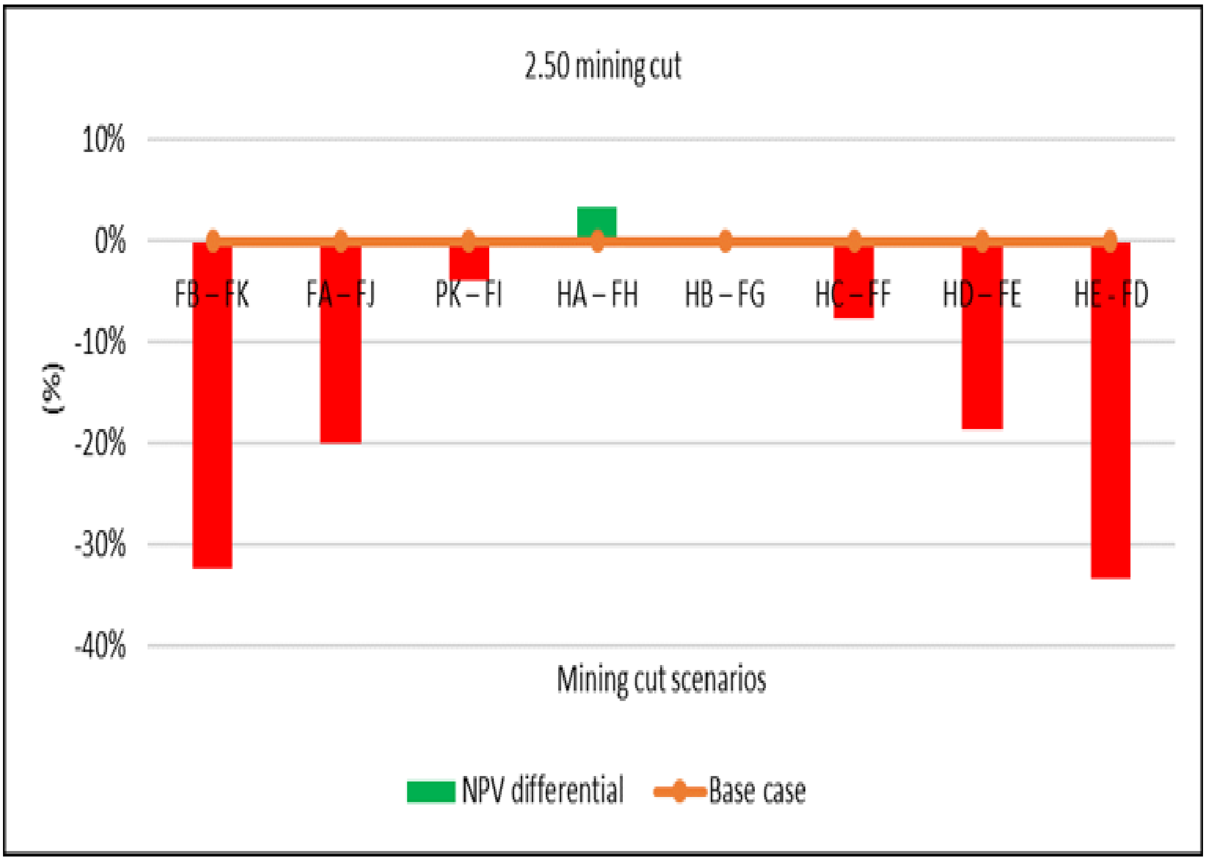

Figure 4.9: NPVs differential for 2.50 m mining cut

On 2.50 m mining cut scenarios, all options achieved positive NPVs. However, in comparison to current practice, all but one scenario had a negative NPV differential. As shown in Figure 4.9, mining cut scenario HA-FH had an NPV of 3.3% better than the base case option. This was driven by partly by Pd enrichment as this scenario is a seam lower than the base case scenario, and it is, therefore, closer to the Pd peak. However, the influence of the other 5E on the revenue calculation also contributed from one mining cut option to the next with the effect increasing towards the Pd peak. All other factors, namely tonnage, operating cost and recoveries, are the same as the base case and thus had no influence in seams HA-FH having a better NPV differential. Zimplats has the option to shift the mining cut to this option as it has a better NPV. This is however subject to how it will compare with the other options in the next sub-sections. Figure 4.10 and Figure 4.11 are explaining the 2.75 m mining cut options.

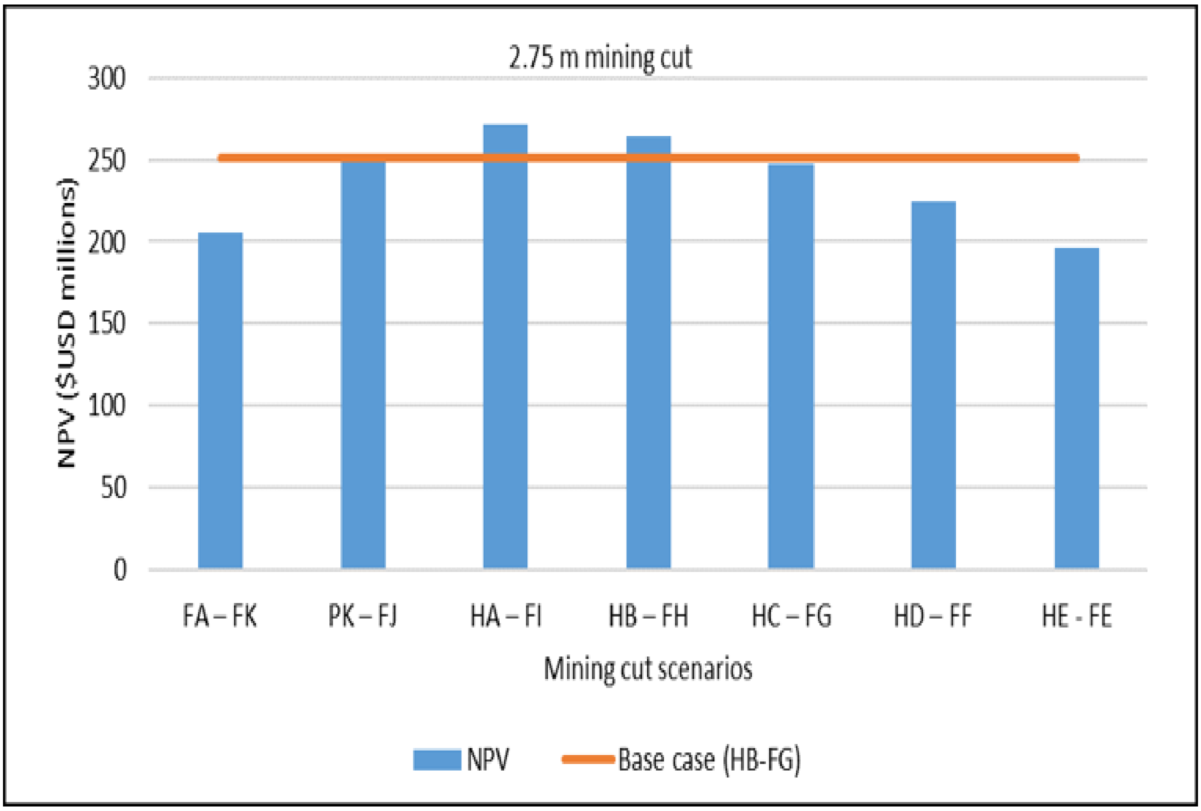

Figure 4.10: NPVs for 2.75 m mining cut plotted versus base case (current 2.50 m)

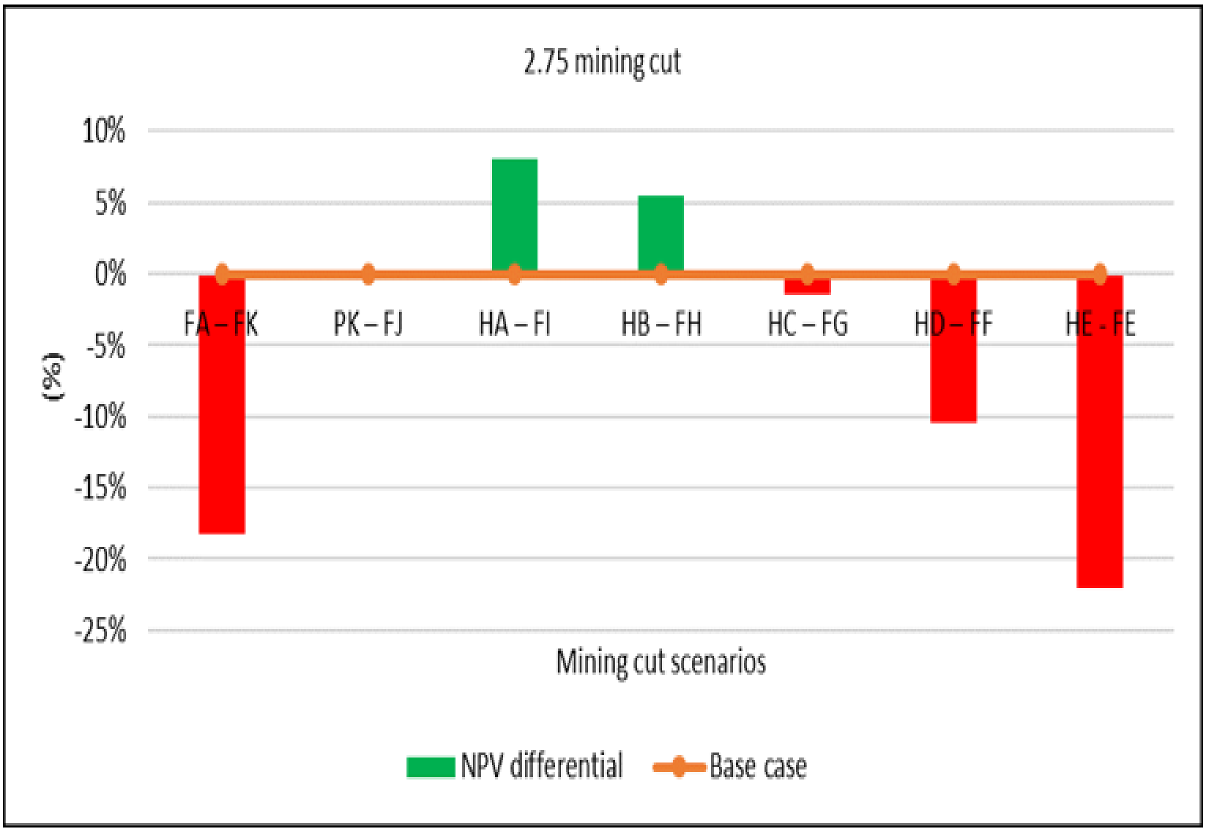

Figure 4.11: NPVs differential for 2.75 m mining cut

As shown in Figure 4.10, all scenarios on the 2.75 m mining cut achieved positive NPVs with two options HA-FI and HB-FH, performing better than the base case. Figure 4.10 goes on to illustrate that the two options mentioned above had an NPV differential of 8.0% and 3.4% better, respectively. This means that Zimplats has the option to adopt any of these two mining cut options to increase revenue. The key factor in HA-FI mining cut option performing better than the base case is due to Pd enrichment as it has more bias towards the Pd peak despite a 3% higher operating cost. The higher operating cost per tonne, as shown in Appendix 7.13, is due to:

- an increase in consumption of drilling consumables for the larger 2.75 m excavation;
- higher consumption of powder which slightly drives the cost of the explosives;
- air tonnage ratio increases causing electrical power to marginally increase;
- the extra tonnage increases causing re-handling costs and
- an increase in TMM maintenance cost as the machines will be handling more tonnage.

Scenario HB–FH has a seam longer than the base case and, therefore, performed better in the economic evaluation due to the influence of increased tonnage despite a higher operating cost as explained above. Figure 4.12 and Figure 4.13 show a comparison of the 3.00 m scenarios.

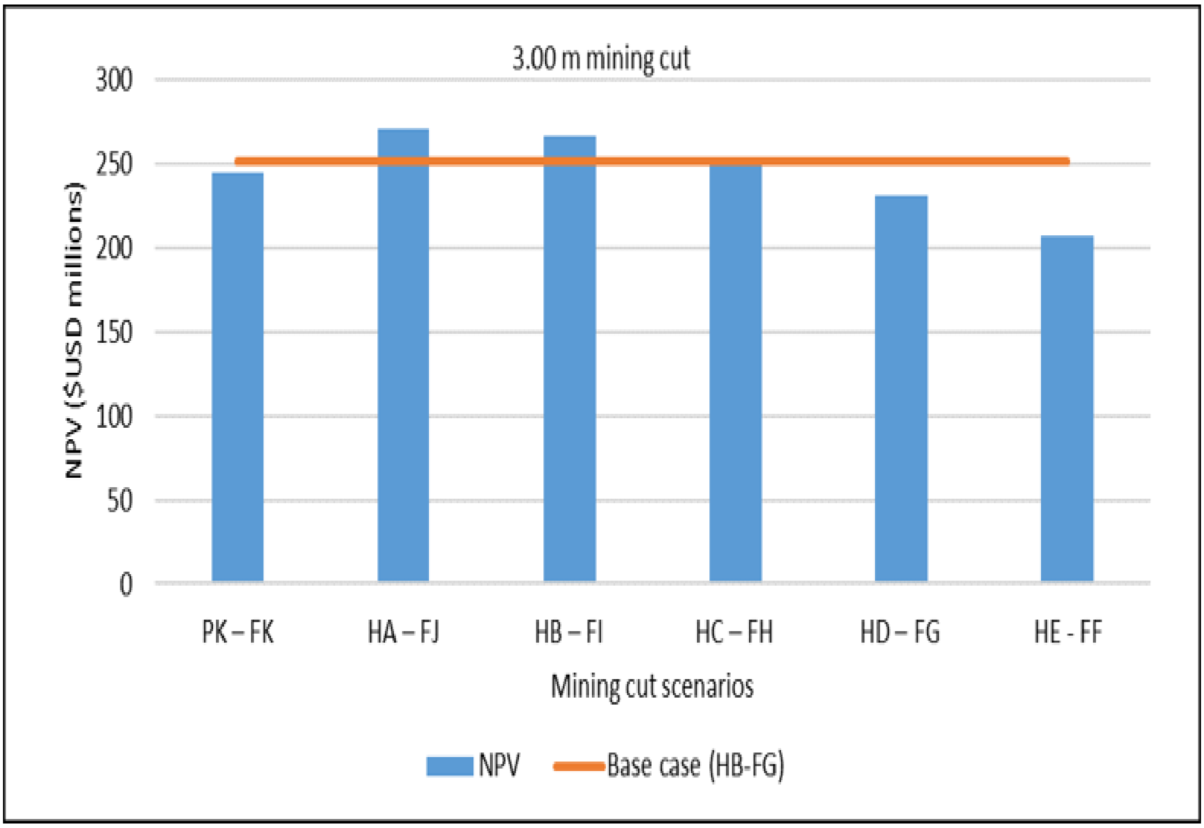

Figure 4.12: NPVs for 3.00 m mining cut plotted versus base case (current 2.50 m)

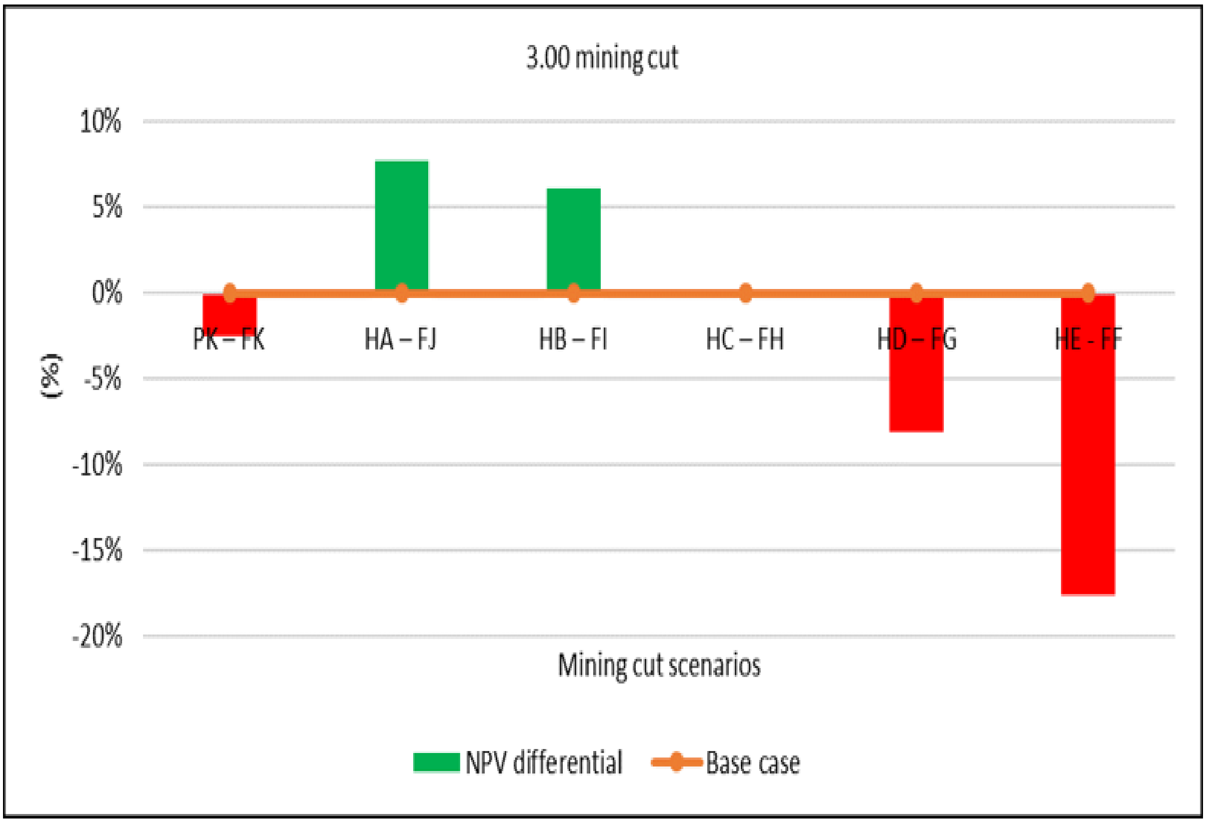

Figure 4.13: NPVs differential for 3.00 m mining cut

As shown in Figure 4.12, all mining cut scenarios had a positive NPV with scenarios HA–FJ, HB–FJ and HC–FH achieving better than the base case, which is the current mining cut at Zimplats mines. As earlier explained on the 2.50 m and 2.75 m mining cut options, lowering the mining cut by 0.25 m is beneficial due to Pd enrichment. This is also demonstrated in the 3.00 m case where the seams HA–FH had a 7.7% NPV differential better than the base case. Scenario HB–FJ and HC–FH were 6.2% and 0.1% better than the base case, respectively. The two latter options performed better than the base case due to higher tonnage despite a higher operating cost per tonne of 16%. As explained on the 2.75 m options, the increase in tonnage comes with a proportional increase in the drilling cost, explosives cost, power consumption, ore re-handling costs and maintenance of TMM. Therefore, on the 3.00 m scenarios, there are three possible options that are amenable for adoption according to the economic evaluation. A review of the 3.25 m options in Figure 4.15, will ultimately show which of the options is came out the best.

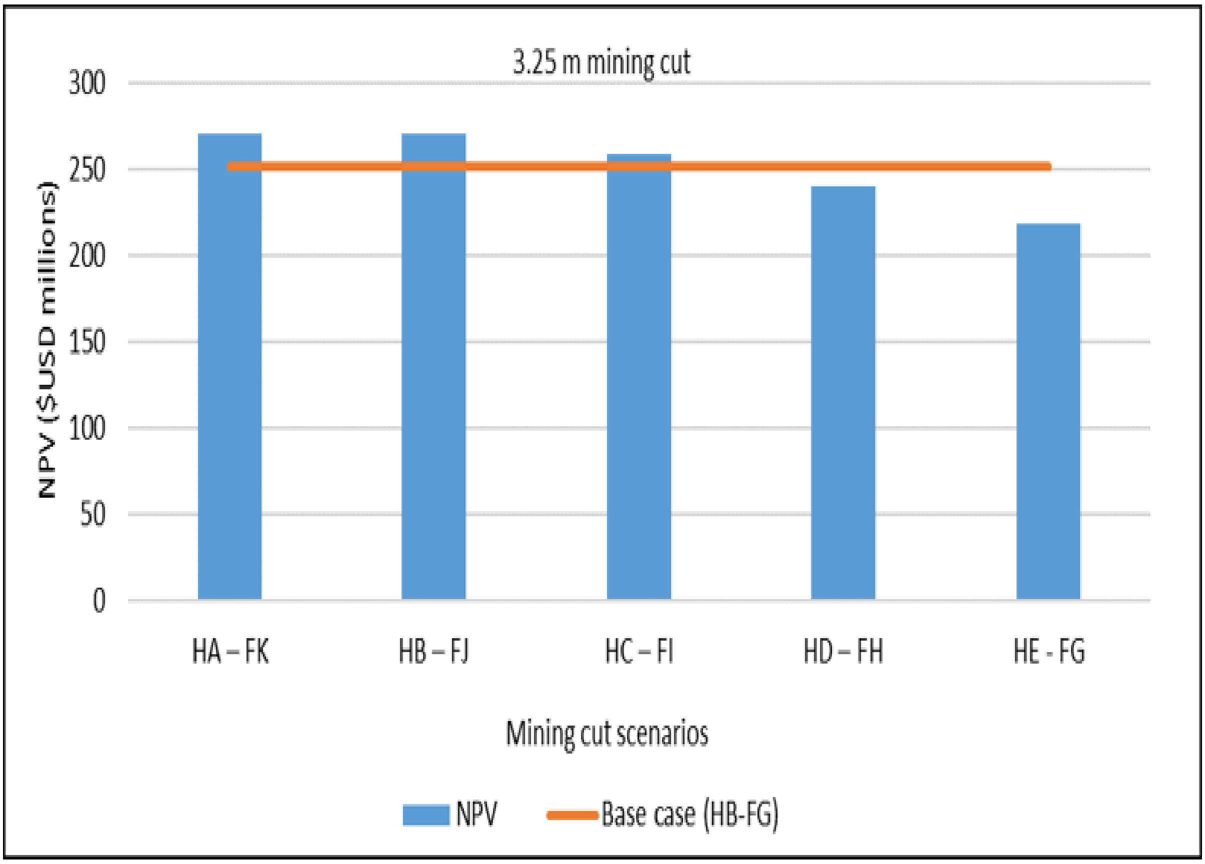

Figure 4.14: NPVs for 3.25 m mining cut plotted versus base case (current 2.50 m)

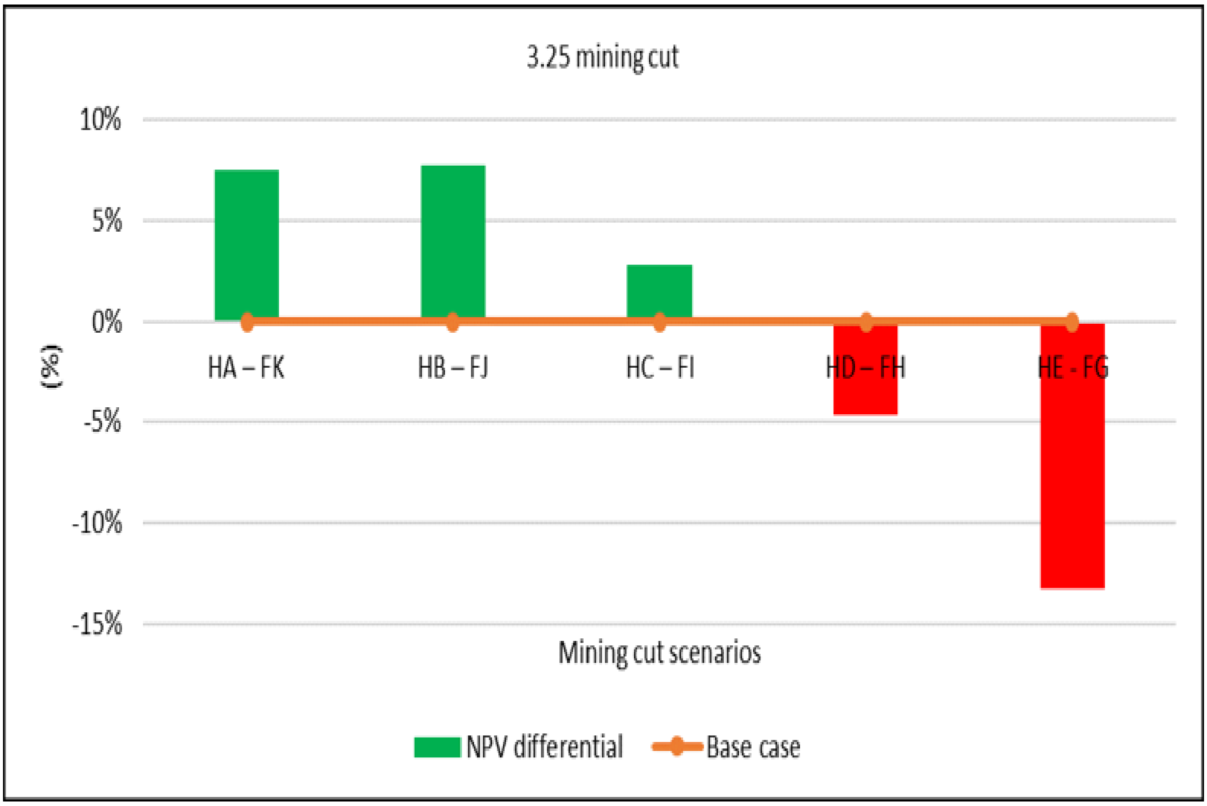

Figure 4.15: NPVs differential for 3.25 m mining cut

As shown in Figure 4.14, all mining cut scenarios had positive NPVs. However, Figure 4.15 illustrates that not all the options are as profitable as the current practice. Scenarios HD–FH and HE–FG are discounted as they have lower NPV differentials compared to the base case. Scenario with seams HA–FK had a 7.5% greater NPV compared to the base case, HB–FJ had 7.8% better than the base case, and HC–FI was 2.8% better. The better NPVs are underscored by an increase in tonnage, Pd enrichment, and an increase in base metal contribution as the mining cut increases. As explained in the mining cut evaluation above, an increase in the mining cut, whilst it brings more tonnage, also increases operating costs. Due to increased tonnage being handled, the machines work more, leading to an increase in TMM maintenance costs, drilling costs increase as machines drills more holes per rock face leading to higher consumption of explosives. Ore re-handle costs increase due to increased volumes as well as the costs of electrical power. These are shown in Appendix 7.13.

The highest differential cash flow was achieved on the 2.75 m mining cut defined by seams HA–FI with an absolute net NPV of $20.2 million, which was 8.0% better than the base case. The main determinant was the amount of mineral content per mining cut plus the tonnage. The capital expenditure cited in the cashflows is Stay in Business (SIB) capital, and it was equalised in all scenarios. Capital for mine establishment was assumed as a sunk cost and was therefore, not incorporated in the evaluation. This economic evaluation was important in demonstrating which mining cut scenario is viable under the current and short-term economic forecast-based economic assumptions. However, the viability of a chosen mining cut also depends on technical constraints, mining extraction being one of the key ones. As explained in Chapter 2, mining extraction is the amount of ore that is recovered from the orebody versus what is left as in-situ pillars, which act as the primary support for the mine. High extraction means the Mineral Reserve is being extracted optimally and is therefore good for the shareholders. A low extraction means potentially, the ore is being left underground as pillars and therefore signifies lower Mineral Reserve utilisation. The extractions for the mining cut options are reviewed in the next subsection.

4.4 Mining extraction

The effective extraction ratios for each mining cut were calculated based on the Ngezi Mines standard operating template for pillar design. The inputs to the design template are shown in Table 4.1.

Table 4.1: Input parameters for pillar strength calculation (3.25 m mining cut used for illustration only)

Overburden Density	32.4	kN/m^3		
Stoping Width	3.25	m		
Orebody Dip	9	°		
Orebody Dip Direction	270	°		
Pillar Size - Dip	7	m		
Pillar Size - Strike	4	m		
Pillar Intact Material UCS	250	MPa		
Pillar RMR	55			
Major Joint Sets	Set 1 Dip	Set 1 Dip Dir	Set 2 Dip	Set 2 Dip Dir
Joint Angle (°)	60	220	60	135
Joint Frequency (J/m)	3		2	
Weathering	2	1 - Fresh, 2 - Slight, 3 - Moderate, 4 - High		
Shear - Strength	15	MPa		
Shear - Average Thickness	0.3	m		
Shear - Splays	0	number		
Blasting Quality	2	1 - Good, 2 - Average, 3 - Poor		
Pillar strength	38.3	**MPa**		

Table 4.1 only shows the input for the 3.25 m mining cut. The parameters for the other mining cut scenarios are similar to those in Table 4.1. The stoping width, orebody dip and direction, as well as the pillar sizes, are populated with dimension data, while the rest of the other cells are populated with rock mass data. This data is transferred to a 'Pillar Design System' calculator to calculate the extraction ratio. Due to the size of the worksheet, it was not possible to attach it directly in this research report. However, the outcome from the evaluation for the mining cut sizes is shown in Table 4.2.

Table 4.2: Mining extraction ratio calculation results

Mining cut size	DBS	Ground class	Pillar size			Pillar centre spacings		Pillar strength	Extraction ratio
(m)	(m)		Dip (m)	Strike (m)	Area (m2)	Dip (m)	Strike (m)	MPa	%
2.25	80	C	5	4	20	11	14	60	82.8
2.5	80	C	5.5	4	22	11	14	52.9	80.6
2.75	80	C	6	4	24	11	14	47.1	78.9
3.0	80	C	6.5	4	26	11	14	42.3	76.2
3.25	80	C	7	4	28	11	14	38.3	73.9

The results in Table 4.2 show that a smaller mining cut will require smaller pillars as the pillar strength will be high. As the mining cut increases, which in this research is a function of the mining cut, the pillar strength starts reducing. The pillar sizes increase in order to maintain good safety factors on the pillars without compromising the stability of the operation. This invariably reflects on the decrease in overall extraction. The optimal extraction for Ngezi mines, according to the Rock Engineering COP, lies between 70% and 85%. An extraction ratio that is too low, outside the mentioned range, affects the profitability of the mine, while an extraction ratio that is too high compromises the regional stability of the mine. Table 4.2 show that the extraction ratios for the mining cuts evaluated in this research are within the tolerance limits for rock mechanics.

4.5 Sensitivity analysis

The economic and technical evaluation done in this research are important to show which mining cut is viable for Ngwarati Mine under prevailing assumptions. However, some input factors which were used in the evaluation are uncertain and subject to volatility such that any change one of the factors can result in the chosen mining cut option becoming unviable and vice-versa. These factors include commodity prices, operating cost and head grade. To analyse the impact of the uncertainty a sensitivity analysis was carried out for the three factors for the 2.75 m mining cut option (HA-FI) that had the highest NPV from the financial evaluation. Each factor was iterated on a sliding scale between -10% and 10% whilst other factors remained constant and assessed the impact on the overall NPV. The outcomes are presented in Figure 4.16.

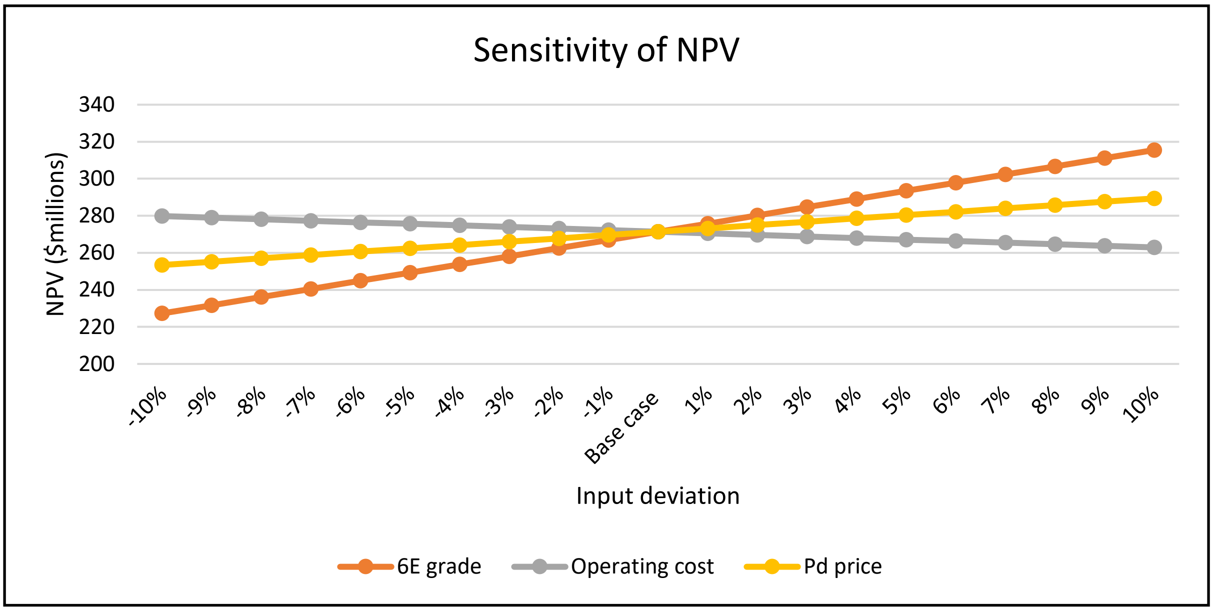

Figure 4-16: Sensitivity analysis results.

Figure 4.16 shows that the NPV was responding to the variation on the factors. As the operating cost increases the NPV goes down and vice versa. As the 6E grade increases, the NPV also takes an upward trend. The same can be said for Pd price. The converse also holds true for 6E grade and Pd price. However, the rate of increase is not the same for the tree factors. Figure 4.16 shows that the gradient for grade is 28%, the gradient for Pd price is 12% and the gradient for operating cost is 6%. This shows the NPV is most sensitivity to 6E grade changes followed by Pd price changes and lastly changes in operating cost. The company must manage these factors to sustain shareholder value.

4.6 Chapter summary

The chapter evaluated different mining cut scenarios against the Ngwarati Mine block model to get a head grade and Mineral Reserve tonnage for each scenario. Financial assumptions, which include metal prices, processing recoveries, taxes, royalties and SIB capital, were then inputted into a DCF to calculate the NPV. A discount rate of 20% was used in the DCF to evaluate the different mining cut options. The resultant NPV of each possible mining cut was compared against the current practice, which was the base case for the research. From the analysis, all options on the 2.25 m mining cuts are not viable as they all had lower NPV. One option on the 2.50 m scenarios had better NPV than the base case. Two scenarios on the 2.75 m scenarios had better NPV than the base case. Three scenarios had better NPV for both the 3.00m and 3.25 m mining cut options. The 2.75 m mining cut scenario defined by seams HA–FI had the highest NPV, which was 8.0% better than the base case. The extraction ratio for each mining cut was calculated, and all are within the tolerance ratio of the Zimplats rock mechanics COP. Chapter 5 presents a summary of the research and concluding remarks. It ends the research with recommendations on the optimal mining cut for the Ngezi mines and opportunities for further studies to optimise the mining cut.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Chapter overview

From the research analysis, several findings were drawn in the optimisation of the mining cut. These determined the final NPV of each mining cut scenario and will be discussed in the following sections. This chapter concludes by giving recommendations to improve and validate mining cut optimisation for Ngwarati Mine.

5.2 Summary

The literature review highlighted the opportunity associated with the envisioned long-term trend between the supply and demand of PGMs. This might enable PGM producers on the Great Dyke to take advantage of mineral pricing projections in short to medium-term. The literature review also highlighted the importance of value creation in the mining industry. It demonstrated that shareholders invest in a business to create value. It goes on to state that value is created through the optimisation of the production processes. Traditionally, optimisation techniques have been largely used in open-pit operations for the reasons cited in the report. Underground operations have been lagging in terms of optimisation techniques largely due to varying extraction methods that make generic optimisation difficult. However, recent research has seen new optimisation techniques suited for underground mining being developed. This research focussed on underground stope optimisation with a particular focus on the mining cut. It aimed to show the economic benefit of optimising Pd extraction on the Great Dyke reef to maximise the NPV of the mining project.

Various mining cut scenarios were determined from the mineralised and economic zone of Ngwarati Mine, which was used as the case study. The mining cut options were economically evaluated to get the option with the highest NPV. The research revealed that the smaller the mining cut, the higher the head grade but with lesser tonnage. Conversely, the higher the mining cut, the lower the grade but higher tonnage. The main determinant in calculating the NPV was the operating costs assumed to mine each mining cut. The research showed that the smaller mining cut options were cheaper to mine. This is because as the mining cut increases, variable costs (for example, drilling consumables, electrical power, TMM maintenance, explosives and ore handling costs) negates some of the perceived benefits that come with increased tonnage.

The financial evaluation showed that all mining cut options were profitable based on the calculated NPVs. The base case for the research was set as current practice, which is the 2.50 m mining cut defined by seams HB–FG. All options on the 2.25 m scenarios had lower NPVs compared to the base case; therefore, these are not considered viable for adoption by Zimplats. On the 2.50 m scenarios, one option defined by seams HA–FH had a 3.3% better NPV. The explanation as detailed in Chapter 4 is due to Pd enrichment in the mining cut as it has more bias towards the Pd peak compared to the base case. Three of the scenarios on the 3.00 m and 3.25 m mining cut scenarios were viable with better NPVs than the base case. This was attributed to an increase in tonnage recovered for the mining cut and improved processing recovery of Pd plus base metals.

The IRR for the project was not calculated since the Ngwarati mine is a going concern. The mine is already operating, and the research did not consider the capital expenditure for mine development. This was deemed a sunk cost in all scenarios.

5.3 Research findings

The base case mining cut (seams HB-FG) had a net positive NPV of $251,150,853. Within the 2.50 m options, the mining cut scenario (seams HA–FH) had a higher NPV with a net positive of $259,643,729. Relatively the study shows that shifting the mining slice by 0.25 m into the footwall towards a Pd peak whilst maintaining the 2.5 m cut delivers a higher grade and enriches Pd extraction. Reducing the mining cut by 0.25 m to the 2.25 m mining cut options is not recommended, given its negative impact on productivity. Total tonnes decrease by 10% and choosing this option affect mill feed tonnage without a commensurate gain in recovered metal ounces.

The option to mine wider at 2.75 m which was the third scenario, delivers improved productivity and revenues. Relative to the base case, the cut option with the highest NPV (seams HA–FI) had an 8% better NPV of $271,394,963 and produced 10% better than the base case on tonnage. This option is possible for implementation with extra tonnage available for stockpiling. No new equipment would be required to operate in the increased stopes as the current machine suite is suitable. However, the overall extraction ratio would be reduced by 2% due to larger pillars required to compensate for the increase in height though it remains within Zimplats rock mechanics tolerance. The fourth scenario at 3.00 m increases the mining cut by 0.5 m relative to the base case. The option that achieved the highest NPV (seams HA–FJ) was 7.7% better than the base case and gave 1.01 Mt of extra tonnage. This increases the surface ore stockpiles and the re-handling costs, which feed the stockpiles. Overall, it marginally falls behind the best option on the 2.75 m cut option. The overall extraction ratio is reduced by 4% due to an increase in pillar width relative to height.

The scenario to mine to 3.25 m was evaluated as the fifth option. The option defined by seams 'HB–FJ' achieved an NPV that was 7.8% better relative to the base case. In terms of tonnage, the option produces 1.5 Mt, which is 30% higher than the current volumes. This increases the surface ore stockpile and thus, escalates ore re-handling costs. Overall, it achieves the highest operating costs. This option is also discounted because at an average of 3.25 m height, ends that get into the poor ground, and inadvertently over-break will be difficult to operate in using the current equipment. As stated earlier in the research, Capex has no provision to purchase an additional or a different suite of underground TMM.

5.4 Conclusion

The geological block model of the Zimplats' Ngwarati Mine orebody was reviewed during the research study and was validated using Vulcan mine planning software. Head grade and Mineral Reserve tonnages used in the mining cut evaluation were from the aforementioned block model. The orebody model showed the metal distribution in the MSZ for Ngwarati Mine to give a 6-E head grade for each mining cut. The research also focussed on the available literature and concluded that optimisation in underground mines was lagging relative to open-pit operations. However, recent years have seen traction in underground optimisation because, globally, close to the surface, Mineral Resources are fast getting depleted, and mineral grades are also going down. The remaining Mineral Resources are seated deeper into the ground, making them more amenable to underground mining. The research focused on underground optimisation, in particular, the mining cut for Ngezi mines on the Great Dyke of Zimbabwe. Several iterations were carried out with different mining cut scenarios within the orebody of Ngwarati Mine, which was the project area. The current mining cut of 2.50 m (seams HB–FG) was used as the base case for the research. From the research findings above, the initiative to lower the mining cut by 0.25 m and add another seam of 0.25 m to give an overall mining cut of 2.75 m achieved the highest NPV of $ 271,394,963. According to the economic evaluation, the optimum mining cut was defined by seams 'HA–FI', and it was the one recommended for Ngezi mining operations under current technical and economic assumptions.

5.5. Research limitations

The economic evaluation was done using a 6E head grade to calculate the revenues and subsequently the NPVs. However, it excluded other minerals which occur in smaller quantities which are silver, osmium and cobalt which are by-products of the refining process. Including these minerals in the analysis could potentially change the NPVs if supply and demands patterns change. The other limitation is that the research assumed no capital injection on new TMM. That invariably fixes the capital expenditure section of the economic evaluation and assumes all scenarios are the same on that line which might not be a true reflection. A bigger mining cut may require, for example, a bigger LHD to move the increased tonnage but this was not catered for in the research.

5.6 Recommendations and suggestions for future research work

Since the mining cut has been lowered towards the Pd peak, the risk of losing Pt peak due to hangingwall under-breaks increases. This could potentially erode the anticipated benefit of optimising the mining cut. The mining teams are required to monitor mining practices diligently to avoid losing the benefit of the mining cut optimisation. It is, therefore, recommended to put Ngwarati Mine on a trial period of at least six months mining the 2.75 m mining cut before rolling out the initiative to the other mines. Geology and mineral processing departments will monitor feed ratios to the processing plant and trend results to qualify the benefit of the initiative.

The following are recommendations for future research work:

- Carry out the economic evaluation using all the recoverable minerals in addition to the 6Es.
- Introduce variables like changing the equipment into the research and evaluate the effect on NPV.

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APPENDICES

7.1 Actual production performance year 2018 to 2020

	Year 2018 actual	Year 2019 actual	Year 2020 actual	Year 2021 budget
Ore mined				
Ngwarati Mine (t)	1,204,803	1,133,737	1,166,388	1,177,832
Head grade				
Ngwarati Mine (g/t)	3.52	3.50	3.50	3.50
Mill Feed Grade				
Ngezi concentrator (g/t)	3.48	3.48	3.47	3.47
SMC concentrator (g/t)	3.52	3.52	3.53	3.48
Total 6E (g/t)	3.50	3.49	3.49	3.48

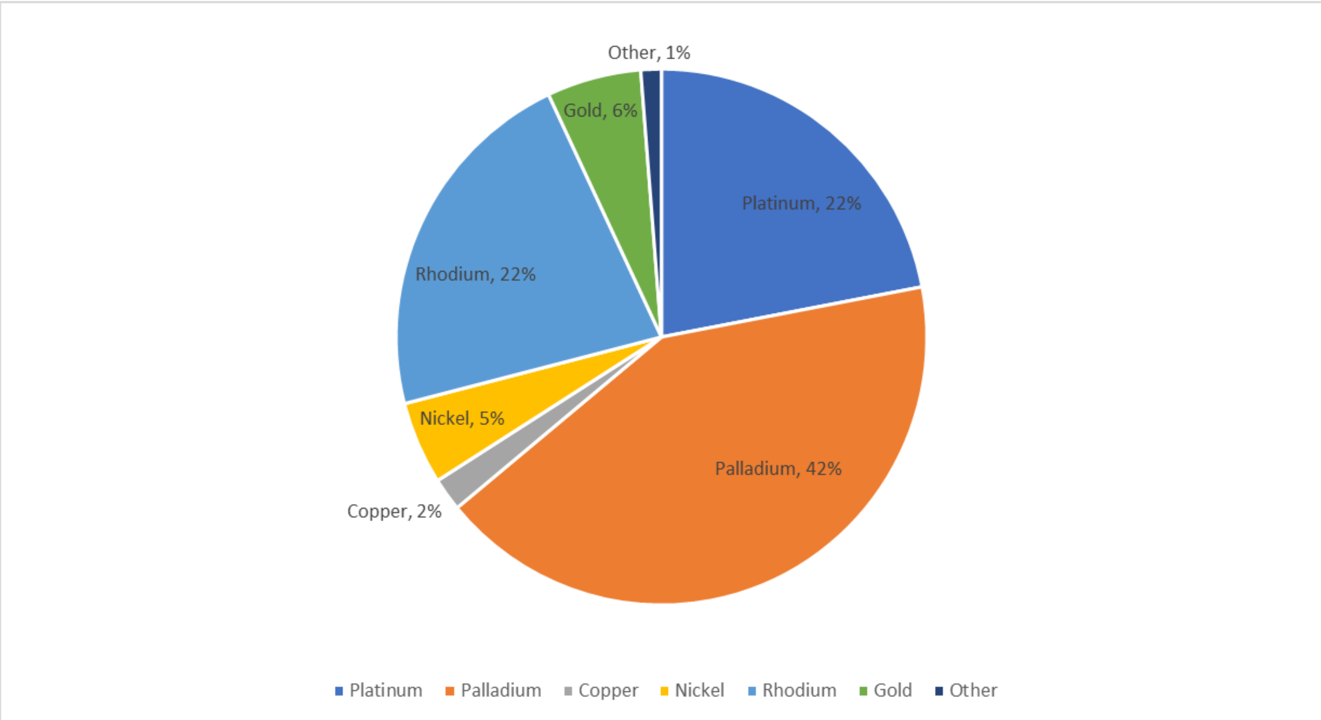
7.2 Metal Prices Forecast

Metal prices & exchange rate		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Assumption											
Exchange rate	R/$	14.90	15.22	15.81	16.43	17.08	17.08	17.76	18.47	19.21	19.98
Platinum	$/oz	923	850	875	925	1,071	1,071	1,092	1,114	1,137	1,159
Palladium	$/oz	2,171	1,846	1,773	1,669	1,384	1,384	1,412	1,440	1,469	1,498
Rhodium	$/Oz	12,984	11,000	10,350	9,375	3,500	3,500	3,570	3,641	3,714	3,789
Ruthenium	$/Oz	236	240	244	249	190	190	194	198	202	206
Iridium	$/Oz	1,706	1,632	1,665	1,698	1,173	1,173	1,196	1,220	1,245	1,270
Gold	$/Oz	1,937	1,721	1,637	1,574	1,490	1,490	1,520	1,550	1,581	1,613
Nickel	$/t	15,351	14,946	14,948	15,865	18,400	18,400	18,768	19,143	19,526	19,917
Copper	$/t	6,964	6,438	6,219	6,367	7,100	7,100	7,242	7,387	7,535	7,685

7.3 Taxation and royalties

Zimplats - Unconstrained	Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Zimbabwe tax rate	%	25.75	25.75	25.75	25.75	25.75	25.75	25.75	25.75	25.75	25.75
Pt royalty		3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38
PGM royalty	%	4.88	4.88	4.88	4.88	4.88	4.88	4.88	4.88	4.88	4.88
Au royalty	%	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Base metal royalty	%	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88
Export levy	%	-	-	-	-	-	-	-	-	-	-

7.4 Average actual contributions to revenue by each metal for the year 2018-2020



7.5 Pillar sizes according to ground conditions

DBS vs Mining cut																	
DBS (m)	Mining cut																
	1.9	2.0	2.05	2.1	2.15	2.2	2.25	2.3	2.35	2.4	2.45	2.5	2.55	2.6	2.65	2.7	2.75
150	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
200	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
250	4	4	4	4	4.25	4.5	4.5	4.5	4.75	5	5	5	5	5	5	5	5
300	4.5	5	5	5	5	5	5.25	5.5	5.5	5.5	5.75	6	6.5	6.75	7	7	7
350	5	5.5	5.75	6	6	6	6.25	6.5	6.5	6.5	6.75	7	7	7	7	7	7
400	6	6.5	6.5	6.5	6.75	7	7.25	7.5	7.75	8	8	8	8	8	8	8	8
450	7	7	7.25	7.5	7.75	8	8.25	8.5	8.75	9	9.25	9.5	9.5	9.5	9.5	9.5	9.5
500	7.5	8	8.25	8.5	8.75	9	9.5	10	10.25	10.5	10.75	11	11	11	11	11	11
550	8.5	9.5	9.75	10	10.25	10.5	10.75	11	11.5	12	12.5	13	13	13	13	13	13
600	10	10.5	10.75	11	11.5	12	12.5	13	13	13	13.25	13.5	13.5	13.5	13.5	13.5	13.5
650	11	12	12.25	12.5	13	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	14	14	14

7.7 2.25 m mining cut total Mineral Reserve and grade calculation

Seams defining mining cut	Pt (g/t)	Pd (g/t)	Au (g/t)	Rh (g/t)	Ru (g/t)	Ir (g/t)	Ni	NS	Cu	6E (g/t)	SG	Tonnes
FC - FK	1.09	1.43	0.07	0.14	0.13	0.06	839	479	256	2.96	3.23	4,498,100
FB – FJ	1.27	1.50	0.09	0.15	0.14	0.06	898	544	297	3.22	3.22	4,488,825
FA - FI	1.49	1.53	0.12	0.15	0.14	0.06	981	633	353	3.51	3.22	4,481,651
PK – FH	1.79	1.55	0.18	0.16	0.14	0.07	1,149	815	472	3.91	3.21	4,479,813
HA – FG	1.95	1.51	0.25	0.16	0.13	0.07	1,362	1,042	623	4.08	3.21	4,478,103
HB – FF	1.94	1.39	0.29	0.14	0.12	0.06	1,518	1,210	731	3.97	3.22	4,481,822
HC – FE	1.86	1.22	0.31	0.13	0.11	0.06	1,605	1,304	794	3.71	3.22	4,485,867
HD – FD	1.71	1.02	0.32	0.11	0.09	0.05	1,646	1,352	826	3.33	3.22	4,493,582
HE - FC	1.52	0.82	0.32	0.09	0.08	0.04	1,680	1,392	860	2.90	3.23	4,504,310

7.8 2.50 m mining cut total Mineral Reserve and grade calculation

Seams defining mining cut	Pt (g/t)	Pd (g/t)	Au (g/t)	Rh (g/t)	Ru (g/t)	Ir (g/t)	Ni	NS	Cu	6E (g/t)	SG	Tonnes

FB – FK	1.19	1.43	0.09	0.14	0.13	0.06	874	518	280	3.06	3.22	4,994,594
FA – FJ	1.40	1.48	0.11	0.15	0.14	0.06	949	599	332	3.36	3.22	4,987,095
PK – FI	1.67	1.52	0.16	0.15	0.14	0.06	1,102	763	440	3.75	3.22	4,983,179
HA – FH	1.83	1.49	0.23	0.15	0.13	0.06	1,297	973	578	3.92	3.22	4,983,140
HB – FG	1.83	1.39	0.27	0.14	0.12	0.06	1,440	1,127	677	3.84	3.22	4,982,846
HC – FF	1.78	1.26	0.29	0.13	0.11	0.06	1,527	1,220	740	3.65	3.22	4,984,873
HD – FE	1.69	1.10	0.30	0.12	0.10	0.05	1,583	1,283	781	3.39	3.22	4,988,816
HE - FD	1.56	0.92	0.31	0.10	0.08	0.04	1,626	1,332	818	3.04	3.23	4,995,037

7.9 2.75 m mining cut total Mineral Reserve and Grade calculation

Seams defining mining cut	Pt (g/t)	Pd (g/t)	Au (g/t)	Rh (g/t)	Ru (g/t)	Ir (g/t)	Ni	NS	Cu	6E (g/t)	SG	Tonnes
FA – FK	1.32	1.42	0.10	0.14	0.13	0.06	923	570	314	3.20	3.22	5,492,865
PK – FJ	1.59	1.48	0.15	0.15	0.14	0.06	1,062	720	413	3.59	3.22	5,488,624
HA – FI	1.73	1.47	0.21	0.15	0.13	0.06	1,240	911	539	3.77	3.22	5,486,506
HB – FH	1.74	1.39	0.24	0.14	0.12	0.06	1,374	1,056	632	3.71	3.22	5,487,883
HC – FG	1.70	1.28	0.27	0.13	0.11	0.06	1,455	1,143	690	3.57	3.22	5,485,897
HB – FF	1.64	1.16	0.28	0.12	0.10	0.05	1,514	1,208	733	3.37	3.22	5,487,821
HE - FE	1.55	1.01	0.29	0.11	0.09	0.05	1,570	1,271	777	3.12	3.22	5,490,271

7.10 3.00 m mining cut total Mineral Reserve and grade calculation

Seams defining mining cut	Pt (g/t)	Pd (g/t)	Au (g/t)	Rh (g/t)	Ru (g/t)	Ir (g/t)	Ni	NS	Cu	6E (g/t)	SG	Tonnes
PK – FK	1.49	1.42	0.14	0.15	0.14	0.06	1,028	683	390	3.42	3.23	5,994,393
HA – FJ	1.64	1.43	0.19	0.15	0.13	0.06	1,192	860	506	3.62	3.22	5,991,951
HB – FI	1.65	1.38	0.23	0.14	0.12	0.06	1,315	993	592	3.59	3.22	5,991,249
HC – FH	1.62	1.29	0.25	0.13	0.11	0.05	1,393	1,077	647	3.47	3.22	5,990,933
HD – FG	1.58	1.18	0.26	0.12	0.10	0.05	1,449	1,139	688	3.31	3.22	5,988,845
HE - FF	1.51	1.06	0.27	0.11	0.09	0.05	1,508	1,204	734	3.12	3.22	5,989,276

7.11 3.25 m mining cut total Mineral Reserve and grade calculation

Seams defining mining cut	Pt (g/t)	Pd (g/t)	Au (g/t)	Rh (g/t)	Ru (g/t)	Ir (g/t)	Ni	NS	Cu	6E (g/t)	SG	Tonnes
HA – FK	1.55	1.39	0.18	0.14	0.13	0.06	1,150	815	478	3.47	3.23	6,497,720
HB – FJ	1.57	1.35	0.21	0.14	0.12	0.06	1,265	939	557	3.47	3.23	6,496,694
HC – FI	1.55	1.28	0.23	0.13	0.11	0.05	1,337	1,017	609	3.38	3.23	6,494,300
HD – FH	1.51	1.19	0.24	0.12	0.10	0.05	1,392	1,078	649	3.25	3.23	6,493,882
HE - FG	1.46	1.09	0.26	0.11	0.10	0.05	1,448	1,140	692	3.09	3.22	6,490,300

7.12 Mining cut evaluation financial model

Mining Cut Evaluation	Year	2021	2022	2023	2024
365	Month	[All]	[All]	[All]	[All]
Year	n	0	1	2	3
Tonnes mined					
Tonnes mined	t	1,648,161	1,642,272	1,630,552	1,569,315
Grade	6E g/t	3.10	3.10	3.10	3.10
Kilograms	6E kg	5,110	5,092	5,056	4,866
Tonnes milled					
Tonnes milled	t	1,648,161	1,642,272	1,630,552	1,569,315
Grade	6E g/t	3.10	3.10	3.10	3.10
Kilograms	6E kg	5,110	5,092	5,056	4,866
Concentrator					
FACF	factor	1.030	1.030	1.030	1.030
Metal split | pt	%	46.44	46.43	46.43	46.43
Metal split | pd	%	36.45	36.45	36.45	36.45
Metal split | rh	%	3.90	3.90	3.90	3.90
Metal split | ru	%	4.13	4.13	4.13	4.13
Metal split | ir	%	2.21	2.20	2.20	2.20
Metal split | au	%	6.88	6.88	6.88	6.88
Metal split | ni	%	0.10	0.10	0.10	0.10
Metal split | cu	%	0.07	0.07	0.07	0.07
Recovery | overall	%	79.18	79.19	79.11	79.14
Recovery | pt	%	79.64	79.64	79.56	79.59
Recovery | pd	%	86.34	86.35	86.27	86.30
Recovery | rh	%	77.15	77.10	76.97	76.99
Recovery | ru	%	55.79	55.75	76.97	76.99
Recovery | ir	%	55.50	55.46	55.36	55.38
Recovery | au	%	63.73	63.77	63.76	63.78
Recovery | ni	%	85.86	85.85	85.74	85.77
Recovery | cu	%	90.77	90.76	90.66	90.69
Concentrate | Total	oz	129,640	129,184	128,135	123,365
Platinum	oz	60,202	59,985	59,495	57,284
Palladium	oz	47,255	47,092	46,711	44,971
Rhodium	oz	5,060	5,043	5,002	4,816
Ruthenium	oz	5,349	5,336	5,295	5,095
Iridium	oz	2,860	2,845	2,819	2,717
Gold	oz	8,913	8,884	8,812	8,483
Nickel	oz	1,261	1,266	1,260	1,211
Copper	oz	895	899	895	860
Smelter					
Recovery | pt	%	98.00	98.00	98.00	98.00
Recovery | pd	%	98.00	98.00	98.00	98.00
Recovery | rh	%	98.00	98.00	98.00	98.00
Recovery | ru	%	98.00	98.00	98.00	98.00
Recovery | ir	%	98.00	98.00	98.00	98.00
Recovery | au	%	98.00	98.00	98.00	98.00
Recovery | ni	%	95.80	95.80	95.80	95.80
Recovery | cu	%	96.00	96.00	96.00	96.00
Matte | Total	oz	127,047	126,600	125,572	120,898
Platinum	oz	58,998	58,786	58,305	56,138
Palladium	oz	46,310	46,150	45,776	44,071
Rhodium	oz	4,959	4,942	4,902	4,719
Ruthenium	oz	5,242	5,229	5,189	4,993
Iridium	oz	2,803	2,788	2,763	2,663
Gold	oz	8,735	8,706	8,636	8,314
Nickel	oz	1,208	1,213	1,207	1,160
Copper	oz	859	863	860	826
Agreed offtake recovery - Concentrates					
Recovery | pt	%	85.50	85.50	85.50	85.50
Recovery | pd	%	85.50	85.50	85.50	85.50
Recovery | rh	%	85.50	85.50	85.50	85.50
Recovery | ru	%	54.50	54.50	54.50	54.50
Recovery | ir	%	54.50	54.50	54.50	54.50

Agreed offtake recovery - converter matte					
Recovery | pt	%	90.00	90.00	90.00	90.00
Recovery | pd	%	90.00	90.00	90.00	90.00
Recovery | rh	%	90.00	90.00	90.00	90.00
Recovery | ru	%	60.00	60.00	60.00	60.00
Recovery | ir	%	60.00	60.00	60.00	60.00
Recovery | au	%	90.00	90.00	90.00	90.00
Recovery | ni	%	77.50	77.50	77.50	77.50
Recovery | cu	%	72.50	72.50	72.50	72.50
Agreed metal	oz	111,929	111,535	110,629	106,511
Platinum	oz	53,098	52,907	52,475	50,524
Palladium	oz	41,679	41,535	41,199	39,664
Rhodium	oz	4,463	4,448	4,412	4,247
Ruthenium	oz	3,145	3,137	3,113	2,996
Iridium	oz	1,682	1,673	1,658	1,598
Gold	oz	7,861	7,835	7,772	7,482
Nickel	oz	936	940	936	899
Copper	oz	623	626	623	599
Metal Prices					
Platinum	$	923	850	875	925
Palladium	$	2,171	1,846	1,773	1,669
Rhodium	$	12,984	11,000	10,350	9,375
Ruthenium	$	236	240	244	249
Iridium	$	1,706	1,632	1,665	1,698
Gold	$	1,937	1,721	1,637	1,574
Nickel	$	15,351	14,946	14,948	15,865
Copper	$	6,964	6,438	6,219	6,367
Gross Revenue (Total)		**234,722,387**	**205,361,661**	**198,522,194**	**185,810,205**
Platinum	$	48,984,395	44,970,960	45,939,588	46,715,835
Palladium	$	90,501,184	76,666,689	73,042,105	66,189,399
Rhodium	$	57,950,103	48,925,787	45,662,967	39,818,888
Ruthenium	$	743,164	751,391	759,945	746,480
Iridium	$	2,868,581	2,729,418	2,760,208	2,713,239
Gold	$	15,223,361	13,481,928	12,725,840	11,779,917
Nickel	$	14,372,656	14,048,457	13,988,309	14,263,968
Copper	6	4,078,944	3,787,031	3,643,232	3,582,479
Royalties & MMCZ Commission					
Platinum	%	3.375	3.375	3.375	3.375
Palladium	%	4.875	4.875	4.875	4.875
Rhodium	%	4.875	4.875	4.875	4.875
Ruthenium	%	4.875	4.875	4.875	4.875
Iridium	%	4.875	4.875	4.875	4.875
Gold	%	5.000	6.000	7.000	8.000
Nickel	%	2.875	2.875	2.875	2.875
Copper	%	2.875	2.875	2.875	2.875
Royalties & MMCZ Commission		**10,357,948**	**8,996,959**	**8,652,140**	**8,015,306**
Platinum	$	1,653,223	1,517,770	1,550,461	1,576,659
Palladium	$	4,411,933	3,737,501	3,560,803	3,226,733
Rhodium	$	2,825,068	2,385,132	2,226,070	1,941,171
Ruthenium	$	36,229	36,630	37,047	36,391
Iridium	$	139,843	133,059	134,560	132,270
Gold	$	761,168	674,096	636,292	588,996
Nickel	$	413,214	403,893	402,164	410,089
Copper	$	117,270	108,877	104,743	102,996

7.13 Operating cost per tonne for each mining cut option

Ngwarati - Mining Operating Cost	Units	2.25 m cut	2.5 m cut- Base case	2.75 m cut	3.0 m cut	3.25 m cut
		Total	Total	Total	Total	Total
Total Labour	$USD/t	6.98	6.98	6.98	6.98	6.98
Drilling	$USD/t	1.25	1.38	1.45	1.80	2.22
Consumables	$USD/t	0.05	0.06	0.06	0.08	0.09
Explosives	$USD/t	1.33	1.47	1.60	2.01	2.29
Support	$USD/t	1.96	1.96	1.96	1.96	1.96
PPE	$USD/t	0.34	0.34	0.34	0.34	0.34
Ventilation	$USD/t	0.04	0.04	0.04	0.05	0.06
Technical Services	$USD/t	0.09	0.09	0.10	0.13	0.15
Power	$USD/t	0.96	0.98	1.00	1.09	1.15
Engineering maintenance	$USD/t	0.29	0.30	0.31	0.34	0.36
Ore crushing & conveying	$USD/t	0.19	0.20	0.21	0.24	0.26
Ore rehandle	$USD/t	0.19	0.20	0.22	0.28	0.32
Village	$USD/t	0.19	0.19	0.19	0.19	0.19
Overheads	$USD/t	0.29	0.29	0.29	0.29	0.29
Trackless maintenance		**8.70**	**8.93**	**9.40**	**11.73**	**12.43**
Spares and Equipment	$USD/t	4.42	4.66	5.12	7.45	8.15
Hoses	$USD/t	-	-	-	-	-
Overheads	$USD/t	0.37	0.37	0.37	0.37	0.37
Fuel	$USD/t	1.37	1.37	1.37	1.37	1.37
Contracted labour	$USD/t	1.34	1.34	1.34	1.34	1.34
Tyres	$USD/t	0.58	0.58	0.58	0.58	0.58
Oils	$USD/t	0.37	0.37	0.37	0.37	0.37
Other	$USD/t	0.23	0.23	0.23	0.23	0.23
Operating Cash Cost	$USD/t	15.87	16.42	17.18	20.53	22.09
Renewals	$USD/t	1.52	1.52	1.52	1.52	1.52
Total Operating Cash Costs	**$USD/t**	**24.38**	**24.93**	**25.69**	**29.04**	**30.60**

7.14 Calculated revenues for the possible 2.25 m mining cut scenarios

2.25 m cut options	Year 1	Year 2	Year 3	Year 4	Total revenue
FC - FK	157,461,641	137,600,751	132,613,247	122,030,051	549,705,690
FB – FJ	170,040,024	148,486,276	143,077,135	131,561,932	593,165,367
FA - FI	183,573,825	160,199,663	154,337,482	141,822,444	639,933,415
PK – FH	202,738,473	176,790,143	170,289,422	156,373,133	706,191,171
HA – FG	210,931,558	183,882,274	177,108,115	162,590,532	734,512,479
HB – FF	187,311,529	163,435,574	157,449,083	144,661,861	652,858,047
HC – FE	193,322,383	168,641,228	162,456,401	149,239,178	673,659,190
HD – FD	175,530,361	153,241,591	147,651,640	135,745,381	612,168,973
HE - FC	154,751,128	135,256,808	130,361,547	119,985,912	540,355,395

7.15 DCF analysis for the 2.25 m mining cut for seams FC-FK

FC - FK									
Production Years	Unit	Proportion	Value	Value	2021	2022	2023	2024	Total
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**157,461,641**	**137,600,751**	**132,613,247**	**122,030,051**	
Less operating costs	$				68,745,602	69,902,389	70,857,686	69,915,062	
Direct mining cost	$				28,036,486	28,450,783	28,722,570	27,712,850	
Mining unit cost	$				24	25	25	26	
Tonnage	$				1,150,111	1,144,222	1,132,502	1,071,265	
Haulage cost	$			$ 3.26	3,749,362	3,804,767	3,841,113	3,706,082	
Processing	$				18,436,280	18,756,860	19,034,271	18,894,095	
Fixed costs	$	50%		$ 16.03	9,218,140	9,402,503	9,590,553	9,782,364	
Variable costs	$	50%		$ 16.03	9,218,140	9,354,357	9,443,718	9,111,731	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	759,073	770,290	777,649	750,311	
Operating cashflow	$				**88,716,040**	**67,698,362**	**61,755,561**	**52,114,988**	
Royalties	$				6,940,240	6,020,481	5,772,028	5,256,665	
Operating cashflow net of royalties	$				**81,775,800**	**61,677,881**	**55,983,534**	**46,858,323**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**77,593,771**	**55,977,335**	**51,833,173**	**42,707,963**	
Taxable income	$				77,593,771	55,977,335	51,833,173	42,707,963	
Cashflow before capex	$				81,775,800	61,677,881	55,983,534	46,858,323	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			19,181,180	13,837,597	12,813,160	10,557,408	
Cash flow after tax	$				**58,412,591**	**42,139,737**	**39,020,013**	**32,150,554**	
Revenue	$				157,461,641	137,600,751	132,613,247	122,030,051	
Opex	$				(68,745,602)	(69,902,389)	(70,857,686)	(69,915,062)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(6,940,240)	(6,020,481)	(5,772,028)	(5,256,665)	
Export levy	$								
Tax	$				(19,181,180)	(13,837,597)	(12,813,160)	(10,557,408)	
Total undiscounted cashflow	$				**58,412,591**	**42,139,737**	**39,020,013**	**32,150,554**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				157,461,641	114,667,292	92,092,533	70,619,242	434,840,709
Opex	$				(68,745,602)	(58,251,990)	(49,206,726)	(40,460,106)	(216,664,424)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(6,940,240)	(5,017,068)	(4,008,352)	(3,042,051)	(19,007,712)
Export levy	$				-	-	-	-	-
Tax	$				(19,181,180)	(11,531,331)	(8,898,028)	(6,109,611)	(45,720,151)
Total discounted cashflow	$				**58,412,591**	**35,116,448**	**27,097,231**	**18,605,645**	**139,231,915**
NPV=	$	**139,231,915**							

7.16 DCF analysis for the 2.25 m mining cut for seams FB-FJ

FB – FJ									
Production Years	**Unit**	**Proportion**	**Value**	**Value**	**2021**	**2022**	**2023**	**2024**	**Total**
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**170,040,024**	**148,486,276**	**143,077,135**	**131,561,932**	
Less operating costs	$				68,642,812	69,797,543	70,750,743	69,805,981	
Direct mining cost	$				27,979,958	28,393,124	28,663,758	27,652,862	
Mining unit cost	$				24	25	25	26	
Tonnage	$				1,147,792	1,141,903	1,130,184	1,068,946	
Haulage cost	$			$ 3.26	3,741,802	3,797,056	3,833,248	3,698,059	
Processing	$				18,399,108	18,718,944	18,995,597	18,854,648	
Fixed costs	$	50%		$ 16.03	9,199,554	9,383,545	9,571,216	9,762,640	
Variable costs	$	50%		$ 16.03	9,199,554	9,335,399	9,424,381	9,092,008	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	757,543	768,729	776,056	748,687	
Operating cashflow	$				**101,397,212**	**78,688,734**	**72,326,393**	**61,755,951**	
Royalties	$				7,512,242	6,513,387	6,243,609	5,682,833	
Operating cashflow net of royalties	$				**93,884,970**	**72,175,346**	**66,082,784**	**56,073,118**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**89,702,942**	**66,474,800**	**61,932,423**	**51,922,758**	
Taxable income	$				89,702,942	66,474,800	61,932,423	51,922,758	
Cashflow before capex	$				93,884,970	72,175,346	66,082,784	56,073,118	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			22,174,567	16,432,571	15,309,695	12,835,306	
Cash flow after tax	$				**67,528,375**	**50,042,230**	**46,622,728**	**39,087,452**	
Revenue	$				170,040,024	148,486,276	143,077,135	131,561,932	
Opex	$				(68,642,812)	(69,797,543)	(70,750,743)	(69,805,981)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(7,512,242)	(6,513,387)	(6,243,609)	(5,682,833)	
Export levy	$								
Tax	$				(22,174,567)	(16,432,571)	(15,309,695)	(12,835,306)	
Total undiscounted cashflow	$				**67,528,375**	**50,042,230**	**46,622,728**	**39,087,452**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				170,040,024	123,738,564	99,359,122	76,135,377	469,273,086
Opex	$				(68,642,812)	(58,164,619)	(49,132,460)	(40,396,980)	(216,336,870)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(7,512,242)	(5,427,823)	(4,335,839)	(3,288,676)	(20,564,580)
Export levy	$				-	-	-	-	-
Tax	$				(22,174,567)	(13,693,809)	(10,631,733)	(7,427,839)	(53,927,948)
Total discounted cashflow	$				**67,528,375**	**41,701,858**	**32,376,895**	**22,620,053**	**164,227,181**
NPV=	$	**164,227,181**							

7.17 DCF analysis for the 2.25 m mining cut for seams FA-FI

FA - FI									
Production Years	**Unit**	**Proportion**	**Value**	**Value**	**2021**	**2022**	**2023**	**2024**	**Total**
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**183,573,825**	**160,199,663**	**154,337,482**	**141,822,444**	
Less operating costs	$				68,563,316	69,716,457	70,668,036	69,721,619	
Direct mining cost	$				27,936,240	28,348,532	28,618,274	27,606,468	
Mining unit cost	$				24	25	25	26	
Tonnage	$				1,145,999	1,140,110	1,128,390	1,067,153	
Haulage cost	$			$ 3.26	3,735,956	3,791,092	3,827,165	3,691,855	
Processing	$				18,370,360	18,689,622	18,965,688	18,824,141	
Fixed costs	$	50%		$ 16.03	9,185,180	9,368,884	9,556,261	9,747,386	
Variable costs	$	50%		$ 16.03	9,185,180	9,320,738	9,409,427	9,076,754	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	756,359	767,522	774,825	747,431	
Operating cashflow	$				**115,010,509**	**90,483,206**	**83,669,447**	**72,100,825**	
Royalties	$				8,127,560	7,043,654	6,750,961	6,141,450	
Operating cashflow net of royalties	$				**106,882,949**	**83,439,553**	**76,918,486**	**65,959,374**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**102,700,921**	**77,739,006**	**72,768,125**	**61,809,014**	
Taxable income	$				102,700,921	77,739,006	72,768,125	61,809,014	
Cashflow before capex	$				106,882,949	83,439,553	76,918,486	65,959,374	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			25,387,668	19,217,082	17,988,281	15,279,188	
Cash flow after tax	$				**77,313,253**	**58,521,924**	**54,779,845**	**46,529,825**	
Revenue	$				183,573,825	160,199,663	154,337,482	141,822,444	
Opex	$				(68,563,316)	(69,716,457)	(70,668,036)	(69,721,619)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(8,127,560)	(7,043,654)	(6,750,961)	(6,141,450)	
Export levy	$								
Tax	$				(25,387,668)	(19,217,082)	(17,988,281)	(15,279,188)	
Total undiscounted cashflow	$				**77,313,253**	**58,521,924**	**54,779,845**	**46,529,825**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				183,573,825	133,499,719	107,178,807	82,073,174	506,325,526
Opex	$				(68,563,316)	(58,097,048)	(49,075,025)	(40,348,159)	(216,083,548)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(8,127,560)	(5,869,711)	(4,688,167)	(3,554,080)	(22,239,519)
Export levy	$				-	-	-	-	-
Tax	$				(25,387,668)	(16,014,235)	(12,491,862)	(8,842,123)	(62,735,887)
Total discounted cashflow	$				**77,313,253**	**48,768,270**	**38,041,559**	**26,926,982**	**191,050,064**
NPV=	$	**191,050,064**							

7.18 DCF analysis for the 2.25 m mining cut for seams PK-FH

PK – FH									
Production Years	**Unit**	**Proportion**	**Value**	**Value**	**2021**	**2022**	**2023**	**2024**	**Total**
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**202,738,473**	**176,790,143**	**170,289,422**	**156,373,133**	
Less operating costs	$				68,542,944	69,695,677	70,646,840	69,700,000	
Direct mining cost	$				27,925,036	28,337,105	28,606,618	27,594,579	
Mining unit cost	$				24	25	25	26	
Tonnage	$				1,145,539	1,139,650	1,127,931	1,066,693	
Haulage cost	$			$ 3.26	3,734,458	3,789,564	3,825,607	3,690,265	
Processing	$				18,362,993	18,682,107	18,958,023	18,816,322	
Fixed costs	$	50%		$ 16.03	9,181,496	9,365,126	9,552,429	9,743,477	
Variable costs	$	50%		$ 16.03	9,181,496	9,316,981	9,405,594	9,072,845	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	756,056	767,212	774,509	747,109	
Operating cashflow	$				**134,195,530**	**107,094,466**	**99,642,582**	**86,673,133**	
Royalties	$				8,998,498	7,794,334	7,469,334	6,791,450	
Operating cashflow net of royalties	$				**125,197,031**	**99,300,132**	**92,173,249**	**79,881,683**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**121,015,003**	**93,599,586**	**88,022,888**	**75,731,322**	
Taxable income	$				121,015,003	93,599,586	88,022,888	75,731,322	
Cashflow before capex	$				125,197,031	99,300,132	92,173,249	79,881,683	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			29,914,909	23,137,818	21,759,258	18,720,783	
Cash flow after tax	$				**91,100,094**	**70,461,768**	**66,263,630**	**57,010,539**	
Revenue	$				202,738,473	176,790,143	170,289,422	156,373,133	
Opex	$				(68,542,944)	(69,695,677)	(70,646,840)	(69,700,000)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(8,998,498)	(7,794,334)	(7,469,334)	(6,791,450)	
Export levy	$								
Tax	$				(29,914,909)	(23,137,818)	(21,759,258)	(18,720,783)	
Total undiscounted cashflow	$				**91,100,094**	**70,461,768**	**66,263,630**	**57,010,539**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				202,738,473	147,325,119	118,256,543	90,493,711	558,813,847
Opex	$				(68,542,944)	(58,079,731)	(49,060,305)	(40,335,648)	(216,018,628)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(8,998,498)	(6,495,278)	(5,187,037)	(3,930,238)	(24,611,051)
Export levy	$				-	-	-	-	-
Tax	$				(29,914,909)	(19,281,515)	(15,110,596)	(10,833,786)	(75,140,806)
Total discounted cashflow	$				**91,100,094**	**58,718,140**	**46,016,410**	**32,992,210**	**228,826,855**
NPV=	$	**228,826,855**							

7.19 DCF analysis for the 2.25 m mining cut for seams HA-FG

HA – FG									
Production Years	Unit	Proportion	Value	Value	2021	2022	2023	2024	Total
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**210,931,558**	**183,882,274**	**177,108,115**	**162,590,532**	
Less operating costs	$				68,523,998	69,676,352	70,627,129	69,679,894	
Direct mining cost	$				27,914,617	28,326,477	28,595,778	27,583,522	
Mining unit cost	$				24	25	25	26	
Tonnage	$				1,145,112	1,139,223	1,127,503	1,066,266	
Haulage cost	$			$ 3.26	3,733,064	3,788,143	3,824,157	3,688,786	
Processing	$				18,356,141	18,675,118	18,950,895	18,809,052	
Fixed costs	$	50%		$ 16.03	9,178,071	9,361,632	9,548,865	9,739,842	
Variable costs	$	50%		$ 16.03	9,178,071	9,313,486	9,402,030	9,069,210	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	755,774	766,925	774,216	746,810	
Operating cashflow	$				**142,407,560**	**114,205,922**	**106,480,986**	**92,910,637**	
Royalties	$				9,370,877	8,115,278	7,776,444	7,069,232	
Operating cashflow net of royalties	$				**133,036,683**	**106,090,644**	**98,704,542**	**85,841,405**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**128,854,655**	**100,390,098**	**94,554,181**	**81,691,044**	
Taxable income	$				128,854,655	100,390,098	94,554,181	81,691,044	
Cashflow before capex	$				133,036,683	106,090,644	98,704,542	85,841,405	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			31,852,871	24,816,432	23,373,794	20,194,026	
Cash flow after tax	$				**97,001,784**	**75,573,666**	**71,180,388**	**61,497,018**	
Revenue	$				210,931,558	183,882,274	177,108,115	162,590,532	
Opex	$				(68,523,998)	(69,676,352)	(70,627,129)	(69,679,894)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(9,370,877)	(8,115,278)	(7,776,444)	(7,069,232)	
Export levy	$								
Tax	$				(31,852,871)	(24,816,432)	(23,373,794)	(20,194,026)	
Total undiscounted cashflow	$				**97,001,784**	**75,573,666**	**71,180,388**	**61,497,018**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				210,931,558	153,235,229	122,991,746	94,091,743	581,250,276
Opex	$				(68,523,998)	(58,063,627)	(49,046,617)	(40,324,013)	(215,958,255)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(9,370,877)	(6,762,731)	(5,400,309)	(4,090,991)	(25,624,907)
Export levy	$				-	-	-	-	-
Tax	$				(31,852,871)	(20,680,360)	(16,231,801)	(11,686,358)	(80,451,390)
Total discounted cashflow	$				**97,001,784**	**62,978,055**	**49,430,825**	**35,588,552**	**244,999,216**
NPV=	$	**244,999,216**							

7.20 DCF analysis for the 2.25 m mining cut for seams HB-FF

HB – FF									
Production Years	**Unit**	**Proportion**	**Value**	**Value**	**2021**	**2022**	**2023**	**2024**	**Total**
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**187,311,529**	**163,435,574**	**157,449,083**	**144,661,861**	
Less operating costs	$				68,565,214	69,718,393	70,670,010	69,723,633	
Direct mining cost	$				27,937,284	28,349,597	28,619,360	27,607,576	
Mining unit cost	$				24	25	25	26	
Tonnage	$				1,146,042	1,140,152	1,128,433	1,067,195	
Haulage cost	$			$ 3.26	3,736,095	3,791,235	3,827,311	3,692,003	
Processing	$				18,371,046	18,690,321	18,966,402	18,824,869	
Fixed costs	$	50%		$ 16.03	9,185,523	9,369,234	9,556,618	9,747,751	
Variable costs	$	50%		$ 16.03	9,185,523	9,321,088	9,409,784	9,077,118	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	756,387	767,551	774,854	747,461	
Operating cashflow	$				**118,746,315**	**93,717,181**	**86,779,073**	**74,938,228**	
Royalties	$				8,297,396	7,190,047	6,891,064	6,268,267	
Operating cashflow net of royalties	$				**110,448,919**	**86,527,134**	**79,888,009**	**68,669,961**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**106,266,891**	**80,826,588**	**75,737,649**	**64,519,600**	
Taxable income	$				106,266,891	80,826,588	75,737,649	64,519,600	
Cashflow before capex	$				110,448,919	86,527,134	79,888,009	68,669,961	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			26,269,176	19,980,333	18,722,347	15,949,245	
Cash flow after tax	$				**79,997,716**	**60,846,255**	**57,015,302**	**48,570,355**	
Revenue	$				187,311,529	163,435,574	157,449,083	144,661,861	
Opex	$				(68,565,214)	(69,718,393)	(70,670,010)	(69,723,633)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(8,297,396)	(7,190,047)	(6,891,064)	(6,268,267)	
Export levy	$								
Tax	$				(26,269,176)	(19,980,333)	(18,722,347)	(15,949,245)	
Total undiscounted cashflow	$				**79,997,716**	**60,846,255**	**57,015,302**	**48,570,355**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				187,311,529	136,196,312	109,339,641	83,716,355	516,563,836
Opex	$				(68,565,214)	(58,098,661)	(49,076,396)	(40,349,325)	(216,089,594)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(8,297,396)	(5,991,706)	(4,785,461)	(3,627,469)	(22,702,032)
Export levy	$				-	-	-	-	-
Tax	$				(26,269,176)	(16,650,277)	(13,001,630)	(9,229,887)	(65,150,970)
Total discounted cashflow	$				**79,997,716**	**50,705,213**	**39,593,960**	**28,107,844**	**198,404,733**
NPV=	$	**198,404,733**							

7.21 DCF analysis for the 2.25 m mining cut for seams HC-FE

HC – FE									
Production Years	**Unit**	**Proportion**	**Value**	**Value**	**2021**	**2022**	**2023**	**2024**	**Total**
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**157,461,641**	**137,600,751**	**132,613,247**	**122,030,051**	
Less operating costs	$				68,745,602	69,902,389	70,857,686	69,915,062	
Direct mining cost	$				28,036,486	28,450,783	28,722,570	27,712,850	
Mining unit cost	$				24	25	25	26	
Tonnage	$				1,150,111	1,144,222	1,132,502	1,071,265	
Haulage cost	$			$ 3.26	3,749,362	3,804,767	3,841,113	3,706,082	
Processing	$				18,436,280	18,756,860	19,034,271	18,894,095	
Fixed costs	$	50%		$ 16.03	9,218,140	9,402,503	9,590,553	9,782,364	
Variable costs	$	50%		$ 16.03	9,218,140	9,354,357	9,443,718	9,111,731	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	759,073	770,290	777,649	750,311	
Operating cashflow	$				**88,716,040**	**67,698,362**	**61,755,561**	**52,114,988**	
Royalties	$				6,940,240	6,020,481	5,772,028	5,256,665	
Operating cashflow net of royalties	$				**81,775,800**	**61,677,881**	**55,983,534**	**46,858,323**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**77,593,771**	**55,977,335**	**51,833,173**	**42,707,963**	
Taxable income	$				77,593,771	55,977,335	51,833,173	42,707,963	
Cashflow before capex	$				81,775,800	61,677,881	55,983,534	46,858,323	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			19,181,180	13,837,597	12,813,160	10,557,408	
Cash flow after tax	$				**58,412,591**	**42,139,737**	**39,020,013**	**32,150,554**	
Revenue	$				157,461,641	137,600,751	132,613,247	122,030,051	
Opex	$				(68,745,602)	(69,902,389)	(70,857,686)	(69,915,062)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(6,940,240)	(6,020,481)	(5,772,028)	(5,256,665)	
Export levy	$								
Tax	$				(19,181,180)	(13,837,597)	(12,813,160)	(10,557,408)	
Total undiscounted cashflow	$				**58,412,591**	**42,139,737**	**39,020,013**	**32,150,554**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				157,461,641	114,667,292	92,092,533	70,619,242	434,840,709
Opex	$				(68,745,602)	(58,251,990)	(49,206,726)	(40,460,106)	(216,664,424)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(6,940,240)	(5,017,068)	(4,008,352)	(3,042,051)	(19,007,712)
Export levy	$				-	-	-	-	-
Tax	$				(19,181,180)	(11,531,331)	(8,898,028)	(6,109,611)	(45,720,151)
Total discounted cashflow	$				**58,412,591**	**35,116,448**	**27,097,231**	**18,605,645**	**139,231,915**
NPV=	$	**139,231,915**							

7.22 DCF analysis for the 2.25 m mining cut for seams HD-FD

HD – FD									
Production Years	Unit	Proportion	Value	Value	2021	2022	2023	2024	Total
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**193,322,383**	**168,641,228**	**162,456,401**	**149,239,178**	
Less operating costs	$				68,610,040	69,764,115	70,716,647	69,771,203	
Direct mining cost	$				27,961,935	28,374,741	28,645,008	27,633,736	
Mining unit cost	$				24	25	25	26	
Tonnage	$				1,147,053	1,141,164	1,129,444	1,068,207	
Haulage cost	$			$ 3.26	3,739,392	3,794,597	3,830,740	3,695,502	
Processing	$				18,387,257	18,706,856	18,983,267	18,842,071	
Fixed costs	$	50%		$ 16.03	9,193,628	9,377,501	9,565,051	9,756,352	
Variable costs	$	50%		$ 16.03	9,193,628	9,329,355	9,418,216	9,085,720	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	757,055	768,231	775,549	748,169	
Operating cashflow	$				**124,712,343**	**98,877,113**	**91,739,754**	**79,467,975**	
Royalties	$				8,570,343	7,425,384	7,116,358	6,472,533	
Operating cashflow net of royalties	$				**116,142,000**	**91,451,729**	**84,623,396**	**72,995,441**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**111,959,972**	**85,751,183**	**80,473,035**	**68,845,081**	
Taxable income	$				111,959,972	85,751,183	80,473,035	68,845,081	
Cashflow before capex	$				116,142,000	91,451,729	84,623,396	72,995,441	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			27,676,505	21,197,692	19,892,934	17,018,504	
Cash flow after tax	$				**84,283,467**	**64,553,490**	**60,580,101**	**51,826,577**	
Revenue	$				193,322,383	168,641,228	162,456,401	149,239,178	
Opex	$				(68,610,040)	(69,764,115)	(70,716,647)	(69,771,203)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(8,570,343)	(7,425,384)	(7,116,358)	(6,472,533)	
Export levy	$								
Tax	$				(27,676,505)	(21,197,692)	(19,892,934)	(17,018,504)	
Total undiscounted cashflow	$				**84,283,467**	**64,553,490**	**60,580,101**	**51,826,577**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				193,322,383	140,534,357	112,816,945	86,365,265	533,038,950
Opex	$				(68,610,040)	(58,136,763)	(49,108,782)	(40,376,854)	(216,232,439)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(8,570,343)	(6,187,820)	(4,941,915)	(3,745,679)	(23,445,757)
Export levy	$				-	-	-	-	-
Tax	$				(27,676,505)	(17,664,744)	(13,814,538)	(9,848,671)	(69,004,458)
Total discounted cashflow	$				**84,283,467**	**53,794,575**	**42,069,515**	**29,992,232**	**210,139,789**
NPV=	$	**210,139,789**							

7.23 DCF analysis for the 2.25 m mining cut for seams HE-FC

HE - FC									
Production Years	Unit	Proportion	Value	Value	2021	2022	2023	2024	Total
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	**$**				**175,530,361**	**153,241,591**	**147,651,640**	**135,745,381**	
Less operating costs	$				68,695,536	69,851,321	70,805,597	69,861,932	
Direct mining cost	$				28,008,953	28,422,699	28,693,925	27,683,632	
Mining unit cost	$				24	25	25	26	
Tonnage	$				1,148,982	1,143,092	1,131,373	1,070,135	
Haulage cost	$			$ 3.26	3,745,680	3,801,011	3,837,282	3,702,174	
Processing	$				18,418,174	18,738,392	19,015,434	18,874,882	
Fixed costs	$	50%		$ 16.03	9,209,087	9,393,269	9,581,134	9,772,757	
Variable costs	$	50%		$ 16.03	9,209,087	9,345,123	9,434,300	9,102,125	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	758,328	769,530	776,873	749,520	
Operating cashflow	**$**				**106,834,826**	**83,390,269**	**76,846,043**	**65,883,449**	
Royalties	$				7,761,504	6,728,317	6,449,383	5,869,474	
Operating cashflow net of royalties	**$**				**99,073,322**	**76,661,952**	**70,396,661**	**60,013,975**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	**$**				**94,891,294**	**70,961,406**	**66,246,300**	**55,863,614**	
Taxable income	$				94,891,294	70,961,406	66,246,300	55,863,614	
Cashflow before capex	$				99,073,322	76,661,952	70,396,661	60,013,975	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			23,457,128	17,541,660	16,376,085	13,809,485	
Cash flow after tax	**$**				**71,434,166**	**53,419,746**	**49,870,215**	**42,054,129**	
Revenue	$				175,530,361	153,241,591	147,651,640	135,745,381	
Opex	$				(68,695,536)	(69,851,321)	(70,805,597)	(69,861,932)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(7,761,504)	(6,728,317)	(6,449,383)	(5,869,474)	
Export levy	$								
Tax	$				(23,457,128)	(17,541,660)	(16,376,085)	(13,809,485)	
Total undiscounted cashflow	**$**				**71,434,166**	**53,419,746**	**49,870,215**	**42,054,129**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				175,530,361	127,701,326	102,535,861	78,556,355	484,323,903
Opex	$				(68,695,536)	(58,209,434)	(49,170,553)	(40,429,359)	(216,504,882)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(7,761,504)	(5,606,931)	(4,478,738)	(3,396,686)	(21,243,859)
Export levy	$				-	-	-	-	-
Tax	$				(23,457,128)	(14,618,050)	(11,372,282)	(7,991,600)	(57,439,059)
Total discounted cashflow	**$**				**71,434,166**	**44,516,455**	**34,632,094**	**24,336,880**	**174,919,595**
NPV=	$	**174,919,595**							

7.24 Summary of differential cashflow for the 2.25 m cut scenarios

											Differential Cash Flows (US$m)								
US$m	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Base Case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Mining Height	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m	2.25 m
Seams	FC - FK	FB – FJ	FA - FI	PK – FH	HA – FG	HB – FF	HC – FE	HD – FD	HE - FC	HB - FG	FC - FK	FB – FJ	FA - FI	PK – FH	HA – FG	HB – FF	HC – FE	HD – FD	HE - FC
Revenue	434.8	469.3	506.3	558.8	581.3	516.6	434.8	533.0	484.3	610.7	(176)	(141)	(104)	(52)	(29)	(94)	(176)	(78)	(126)
Operating expenditure	(217)	(216)	(216)	(216)	(216)	(216)	(217)	(216)	(217)	(236)	19	20	20	20	20	20	19	20	19
Capital expenditure	(14)	(14)	(14)	(14)	(14)	(14)	(14)	(14)	(14)	(14)	0	0	0	0	0	0	0	0	0
Royalties	(19)	(21)	(22)	(25)	(26)	(23)	(19)	(23)	(21)	(27)	8	6	5	2	1	4	8	3	6
Export levy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Taxation	(46)	(54)	(63)	(75)	(80)	(65)	(46)	(69)	(57)	(82)	37	29	20	7	2	17	37	13	25
NPV	139.2	164.2	191.1	228.8	245.0	198.4	139.2	210.1	174.9	251.2	(111.9)	(86.9)	(60.1)	(22.3)	(6.2)	(52.7)	(111.9)	(41.0)	(76.2)

7.25 Calculated revenues for the possible 2.50 m mining cut scenarios

2.5 m cut options	Year 1	Year 2	Year 3	Year 4	Total revenue
FB – FK	165,747,403	143,566,630	138,193,151	126,827,568	574,334,752
FA – FJ	181,515,747	157,223,735	151,337,002	138,879,782	628,956,266
PK – FI	202,099,690	175,052,330	168,496,846	154,620,928	700,269,795
HA – FH	211,258,921	182,985,758	176,133,164	161,628,320	732,006,163
HB – FG	206,949,360	179,252,905	172,540,009	158,330,592	717,072,866
HC – FF	197,235,209	170,839,135	164,441,944	150,902,568	683,418,857
HD – FE	183,216,635	158,697,245	152,755,826	140,184,281	634,853,986
HE - FD	164,665,869	142,629,888	137,291,581	126,000,715	570,588,053

7.26 DCF analysis for the 2.50 m mining cut for seams FB-FK

				FB – FK					
Production Years	Unit	Proportion	Value	Value	2021	2022	2023	2024	Total
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	**$**				**180,012,797**	**157,341,183**	**151,781,339**	**140,421,676**	
Less operating costs	$				74,955,363	76,233,008	77,308,145	76,458,438	
Direct mining cost	$				31,769,982	32,255,613	32,596,724	31,628,394	
Mining unit cost	$				25	25	26	26	
Tonnage	$				1,274,235	1,268,345	1,256,626	1,195,388	
Haulage cost	$			$ 3.26	4,154,005	4,217,502	4,262,103	4,135,492	
Processing	$				20,425,980	20,786,354	21,104,355	21,005,581	
Fixed costs	$	50%		$ 16.03	10,212,990	10,417,250	10,625,595	10,838,107	
Variable costs	$	50%		$ 16.03	10,212,990	10,369,104	10,478,760	10,167,474	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	840,995	853,850	862,880	837,247	
Operating cashflow	**$**				**105,057,435**	**81,108,175**	**74,473,194**	**63,963,238**	
Royalties	$				7,941,784	6,891,359	6,613,289	6,055,674	
Operating cashflow net of royalties	**$**				**97,115,651**	**74,216,816**	**67,859,905**	**57,907,564**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	**$**				**92,933,623**	**68,516,269**	**63,709,544**	**53,757,203**	
Taxable income	$				92,933,623	68,516,269	63,709,544	53,757,203	
Cashflow before capex	$				97,115,651	74,216,816	67,859,905	57,907,564	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			22,973,192	16,937,222	15,748,999	13,288,781	
Cash flow after tax	**$**				**69,960,431**	**51,579,047**	**47,960,545**	**40,468,423**	
Revenue	$				180,012,797	157,341,183	151,781,339	140,421,676	
Opex	$				(74,955,363)	(76,233,008)	(77,308,145)	(76,458,438)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(7,941,784)	(6,891,359)	(6,613,289)	(6,055,674)	
Export levy	$								
Tax	$				(22,973,192)	(16,937,222)	(15,748,999)	(13,288,781)	
Total undiscounted cashflow	**$**				**69,960,431**	**51,579,047**	**47,960,545**	**40,468,423**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				180,012,797	131,117,653	105,403,708	81,262,544	497,796,702
Opex	$				(74,955,363)	(63,527,507)	(53,686,212)	(44,246,781)	(236,415,863)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(7,941,784)	(5,742,799)	(4,592,562)	(3,504,441)	(21,781,586)
Export levy	$				-	-	-	-	-
Tax	$				(22,973,192)	(14,114,351)	(10,936,805)	(7,690,267)	(55,714,615)
Total discounted cashflow	**$**				**69,960,431**	**42,982,540**	**33,305,934**	**23,419,226**	**169,668,131**
NPV=	**$**	**169,668,131**							

7.27 DCF analysis for the 2.50 m mining cut for seams FB-FK

FA – FJ									
Production Years	**Unit**	**Proportion**	**Value**	**Value**	**2021**	**2022**	**2023**	**2024**	**Total**
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**195,760,153**	**170,977,927**	**164,904,918**	**152,452,571**	
Less operating costs	$				74,871,220	76,147,182	77,220,603	76,369,145	
Direct mining cost	$				31,723,240	32,207,936	32,548,094	31,578,791	
Mining unit cost	$				25	25	26	26	
Tonnage	$				1,272,360	1,266,471	1,254,751	1,193,514	
Haulage cost	$			$ 3.26	4,147,893	4,211,268	4,255,745	4,129,006	
Processing	$				20,395,928	20,755,701	21,073,089	20,973,690	
Fixed costs	$	50%		$ 16.03	10,197,964	10,401,923	10,609,962	10,822,161	
Variable costs	$	50%		$ 16.03	10,197,964	10,353,778	10,463,127	10,151,529	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	839,757	852,588	861,592	835,934	
Operating cashflow	$				**120,888,933**	**94,830,745**	**87,684,315**	**76,083,426**	
Royalties	$				8,657,703	7,508,658	7,204,554	6,593,382	
Operating cashflow net of royalties	$				**112,231,230**	**87,322,087**	**80,479,761**	**69,490,044**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**108,049,202**	**81,621,541**	**76,329,400**	**65,339,684**	
Taxable income	$				108,049,202	81,621,541	76,329,400	65,339,684	
Cashflow before capex	$				112,231,230	87,322,087	80,479,761	69,490,044	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			26,709,763	20,176,845	18,868,628	16,151,970	
Cash flow after tax	$				**81,339,439**	**61,444,696**	**57,460,773**	**49,187,714**	
Revenue	$				195,760,153	170,977,927	164,904,918	152,452,571	
Opex	$				(74,871,220)	(76,147,182)	(77,220,603)	(76,369,145)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(8,657,703)	(7,508,658)	(7,204,554)	(6,593,382)	
Export levy	$								
Tax	$				(26,709,763)	(20,176,845)	(18,868,628)	(16,151,970)	
Total undiscounted cashflow	$				**81,339,439**	**61,444,696**	**57,460,773**	**49,187,714**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				195,760,153	142,481,606	114,517,304	88,224,868	540,983,931
Opex	$				(74,871,220)	(63,455,985)	(53,625,419)	(44,195,107)	(236,147,731)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(8,657,703)	(6,257,215)	(5,003,163)	(3,815,614)	(23,733,695)
Export levy	$				-	-	-	-	-
Tax	$				(26,709,763)	(16,814,037)	(13,103,214)	(9,347,205)	(65,974,219)
Total discounted cashflow	$				**81,339,439**	**51,203,913**	**39,903,314**	**28,465,112**	**200,911,779**
NPV=	$	**200,911,779**							

7.28 DCF analysis for the 2.50 m mining cut for seams PK-FI

				PK – FI					
Production Years	Unit	Proportion	Value	Value	2021	2022	2023	2024	Total
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	**$**				**216,333,136**	**188,795,891**	**182,054,176**	**168,182,584**	
Less operating costs	$				74,827,280	76,102,364	77,174,888	76,322,516	
Direct mining cost	$				31,698,831	32,183,039	32,522,699	31,552,888	
Mining unit cost	$				25	25	26	26	
Tonnage	$				1,271,381	1,265,492	1,253,772	1,192,535	
Haulage cost	$			$ 3.26	4,144,702	4,208,013	4,252,424	4,125,619	
Processing	$				20,380,235	20,739,694	21,056,762	20,957,036	
Fixed costs	$	50%		$ 16.03	10,190,117	10,393,920	10,601,798	10,813,834	
Variable costs	$	50%		$ 16.03	10,190,117	10,345,774	10,454,963	10,143,202	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	839,111	851,929	860,920	835,248	
Operating cashflow	**$**				**141,505,857**	**112,693,527**	**104,879,288**	**91,860,068**	
Royalties	$				9,592,733	8,314,966	7,976,932	7,296,151	
Operating cashflow net of royalties	**$**				**131,913,123**	**104,378,561**	**96,902,356**	**84,563,917**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	**$**				**127,731,095**	**98,678,014**	**92,751,995**	**80,413,556**	
Taxable income	$				127,731,095	98,678,014	92,751,995	80,413,556	
Cashflow before capex	$				131,913,123	104,378,561	96,902,356	84,563,917	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			31,575,127	24,393,205	22,928,293	19,878,231	
Cash flow after tax	**$**				**96,155,968**	**74,284,809**	**69,823,702**	**60,535,325**	
Revenue	$				216,333,136	188,795,891	182,054,176	168,182,584	
Opex	$				(74,827,280)	(76,102,364)	(77,174,888)	(76,322,516)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(9,592,733)	(8,314,966)	(7,976,932)	(7,296,151)	
Export levy	$								
Tax	$				(31,575,127)	(24,393,205)	(22,928,293)	(19,878,231)	
Total undiscounted cashflow	**$**				**96,155,968**	**74,284,809**	**69,823,702**	**60,535,325**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				216,333,136	157,329,909	126,426,511	97,327,884	597,417,440
Opex	$				(74,827,280)	(63,418,637)	(53,593,672)	(44,168,123)	(236,007,712)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(9,592,733)	(6,929,138)	(5,539,536)	(4,222,310)	(26,283,717)
Export levy	$				-	-	-	-	-
Tax	$				(31,575,127)	(20,327,671)	(15,922,426)	(11,503,606)	(79,328,829)
Total discounted cashflow	**$**				**96,155,968**	**61,904,008**	**48,488,682**	**35,032,017**	**241,580,675**
NPV=	$	**241,580,675**							

7.29 DCF analysis for the 2.50 m mining cut for seams HA-FH

HA – FH									
Production Years	Unit	Proportion	Value	Value	2021	2022	2023	2024	Total
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	**$**				**225,492,255**	**196,729,210**	**189,690,386**	**175,189,863**	
Less operating costs	$				74,826,833	76,101,908	77,174,423	76,322,041	
Direct mining cost	$				31,698,583	32,182,786	32,522,441	31,552,625	
Mining unit cost	$				25	25	26	26	
Tonnage	$				1,271,371	1,265,482	1,253,762	1,192,525	
Haulage cost	$			$ 3.26	4,144,669	4,207,980	4,252,391	4,125,585	
Processing	$				20,380,075	20,739,531	21,056,595	20,956,866	
Fixed costs	$	50%		$ 16.03	10,190,038	10,393,838	10,601,715	10,813,749	
Variable costs	$	50%		$ 16.03	10,190,038	10,345,693	10,454,880	10,143,117	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	839,105	851,922	860,913	835,241	
Operating cashflow	**$**				**150,665,423**	**120,627,302**	**112,515,963**	**98,867,821**	
Royalties	$				10,008,931	8,673,893	8,320,780	7,609,138	
Operating cashflow net of royalties	**$**				**140,656,492**	**111,953,410**	**104,195,183**	**91,258,683**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	**$**				**136,474,464**	**106,252,863**	**100,044,822**	**87,108,323**	
Taxable income	$				136,474,464	106,252,863	100,044,822	87,108,323	
Cashflow before capex	$				140,656,492	111,953,410	104,195,183	91,258,683	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			33,736,487	26,265,708	24,731,080	21,533,177	
Cash flow after tax	**$**				**102,737,976**	**79,987,156**	**75,313,742**	**65,575,145**	
Revenue	$				225,492,255	196,729,210	189,690,386	175,189,863	
Opex	$				(74,826,833)	(76,101,908)	(77,174,423)	(76,322,041)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(10,008,931)	(8,673,893)	(8,320,780)	(7,609,138)	
Export levy	$								
Tax	$				(33,736,487)	(26,265,708)	(24,731,080)	(21,533,177)	
Total undiscounted cashflow	**$**				**102,737,976**	**79,987,156**	**75,313,742**	**65,575,145**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				225,492,255	163,941,008	131,729,435	101,383,022	622,545,721
Opex	$				(74,826,833)	(63,418,256)	(53,593,349)	(44,167,848)	(236,006,286)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(10,008,931)	(7,228,244)	(5,778,320)	(4,403,436)	(27,418,930)
Export levy	$				-	-	-	-	-
Tax	$				(33,736,487)	(21,888,090)	(17,174,361)	(12,461,329)	(85,260,268)
Total discounted cashflow	**$**				**102,737,976**	**66,655,963**	**52,301,210**	**37,948,579**	**259,643,729**
NPV=	**$**	**259,643,729**							

7.30 DCF analysis for the 2.50 m mining cut for seams HB-FG

HB – FG									
Production Years	Unit	Proportion	Value	Value	2021	2022	2023	2024	Total
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	**$**				**221,181,873**	**192,995,561**	**186,096,438**	**171,891,299**	
Less operating costs	$				74,823,540	76,098,549	77,170,997	76,318,547	
Direct mining cost	$				31,696,753	32,180,920	32,520,537	31,550,684	
Mining unit cost	$				25	25	26	26	
Tonnage	$				1,271,297	1,265,408	1,253,689	1,192,451	
Haulage cost	$			$ 3.26	4,144,430	4,207,736	4,252,142	4,125,331	
Processing	$				20,378,899	20,738,331	21,055,372	20,955,618	
Fixed costs	$	50%		$ 16.03	10,189,449	10,393,238	10,601,103	10,813,125	
Variable costs	$	50%		$ 16.03	10,189,449	10,345,093	10,454,269	10,142,493	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	839,056	851,873	860,863	835,190	
Operating cashflow	**$**				**146,358,334**	**116,897,012**	**108,925,441**	**95,572,753**	
Royalties	$				9,813,078	8,504,985	8,158,963	7,461,819	
Operating cashflow net of royalties	**$**				**136,545,256**	**108,392,027**	**100,766,477**	**88,110,934**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	**$**				**132,363,227**	**102,691,480**	**96,616,117**	**83,960,573**	
Taxable income	$				132,363,227	102,691,480	96,616,117	83,960,573	
Cashflow before capex	$				136,545,256	108,392,027	100,766,477	88,110,934	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			32,720,190	25,385,334	23,883,504	20,755,054	
Cash flow after tax	**$**				**99,643,038**	**77,306,146**	**72,732,613**	**63,205,520**	
Revenue	$				221,181,873	192,995,561	186,096,438	171,891,299	
Opex	$				(74,823,540)	(76,098,549)	(77,170,997)	(76,318,547)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(9,813,078)	(8,504,985)	(8,158,963)	(7,461,819)	
Export levy	$								
Tax	$				(32,720,190)	(25,385,334)	(23,883,504)	(20,755,054)	
Total undiscounted cashflow	**$**				**99,643,038**	**77,306,146**	**72,732,613**	**63,205,520**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				221,181,873	160,829,634	129,233,637	99,474,132	610,719,276
Opex	$				(74,823,540)	(63,415,457)	(53,590,970)	(44,165,826)	(235,995,793)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(9,813,078)	(7,087,488)	(5,665,947)	(4,318,182)	(26,884,695)
Export levy	$				-	-	-	-	-
Tax	$				(32,720,190)	(21,154,445)	(16,585,767)	(12,011,026)	(82,471,428)
Total discounted cashflow	**$**				**99,643,038**	**64,421,789**	**50,508,759**	**36,577,268**	**251,150,853**
NPV=	**$**	**251,150,853**							

7.31 DCF analysis for the 2.50 m mining cut for seams HC-FF

HC – FF									
Production Years	Unit	Proportion	Value	Value	2021	2022	2023	2024	Total
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**211,473,395**	**184,587,294**	**178,003,852**	**164,469,039**	
Less operating costs	$				74,846,282	76,121,746	77,194,658	76,342,681	
Direct mining cost	$				31,709,387	32,193,806	32,533,681	31,564,090	
Mining unit cost	$				25	25	26	26	
Tonnage	$				1,271,804	1,265,915	1,254,196	1,192,958	
Haulage cost	$			$ 3.26	4,146,082	4,209,421	4,253,860	4,127,084	
Processing	$				20,387,021	20,746,616	21,063,822	20,964,238	
Fixed costs	$	50%		$ 16.03	10,193,511	10,397,381	10,605,329	10,817,435	
Variable costs	$	50%		$ 16.03	10,193,511	10,349,235	10,458,494	10,146,803	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	839,391	852,214	861,211	835,545	
Operating cashflow	$				**136,627,113**	**108,465,548**	**100,809,194**	**88,126,357**	
Royalties	$				9,371,825	8,124,482	7,794,477	7,130,206	
Operating cashflow net of royalties	$				**127,255,288**	**100,341,066**	**93,014,717**	**80,996,151**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**123,073,260**	**94,640,520**	**88,864,356**	**76,845,790**	
Taxable income	$				123,073,260	94,640,520	88,864,356	76,845,790	
Cashflow before capex	$				127,255,288	100,341,066	93,014,717	80,996,151	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			30,423,710	23,395,136	21,967,269	18,996,279	
Cash flow after tax	$				**92,649,550**	**71,245,383**	**66,897,087**	**57,849,511**	
Revenue	$				211,473,395	184,587,294	178,003,852	164,469,039	
Opex	$				(74,846,282)	(76,121,746)	(77,194,658)	(76,342,681)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(9,371,825)	(8,124,482)	(7,794,477)	(7,130,206)	
Export levy	$								
Tax	$				(30,423,710)	(23,395,136)	(21,967,269)	(18,996,279)	
Total undiscounted cashflow	$				**92,649,550**	**71,245,383**	**66,897,087**	**57,849,511**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				211,473,395	153,822,745	123,613,786	95,178,842	584,088,768
Opex	$				(74,846,282)	(63,434,788)	(53,607,401)	(44,179,792)	(236,068,264)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(9,371,825)	(6,770,402)	(5,412,831)	(4,126,277)	(25,681,335)
Export levy	$				-	-	-	-	-
Tax	$				(30,423,710)	(19,495,947)	(15,255,048)	(10,993,217)	(76,167,922)
Total discounted cashflow	$				**92,649,550**	**59,371,153**	**46,456,311**	**33,477,726**	**231,954,740**
NPV=	$	**231,954,740**							

7.32 DCF analysis for the 2.50 m mining cut for seams HD-FE

HD – FE									
Production Years	**Unit**	**Proportion**	**Value**	**Value**	**2021**	**2022**	**2023**	**2024**	**Total**
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	**$**				**197,465,856**	**172,456,109**	**166,328,393**	**153,761,961**	
Less operating costs	$				74,890,525	76,166,873	77,240,688	76,389,632	
Direct mining cost	$				31,733,964	32,218,875	32,559,251	31,590,172	
Mining unit cost	$				25	25	26	26	
Tonnage	$				1,272,790	1,266,901	1,255,181	1,193,944	
Haulage cost	$			$ 3.26	4,149,295	4,212,698	4,257,204	4,130,494	
Processing	$				20,402,823	20,762,734	21,080,262	20,981,006	
Fixed costs	$	50%		$ 16.03	10,201,411	10,405,440	10,613,548	10,825,819	
Variable costs	$	50%		$ 16.03	10,201,411	10,357,294	10,466,714	10,155,187	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	840,041	852,878	861,888	836,235	
Operating cashflow	**$**				**122,575,332**	**96,289,235**	**89,087,705**	**77,372,329**	
Royalties	$				8,735,130	7,575,458	7,268,575	6,651,789	
Operating cashflow net of royalties	**$**				**113,840,201**	**88,713,777**	**81,819,129**	**70,720,541**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	**$**				**109,658,173**	**83,013,231**	**77,668,769**	**66,570,180**	
Taxable income	$				109,658,173	83,013,231	77,668,769	66,570,180	
Cashflow before capex	$				113,840,201	88,713,777	81,819,129	70,720,541	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			27,107,500	20,520,871	19,199,720	16,456,149	
Cash flow after tax	**$**				**82,550,673**	**62,492,360**	**58,469,049**	**50,114,032**	
Revenue	$				197,465,856	172,456,109	166,328,393	153,761,961	
Opex	$				(74,890,525)	(76,166,873)	(77,240,688)	(76,389,632)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(8,735,130)	(7,575,458)	(7,268,575)	(6,651,789)	
Export levy	$								
Tax	$				(27,107,500)	(20,520,871)	(19,199,720)	(16,456,149)	
Total undiscounted cashflow	**$**				**82,550,673**	**62,492,360**	**58,469,049**	**50,114,032**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				197,465,856	143,713,424	115,505,828	88,982,616	545,667,725
Opex	$				(74,890,525)	(63,472,394)	(53,639,367)	(44,206,963)	(236,209,249)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(8,735,130)	(6,312,882)	(5,047,622)	(3,849,415)	(23,945,049)
Export levy	$				-	-	-	-	-
Tax	$				(27,107,500)	(17,100,726)	(13,333,139)	(9,523,234)	(67,064,599)
Total discounted cashflow	**$**				**82,550,673**	**52,076,967**	**40,603,506**	**29,001,176**	**204,232,322**
NPV=	**$**	**204,232,322**							

7.33 DCF analysis for the 2.50 m mining cut for seams HE-FD

HE - FD									
Production Years	Unit	Proportion	Value	Value	2021	2022	2023	2024	Total
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**178,932,503**	**156,405,643**	**150,880,966**	**139,596,082**	
Less operating costs	$				74,960,330	76,238,075	77,313,314	76,463,710	
Direct mining cost	$				31,772,742	32,258,428	32,599,596	31,631,323	
Mining unit cost	$				25	25	26	26	
Tonnage	$				1,274,345	1,268,456	1,256,737	1,195,499	
Haulage cost	$			$ 3.26	4,154,366	4,217,870	4,262,479	4,135,875	
Processing	$				20,427,754	20,788,164	21,106,201	21,007,464	
Fixed costs	$	50%		$ 16.03	10,213,877	10,418,155	10,626,518	10,839,048	
Variable costs	$	50%		$ 16.03	10,213,877	10,370,009	10,479,683	10,168,416	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	841,068	853,925	862,956	837,324	
Operating cashflow	$				**103,972,172**	**80,167,567**	**73,567,652**	**63,132,372**	
Royalties	$				7,892,674	6,849,013	6,572,727	6,018,778	
Operating cashflow net of royalties	$				**96,079,498**	**73,318,554**	**66,994,925**	**57,113,594**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**91,897,470**	**67,618,008**	**62,844,564**	**52,963,233**	
Taxable income	$				91,897,470	67,618,008	62,844,564	52,963,233	
Cashflow before capex	$				96,079,498	73,318,554	66,994,925	57,113,594	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			22,717,055	16,715,171	15,535,176	13,092,511	
Cash flow after tax	$				**69,180,416**	**50,902,836**	**47,309,388**	**39,870,722**	
Revenue	$				178,932,503	156,405,643	150,880,966	139,596,082	
Opex	$				(74,960,330)	(76,238,075)	(77,313,314)	(76,463,710)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(7,892,674)	(6,849,013)	(6,572,727)	(6,018,778)	
Export levy	$								
Tax	$				(22,717,055)	(16,715,171)	(15,535,176)	(13,092,511)	
Total undiscounted cashflow	$				**69,180,416**	**50,902,836**	**47,309,388**	**39,870,722**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				178,932,503	130,338,035	104,778,449	80,784,770	494,833,757
Opex	$				(74,960,330)	(63,531,730)	(53,689,802)	(44,249,832)	(236,431,694)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(7,892,674)	(5,707,511)	(4,564,394)	(3,483,089)	(21,647,668)
Export levy	$				-	-	-	-	-
Tax	$				(22,717,055)	(13,929,310)	(10,788,317)	(7,576,685)	(55,011,366)
Total discounted cashflow	$				**69,180,416**	**42,419,030**	**32,853,742**	**23,073,334**	**167,526,522**
NPV=	$	**167,526,522**							

7.34 Summary of differential cashflow for the 2.50 m cut scenarios

										Differential Cash Flows (US$m)							
US$m	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Base Case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Mining Height	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m
Seams	FB – FK	FA – FJ	PK – FI	HA – FH	HB – FG	HC – FF	HD – FE	HE - FD	HB - FG	FB – FK	FA – FJ	PK – FI	HA – FH	HB – FG	HC – FF	HD – FE	HE - FD
Revenue	497.8	541.0	597.4	622.5	610.7	584.1	545.7	494.8	610.7	(113)	(70)	(13)	12	0	(27)	(65)	(116)
Operating expenditure	(236)	(236)	(236)	(236)	(236)	(236)	(236)	(236)	(236)	(0)	(0)	(0)	(0)	0	(0)	(0)	(0)
Capital expenditure	(14)	(14)	(14)	(14)	(14)	(14)	(14)	(14)	(14)	0	0	0	0	0	0	0	0
Royalties	(22)	(24)	(26)	(27)	(27)	(26)	(24)	(22)	(27)	5	3	1	(1)	0	1	3	5
Export levy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Taxation	(56)	(66)	(79)	(85)	(82)	(76)	(67)	(55)	(82)	27	16	3	(3)	0	6	15	27
NPV	**169.7**	**200.9**	**241.6**	**259.6**	**251.2**	**232.0**	**204.2**	**167.5**	**251.2**	**(81.5)**	**(50.2)**	**(9.6)**	**8.5**	**0.0**	**(19.2)**	**(46.9)**	**(83.6)**

7.35 Calculated revenues for the possible 2.75 m mining cut scenarios

2.75 m cut options	Year 1	Year 2	Year 3	Year 4	Total revenue
FA – FK	190,086,690	164,716,847	158,683,985	146,306,002	659,793,524
PK – FJ	212,874,999	184,463,133	177,705,901	163,838,293	738,882,326
HA – FI	223,452,410	193,628,493	186,534,915	171,975,254	775,591,072
HB – FH	220,110,558	190,732,874	183,745,762	169,405,766	763,994,960
HC – FG	211,396,514	183,181,599	176,470,578	162,695,637	733,744,328
HB – FF	200,004,764	173,310,549	166,961,653	153,931,453	694,208,419
HE - FE	185,251,905	160,527,020	154,647,001	142,580,811	643,006,737

7.36 DCF analysis for the 2.75 m mining cut for seams FA-FK

FA – FK									
Production Years	Unit	Proportion	Value	Value	2021	2022	2023	2024	Total
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**205,746,652**	**179,844,237**	**173,619,152**	**161,316,710**	
Less operating costs	$				81,603,098	83,009,160	84,210,608	83,449,853	
Direct mining cost	$				35,932,592	36,496,937	36,913,663	35,982,574	
Mining unit cost	$				26	26	27	27	
Tonnage	$				1,398,802	1,392,913	1,381,194	1,319,956	
Haulage cost	$			$ 3.26	4,560,095	4,631,715	4,684,600	4,566,438	
Processing	$				22,422,800	22,823,110	23,181,847	23,124,622	
Fixed costs	$	50%		$ 16.03	11,211,400	11,435,628	11,664,341	11,897,627	
Variable costs	$	50%		$ 16.03	11,211,400	11,387,482	11,517,506	11,226,995	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	923,209	937,709	948,416	924,494	
Operating cashflow	$				**124,143,554**	**96,835,077**	**89,408,544**	**77,866,857**	
Royalties	$				9,087,868	7,887,146	7,574,686	6,966,419	
Operating cashflow net of royalties	$				**115,055,686**	**88,947,931**	**81,833,858**	**70,900,438**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**110,873,658**	**83,247,384**	**77,683,497**	**66,750,077**	
Taxable income	$				110,873,658	83,247,384	77,683,497	66,750,077	
Cashflow before capex	$				115,055,686	88,947,931	81,833,858	70,900,438	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			27,407,968	20,578,753	19,203,360	16,500,619	
Cash flow after tax	$				**83,465,690**	**62,668,631**	**58,480,137**	**50,249,458**	
Revenue	$				205,746,652	179,844,237	173,619,152	161,316,710	
Opex	$				(81,603,098)	(83,009,160)	(84,210,608)	(83,449,853)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(9,087,868)	(7,887,146)	(7,574,686)	(6,966,419)	
Export levy	$								
Tax	$				(27,407,968)	(20,578,753)	(19,203,360)	(16,500,619)	
Total undiscounted cashflow	$				**83,465,690**	**62,668,631**	**58,480,137**	**50,249,458**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				205,746,652	149,870,197	120,568,856	93,354,578	569,540,283
Opex	$				(81,603,098)	(69,174,300)	(58,479,589)	(48,292,739)	(257,549,726)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(9,087,868)	(6,572,622)	(5,260,199)	(4,031,493)	(24,952,181)
Export levy	$				-	-	-	-	-
Tax	$				(27,407,968)	(17,148,961)	(13,335,667)	(9,548,969)	(67,441,566)
Total discounted cashflow	$				**83,465,690**	**52,223,859**	**40,611,206**	**29,079,547**	**205,380,302**
NPV=	$	**205,380,302**							

7.37 DCF analysis for the 2.75 m mining cut for seams PK-FJ

PK – FJ									
Production Years	**Unit**	**Proportion**	**Value**	**Value**	**2021**	**2022**	**2023**	**2024**	**Total**
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**228,523,091**	**199,579,007**	**192,629,603**	**178,836,943**	
Less operating costs	$				81,554,706	82,959,800	84,160,261	83,398,499	
Direct mining cost	$				35,905,354	36,469,154	36,885,324	35,953,668	
Mining unit cost	$				26	26	27	27	
Tonnage	$				1,397,742	1,391,853	1,380,133	1,318,896	
Haulage cost	$			$ 3.26	4,556,639	4,628,189	4,681,004	4,562,770	
Processing	$				22,405,803	22,805,773	23,164,163	23,106,585	
Fixed costs	$	50%		$ 16.03	11,202,901	11,426,959	11,655,499	11,888,609	
Variable costs	$	50%		$ 16.03	11,202,901	11,378,814	11,508,664	11,217,976	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	922,510	936,995	947,688	923,751	
Operating cashflow	$				**146,968,385**	**116,619,207**	**108,469,342**	**95,438,444**	
Royalties	$				10,123,040	8,780,190	8,430,885	7,749,165	
Operating cashflow net of royalties	$				**136,845,345**	**107,839,016**	**100,038,457**	**87,689,279**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**132,663,317**	**102,138,470**	**95,888,096**	**83,538,918**	
Taxable income	$				132,663,317	102,138,470	95,888,096	83,538,918	
Cashflow before capex	$				136,845,345	107,839,016	100,038,457	87,689,279	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			32,794,372	25,248,630	23,703,537	20,650,821	
Cash flow after tax	$				**99,868,945**	**76,889,840**	**72,184,559**	**62,888,098**	
Revenue	$				228,523,091	199,579,007	192,629,603	178,836,943	
Opex	$				(81,554,706)	(82,959,800)	(84,160,261)	(83,398,499)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(10,123,040)	(8,780,190)	(8,430,885)	(7,749,165)	
Export levy	$								
Tax	$				(32,794,372)	(25,248,630)	(23,703,537)	(20,650,821)	
Total undiscounted cashflow	$				**99,868,945**	**76,889,840**	**72,184,559**	**62,888,098**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				228,523,091	166,315,839	133,770,557	103,493,601	632,103,088
Opex	$				(81,554,706)	(69,133,167)	(58,444,626)	(48,263,020)	(257,395,518)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(10,123,040)	(7,316,825)	(5,854,781)	(4,484,470)	(27,779,117)
Export levy	$				-	-	-	-	-
Tax	$				(32,794,372)	(21,040,525)	(16,460,790)	(11,950,706)	(82,246,393)
Total discounted cashflow	$				**99,868,945**	**64,074,867**	**50,128,166**	**36,393,575**	**250,465,553**
NPV=	$	**250,465,553**							

7.38 DCF analysis for the 2.75 m mining cut for seams HA-FI

HA – FI									
Production Years	**Unit**	**Proportion**	**Value**	**Value**	**2021**	**2022**	**2023**	**2024**	**Total**
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**239,094,575**	**208,738,618**	**201,452,892**	**186,967,884**	
Less operating costs	$				81,530,547	82,935,158	84,135,126	83,372,861	
Direct mining cost	$				35,891,755	36,455,283	36,871,177	35,939,238	
Mining unit cost	$				26	26	27	27	
Tonnage	$				1,397,213	1,391,323	1,379,604	1,318,366	
Haulage cost	$			$ 3.26	4,554,913	4,626,429	4,679,208	4,560,939	
Processing	$				22,397,317	22,797,118	23,155,334	23,097,580	
Fixed costs	$	50%		$ 16.03	11,198,659	11,422,632	11,651,084	11,884,106	
Variable costs	$	50%		$ 16.03	11,198,659	11,374,486	11,504,250	11,213,474	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	922,160	936,639	947,324	923,380	
Operating cashflow	$				**157,564,028**	**125,803,460**	**117,317,766**	**103,595,023**	
Royalties	$				10,603,513	9,194,690	8,828,277	8,112,435	
Operating cashflow net of royalties	$				**146,960,515**	**116,608,770**	**108,489,489**	**95,482,588**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**142,778,487**	**110,908,224**	**104,339,128**	**91,332,227**	
Taxable income	$				142,778,487	110,908,224	104,339,128	91,332,227	
Cashflow before capex	$				146,960,515	116,608,770	108,489,489	95,482,588	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			35,294,842	27,416,513	25,792,632	22,577,327	
Cash flow after tax	$				**107,483,645**	**83,491,711**	**78,546,496**	**68,754,901**	
Revenue	$				239,094,575	208,738,618	201,452,892	186,967,884	
Opex	$				(81,530,547)	(82,935,158)	(84,135,126)	(83,372,861)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(10,603,513)	(9,194,690)	(8,828,277)	(8,112,435)	
Export levy	$								
Tax	$				(35,294,842)	(27,416,513)	(25,792,632)	(22,577,327)	
Total undiscounted cashflow	$				**107,483,645**	**83,491,711**	**78,546,496**	**68,754,901**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				239,094,575	173,948,849	139,897,842	108,199,007	661,140,272
Opex	$				(81,530,547)	(69,112,632)	(58,427,171)	(48,248,184)	(257,318,533)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(10,603,513)	(7,662,242)	(6,130,748)	(4,694,696)	(29,091,200)
Export levy	$				-	-	-	-	-
Tax	$				(35,294,842)	(22,847,094)	(17,911,550)	(13,065,582)	(89,119,069)
Total discounted cashflow	$				**107,483,645**	**69,576,426**	**54,546,178**	**39,788,716**	**271,394,963**
NPV=	$	**271,394,963**							

7.39 DCF analysis for the 2.75 m mining cut for seams HB-FH

HB – FH									
Production Years	**Unit**	**Proportion**	**Value**	**Value**	**2021**	**2022**	**2023**	**2024**	**Total**
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**235,756,576**	**205,846,735**	**198,667,460**	**184,402,308**	
Less operating costs	$				81,546,250	82,951,175	84,151,464	83,389,525	
Direct mining cost	$				35,900,594	36,464,299	36,880,372	35,948,617	
Mining unit cost	$				26	26	27	27	
Tonnage	$				1,397,557	1,391,667	1,379,948	1,318,710	
Haulage cost	$			$ 3.26	4,556,035	4,627,573	4,680,375	4,562,129	
Processing	$				22,402,833	22,802,744	23,161,072	23,103,433	
Fixed costs	$	50%		$ 16.03	11,201,416	11,425,445	11,653,954	11,887,033	
Variable costs	$	50%		$ 16.03	11,201,416	11,377,299	11,507,119	11,216,400	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	922,387	936,871	947,561	923,621	
Operating cashflow	$				**154,210,326**	**122,895,560**	**114,515,996**	**101,012,783**	
Royalties	$				10,451,768	9,063,792	8,702,793	7,997,779	
Operating cashflow net of royalties	$				**143,758,558**	**113,831,768**	**105,813,204**	**93,015,004**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**139,576,529**	**108,131,222**	**101,662,843**	**88,864,643**	
Taxable income	$				139,576,529	108,131,222	101,662,843	88,864,643	
Cashflow before capex	$				143,758,558	113,831,768	105,813,204	93,015,004	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			34,503,318	26,730,038	25,131,055	21,967,340	
Cash flow after tax	$				**105,073,211**	**81,401,184**	**76,531,788**	**66,897,303**	
Revenue	$				235,756,576	205,846,735	198,667,460	184,402,308	
Opex	$				(81,546,250)	(82,951,175)	(84,151,464)	(83,389,525)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(10,451,768)	(9,063,792)	(8,702,793)	(7,997,779)	
Export levy	$								
Tax	$				(34,503,318)	(26,730,038)	(25,131,055)	(21,967,340)	
Total undiscounted cashflow	$				**105,073,211**	**81,401,184**	**76,531,788**	**66,897,303**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				235,756,576	171,538,946	137,963,514	106,714,299	651,973,335
Opex	$				(81,546,250)	(69,125,979)	(58,438,516)	(48,257,827)	(257,368,572)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(10,451,768)	(7,553,160)	(6,043,606)	(4,628,345)	(28,676,879)
Export levy	$				-	-	-	-	-
Tax	$				(34,503,318)	(22,275,032)	(17,452,121)	(12,712,581)	(86,943,052)
Total discounted cashflow	$				**105,073,211**	**67,834,320**	**53,147,075**	**38,713,717**	**264,768,324**
NPV=	$	**264,768,324**							

7.40 DCF analysis for the 2.75 m mining cut for seams HC-FG

HC – FG									
Production Years	Unit	Proportion	Value	Value	2021	2022	2023	2024	Total
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**227,036,974**	**198,290,069**	**191,386,908**	**177,686,534**	
Less operating costs	$				81,523,592	82,928,063	84,127,890	83,365,480	
Direct mining cost	$				35,887,841	36,451,290	36,867,104	35,935,083	
Mining unit cost	$				26	26	27	27	
Tonnage	$				1,397,060	1,391,171	1,379,452	1,318,214	
Haulage cost	$			$ 3.26	4,554,416	4,625,922	4,678,691	4,560,412	
Processing	$				22,394,874	22,794,626	23,152,792	23,094,987	
Fixed costs	$	50%		$ 16.03	11,197,437	11,421,386	11,649,814	11,882,810	
Variable costs	$	50%		$ 16.03	11,197,437	11,373,240	11,502,979	11,212,177	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	922,060	936,536	947,220	923,273	
Operating cashflow	$				**145,513,382**	**115,362,005**	**107,259,018**	**94,321,053**	
Royalties	$				10,055,638	8,721,997	8,375,048	7,697,904	
Operating cashflow net of royalties	$				**135,457,744**	**106,640,008**	**98,883,970**	**86,623,149**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**131,275,716**	**100,939,462**	**94,733,609**	**82,472,788**	
Taxable income	$				131,275,716	100,939,462	94,733,609	82,472,788	
Cashflow before capex	$				135,457,744	106,640,008	98,883,970	86,623,149	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			32,451,357	24,952,235	23,418,148	20,387,273	
Cash flow after tax	$				**98,824,359**	**75,987,227**	**71,315,461**	**62,085,515**	
Revenue	$				227,036,974	198,290,069	191,386,908	177,686,534	
Opex	$				(81,523,592)	(82,928,063)	(84,127,890)	(83,365,480)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(10,055,638)	(8,721,997)	(8,375,048)	(7,697,904)	
Export levy	$								
Tax	$				(32,451,357)	(24,952,235)	(23,418,148)	(20,387,273)	
Total undiscounted cashflow	$				**98,824,359**	**75,987,227**	**71,315,461**	**62,085,515**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				227,036,974	165,241,724	132,907,575	102,827,855	628,014,127
Opex	$				(81,523,592)	(69,106,720)	(58,422,146)	(48,243,912)	(257,296,369)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(10,055,638)	(7,268,331)	(5,816,006)	(4,454,806)	(27,594,780)
Export levy	$				-	-	-	-	-
Tax	$				(32,451,357)	(20,793,529)	(16,262,603)	(11,798,191)	(81,305,680)
Total discounted cashflow	$				**98,824,359**	**63,322,689**	**49,524,626**	**35,929,118**	**247,600,791**
NPV=	$	**247,600,791**							

7.41 DCF analysis for the 2.75 m mining cut for seams HD-FF

HD – FF									
Production Years	Unit	Proportion	Value	Value	2021	2022	2023	2024	Total
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**215,650,611**	**188,424,244**	**181,883,186**	**168,927,822**	
Less operating costs	$				81,545,552	82,950,463	84,150,738	83,388,785	
Direct mining cost	$				35,900,201	36,463,898	36,879,964	35,948,201	
Mining unit cost	$				26	26	27	27	
Tonnage	$				1,397,541	1,391,652	1,379,933	1,318,695	
Haulage cost	$			$ 3.26	4,555,985	4,627,522	4,680,323	4,562,076	
Processing	$				22,402,588	22,802,494	23,160,818	23,103,173	
Fixed costs	$	50%		$ 16.03	11,201,294	11,425,320	11,653,826	11,886,903	
Variable costs	$	50%		$ 16.03	11,201,294	11,377,174	11,506,991	11,216,270	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	922,377	936,860	947,550	923,611	
Operating cashflow	$				**134,105,058**	**105,473,781**	**97,732,448**	**85,539,037**	
Royalties	$				9,538,145	8,275,555	7,947,025	7,306,603	
Operating cashflow net of royalties	$				**124,566,913**	**97,198,226**	**89,785,423**	**78,232,434**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**120,384,885**	**91,497,680**	**85,635,062**	**74,082,073**	
Taxable income	$				120,384,885	91,497,680	85,635,062	74,082,073	
Cashflow before capex	$				124,566,913	97,198,226	89,785,423	78,232,434	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			29,759,144	22,618,227	21,168,987	18,313,088	
Cash flow after tax	$				**90,625,741**	**68,879,454**	**64,466,075**	**55,768,985**	
Revenue	$				215,650,611	188,424,244	181,883,186	168,927,822	
Opex	$				(81,545,552)	(82,950,463)	(84,150,738)	(83,388,785)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(9,538,145)	(8,275,555)	(7,947,025)	(7,306,603)	
Export levy	$								
Tax	$				(29,759,144)	(22,618,227)	(21,168,987)	(18,313,088)	
Total undiscounted cashflow	$				**90,625,741**	**68,879,454**	**64,466,075**	**55,768,985**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				215,650,611	157,020,204	126,307,768	97,759,156	596,737,738
Opex	$				(81,545,552)	(69,125,386)	(58,438,012)	(48,257,399)	(257,366,349)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(9,538,145)	(6,896,295)	(5,518,767)	(4,228,358)	(26,181,566)
Export levy	$				-	-	-	-	-
Tax	$				(29,759,144)	(18,848,522)	(14,700,686)	(10,597,852)	(73,906,203)
Total discounted cashflow	$				**90,625,741**	**57,399,545**	**44,768,108**	**32,273,718**	**225,067,112**
NPV=	$	**225,067,112**							

7.42 DCF analysis for the 2.75 m mining cut for seams HE-FE

HE - FE									
Production Years	Unit	Proportion	Value	Value	2021	2022	2023	2024	Total
Year	n				0	1	2	3	
Inflation factor	%			2%					
Revenue	$				**200,904,606**	**175,647,365**	**169,575,155**	**157,584,143**	
Less operating costs	$				81,573,496	82,978,966	84,179,811	83,418,439	
Direct mining cost	$				35,915,930	36,479,942	36,896,328	35,964,892	
Mining unit cost	$				26	26	27	27	
Tonnage	$				1,398,154	1,392,264	1,380,545	1,319,307	
Haulage cost	$			$ 3.26	4,557,981	4,629,558	4,682,400	4,564,194	
Processing	$				22,412,403	22,812,505	23,171,029	23,113,589	
Fixed costs	$	50%		$ 16.03	11,206,201	11,430,325	11,658,932	11,892,111	
Variable costs	$	50%		$ 16.03	11,206,201	11,382,180	11,512,097	11,221,478	
Ngwarati portion of mining shared services	$	0.23	2.08	14,857,440	3,348,155	3,415,119	3,483,421	3,553,089	
Ngwarati portion of Head Office expenses	$	0.23	9.63	63,972,090	14,416,246	14,704,571	14,998,662	15,298,635	
Selling expenses	$			66%	922,781	937,272	947,971	924,039	
Operating cashflow	$				**119,331,110**	**92,668,399**	**85,395,344**	**74,165,704**	
Royalties	$				8,867,964	7,697,384	7,392,705	6,799,819	
Operating cashflow net of royalties	$				**110,463,145**	**84,971,014**	**78,002,639**	**67,365,885**	
Stay-in-Business Capex	$				4,182,028	5,700,546	4,150,361	4,150,361	
Operating cashflow net of Capex	$				**106,281,117**	**79,270,468**	**73,852,278**	**63,215,524**	
Taxable income	$				106,281,117	79,270,468	73,852,278	63,215,524	
Cashflow before capex	$				110,463,145	84,971,014	78,002,639	67,365,885	
Capital allowance	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Tax	$	25%			26,272,692	19,595,660	18,256,283	15,626,878	
Cash flow after tax	$				**80,008,425**	**59,674,808**	**55,595,995**	**47,588,647**	
Revenue	$				200,904,606	175,647,365	169,575,155	157,584,143	
Opex	$				(81,573,496)	(82,978,966)	(84,179,811)	(83,418,439)	
Capex	$				(4,182,028)	(5,700,546)	(4,150,361)	(4,150,361)	
Royalties	$				(8,867,964)	(7,697,384)	(7,392,705)	(6,799,819)	
Export levy	$								
Tax	$				(26,272,692)	(19,595,660)	(18,256,283)	(15,626,878)	
Total undiscounted cashflow	$				**80,008,425**	**59,674,808**	**55,595,995**	**47,588,647**	
						1	2	3	
Discount factor (WACC)	%	20%			1.00	0.83	0.69	0.58	
Revenue	$				200,904,606	146,372,804	117,760,524	91,194,527	556,232,462
Opex	$				(81,573,496)	(69,149,139)	(58,458,202)	(48,274,560)	(257,455,397)
Capex	$				(4,182,028)	(4,750,455)	(2,882,195)	(2,401,829)	(14,216,507)
Royalties	$				(8,867,964)	(6,414,487)	(5,133,823)	(3,935,080)	(24,351,355)
Export levy	$				-	-	-	-	-
Tax	$				(26,272,692)	(16,329,716)	(12,677,974)	(9,043,332)	(64,323,715)
Total discounted cashflow	$				**80,008,425**	**49,729,007**	**38,608,330**	**27,539,726**	**195,885,488**
NPV=	$	**195,885,488**							

7.43 Summary of differential cashflow for the 2.75 m cut scenarios

									Differential Cash Flows (US$m)						
US$m	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Base Case**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**
Mining Height	2.75 m	2.75 m	2.75 m	2.75 m	2.75 m	2.75 m	2.75 m	2.75 m	2.75 m	2.75 m	2.75 m	2.75 m	2.75 m	2.75 m	2.75 m
Seams	FC - FK	FB – FJ	FA - FI	PK – FH	HA – FG	HB – FF	HC – FE	HB - FG	FC - FK	FB – FJ	FA - FI	PK – FH	HA – FG	HB – FF	HC – FE
Revenue	569.5	632.1	661.1	652.0	628.0	596.7	556.2	610.7	(41)	21	50	41	17	(14)	(54)
Operating expenditure	(258)	(257)	(257)	(257)	(257)	(257)	(257)	(236)	(22)	(21)	(21)	(21)	(21)	(21)	(21)
Capital expenditure	(14)	(14)	(14)	(14)	(14)	(14)	(14)	(14)	0	0	0	0	0	0	0
Royalties	(25)	(28)	(29)	(29)	(28)	(26)	(24)	(27)	2	(1)	(2)	(2)	(1)	1	3
Export levy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Taxation	(67)	(82)	(89)	(87)	(81)	(74)	(64)	(82)	15	0	(7)	(4)	1	9	18
NPV	**205.4**	**250.5**	**271.4**	**264.8**	**247.6**	**225.1**	**195.9**	**251.2**	**(45.8)**	**(0.7)**	**20.2**	**13.6**	**(3.6)**	**(26.1)**	**(55.3)**

7.44 Calculated revenues for the possible 3.00 m mining cut scenarios

3.0 m cut options	Year 1	Year 2	Year 3	Year 4	Total revenue
PK – FK	221,451,475	191,962,285	185,061,122	171,284,407	769,759,289
HA – FJ	234,234,681	203,042,923	195,742,791	181,167,776	814,188,172
HB – FI	232,318,422	201,381,751	194,141,170	179,684,525	807,525,869
HC – FH	224,571,805	194,666,673	187,667,453	173,692,484	780,598,415
HD – FG	214,190,129	185,667,227	178,991,102	165,659,796	744,508,254
HE - FF	202,066,032	175,157,699	168,859,564	156,283,332	702,366,627

7.45 Ethical clearance certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SCHOOL OF MINING ETHICS COMMITTEE

CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: EMINN/2021/03W**
PROJECT TITLE	Optimization Of Mining Cut At Zimbabwe Platinum Mines Through Economic Evaluation
INVESTIGATOR	Mr. Harmony Muzhizhizhi
SCHOOL/DEPARTMENT OF INVESTIGATOR	School of Mining
DATE CONSIDERED	12 February 2021
DECISION OF THE COMMITTEE	Approved unconditionally
RISK LEVEL	NO RISK
EXPIRY DATE	16 May 2024

ISSUE DATE OF CERTIFICATE 17 May 2021 **CHAIRPERSON** ____________________
(Mr H Thomas)

cc: Supervisor: Mr T Tholana

DECLARATION OF INVESTIGATOR

To be completed in duplicate and ONE COPY returned to the Chairperson of the School/Department ethics committee.

I fully understand the conditions under which I am are authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.

____
Signature **Date** ______/______/______

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES